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Economically Rational Trading Between the All Island Single Electricity Market and Great Britain; Theory Vs Practice

Aoife Wilson
Technological University Dublin, wilsonao@tcd.ie

Dublin Institute of Technology

School of Electrical and Electronic Engineering

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Aoife Wilson

Project Supervisor: Dr. Martin Barrett

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Declaration

I hereby certify that the material, which is submitted in this dissertation, is entirely my own work and has not been submitted for any academic assessment other than as part fulfilment of the assessment procedures for the program Master of Science in Energy Management (MSc) (DT 711).

Signature of student:

Date: 08/09/2014

Foreword

Our energy systems, and in particular our electricity systems, in Ireland and Europe are undergoing almost revolutionary change at present. This has been driven by the need to address climate challenges, developments in generation technology and the increasing application of information and communications to the sector.

At the same time, energy remains central to the operation of our economy. The policy goals shared by Ireland and the EU of access to secure, sustainable and, from a global competitiveness perspective, affordable energy have not changed.

In relation to electricity, the key energy vector for the future, the EU has decided that it should be delivered on a competitive basis and has set down the general rules for this. The intention is to make electricity as competitive as possible, but there are major risks if the design is flawed.

These developments open up a whole new vista for those involved in the sector and, for me, make it a hugely interesting area to research.

Interconnection is one important aspect of a competitive electricity market. Interconnection is costly but justified based on modelling of the costs and benefits it delivers. The research area chosen examined the assumptions underpinning electricity interconnection in the specific context of the all-island market (The Single Electricity Market, SEM) and the electricity market of Great Britain (The British Electricity and Transmission Arrangements, BETTA). The purpose was to answer the questions: Have the expected benefits been delivered and, if different from expected what has caused this? Are there implications for future interconnection or market design?

Getting the design wrong will have major implications in terms of consumer prices, economically efficient electricity trading and, as a consequence of both, overall economic development on the island.

The study is, by its nature, open-ended as no decisions have been taken as yet in relation to the re-design of the Single Electricity Market (SEM). More

detailed analysis, involving application of the PLEXOS model could add further insights but has not been undertaken due to the limited time available.

I would like to thank the following people who contributed to the completion of this research;

- My Supervisor, Dr. Martin Barrett for his support and encouragement during this project. At many stages in the course of this research project I benefited from his advice, particularly so when exploring new ideas. His careful feedback contributed enormously to the production of this thesis.

- The interviewees who participated in this research. Their insights into the Energy Trading sector were vital components to the research and I would like to thank them for their immense generosity with their time.

- Other members of my class, for gladly assisting with advice and feedback.

- My family and friends; for their kind dedication and patience while completing this research and for all their help and support during my college tenure.

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Glossary of Terms

AI, All Island; This term shall be used throughout the document to describe the All Island electricity system which combines the systems in the Republic of Ireland and Northern Ireland

AMP, The Auction Management Platform is a computerised system that provides the necessary mechanisms and outputs to facilitate trading across Moyle and EWIC.

BETTA, British Electricity Trading and Transmission Arrangements

BSC, Balance and Settlement Code

CER, Commission for Energy Regulation

CPF, Carbon Price Floor

EIL, Eirgrid Interconnector Ltd.

EU, European Union

EWIC, East West Interconnector

FTR, Financial Transmission Right

GB, Great Britain

IA, Interconnector Administrator

MIL, Moyle Interconnector Limited

Ofgem, Office of Gas and Electricity Markets

PCR, Price Coupling of Regions initiative

PTR, Physical Transmission Right

ROI, Republic of Ireland

SEM, Single Electricity Market

SO, System Operator

SMP, System Marginal Price

SONI, System Operator Northern Ireland

TSO, Transmission System Operator

UR, Utility Regulator, Regulates the electricity and gas markets in Northern Ireland

Abstract

Economic trading across electricity interconnectors is considered to be a key factor in delivering the economic welfare benefits of an integrated European electricity market. This research examines this assumption as it applies to the interconnection between the electricity markets in Ireland, Northern Ireland and Great Britain. In doing so it reviews the assumption of economically rational trading behaviour by participants in the market. This assumption underpinned the cost benefit studies justifying construction of the East-West interconnector. Actual patterns of trading that have arisen post commissioning are compared with projected rational behaviour.

The research also considers the consequences of these behavioural differences for the Single Electricity Market re-design project which the Regulatory Authorities on the island are undertaking at present.

The analysis relies on an evaluation and examination of the trading patterns of different operators in the market and also on interviews with selected participants. It concludes that a simple assumption of economically rational behaviour based on apparent price differences between markets can be misleading given a range of other commercial risks apply in the real world.

1 Introduction

By removing barriers and setting fair rules for cross-border exchanges in electricity, the EU plans to forge a competitive and transparent wholesale electricity market with a high level of security of supply that serves the interests of electricity consumers and increases the welfare of European citizens (SEM Committee, 2012).

Across Europe, national energy policies are being shaped by the European Internal Energy Market. The ultimate goal of the European Internal Energy Market is a situation where consumers in any member state can purchase their energy from any supplier in the European Union (EU).

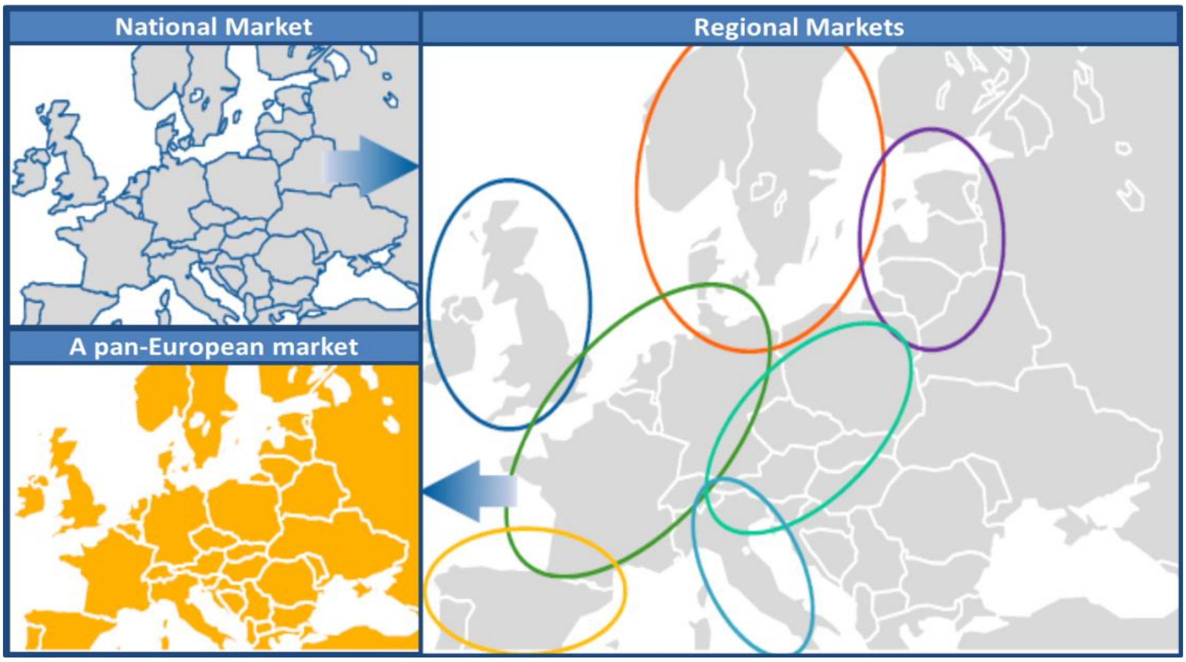


Figure 1.1 Three maps showing the move from traditional national energy markets to intermediary regional markets and finally to the EU's ultimate goal of a pan-European market, Source (EMCC)

A 'Target Market Model' has been designed to facilitate compatible cross border trading arrangements between Member States and all Member States are required to comply with this model by 2014.

Owing to its centralised structure and gross mandatory pool design the magnitude of change required for the SEM to implement the target model is considerably greater than other markets in Europe (SEM Committee, 2012). For this reason a two year transitional period has been provided. The revised SEM, which must be implemented by 2016, is currently being referred to as the Integrated Single Electricity Market, I-SEM. According to the SEM Committee established to oversee the transition, I-SEM should facilitate more efficient trade across borders and further serve to bring together electricity prices across the two islands (Ireland and GB) and the wider EU.

The infrastructure necessary to facilitate this trade is referred to as interconnection.

By offering cross border access to market participants, interconnection has the potential to increase competitiveness and commercial opportunities; ensure greater security of supply; provide important ancillary services such as frequency response, reactive power and black start capability in addition to theoretically facilitating growth in renewable energy.

'*Without interconnection, Ireland will not participate in the internal market, but instead be characterised as a small closed electricity system catering for a few million people and a smaller number of businesses* (Gorecki, 2011).'

However, the theory which describes the welfare benefits of Interconnection is based on a number of assumptions which may not reflect the unfolding reality. This study will examine how the reality has diverged from these assumptions and what impact that has had on expected results.

1.1 Research Background and Context

This section offers an introduction to three areas that are key to understanding the context of this study. First the theory behind interconnection will be presented, next the infrastructure necessary to facilitating interconnection will be described and finally, an overview of the two connected markets in question will be presented.

1.1.1 Theoretical Rationale for Interconnection

1.1.1.1 Economic Welfare Benefits

At its simplest level, the theory of cross-border electricity trade is broadly similar to that of international trade in general.

The following simple two-node example illustrates how trade between two countries should theoretically increase overall welfare.

Figure 1.2 illustrates the supply and demand curves for two countries before trade.

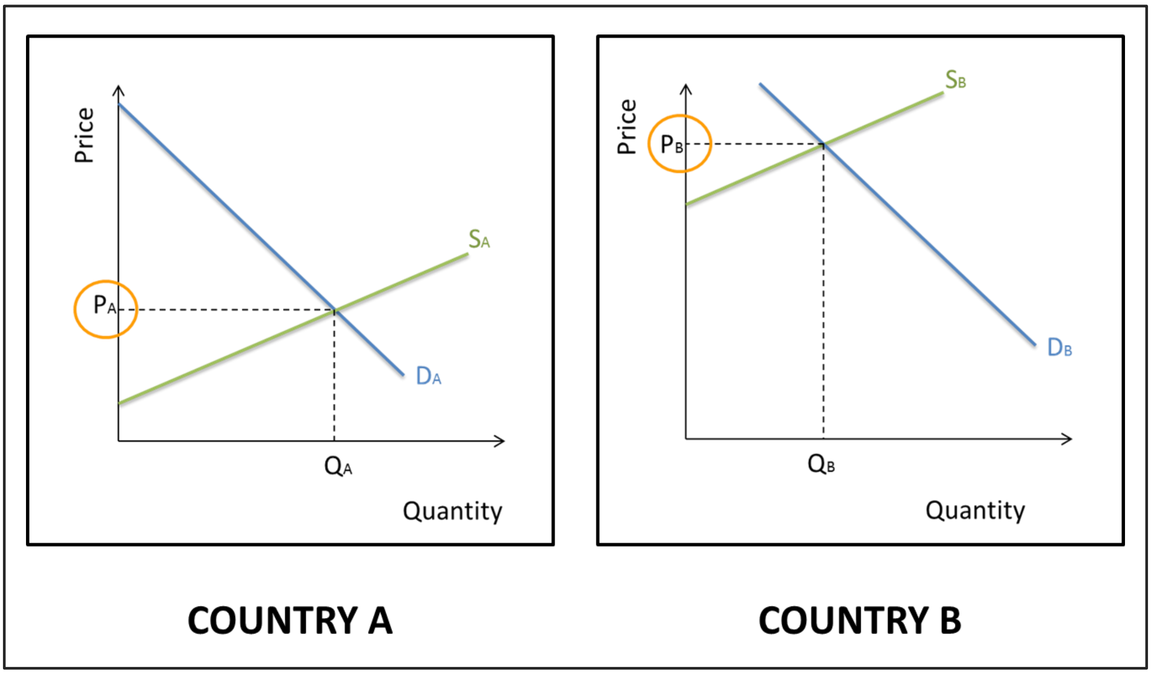


Figure 1.2 Supply Demand Curves for two theoretical electricity markets before interconnection, Adapted from (Turvey, 2006)

Before trade, the price equilibrium in country A is P_A, which is lower than P_B, the marginal price of electricity in country B. The theory of interconnection assumes that the cost of production of electricity is therefore lower in country A and thus more efficient.

In this example, a cross-border electricity interconnector with capacity K is constructed and country B imports quantity K of electricity from country A.

The result is a fall in price in country B to P_B*, while in A, the marginal cost of generation rises due to increased production resulting in a rise in the price of electricity for consumers in A from P_A to P_A* as illustrated in Figure 1.3.

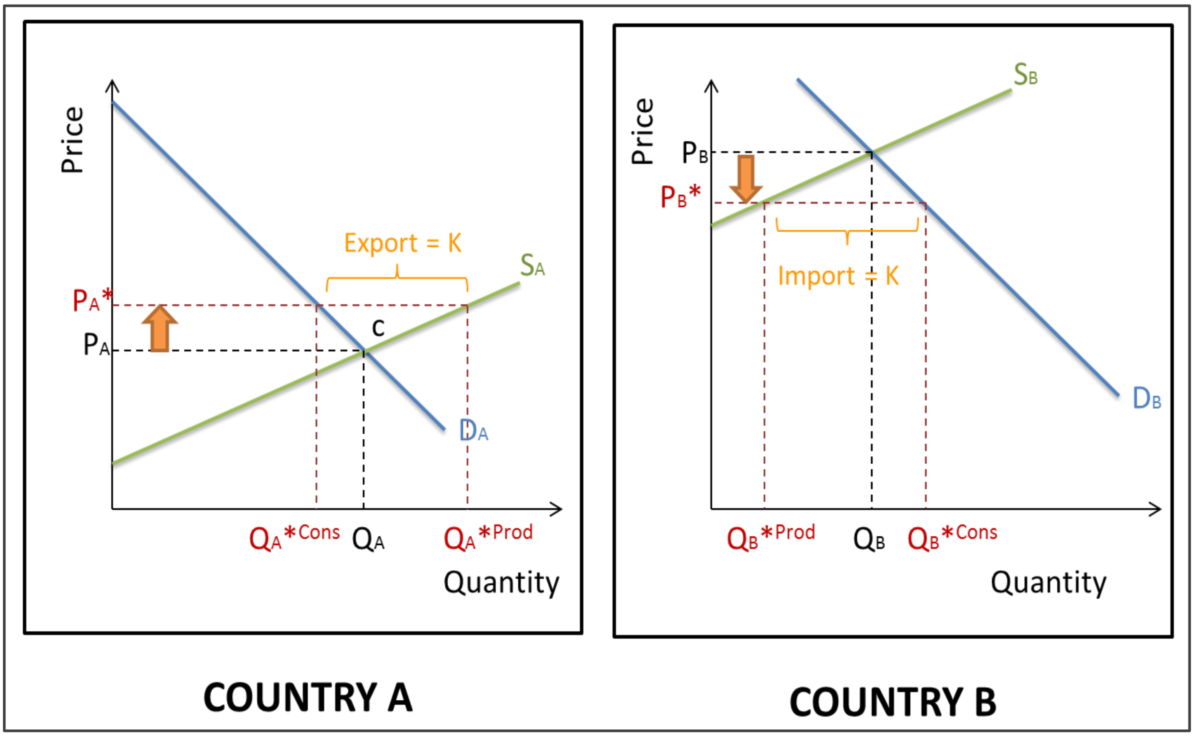


Figure 1.3 Illustration of Impact of interconnection on marginal price in country A and B, Adapted from (Turvey, 2006)

Examining figure 1.4 we can see that there has been a total loss of consumer surplus in country A of area (a + b). Producers in Country A however now have access to a wider market and we can observe that as a result, there have been producer gains of (a + b+ c). As producer gain is greater than consumer loss, it is stated that there is a net welfare gain from Interconnection for country A of area (c).

In country B there has been a loss of producer surplus of (d), but a gain in consumer surplus of area (d + e + f); there is thus a net welfare gain of (e + f) for country B.

So while there is redistribution of a, b and d between the consumers and producers of the two countries, there is overall, a net welfare gain from trade of (c + e + f).

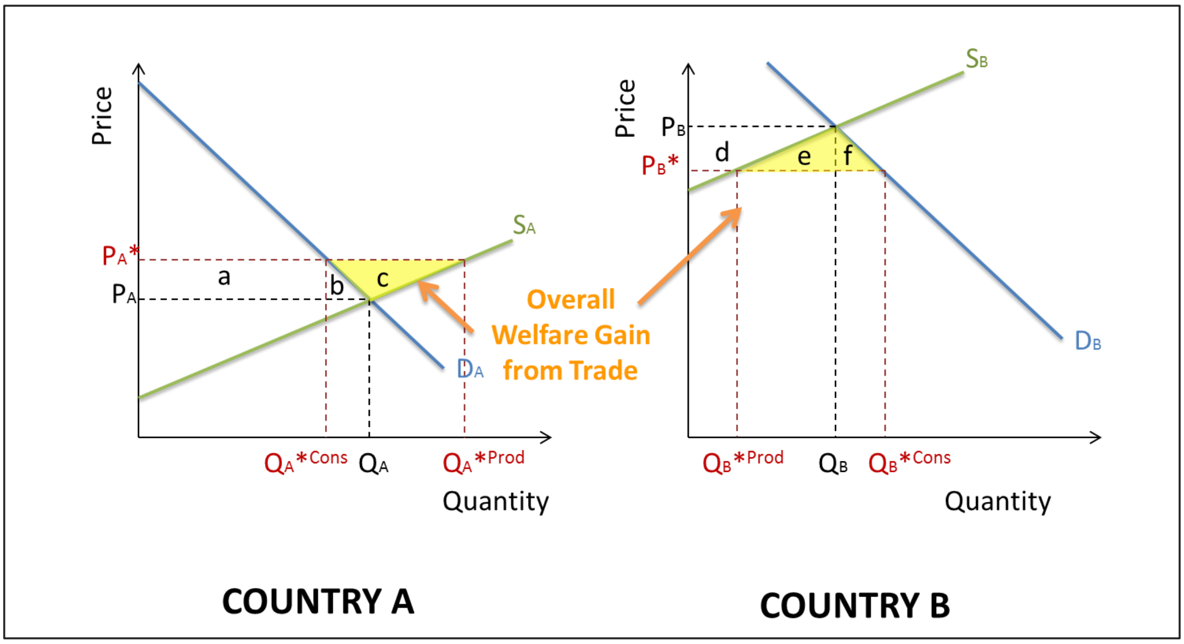


Figure 1.4 Illustration of theoretical net impact of interconnection on welfare, adapted from (Turvey, 2006)

The interconnector provider in this example gains rents for use of the interconnector of (P_B* - P_A*) x K.

It is generally accepted that the incremental benefits of interconnection decrease with each subsequent interconnector (EirGrid, 2009)

This example highlights the reason why individual Member States may be for or against increased interconnection, depending on their original wholesale electricity prices and those of potential trading partners. However, the European Commission (EC) sees the potential for net welfare gains for the EU as a whole. As a central body, the EC is in a freer position to advocate trade however Individual Member States, in particular national regulatory authorities (NRAs) who generally have duties to protect the interest of consumers within their respective countries, may not be keen to see consumer prices rise if they are in the country where production costs are initially lower (Jacottet, 2012).

1.1.1.2 Additional Welfare Effects of Interconnection

Interconnection has the potential to offer a range of benefits in addition to the direct economic welfare benefits outlined above. The following benefits are commonly referred to in the literature;

1. Enhanced Security of Supply
2. Provision of ancillary services such as frequency response, reactive power and black start capability
3. Promotion of competition
4. Facilitation of Renewable Generation
5. Reduction in required operating reserve.

These benefits, combined with the potential for direct economic welfare gains (illustrated in section 1.1.1.1) broadly speaking explain the motivation for interconnection of the SEM and BETTA electricity markets.

As wholesale electricity prices in the SEM have historically been higher than GB, Irish consumers are positioned to gain most from Interconnection according to this theory.

1.1.2 All Island Current and Future Installed Interconnector Capacity

The island of Ireland is connected to Great Britain by two High Voltage DC (HVDC) submarine interconnectors; The East-West Interconnector and The Moyle Interconnector. Combined, they represent approximately 10% of all-island electricity demand (EirGrid Group, 2013). GB is further connected to mainland Europe via the 1000 MW *BritNed* Interconnector to the Netherlands and the 2000 MW *IFA* Interconnector to France.

1.1.2.1 The Moyle Interconnector

The Moyle Interconnector owned and managed by Moyle Interconnector Ltd. (part of Northern Irish company Mutual Energy), commenced commercial operation in 2002. It comprises a dual monopole HVDC link with two coaxial sub-sea cables from Ballycronan More in Islandmagee, Northern Ireland to

Auchencrosh in Ayrshire, Scotland (EirGrid & SONI, 2013). The link has a physical installed capacity of 500MW. Moyle originally had an import capacity of 450 MW and an export capacity of 295 MW, however a fault on one of the cables has reduced this to 250 MW in both directions since 2012. Issues with transmission access rights in Scotland may further limit its export capacity to 80 MW from 2017 (Eirgrid & SONI, 2014).

1.1.2.2 The East-West Interconnector

The East-West Interconnector links converter stations at Rush North Beach, Dublin with Barkby Beach in North Wales. The Interconnector, developed, owned and managed by EirGrid Interconnector Ltd. (EIL) and co-financed by the EU has been in full commercial operation since May 2013, and has the capability of importing or exporting up to 500 MW at any given moment. It is not easy to predict whether or not imports for the full 500 MW will be available at all time however and EirGrid has estimated the capacity value of the interconnector to be 440 MW in their most recent generation adequacy study (EirGrid & SONI, 2014). EWIC uses Voltage Source Converter (VSC) technology and is the largest capacity VSC interconnector in operation worldwide (EirGrid, 2014). The East West Interconnector represents an investment of approximately €580 million. EirGrid were granted a loan of up to €300 million from the European Investment Bank and the balance of the project was funded by a combination of further capital investment from commercial banks, EirGrid equity and a €110 million grant from the European Commission (CER, 2012).

1.1.2.3 Proposed Interconnection

A number of studies have attempted to project how much further interconnection is viable and of benefit to the SEM. This issue will be discussed further in the literature review. At present however, any plans for additional interconnection are still in the preliminary phase.

In 2013, EirGrid and its French counterpart RTE (Réseau de Transport d'Électricité) signed a Memorandum of Understanding to begin preliminary studies on the feasibility of building a submarine electricity interconnector between Ireland and France. An Ireland-France interconnector would, if developed, run between the South coast of Ireland and the North West coast of France. According to a Press Release from Eirgrid in June 2013, the capacity of the Ireland-France interconnector could be approximately 700 MW (EirGrid, 2013).

1.1.2.3.1 Interconnection infrastructure exclusively for Export of Renewables

Several developers have proposed large-scale renewable energy export projects in Ireland that would access the GB market by connecting directly to its transmission system via one or more High Voltage Direct Current (HVDC) links (National Grid & EirGrid, 2013). These proposed projects have however come up against a number of obstacles and their status is currently unknown. A number of studies have explored the benefits of connecting Irish renewable energy projects to GB via an integrated network solution. A 2013 joint EirGrid - National Grid study reported the estimated annual benefits of such a project to be €75m per annum. At present however this type of connection does not fit into the existing regulatory framework for either GB or Ireland (National Grid & EirGrid, 2013).

1.1.3 SEM Vs. BETTA: High level overview

While the theory behind interconnection is relatively simple, the fundamental differences between the SEM and BETTA markets presents a significant challenge to optimising trade over the Moyle and East West Interconnectors.

The Single Electricity Market (SEM) is the wholesale electricity market operating on the island of Ireland. It operates as a gross mandatory pool market, into which all electricity generated on or imported onto the island of Ireland must be sold, and from which all wholesale electricity for consumption on or export from the island of Ireland must be purchased (EirGrid, 2014)

The British Electricity Trading and Transmission Arrangements (BETTA) is the wholesale electricity market operating in Great Britain. It operates as a bilateral trading market between generators, suppliers and energy traders. There are also power exchanges available in Great Britain which facilitate further trade in the BETTA market (EirGrid, 2014).

The key differences with respect to bidding, pricing, price visibility and capacity payments between the SEM and BETTA markets are summarised in figure 1.2.

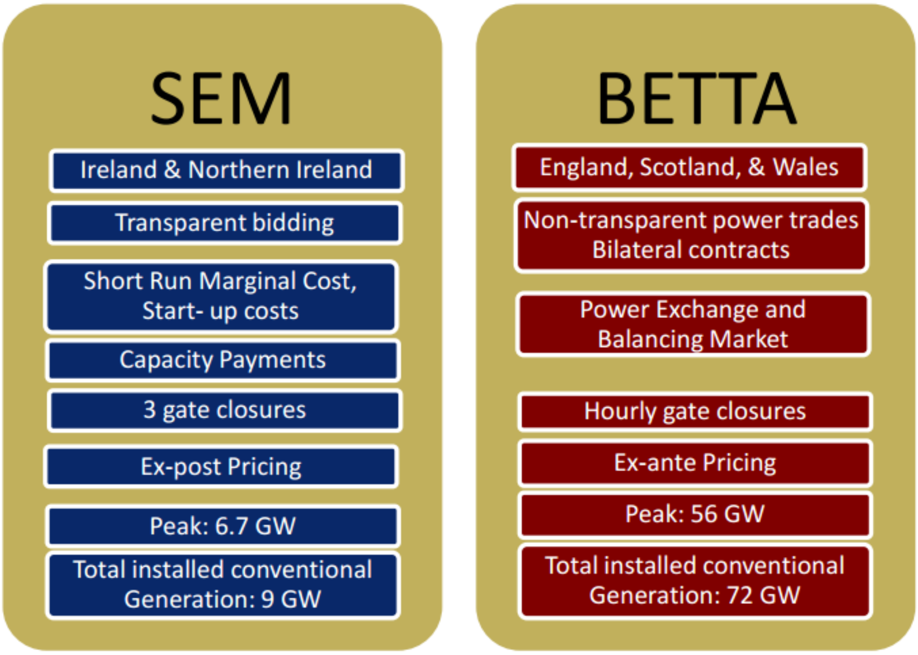


Figure 1.5 Comparison of the components of SEM and BETTA (EirGrid & SONI, 2014)

Chapter three will go into further detail on the difference between the SEM and BETTA, however two of the key differences with respect to economic trade across the interconnection will be highlighted here given their significance. These are;

1. Real Time Price Firmness: A consequence of the SEM design is that the final System Marginal Price, paid to generators, and by suppliers, is not known until four days after trading. This presents a high level of risk for anybody trading between the SEM and other markets. In interviews with Interconnector Users, the SMP was described as being 'notoriously hard to predict'.
2. Capacity Payment Regime: In accordance with SEM regulations, capacity payments are provided to imported electricity but deducted from exports to GB. There is currently no capacity payment mechanism in place in GB.
3. Gate Window Closures: As will be explained in Chapter 3, in the SEM there are just three opportunities for market participants submit data

to the market operators for use in the associated marginal price software run. Two gate closures occur occur the day before trading (each closing 90 minutes before the relevant software run) and one gate closure occurs on the day of trading, 90 minutes before the Within Day software run. Gate closures occur on an hourly basis in GB.

1.2 Research Selection Rationale

Interconnectors are a key part of the physical infrastructure that is required in order to deliver the concept of a single Internal Electricity Market in the EU. The value of interconnection is based on assumptions regarding their use, including that of rational economic behaviour by those trading.

Studies supporting the East-West interconnector in advance of its construction projected a positive benefit for consumers in Ireland. It is of value to review the actual results against those projected and identify the possible causes for differences form original projections. It is also of interest to examine if the reasons for these differences may also have implications or the redesign of the SEM.

1.3 Main Aims and Key Objectives

1.3.1 Key Objectives

There are three key aims to this study. They are listed with their associated objectives below:

Aims	Objectives

1. Examine interconnector flows between the SEM/All-island (AI) and BETTA markets	**1a.** Collect, organise and analyse SEMO Interconnector Flow Data to identify trends in volumes and direction over time and by type of trade.
	1b. Identify trading patterns and strategies of Interconnector Users
2. Determine whether the actual utilisation of the interconnectors; corresponds with pre-interconnector delivery projections;	**2a.** Compare findings with assumptions underpinning previous studies.
	2b. Assess whether EWIC is reducing SMP
	2c. Assess whether EWIC is helping us to achieve renewable targets
3. Consider the reasons for any variances that have arisen under the current SEM market arrangements and what lessons can be provided in terms of developing the revised I-SEM market	**3a.** Analyse results and determine whether there is a connection between the difference in assumed trading patterns and the differences in results.

Table 1.1 Thesis aims and associated objectives.

1.4 Dissertation Scope and Limitations

This study examines electricity flows on the Moyle and East-West interconnectors and the behaviour of those engaged in trading. It utilises publicly available data to determine these. The study also researched opinions form those actively engaged in trading on the interconnector and the East-West interconnector operator.

Data analysis was therefore necessarily limited to that available. It would have been of interest to undertake a number of modelling runs using the modelling tool (PLEXOS) used originally to assess the interconnector benefits with modified assumptions in the light of actual experience. In the absence of this the results and conclusions are more qualitative.

While interviews were conducted with a number of individuals the sample was not fully representative of all parties trading on the interconnector. As a result it has the potential to be biased although enquiries were constructed to minimise this possibility.

The scope of work that could be undertaken was also limited by the time available; some sections of the analysis could only be applied to one month given time restrictions, analysis of a longer time period would have offered more comprehensive results.

1.5 Dissertation Structure

This dissertation is divided into seven chapters.

Chapter 1 provides an overview of the research topic including the policy background, rationale for electricity trading, market structures in Ireland (AI) and Great Britain and the current status of interconnection between the markets in both regions.

Chapter 2 present a literature review of key aspects of this study including materials pre and post completion of the East-West interconnector.

Chapter 3 describes in more detail the design of the markets in Ireland and Northern Ireland (SEM) and Great Britain (BETTA) and the arrangements for trading across the interconnectors.

Chapter 4 examines the possible implications for interconnector trading of upcoming changes to the SEM, which are intended to improve the economic efficiency of such trading.

Chapter 5 describes the methodology used in researching this thesis and identifies the data sources and approximations used to determine results.

The results and discussion are presented in Chapter 6. These compare the projected behaviours anticipated before construction of the East-West interconnector with those observed subsequently. The implications for the restructured SEM are also addressed.

Chapter 7 presents the conclusions of this thesis, describe the degree to which the original objectives were achieved and indicates possible further areas for study.

1.6 Original Contribution

The following analyses constitute work the author has not found to be previously published;

- Disaggregation of trading on the GB-SEM interconnectors.
- Identification and classification of trading behaviours across the Moyle and East West Interconnectors.
- Analysis of the differences between forecasted and actual trading behaviours across the Moyle and East West Interconnectors.
- Analysis of possible implications resulting from this behavioural difference for the development of I-SEM.

2 Literature Review

This literature review will focus on a number of key aspects that will support a proper understanding of the relevant factors relating to this research topic of Interconnection between the SEM and its neighbouring countries, including the basis on which it was justified, it's projected and actual impact on wholesale prices and its ability to facilitate renewables.

Note that a review of the relevant literature associated with the following topics has been undertaken and referenced in the relevant chapters;

- General Theory of Interconnection (Chapter 1)
- Trading Across the Interconnector; The Fundamentals (Chapter X)
- The Integrated European Electricity Market (Chapter X)
- Barriers to Trade and ability of proposed I-SEM Changes to Address them (Chapter X –includes review of I-SEM Consultation responses)

As such, these topics are not repeated here.

In addition to researching literature specifically related to interconnection and the SEM, this review is also informed by related international research so as to provide a broader context to this work.

2.1 Economic Welfare Gains from Interconnection in the SEM

2.1.1 Analysis prior to EWIC Project Completion

In the years preceding the East West Interconnector Project, several reports examining the impact of increased interconnection on production costs and electricity prices in the SEM were published. These reports broadly agreed that the proposed 500 MW of interconnection would have the effect of reducing the wholesale price of electricity in the SEM but results diverged on the extent of the reduction and on the impact of further interconnection after EWIC on economic welfare in the SEM.

Valari (2008) projected the effects of additional interconnection between Ireland and GB using a static optimal dispatch model in a study published by the ESRI. The analysis was based on 2005 fuel prices and generation plant mix and assumed perfect competition in wholesale generation markets. As the basic theory of Interconnection would predict, Valeri found that in general, 'Ireland enjoys larger net benefits than Great Britain with interconnection' (Valeri, Working Paper No. 232, 2008). In all scenarios considered she found that Irish consumers were always the group that gained the most and Irish producers the group that lost the most.

Again, consistent with Interconnector Theory, the sum of Irish and British social welfare was found to increase with interconnection, although at a decreasing rate. Table 2.1 summarises the annual welfare changes for the Interconnector owner and consumers and producers in GB and Ireland that were predicted by Valeri's model for various incremental increases in installed interconnector capacity.

Table 2.1 Annual welfare changes in million euro, 2005 prices, Source (Valeri, Working Paper No. 232, 2008)

	Welfare effects of additional interconnection 0 carbon costs			
	500MW	1000MW	1500MW	3400MW
Irish Consumers	166	277	387	680
Irish Producers	-143	-222	-281	-390
GB Consumers	-55	-115	-182	-348
GB Producers	59	124	195	367
Interconnector	54	82	73	-62
Net Benefit	81	145	193	246
Net Benefit/MW	0.16	0.15	0.13	0.07
Net Benefit/MW, last 500MW	0.16	0.13	0.09	0.04
Capital cost/MW±	0.06-0.07			

± yearly capital cost, including fixed O&M

The following year, EirGrid conducted their own Economic Feasibility Report to assess the costs and benefits of further interconnection to GB or France. Their results forecast that the East-West interconnector would bring production cost savings in the range €50-€75 million in 2025 and that an additional 500 MW interconnector would bring production cost savings in the range of €25 – 50 million. A High Renewables generation portfolio resulted in the greatest savings from additional interconnection in this report.

EirGrid's results showed that marginal prices on the island of Ireland would be reduced by the addition of smaller amounts of interconnection to the system (500 MW), however, with more interconnection, the picture was mixed and EirGrid stated it was 'difficult to draw a conclusion'. The only results presented with respect to marginal price in this report were estimated marginal price in

€/MWh for the Base Case scenario for the year 2015. These results were only presented in graphical form, however we can read from the graph reproduced in Figure 2.1 that when 500 additional megawatts are added to an existing installed 500 MW (representing Moyle), Marginal price drops from approximately 61 €/MWh to 60.28 €/MWh. Thus we can infer that the 2009 EirGrid feasibility study projected a drop in marginal price of just 1.2% attributable to the increased 500 MW East West Interconnector.

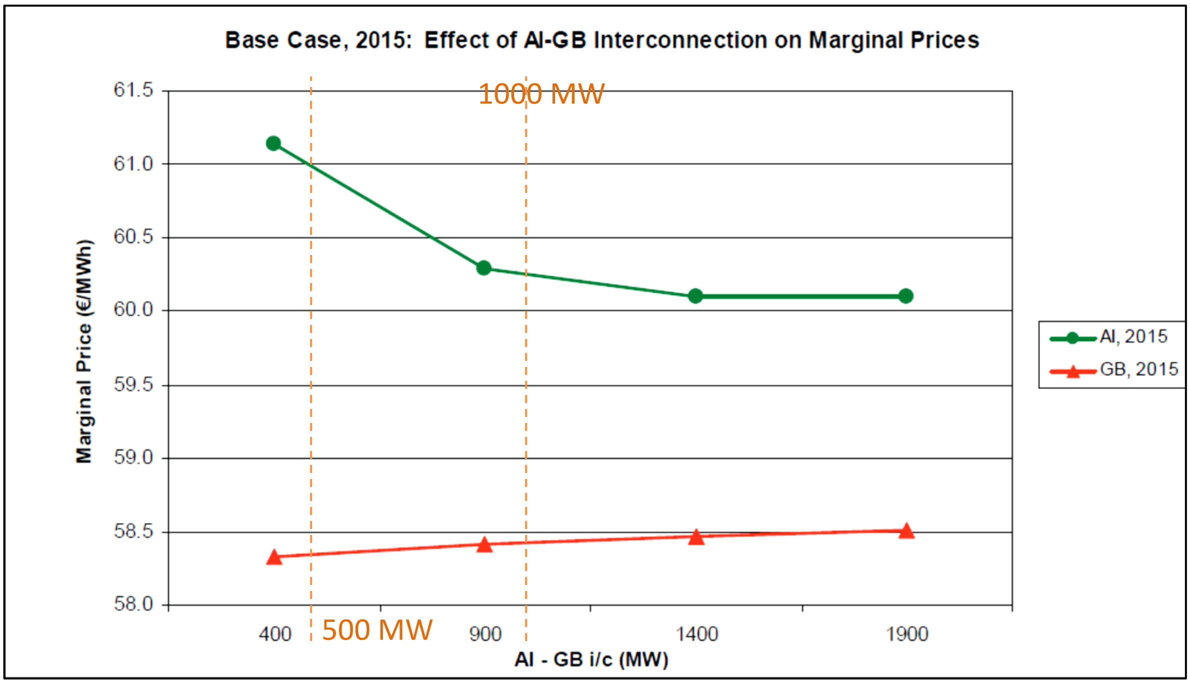


Figure 2.1Effect of additional interconnection on marginal price in 2015, Original graph (EirGrid, 2009), lines representing 500 MW and 1000 MW added to illustrate impact of Moyle and East West Interconnectors.

In the same year, Pöyry Energy Consulting included an Interconnection Sensitivity Analysis as part of their multi-client study 'Implications of Intermittency'.

A 'Base Case' scenario with one interconnector (Moyle) at 400 MW import and export capacity and a second interconnector (the proposed EWIC) at 1 GW was compared with a 'Lower Interconnection' scenario where export on Moyle was reduced to 80 MW and EWIC capacity was reduced to 500 MW both ways.

The impact on GB prices was negligible, however the modelling predicted 200 more periods annually of zero or negative prices and 400 more periods of €0 – 20/ MWh prices in the SEM in the core scenario when compared with the 'lower interconnection' scenario. Overall, monthly and annual prices in the

SEM were found to be 1% higher in 2015 and 5.3% higher in 2025 in the 'lower interconnection' scenario. The report asserted that this was the result of 'stranded wind'. These results do not tally with EirGrid's 2015 projections presented in Figure 2.1 which indicate a drop in marginal price of just 0.3% when AI-GB interconnector capacity is increased beyond 900 MW.

The assumptions underlying all three of these reports have been challenged.

Both the ESRI and the Pöyry studies assumed perfectly functioning interconnectors at full capacity and EirGrid's study assumed flows when there were price differences at both ends of the interconnector. However, a SEM Committee paper *'Short to Medium Term Interconnector Issues in the SEM'* produced later that year indicated that these assumptions did not reflect reality.

This SEM paper was prompted partly by a perception that use of the Moyle Interconnector had changed significantly after the market restructuring which occurred in November 2007 and partly by a concern that the rules governing its use were contributing to security of supply concerns. The paper recognised that flows in both directions across Moyle had not responded as fully as they might have to price arbitrage opportunities between the SEM and BETTA and identified a number of reasons why this might be the case. These issues included the availability of capacity on Moyle and its cost, the risks created by the misalignment of the SEM and BETTA (e.g. gate closure and ex-post pricing), the lack of liquidity in the day ahead markets and network charging in GB (SEM Committee, 2009).

While the addition of 500 MW of installed interconnector capacity helped address the availability issue highlighted in this report and some progress has been made in terms of regulatory changes, for example, the introduction of a 'within day' gate window, many of the fundamental issues hindering economic use of the interconnector raised in this paper persist.

Denny et al. (2010) also found that an increase in interconnection should reduce average price, this time, in a context of high penetration of wind. The results published in the journal *Energy Policy* in a paper entitled 'The Impact of Increased Interconnection on Electricity Systems with Large Penetrations of

Wind Generation: A case study of Ireland and Great Britain' also suggested that increased interconnection would reduce price variability in this context.

This study utilized a stochastic unit commitment model to simulate the impacts of increased interconnection for the island of Ireland with large penetrations of wind generation. A number of scenarios were modelled. The base case assumed 1000 MW of interconnection, Scenario 1 assumed an increase to 2000 MW coupled with a significant increase in wind penetration on the GB system (representing a growth in wind in similar proportion to that assumed in the Irish system). Scenario three modelled the impact of intra-day trading on the interconnector, with an installed capacity of 2000 MW.

The results of the price analysis are indicated in table 2.2 below.

Table 2.2 Average SMP results from Denny et al 2010 study, Source (Denny, et al., 2010)

Scenario	Day-ahead prices		Intra-day prices	
	Average	Std. dev.	Average	Std. dev.
Scenario 1	€59.83	€49.26	€72.81	€62.52
Scenario 3	€51.74	€27.48	€53.49	€32.99
Scenario 4	€52.50	€31.64	€53.23	€32.60

By operating the interconnectors intra-day, the day-ahead prices were reduced slightly while the intra-day prices in Ireland were significantly decreased. This was due to being able to use the interconnectors instead of more expensive peaking units to make up for wind power forecast errors, or unit outages. The variability of prices was also significantly reduced (Denny, et al., 2010)

2.1.2 Analysis Post EWIC Project Completion

Limited analysis of the impact of the Moyle and EWIC on wholesale price post completion of the East West Interconnector has been published.

In Section 6.4 of the All-Island Generation Capacity Statement 2014-2023 published February 2014, results of a study carried out by SEMO are presented.

The study examined the first six months of EWIC operation, effectively rerunning the market schedule for those months and graphing the differential with and without EWIC in full operation. The results are presented in Figure 2.2 below.

According to this analysis, on average EWIC reduced the SMP by 4 €/ MWh, or 8%, for those months (Eirgrid & SONI, 2014). A result substantially higher than the 1.4% difference projected for 2015 in EirGrid's original Feasibility Report (see figure 2.1).

The report did not include the study methodology.

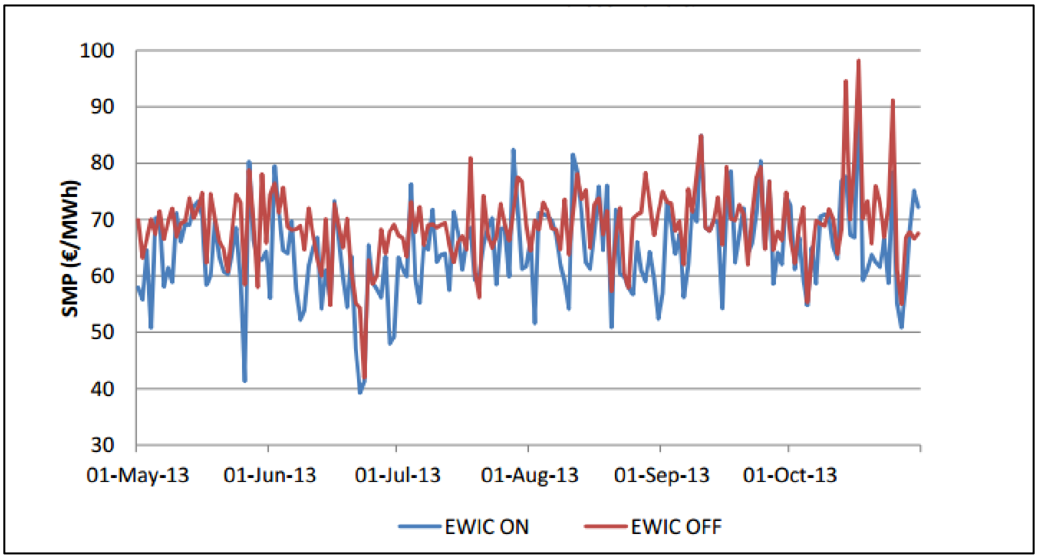
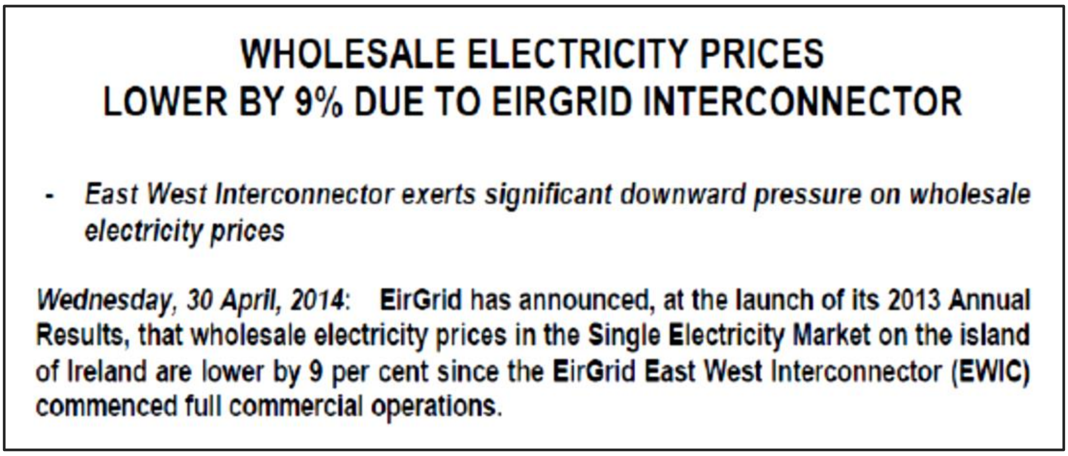


Figure 2.2Results for Load weighted SMP for May - Oct 2013 with and without EWIC as presented in the 2014 All-Island Generation Capacity Statement, Source (Eirgrid & SONI, 2014)

In April 2014, EirGrid conducted their own analysis of EWIC's impact on overall production costs and SMP. These are the only studies of the impact of either the Moyle or East West Interconnector on wholesale price to be undertaken post project completion.

The results were presented in a press release in April 2014, which reported that, for the duration of their analysis, there had been an overall 9% reduction in SMP. Again, this is a substantially greater reduction than pre project projections



WHOLESALE ELECTRICITY PRICES
LOWER BY 9% DUE TO EIRGRID INTERCONNECTOR

- *East West Interconnector exerts significant downward pressure on wholesale electricity prices*

Wednesday, 30 April, 2014: **EirGrid has announced, at the launch of its 2013 Annual Results, that wholesale electricity prices in the Single Electricity Market on the island of Ireland are lower by 9 per cent since the EirGrid East West Interconnector (EWIC) commenced full commercial operations.**

Figure 2.3 Press Release Issued by Eirgrid, Source (EirGrid, 2014)

The analysis was based on a comparison of a base case '*EWIC ON*' scenario representing EWIC being fully available from May 1st 2013 to April 1st 2014 with an '*EWIC OFF*' scenario representing an unconnected AI market for the same period.

The *EWIC ON* base case scenario was built using actual Unconstrained Unit Commitment (UUC) EP2 Gate Window data. Within the Central Market System the unconstrained unit commitment functionality automatically identifies the units, placing them in their relevant market order according to a bid price per MW and production costs as well as demand through the Trading day (SEMO, 2014).

A theoretical UUC was built for the *EWIC OFF* scenario and overall production cost and SMP were compared.

The study analysed economic dispatch only i.e. constraints, reserves or otherwise were not considered. The results showed reductions in production cost and relative average daily savings in SMP of 5.85 €/MWh or 9% on average over the period studied.

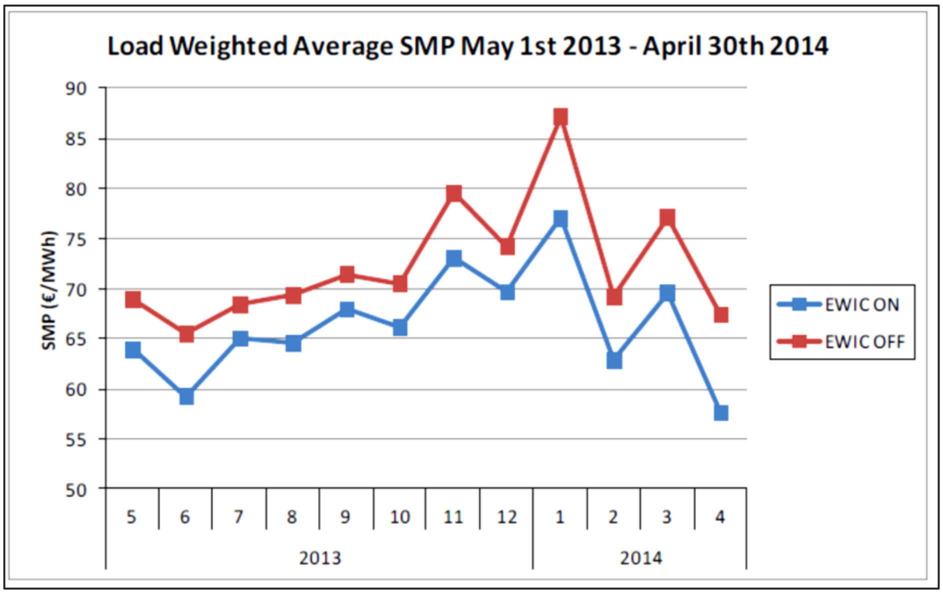


Figure 2.4 EirGrid 2014 Analysis Results, Load Weighted Average SMP May 1st 2013 - April 30th 2014, Source (Campbell, 2014)

To date, no independent analysis of the impact of the EWIC interconnector on production costs or wholesale price based on real data has been published. The assumptions underlying the above study will be further explored in Chapter 6.

2.2 Renewables

Many commentators have highlighted the potential for interconnection to facilitate the integration of wind generation in power systems by increasing system flexibility and balancing variable wind output.

Indeed, a fundamental assumption underlying all of the aforementioned 'Pre EWIC' studies and several subsequent publications is that wind is a driving factor of interconnector flows. Models have been based on the assumption that increased interconnection will allow Ireland to export wind during high wind periods and import power from Britain when wind levels are low, with implications for renewable subsidies, security of supply and renewables targets.

Goreki (2011) in his analysis of the implications of the EU Electricity market in Ireland, reminds us that 'an additional motive for building interconnection is to utilise wind generated electricity in an optimal manner…… In order to ensure wind is not unduly curtailed off the system, interconnection is of vital importance (Gorecki, 2011)'.

Figure 2.5 shows Pöyry's projections for interconnector flows and wind generation in the Irish market for 2030. The flows represented in Figure 2.5 are highly responsive to changing wind output.

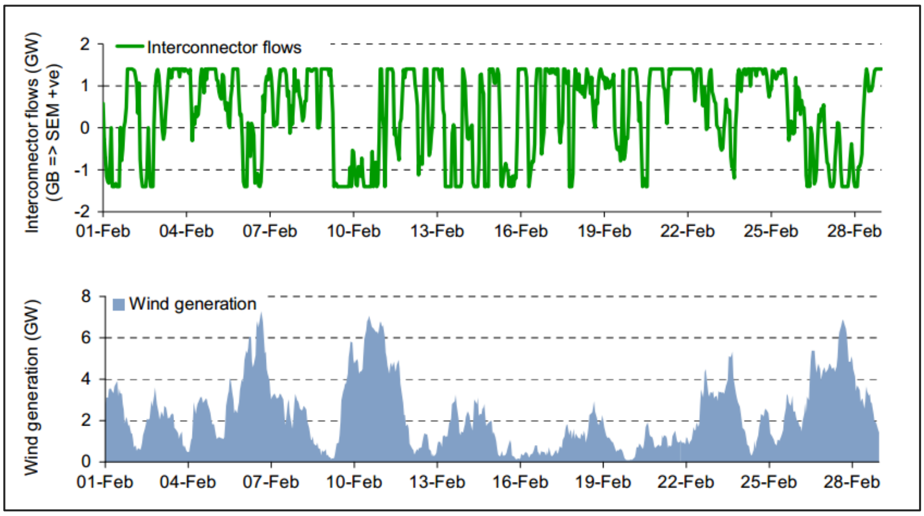


Figure 2.5 Pöyry results, Interconnection flows between markets and wind generation in the Irish market (2030, weather of 2001) Source, (Pöyry Energy Consulting, 2009)

With respect to renewables, the Pöyry study found that more wind curtailment would occur in its 'lower interconnection' scenario, with the number of trading periods of wind loss in Ireland increasing from 61 to 222 in 2020 and from 723 to 1,177 in 2030 by comparison with the core scenario. This would lead to higher carbon emission in the SEM. The Pöyry study concludes that interconnection between Britain and the SEM becomes of critical importance as the volume of installed wind generation increases; observing that the larger the geographical area that installed wind is spread over, the more constant and less intermittent the wind generation becomes.

In EirGrid's 2008 business case for the Interconnector, Environmental benefits with respect to wind curtailment were valued at €10 million per annum and the likelihood that these full benefits would arise, based on the premise of 33% renewable penetration, was reported at 100%. Environmental benefits with respect to reducing the need to carry reserve were valued at €2 million per annum; again with a 100% likelihood that the full benefit would arise. Environmental benefits associated with reduced carbon credit payment were valued at €28 million per annum with a 50% likelihood that the full benefit would arise. These were based on annual total energy requirement figures which have transpired to be much lower than those projected to date.

EirGrid's 2009 Economic Feasibility Report reaffirmed that interconnection would reduce wind curtailment, stating that 'a substantial proportion of the production cost savings derive from reducing wind curtailment on the island of Ireland'.

Diffney et al, in their 2009 paper 'Investment in electricity infrastructure in a small isolated market: the case of Ireland' concluded that investment in interconnection is a sine qua non for high investment in wind, with the former allowing the latter to generate whenever it is available instead of being curtailed at times of low demand. The paper cautioned however that enhanced interconnection between the Irish and British systems must be managed in a manner that will maximise welfare gains, and noted that this issue had not been fully considered by policy makers at that time.

The work of Denny et al. challenged prior studies on the issue of curtailment and emissions. This analysis factored into its model that interconnectors would be scheduled day-ahead, i.e. that operation would be based on forecasted values of load and wind output causing a non-optimal transmission schedule in some operational hours when there were large deviations from the day – ahead forecast.

It was also acknowledged here that the ability to balance variable wind depends on the neighbouring system having spare flexibility, which is likely to be reduced if there is a large amount of wind in both systems.

The results indicated that while increased interconnection improves system adequacy considerably, with a significant reduction in the number of hours when the load and reserve constraints are not met, and reduces the balancing needs for both systems, assuming that they cooperate in providing balancing reserves, it does not reduce excess wind generation.

This was explained by the fact that under unit commitment techniques which incorporate wind power forecasts in the scheduling decisions, wind curtailment is minimal even with low levels of interconnection.

The overall wind production on the Irish system was relatively unchanged in all three scenarios (described in the previous section). Wind curtailment changed from a low level of 23 GWh per annum (0.12% of Irish wind production) in the base case to 30 GWh (0.15%) in scenarios 1 and 2. The cause of the slight increase in absolute terms was the interconnectors being scheduled day –ahead.

The study also covered the impact of interconnection on GB, finding that while increased interconnection may reduce carbon emissions in Ireland, emissions in GB would not be reduced resulting in total emissions remaining almost unchanged although this conclusions does not reflect the impact of the EU-wide Emissions Trading System (ETS) in fixing emission quantities.

Curtis et al in their 2013 paper 'Climate policy, interconnection and carbon leakage: the effects of unilateral UK policy on electricity and GHG emissions in Ireland' have updated and built upon these findings although again ignoring the impact of the EU-wide ETS regime, demonstrating that interconnection enables carbon leakage, particularly if policies relating to the price of carbon are misaligned across countries. The authors used a model of the electricity markets in Ireland and GB to show that GB's Carbon Price Floor would increase both electricity prices and greenhouse gas emissions in Ireland.

Their results suggested the introduction of the CPF would make BETTA generators less competitive compared to the SEM and net exports from the SEM would increase by 154%. Regulations around the Carbon Floor have since been changed meaning these predictions are unlikely to be realised, however, the dramatic results expose the SEM's vulnerability to changes in policy in GB.

EirGrid continue to maintain that the interconnector is facilitating growth in renewable energy. Their 'East West Interconnector –One Year On' report listed 'Facilitating growth in renewable energy' as one of five core benefits.

However, it is possible that they are referring here primarily to TSO Counter Trading as opposed to facilitation of growth in renewable energy by commercial interconnector users. In their 2013 Renewables report, EirGrid group stated that the EWIC is facilitating the increased use of renewable energy by helping to reduce the curtailment of renewables through the use of System Operator trades directly with National Grid Electricity Transmission (EirGrid Group, 2013)

No analysis of the net contribution of the Interconnectors to the facilitation of renewable generation and reduction of emissions in the SEM based on real data has been published to date.

2.3 Impact of Regulatory Decisions in GB on Interconnector Flows

The findings of Curtis et al.'s 2013 paper discussed in section 2.2 indicated the vulnerability of the SEM market to changes in GB policy.

While the impact of the carbon floor on interconnector flows was not as extreme as predicted on account of subsequent changes in policy, the ESRI have more recently published a report (Deane, FitzGerald, Valeri, Tuohy, & Walsh, 2014) that strongly suggests that the wholesale price in Great Britain is much lower than in Ireland and in fact too low to cover long run generating costs making it an unsustainable long-term model.

The study which estimates true costs and price difference for the British model using the simulation tool PLEXOS, finds that the difference between wholesale prices in SEM and BETTA is not driven by technological factors.

BETTA consists of firms that are, for the most part, vertically integrated and therefore have both a generating and a retail function. The study finds that firms in BETTA not making losses as a result of the low wholesale price, as they are compensated by large retail margins. This favours incumbents with established customer bases and makes entry of new generators difficult.

It was also estimated that the cost of supporting renewables per MWh of electricity consumed is much higher in GB than in Ireland, even though renewables account for a smaller share of overall consumption. The report concluded that upward pressure on prices is likely in the future in both jurisdictions, as both aim to increase the share of renewables in electricity generation but that the disparity in subsidy costs across jurisdictions should gradually reduce in size.

In BETTA there has been a dearth of new thermal plants coming online, unlike the SEM where there has been extensive new entry with limited ad-hoc intervention by the regulatory authorities. The report suggests that to encourage new generating plants to come on board, incentives for investment in BETTA must grow, suggesting that the gap between SEM and BETTA wholesale prices will narrow in the future. Their conclusion that some form of remuneration for capacity is inevitable is supported by the literature and policy developments emerging from Ofgem with respect to GB Energy Market Reform.

Changes in the wholesale price in GB and/ or the addition of a capacity payment mechanism are likely influence the ratio of imports to exports across the Moyle and East West Interconnector.

2.4 Literature Review Conclusion

As has been discussed, prior to the completion of EWIC several studies using a range of approaches were undertaken with a view to measuring and assessing the various impacts of interconnection on the SEM.

It would appear that a number of the key assumptions that underpinned this body of work do not reflect the reality of trading since the completion of the EWIC.

According to EirGrid's own recent analysis, EWIC has been much more successful at reducing the wholesale price of electricity in Ireland than was originally anticipated. These results have however not been verified by independent research. This thesis will attempt to determine the margin of error for these results.

As discussed, the net impact of the interconnectors on facilitation of renewables has not yet been formally analysed but the indication from industry responses to the SEM Committees various consultation documents is that the current system does not create conditions favourable for arbitrage trading –i.e. trading that can take advantage of short term price differences, including those as a result of wind. This would indicate that trading is not occurring as predicted in the original analyses. This thesis will attempt to characterise and assess the current patterns of trade across the Moyle and

East West Interconnector. Understanding the trading behaviour of interconnector users should be a vital prerequisite to any future study of interconnector performance and impact.

If it is found that these patterns are sub-optimal, this thesis will attempt to determine what the barriers to optimal trading are and which of the new options being proposed as part of I-SEM can best address them.

3 Trading Across the Interconnector; The Fundamentals

This chapter will begin with an explanation of the SEM and BETTA markets. Their key differences with respect to interconnection are then assessed.

In section 3.4 the process of trading over the interconnectors is outlined, this section draws from published guides to trading and using the Auction Management Platform, Access Agreements for the respective interconnectors and interviews with Market Participants.

The allocation arrangements for Moyle and EWIC currently prescribe that transmission and energy markets are separated. The process of how physical transmission rights are auctioned and traded in advance of energy markets is explained.

3.1 The SEM

3.1.1 How does it work?

The SEM is the wholesale market for the island of Ireland, regulated jointly by the Commission for Energy Regulation (CER) and its counterpart in Belfast, the Utility Regulator. It is structured as a compulsory pool market with capacity payments.

The rules of the all-Island Single Electricity Market (SEM) are detailed in the Trading and Settlement Code (TSC) written by the regulatory authorities in Ireland.

Under the code, all price making generators (with an installed capacity larger than 10 MW) must bid their short run costs into the pool. Electricity suppliers purchase electricity from the pool to cover their consumer's demand for each half hour period throughout the day.

Once generators have submit their bids to the Single Electricity Market Operator (SEMO), an initial software run is conducted to determine a Market

Schedule which forecasts the System Marginal Price (SMP) for each half hour trading period.

The SMP, calculated by the Market Scheduling and Pricing (MSP) software is set by the most expensive generator required to meet supplier demand in a half hour trading period, as illustrated in figure 3.1. All generators who produce electricity in a trading period (that is, all generators including and to the left of the marginal plant in figure 3.1) receive the SEM pool price for that period, which for most generators is greater than their short term cost of producing electricity. Where generator bids are below the SMP, the difference between the price that generator bids into the pool (their short run marginal cost) and the final 'System Marginal Price' all successful generators are paid is referred to as the infra marginal rent. The infra marginal rent, also referred to as the uplift component allows a generator to cover its start-up costs.

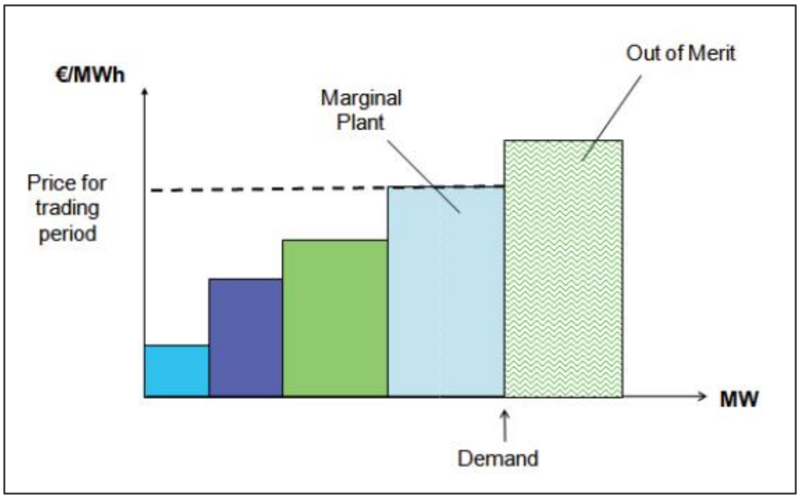


Figure 3.1 Determining the SMP (CER, 2011)

As wind generators do not consume fuel they have no short term costs and hence can bid a zero price to the SEM. As price takers in the SEM, they receive the SMP set by the most expensive generator for their output in that half hour trading period (Clifford & Clancy, 2011).

There are five runs of the MSP Software in respect of each Trading Day; three runs: Ex-Ante One (EA1), Ex-Ante Two (EA2) and Within Day One (WD1) prior to the end of the Trading Day and two after the trading day when accurate data has been received: Ex-Post Indicative (EP1) and Ex-Post Initial (EP2) (CER, 2013).

The final SMP which is paid to generators and by suppliers is calculated by the final SMP software run EP2 which occurs four days after the trading date. The EP2 run which produces this figure accounts for real time factors such as changes in customer demand or wind generation (CER, 2011). This SMP is the energy component of the total cost of producing electricity.

Other market payments are made to generators to ensure that the system has adequate generation capacity in to the future. These payments are called capacity payments. The capacity price and the market SMP price represent the average long term cost of producing electricity in the SEM (Clifford & Clancy, 2011).

In order to maintain a safe and secure power system the Transmission System Operator (TSO) may have to deviate from the generation schedule created by the SEM. This creates additional costs to the system, called Dispatch Balancing Costs, commonly known as constraints costs (Clifford & Clancy, 2011).

The SEM will require significant modifications to implement the Target Model. The magnitude of change required for the SEM to achieve this is considerably greater than most other markets in Europe. This is due to its centralised, gross mandatory pool design which differs in a number of key respects from the prevailing market design in most other European Member States (Northern Ireland Authority for Utility Regulation, 2013).

3.1.2 Key Parties from an Interconnector Perspective

The Trading and Settlement Code (TSC) describes how trading is carried out on the island of Ireland and includes rules around how trading should take place across the interconnectors within the SEM.

The TSC refers to three main parties with respect to the Interconnector; The Interconnector Administrator (IA), The Market Operator (MO) and

Interconnector Units (IUs). The roles of these three parties with respect to the SEM are summarised below;

1. The IA is responsible for the administration of trading between jurisdictions. The designated IA for EWIC and Moyle is the System Operator for Northern Ireland (SONi).
   As IA, SONi facilitates capacity allocation and energy trading on the interconnectors via the *Auction Management Platform* (AMP) which is compatible with both SEM and BETTA arrangements. The AMP is a computerised system that provides the necessary mechanisms and outputs to facilitate trading across Moyle and EWIC. The AMP is currently hosted by UNICORN systems in the Czech Republic.

2. The MO represents any party or system that manages the market place. The Single Electricity Market Operator (SEMO) is the designated market operator for the All Island SEM.

3. Interconnector Units (IUs) or Interconnector Users represent any party that trades on the interconnectors via the SEM. Each Interconnector User must register a single Interconnector Unit, which is the entity against which the user trades in capacity and energy.

EirGrid and SONI are the respective *System Operators* for Ireland and Northern Ireland and the Commission for Energy Regulation (CER) and Northern Ireland Authority for Utility Regulation are the respective *Energy Regulators*.

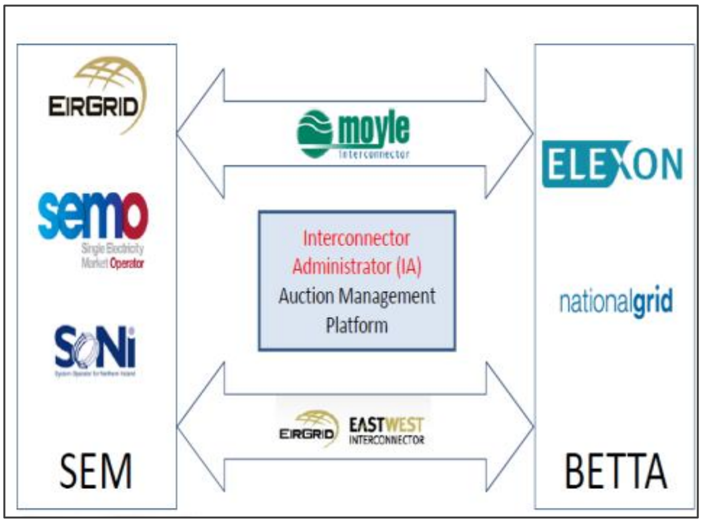


Figure 3.2 Graphic of EWIC and Moyle Interconnector Stakeholders, Source (CER, 2013)

3.2 BETTA

3.2.1 How does it work?

The British Electricity Trading and Transmission Arrangements (BETTA) is the wholesale electricity market operating in Great Britain.

It operates as a bilateral trading market between generators, suppliers and energy traders. The trading process is summarised below.

Futures and Forwards Market

'Over the counter' bilateral trades between sellers and buyers constitute the majority of trading within the BETTA market.

The Grid Trading Master Agreement is the standard contract on which BETTA trades are based.

Power Exchange

The Power Exchange gives electricity suppliers and customers the opportunity to fine tune their position as more accurate information becomes available about their demand requirements.

Gate Closure

The power exchange closes one hour before real time operation. This is known as gate closure. At this point, all participants must submit their final physical notification of their forecast of expected demand or supply to the system operator.

Following this, bids (to reduce generation or increase demand) and offers (to reduce demand or increase generation) can then be submitted to the System Operator (National Grid).

Balancing Mechanism

The balancing mechanism allows the System Operator to ensure that the systems balance during each half hour of real time operation. The bids and offers submitted at gate closure are used to achieve this. The Balancing Mechanism operates from gate closure until real time operation. Should a participant be out of balance at gate closure, they will be subject to the imbalance cash-out price. The penalties for imbalance are high and, as such, this mechanism is seen within the industry as a last resort (HM Revenue & Customs, 2012).

Settlement

Settlement takes place post real time operation. This is where the system operator calculates the participant's settlement.

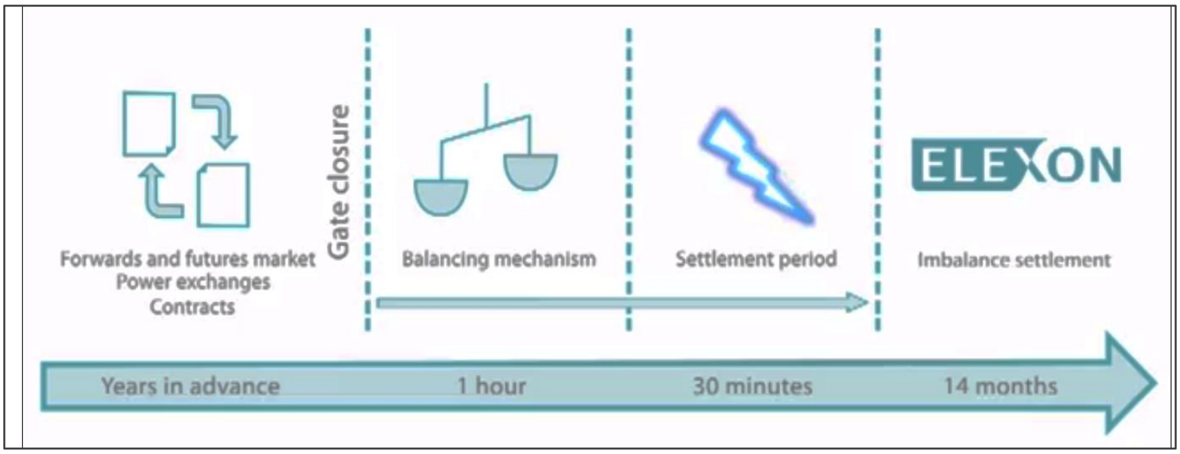


Figure 3.3 Trading and Settlement Timeline following hourly Gate Closure (Elexon, 2013)

National Grid (NG) is the *System Operator* for GB and the Commission for Regulation and Office of Gas and Electricity Markets (Ofgem) acts as *Energy Regulator*.

3.2.2 Key Parties from an Interconnector Perspective

The Balancing and Settlement Code (BSC) describes the trading arrangements for Great Britain and requires formal interfacing roles to be undertaken by the Interconnector Administrator (SONi, 2014). The company Elexon administers the BSC and provides and procures the services needed to implement it.

Under the BSC, the IA (who is the same for both the SEM and BETTA) is responsible for the administration of trading between jurisdictions including management and settlement of IC power imbalances in GB.

The IA must submit 'Physical Notifications' (PNs) to the Transmission Company on behalf of participants as well as submitting energy allocations to the Market Operator.

3.3 SEM Vs BETTA; Summary of Market Differences

3.3.1 Pricing and Price Visibility

In the SEM, all generators and suppliers receive and pay the same wholesale price for electricity, the SMP. In BETTA, the price of power purchased through bilateral contracts is generally not disclosed. The price of power sold through power exchanges is set by the most expensive unit cleared, and these prices are publicly available (Eirgrid & SONI, 2014).

In BETTA, participants know what price they will pay or receive for power in advance of delivery. In the SEM, the final price is calculated after actual power delivery to account for unforeseen changes such as generator failure, changes in wind or demand forecasts, etc. For this reason, participants do not know the final price until four days after the power has been delivered.

3.3.2 Capacity Payments

As outlined above, all generators in the SEM receive capacity payments based on their availability to run. Total payment each year is fixed by the regulators. Interconnector users importing into the SEM receive SMP and Capacity Payments based on flows. Interconnector Users exporting out from SEM pay SMP and Capacity Payments based on flows (Lawlor, 2012). Capacity payments do not exist in GB as of yet, and so these extra payments tend to increase the price differential between the two markets, making it more attractive to import to the SEM from BETTA (Eirgrid & SONI, 2014).

However, the British Government is attempting to deal with the issue of future supply shortages by promoting investment into electricity generation through an initiative known as 'Electricity Market Reform' (EMR). A key component of EMR is the introduction of a capacity market.

The structure of these capacity payments is currently under consultation, and it is uncertain how this might affect trading between the two markets (Eirgrid & SONI, 2014).

3.3.3 Generation by Fuel Type

Figure 3.4 illustrates SEM and BETTA generation portfolio composition.

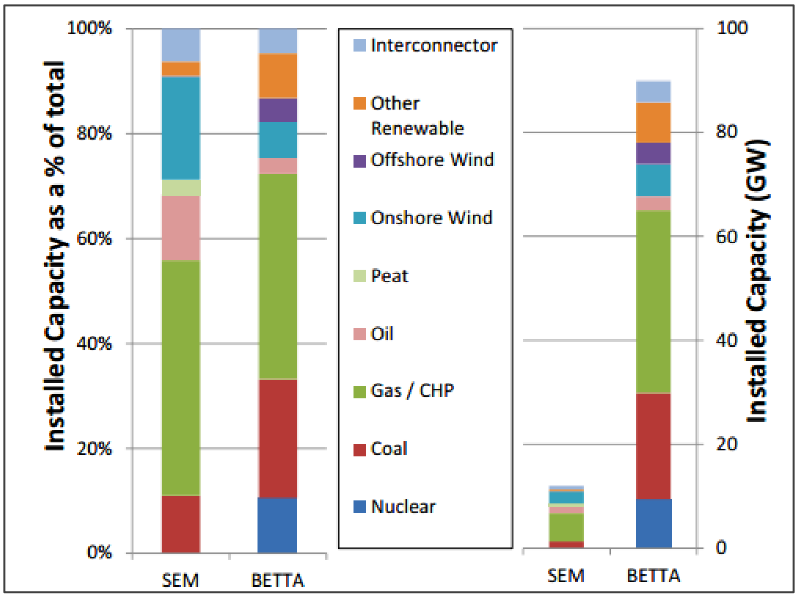


Figure 3.4 Comparison of the generation in both regions by fuel type, Source: (Eirgrid & SONI, 2014)

The most striking differences in plant portfolio between the two markets are 1) BETTA's higher proportion of coal plant and 2) their significant level of nuclear generation. The price of coal is currently low compared to gas, and nuclear power plants have a low short-run marginal cost. This tends to result in a lower cost of generating electricity in BETTA relative to the SEM. In addition, most gas in SEM is transported through the UK and as such is more expensive, further increasing the difference in generation costs between the two regions (Eirgrid & SONI, 2014).

3.3.4 Forecasting Future Flows

As outlined in the literature review, prices in BETTA have to date on average been lower than those in the SEM, particularly once capacity payments are included. This is illustrated in Figure 3.5, which compares 2013 prices from the two regions. The price difference is negligible at night time and is most noticeable around the evening peak, when uplift tends to form a larger component of the SMP.

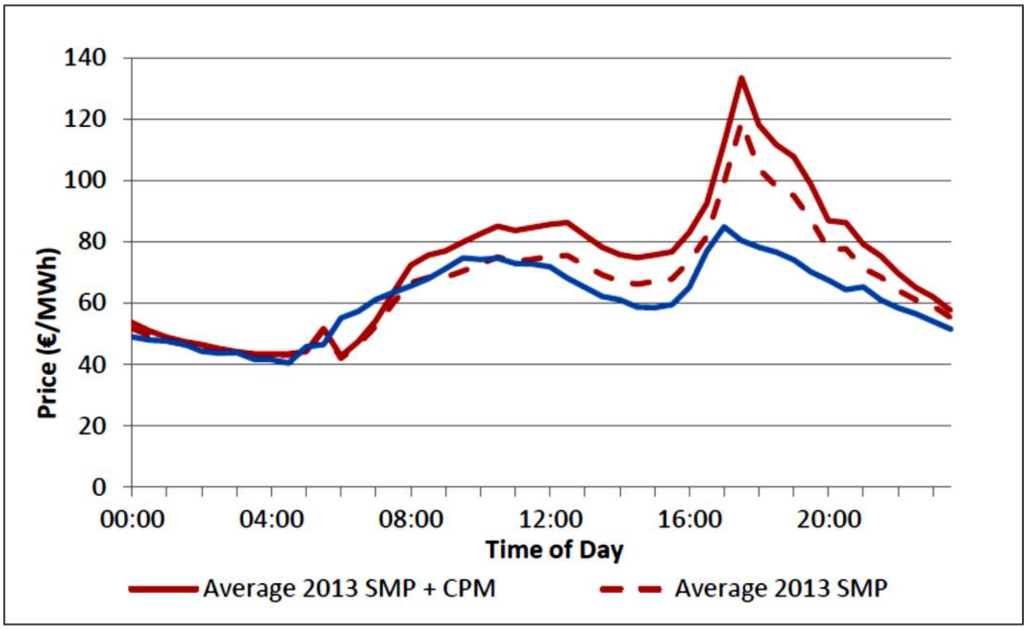


Figure 3.5 Comparison of the SMP in SEM and APX prices (which represent the opportunity cost of power in BETTA) FOR 2013. SMP values are shown with and without capacity prices added on. Source: (Eirgrid & SONI, 2014)

As outlined in the literature review, it is possible that this price difference may shrink over the coming years.

The introduction of the Carbon Price Floor in Britain in 2013 is leading to increasing generation costs for fossil fuel power plants in BETTA. The closure of old plant and plant not compliant with emissions directions in the coming years may compound this. Deane et al. (2014) argue that the wholesale price in Great Britain is in fact too low to cover long run generating costs making it an unsustainable long-term model.

3.4 Trading Across the Interconnector

3.4.1 Why and How to Trade Across the Interconnector

In order to become an interconnector user, candidates must complete the User Agreement Form and Interconnector Administration Deed for the relevant interconnector.

Additionally, they must register to trade in the SEM and BETTA and register with the Auction Management Platform (AMP) as well as registering for an Energy Identification Code which allows users trade within the different European energy markets.

A list of all currently registered Interconnector Units is included in Appendix A.

Broadly speaking, the EWIC and Moyle Interconnectors are used by participants in two ways.

3.4.1.1 Hedging using Explicit Auctions

Firstly, and most commonly, the interconnectors are used by participants to provide hedging opportunities for their existing portfolio positions in the SEM and BETTA market.

In order to purchase and flow energy across the EWIC or Moyle interconnector, an IU must first purchase the right to flow that energy across the interconnector, this means buying capacity. Explicit Capacity auctions are held on the Auction Management Platform. The AMP is a computerised system that provides the necessary mechanism and outputs to facilitate trading across the interconnectors. Here market participants can purchase the right to utilise capacity on the interconnector from one day up to one year ahead of the delivery day.

For example, an IU may purchase a seasonal product for a specified quantity of MW for October – March of the following year. This gives the IU the right to flow the agreed amount of electricity across the interconnector for that period of time.

Once capacity has been secured, the user can then enter a contract to purchase or sell an agreed quantity of energy from the other market (either directly with another participant or via an anonymous platform in GB such as

Trayport) at a fixed price for a period in the future; thus reducing their exposure to future price fluctuations in the wholesale market.

The 'Capacity Products' available via explicit auction are illustrated in Figure 3.6.

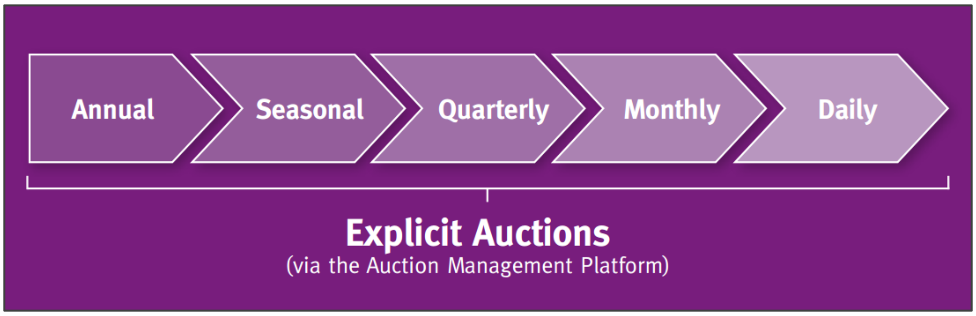


Figure 3.6 Explicit Auctions, Source (EirGrid, 2014)

These 'capacity products' are auctioned throughout the year at predetermined dates. The tranches of capacity auctioned differ for each trading product and direction. A marginal pricing methodology is applied and all successful applicants pay the auction clearing price for capacity.

The screenshot below illustrates what fictional auction participant 'X_Trade' would see following evaluation of an auction to flow energy across Moyle from Northern Ireland to GB from 6am on the 1st of September 2011 to 6am on the 1st of October 2011. There were two participants in this auction and X_Trade made three of the four bids submitted; one for 40 MW at 1.20 GBP/ MWh, one for 50 MW at £1.10 /MWh, and one for 10 MW at £1.00 /MWh. The auction price was evaluated by the AMP system to be 1.10 GBP/ MWh and so the first bid was accepted, the second partially accepted and the third rejected.

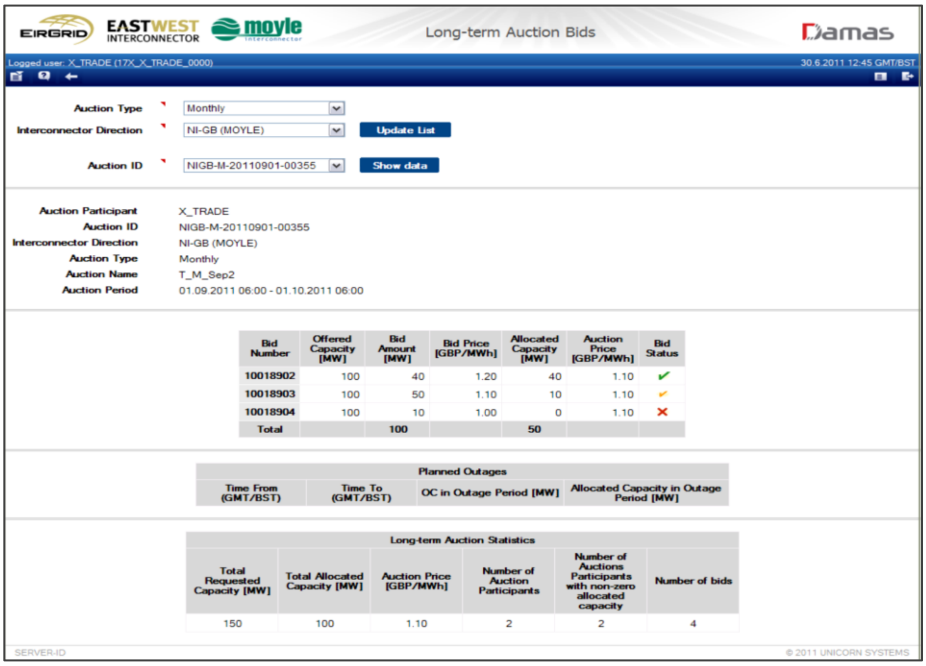


Figure 3.7 Long-term Auction Bids –After Evaluation Auction, Source (UNICORN Systems, 2010)

Figure 3.7 taken from the common FUI portal illustrates the overall results from an auction for 'EWIC Monthly Import' Capacity. The total allocated capacity for this auction was 50 MW. Seven participants bid a collective capacity of 342 MW; the price curve illustrates the spread of price quantity bids. The marginal price to meet the total allocated capacity of 50 MW was €8.13. The three successful applicants who had bid at or above this price paid the auction clearing price and secured the capacity.

Figure 3.8 Auction Results Source (FUI, 2014)

3.4.1.2 Proprietary Trading and Implicit Auctions

Capacity may also be purchased via Implicit Auctions. Implicit auctions allow market participants to purchase capacity and the associated energy on Moyle or the EWIC in one transaction for individual 30 minute interval periods of the trade day.

These auctions are run by SEMO as part of the inter-day market runs (Ex Ante 2 and Within-Day 1). Market participants submit price-quantity pairs directly to the SEM system. Unlike explicit auctions which are used for hedging purposes, trading at the EA2 and WD1 stage is done to capture real time price differences. This is referred to as 'proprietary trading' and is still relatively uncommon across the East West or Moyle Interconnector.

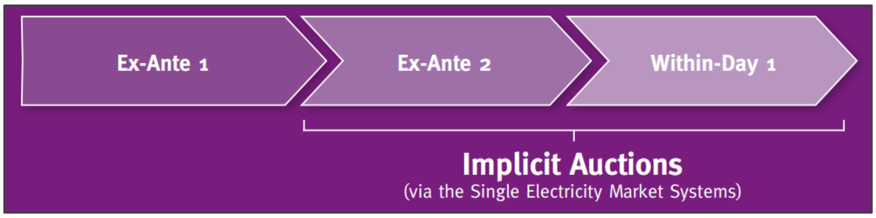


Figure 3.9 Implicit Auctions, Source: (EirGrid, 2014)

The EA1 run is not an auction for interconnector capacity. Market participants must however submit bid prices per trade interval to secure the energy corresponding to their explicit EWIC capacity holdings.

Any residual capacity on the EWIC after the SEM Ex-Ante 1 run is made available to market participants in the subsequent EA2 intraday auction. This auction covers the full SEM trade day (06:00 – 06:00) (EirGrid, 2014).

Any residual capacity on the EWIC after the SEM EA2 run is made available to market participants in the subsequent WD1 intraday auction. This auction covers a twelve hour period within the SEM trade day from 18:00 – 06:00 (EirGrid, 2014).

Given that the final SMP is not known until four days after trading day, participants engaging in this type of trading must have an understanding of how SMP is derived and an ability to estimate future spikes and troughs. There is less uncertainty around the wholesale price of electricity in GB.

An example of a company's trading for one day (6:00 to 01:00 only shown due to space constraints) across multiple gate windows is illustrated in figure 3.10.

As shown, the Company had secured 100 MW of import capacity via explicit auction. Typically, once this capacity has been secured, the company will purchase the associated energy from an anonymous GB power exchange for the periods when they wish to use their capacity. This company used their full 100 MW import capacity for every half hour period shown. The company will typically deliver this energy to a supply company in Ireland with whom they have a Contract for Difference.

When the opportunity arose to purchase further capacity for certain half hour periods at the EA2 gate window, the company entered bids and secured 40 MW import capacity and 120 MW export capacity. We can assume this was because the capacity was available cheaply and that the export capacity was purchased because it was expected that SMP might be lower than the GB wholesale price at night. The 120 MW export capacity was used (by purchasing the allocated quantities of energy for the relevant time periods) from midnight on.

Finally, at the WD1 auction, a further 55 MW was imported between 11:30 and 15:00, 70 MW between 18:30 and 21:00 and 50 MW was exported between midnight and 5am.

The resulting combined metered generation is illustrated in the graph which shows net imports from 6:00 to 00:00 and net exports from midnight.

EA - 8am

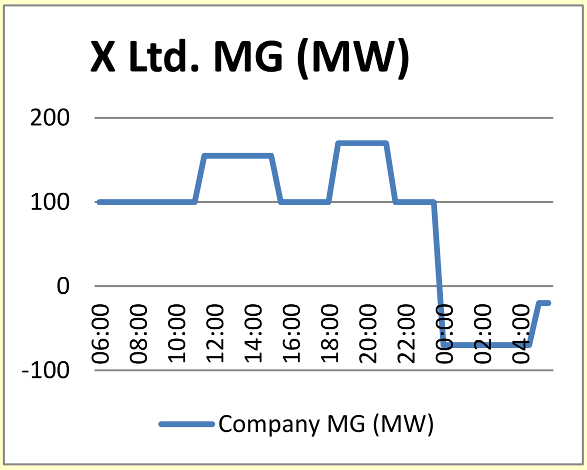
Participant	PT_4000XX
Import Capacity:	100
Export Capacity :	0

WD - 9am

Available Import	40
Available Export	200

EA2 -11am

Available Import	140
Available Export	200



Time	EA1 MIUN	EA2 MIUN	WD MIUN	X_Ltd. MG (MW)
06:00	100	0		100
06:30	100	0		100
07:00	100	0		100
07:30	100	0		100
08:00	100	0		100
08:30	100	0		100
09:00	100	0		100
09:30	100	0		100
10:00	100	0		100
10:30	100	0		100
11:00	100	0		100
11:30	100	0	55	155
12:00	100	0	55	155
12:30	100	0	55	155
13:00	100	0	55	155
13:30	100	0	55	155
14:00	100	0	55	155
14:30	100	0	55	155
15:00	100	0	55	155
15:30	100	0		100
16:00	100	0		100
16:30	100	0		100
17:00	100	0		100
17:30	100	0		100
18:00	100	0		100
18:30	100	0	70	170
19:00	100	0	70	170
19:30	100	0	70	170
20:00	100	0	70	170
20:30	100	0	70	170
21:00	100	0	70	170
21:30	100	0		100
22:00	100	0		100
22:30	100	0		100
23:00	100	0		100
23:30	100	0		100
00:00	100	-120	-50	-70
00:30	100	-120	-50	-70
01:00	100	-120	-50	-70

Figure 3.10 Illustration of a theoretical company's trading for one day (06:00 to 01:00 only shown due to space constraints)

3.4.2 The Rules

EWIC is owned and managed by EirGrid Interconnector Ltd. (EIL) and Moyle by Moyle Interconnector Ltd. (MIL), part of Mutual Energy. The Interconnector Owners are required to prepare relevant access arrangements in respect of the interconnectors. The access arrangements are the agreed rules that need to be adhered to when auctioning and using capacity on the interconnectors. The published access arrangements detail the following information;

1. The procedures for auctioning rights to use interconnector capacity
2. The terms on which users may participant in auctions and
3. The terms for use of interconnector capacity.

In accordance with EU legislation the full transmission capacity of the interconnectors is made available to market participants so that energy can be imported or exported as market prices dictate, for the benefit of customers in AI and Great Britain (EirGrid, 2014).

3.4.3 MO and IA Responsibilities

The Available Transfer Capacity of an Interconnector is determined by the IA and is notified to the Market Operator by 10:00 two days before the trading day (TD-2).

The IA must then submit the Active Interconnector Unit Capacity Holding Data for each Interconnector Unit prior to the EA1 Gate Window Closure that is consistent with the Interconnector Available Transfer Capacity (ATC) in each direction.

Following the completion of each EA1, EA2 and WD1 MSP Software Run the Market Operator shall:

- Determine Interconnector Unit Nominations for each Interconnector Unit and for each Interconnector based on the relevant inputs (including Commercial Offer Data, Interconnector Technical Data and, in the case of the EA1 MSP Software Run only, the Active Interconnector Unit Capacity Holding).
- Calculate the Modified Interconnector Unit Nominations (MIUNs), separately for each Interconnector in accordance with the relevant rules.

- Submit Aggregate Modified Interconnector Unit Nomination (AMIUNs) to the relevant System Operator. AMIUNs represent aggregate import and export MW values per Trading Period over each Interconnector registered (CER & NI Utility Regulator, 2014).

3.4.4 System Operator Trading

Once the market has closed the SOs may initiate changes to the interconnector schedules via SO counter trading for reasons of system security or to facilitate priority dispatch generation (as directed in SEM Committee Decision paper SEM-11-062).

The ability to counter trade is carried out in accordance with commercial parameters approved by the Regulatory Authorities (RAs); any relevant system limitations; and the availability of a counter party to give effect to any potential trade (EirGrid, 2014).

In the past counter-trading on Moyle has been successfully used to alleviate curtailment of priority dispatch generation. EirGrid is already engaged in System Operator to System Operator (SO-SO) trading on EWIC with National Grid UK to alleviate curtailment (EirGrid, 2014).

In addition to this, EirGrid is pursuing options which will allow a greater level of SO counter trading.

Discussions with National Grid UK and the RAs have taken place. Three potential enhanced SO counter trading models are being explored at present:

1. EirGrid and SONI trading directly on a UK Power Exchange;
2. An agent trading on EirGrid and SONI's behalf;
3. EirGrid and SONI trading bilaterally with market participants (EirGrid, 2014).

3.4.5 Interconnector Administrator Trading

The interconnector administrator can also engage in trades on the interconnector for balancing purposes. This constitutes a very small portion of total flows across the interconnector as outlined in Figure 6.18 in Chapter 6.

4 I-SEM and the Internal Energy Market; Implications for Interconnection

4.1 Regulatory Framework

A group of directives and regulations known as the Third Energy Package together with associated Framework Guidelines and Network Codes form the cornerstone of the Internal Energy Market, which Ireland and Northern Ireland have committed to achieving by 2016 (EirGrid & SONI, 2014). Interconnection provides the physical infrastructure necessary for this Internal Energy Market to function.

A parallel and complementary development, *Regional Electricity Markets* (REM), part of the *Electricity Regional Initiative* (ERI) has created several regional electricity markets as an interim step to creating the single market. Ireland belongs to the France-UK-Ireland (FUI) regional electricity market.

4.2 An EU Target for Installed Interconnector Capacity

The European Council have long held the view that low levels of interconnection have the effect of fragmenting the European Electricity market and are an obstacle to both the development of competition and uptake of renewable energy. In March 2002 The European Council agreed on a level of interconnection between Member States of 10% of installed production capacity by 2005. "Eight long years later even this meagre goal remains elusive" said former European Green Party spokesperson Butikofer in 2010.

Determined to accelerate progress, the European Commission adopted a list of 248 key energy infrastructure projects in October 2013. These projects have been selected by twelve regional groups established by the new guidelines for Trans-European Energy Network (TEN-E) (EirGrid Group, 2013).

In March of this year the Council called for 'speedy implementation of measures to meet the target of achieving interconnection of at least 10% of installed electricity production capacity for all member states' (European Council, 2014) and invited the Commission to propose specific interconnection objectives to be attained until 2030. The integrated climate and policy framework to 2030, due to be agreed upon in October 2014, is set to include defined targets for installed interconnection capacity.

4.3 SEM Progress towards the Target Model

While targets for installed interconnector capacity are currently non-binding, the European targets associated with market structure and trading are required by law. These changes are designed to harmonise cross border trading arrangements across all European electricity markets.

The associated new rules will be binding on all EU borders by 2014 and the current SEM is not compliant with these rules.

Because of the significant changes required to the SEM a two year derogation period has been granted to Ireland and Northern Ireland. The new Integrated Single Electricity Market (I-SEM) for the all island electricity market must therefore be compliant with the EU Target Model by the end of 2016 (SEM Committee, 2014).

Aspects of the Internal Energy Market requirements, such as firm day-ahead price coupling and continuous inter-day trading, will have significant impacts on the Single Electricity Market (SEM) arrangements but should, in theory, make it easier to trade across the interconnectors.

The target model does not explicitly prescribe how the national market is to comply with the legislation and so a range of possible new market designs were compiled by a SEM Committee comprising members of the regulatory authorities in Ireland and Northern Ireland plus two independent experts. The Northern Ireland Department of Trade and Industry and the Irish Department of Communications, Energy and Natural Resources provide policy guidance to this SEM Committee.

At a minimum, changes to the high level market design of SEM must provide for the following five pillars by 2016 (as set out in the ACER Framework Guidelines for Capacity Allocation and Congestion Management and the ACER Framework Guidelines on Electricity Balancing):

- Capacity Calculation and zones delimitation including a review of the bidding zones in the SEM and potential interactions with locational signals

- Cross Border Forward Hedging and Harmonisation of allocation rules
- Day Ahead Market Coupling
- Intra Day Continuous Trading
- Cross Border Balancing

In 2012, the SEM Committee first published four new market design options for the SEM which represent different ways of implementing the EU Target Model.

The SEM Committee presented these options in their latest form in February of this year in a Consultation Paper entitled 'Integrated Single Electricity Market; High Level Design for Ireland and Northern Ireland from 2016'. The paper refers to the new wholesale market as the Integrated Single Electricity Market (I-SEM); a title designed to 'recognise the continuity of the existing market while acknowledging the purpose of the new market to integrate more fully with European market arrangements' (SEM Committee, 2014).

The four options presented are

1. The Adapted Decentralised Market
2. The Mandatory ex-post Pool for Net Volumes
3. The Mandatory Centralised Market and
4. The Gross Pool –Net Settlement Market

These options combine different approaches to the following market aspects:

- Participation in European markets for trading of energy in Day ahead and Intra-day timescales
    - Choices pertaining to this aspect of the market design will involve decisions around portfolio vs. unit bidding, Mandatory vs. voluntary and bid format at Day ahead and Intra-day timescales.
- Process for reaching feasible dispatch position
    - Here decisions must be made regarding the starting point of dispatch, bids to the TSO for balancing and dispatch and the timing of bid submissions
- Imbalance/ Pool settlement
- Arrangements for long-term trading; both internal and cross-border

How the four proposed options for I-SEM address each of the above market components is outlined in Appendix B.

At present, Option 3 appears to be the favoured solution. Option 3, 'The Mandatory Centralised Market' emphasises the importance of the Day Ahead Market as the main market for physical trading of energy between market participants. The Intra-Day Market is then the exclusive route for making adjustments. This should, according to the SEM Committee, ensure a high level of trading in these specific markets. Bidding is based on individual generators submissions, which is intended to enhance transparency in the markets. The arrangements for balancing electricity generation and demand involve relatively simple bids for increases and decreases in output (SEM Committee, 2014).

4.4 Key Implications of market changes for Interconnection

The move to I-SEM should impact trade across the interconnector –given that the ultimate goal of the European Target Model is to facilitate more efficient trade. Two of the key areas where changes have been proposed are described below. A detailed description of the proposed options is available from the SEM Committee's I-SEM High Level Design for Ireland and Northern Ireland from 2014 Consultation Paper, available from the All Island Project website.

4.4.1 Market Coupling

Market coupling is a mechanism by which order books from different Power Exchanges and capacity information from corresponding TSOs are centralized and exploited to determine traded volumes, flows and prices (N-Side, 2012).

In simpler terms, it is .an algorithm which takes bids and offers from two (or more) markets at day ahead stage, works out prices for both and schedules interconnector flows to minimise overall cost' (McGuckin, 2014).

4.4.1.1 Price Coupling of Regions

The European Target Model requires optimisation of area and cross-border trades based on implicit auctions. This will be facilitated through Price Coupling of Regions (PCR)

The North-Western Europe (NWE) Price Coupling of Regions initiative (PCR) is an initiative taken by the Transmission System Operators and Power Exchanges of the countries in North-Western Europe to develop a single price coupling solution to be used to calculate electricity prices across Europe and allocate cross border capacity on a day-ahead basis (Nord Pool, 2014). EUPHEMIA is the PCR algorithm that solves optimally the market coupling problem by maximising consumer and supplier surplus and any congestion rent arising from congested cross border links (EirGrid, SONI, SEMO).

The PCR solution went live on February 4th 2014 and the regions currently involved are illustrated in Figure 4.1. As is clear from figure 4.1, the ultimate goal is a pan-European Price Coupling of Day Ahead power market. EirGrid and SEMO are 'associated members' of the PCR which allows them access to the necessary information to keep abreast of developments in the PCR initiative.

The algorithm is quite different from the SEM MSP Software in that it optimises the purchase and sale of energy products (orders) as opposed to optimising the schedule of generation. As such, part of the new I-SEM design will involve implementing bid types that are 'Euphemia-compliant'.

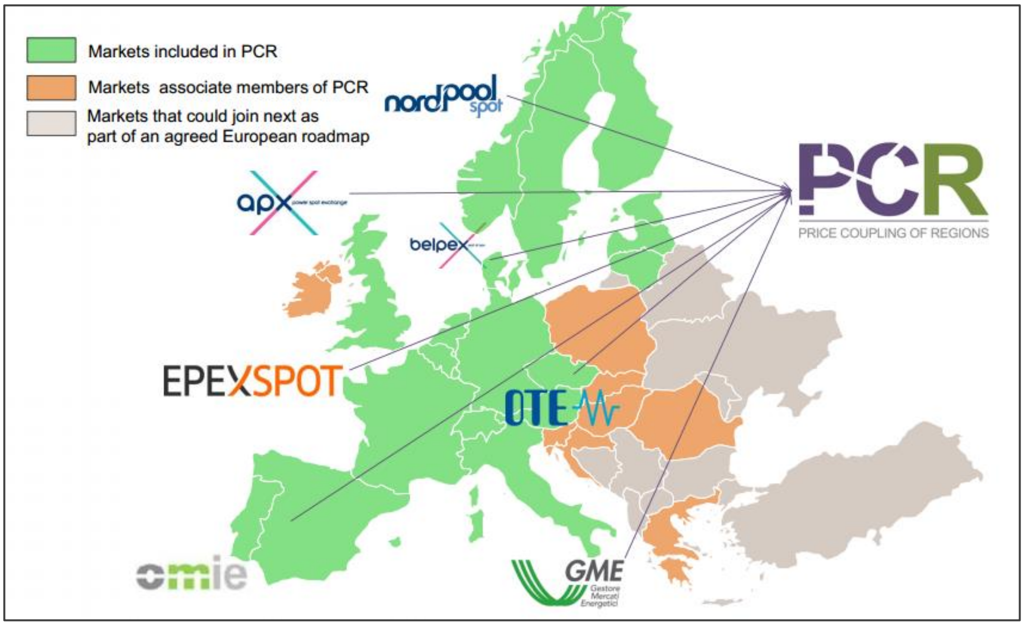


Figure 4.1 Map of Markets included in and associated with the Price Coupling of Regions Initiative

One aspect of this will be to increase the number of gate windows. As outlined in Chapter three, at present there are only two gate windows for implicit capacity allocation (EA2 and WD1). Under I-SEM, this may go to 24 hourly windows or 48 if half hour trading is selected.

4.4.2 Types of Transmission Rights

It has yet to be decided whether physical or financial transmission rights will be implemented under I-SEM.

Physical Transmission Rights (PTRs) represent the current situation. They allow market participants to directly hedge the price and volume risk associated with forward cross-border energy trades. However, PTRs can reduce the amount of physical cross-zonal capacity available for implicit allocation in the day-ahead market which may reduce the effective liquidity of the day-ahead market (SEM Committee, 2014).

A Financial Transmission Right (FTR) does not give the holder a right to physically nominate a flow at the day-ahead stage. Instead they receive the price differential between the two zones for which they hold cross-zonal capacity. FTRs can either be options (in which case the payment to the FTR holder is never less than zero) or they can be obligations (whereby the FTR holder has to make a payment if the price differential is in the opposite direction to their capacity holding) (SEM Committee, 2014).

FTRs allow market participants to directly hedge the price risk associated with forward cross-border energy trades, without reducing the amount of physical capacity available to be used in market coupling. However, they rely on liquid day ahead markets being in place in order to allow the FTR holder to manage its volume risk (i.e. whether or not it will get scheduled) (SEM Committee, 2014).

The type of cross border transmission products (FTRs or PTRs) thus depends largely on the liquidity (and hence the compulsory nature) of the day ahead market (SEM Committee, 2014).

However, as yet no decision has been taken in relation to the proposed future design of the I-SEM and severe criticism has been made of the favoured approach of the SEM Committee by industry and others in responses to its recent consultation on the proposed High Level Design. Industry responses to the consultation can be found at the following address;

http://www.allislandproject.org/en/wholesale_overview.aspx?article=79e244a0-4c06-4729-bd20-92873869df82

5 Methodology

The methodology designed to meet the aims and objectives of this thesis (listed in section 1.3.1) is described in this chapter which is divided into two sections.

Part one outlines the methodology employed for quantitative data analysis. Here data sets and their sources are listed; data collation is explained; analytical tools are described and finally the specific steps taken in the analysis itself are outlined.

Part 2 describes the qualitative component of the study which included an extensive review of published literature; including EU, CER, Utility Regulator, SEM and Ofgem regulations and guidelines, official consultation documents and responses. Stakeholder interviews are also covered in this section.

Both sections begin with a general overview of data sources and analysis techniques used. The approach then taken to answer specific research questions follows. A summary of the specific methodology used to meet each aim and objective is tabulated and presented in Appendix C.

5.1 Part I. Data Analysis

5.1.1 Obtaining the Data

Data for this analysis was primarily acquired from four sources; the dynamic report section of the SEMO website, the apx group website and EirGrid and SONI's Wind Generation data centres.

5.1.1.1 Source 1, SEMO Dynamic and Static Reports

Once registered with the SEMO website, dynamic and static reports covering multiple stages and elements of the market process can be downloaded.

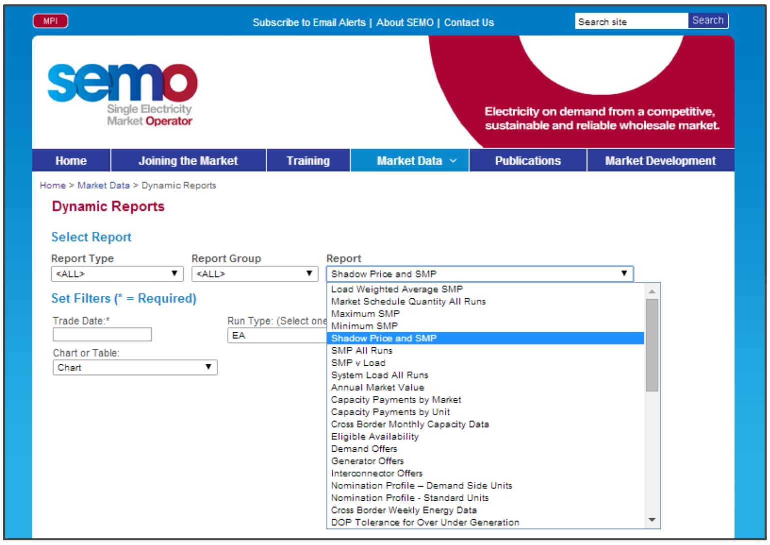


Figure 5.1 Screen shot showing process of selecting data from SEMO's dynamic report database

The following reports were utilised in this analysis. Where the option of selecting a run type was available, Run Type EP2 was selected unless otherwise specified. Run Type EP2 occurs four days after the trading date.

5.1.1.1.1 Registered Units

A list of Registered Generator Units as of 28/05/2014 was downloaded from the 'Joining the Market' section of the SEMO website. This list contains details of the Associated account (ID and Name combined), TS_ID, Unit ID, Unit Name, Unit Type, Registration Status and Final Effective Date.

Figure 5.2 Location of registered units on SEMO website

Data from SEMO's Registered Capacity Report was also utilised. This report lists generator units and includes details registered capacity of that unit, the resource type, fuel type and jurisdiction, and the account with which that generating unit is associated with.

In the Registered List of Generator Units, Interconnector Unit IDs are presented in the following format; Participant ID_I_Resource Name_Gate Window. For example,

PT_500032_I_NIMOYLE_EA

Where PT_500032 represents the Interconnector Participant Viridian Energy Supply Ltd (determined from the Registered Capacity Report), 'I' indicates this is a registered Interconnector Unit, NIMOYLE indicates that this unit is used for trading across the Moyle Interconnector and EA indicates it is used for trading at the EA Gate Window (for an explanation of Gate Windows see Chapter 3) .

5.1.1.1.2 Interconnector Flows

Flows of electricity across the interconnector are available from the SEMO database in a number of formats. The following two datasets were primarily employed:

Interconnector Flow

Interconnector Flow data presents Metered Generator data for the interconnector characterised by Unit ID (which, as outlined above includes information on the participant, on which interconnector the trade took place across and on the Gate Window associated with this trade), Meter Type, Run Type, Trade Date and Delivery Date, hour and interval.

Interconnector Administrator and Transmission System Operator Flows are included here. Given that this dataset presents Metered Generation, Run Type is always EP2.

Modified Interconnector Unit Nominations

MIUN data is presented in MW and categorised by participant name, resource name, run type, trade date, delivery date, delivery hour and delivery interval when downloaded from the SEMO website.

The Market Schedule Quantity for each Interconnector Unit in the EA1 software run is fixed into an *Initial Interconnector Unit Nomination* representing the quantity nominated for import or export for each IC unit.

These IUNs are subsequently adjusted to take into account factors such as IC Dead bands between minimum import and minimum export to produce the *Modified Interconnector Unit Nomination* (MIUN) for each IC unit in each Trading Period (CER, 2013).

Any further capacity on the Interconnector can then be allocated based upon the offers from IUs for the EA2 Gate (performed 13:00 D-1), such allocation is again fixed into MIUNs for those Units.

The remaining capacity (if any) can be allocated to Interconnector Units which make Offers for the WD1 Gate (09:30 D trading window is second half of day (after 18:00) only) (CER, 2013).

Thus if an interconnector has imported and/ or exported flows across the interconnector using multiple gate windows (as illustrated in figure X – Chapter 3) these will be represented in the Market Schedule Quantity as separate MIUNs.

MIUN data does not contain information on Interconnector Administrator or Transmission System Operator Flows. In summary, they represent the final quantity of electricity all commercial interconnector users pay or are paid for.

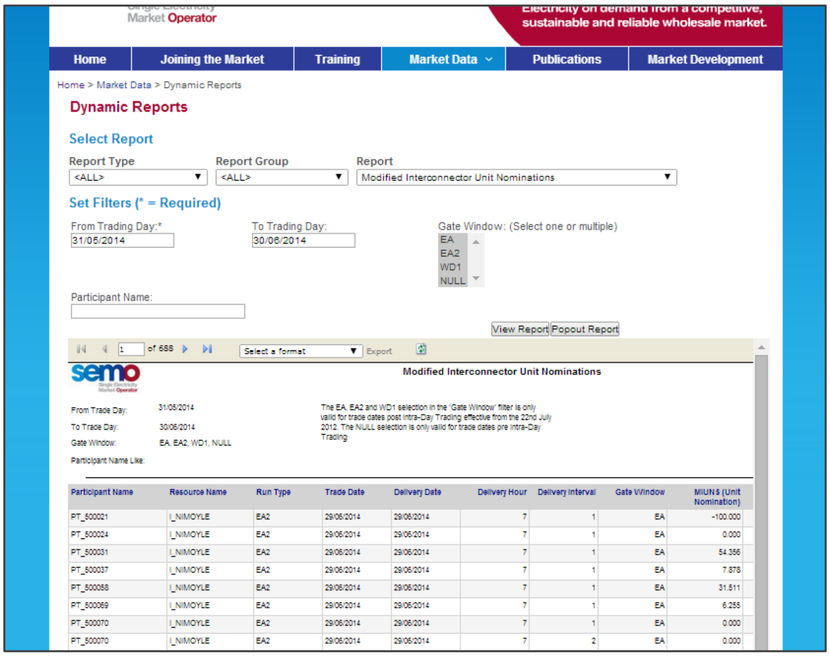


Figure 5.3 Screenshot of Modified Interconnector Unit Nomination Dynamic Report, SEMO website

5.1.1.1.3 Shadow Price and SMP

SMP represents the energy component of the total cost of producing electricity. As outlined in Chapter 3, the final SMP, paid to generators and by suppliers, is calculated by the EP2 software run. Data is classified by Trade Date, Run Type, Currency, Delivery Date, Delivery Time (in the form hh:mm, GMT), SMP and Shadow Price. Shadow price data was not utilised in this analysis.

5.1.1.2 Source 2, GB Power Exchange Data

Given the differences in market structure between the GB and AI systems (described in Chapter 3) there is no single figure comparable with AI SMP in the GB market.

However, power exchanges, which constitute a small portion of trading in GB represent an indication of wholesale price according to the BSC Administrator, Elexon (Elexon, 2013). Reference price data from the apx Power exchange has been employed here. The methodology used to establish the Reference Price Data (RPD) indices for the APX Power UK Spot market is available on the apx group website. The units used are GBP and the data is presented in a date-time interval matrix for each year.

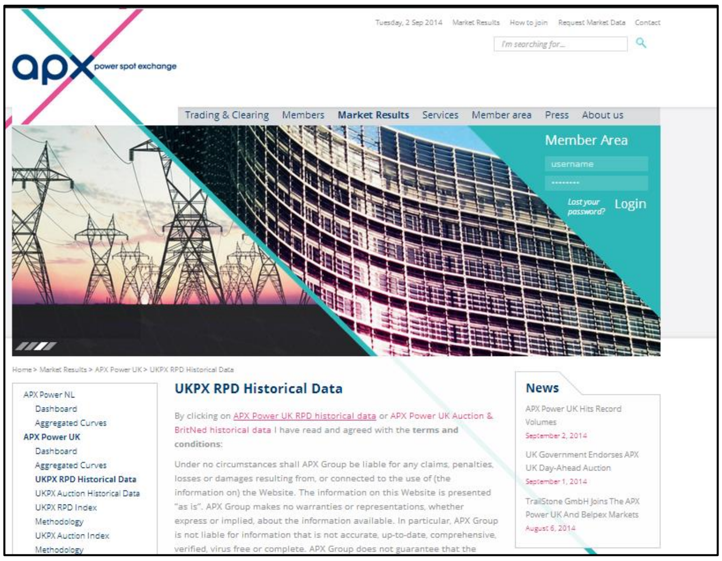


Figure 5.4 Screenshot of the location from which apx RPD data was obtained from the apx Power Exchange website

Historical daily exchange rate data from the SEMO website was used to convert these values from GBP to Euro. A Vlookup was used in excel to match the correct exchange rates with the relevant data entries.

5.1.1.3 Source 3, EirGrid and SONI Wind Data

Wind Generation and Wind Forecast in MW can be downloaded from Eirgrid and SONI’s websites for the Republic of Ireland and Northern Ireland respectively across a specific period of time in fifteen minute intervals.

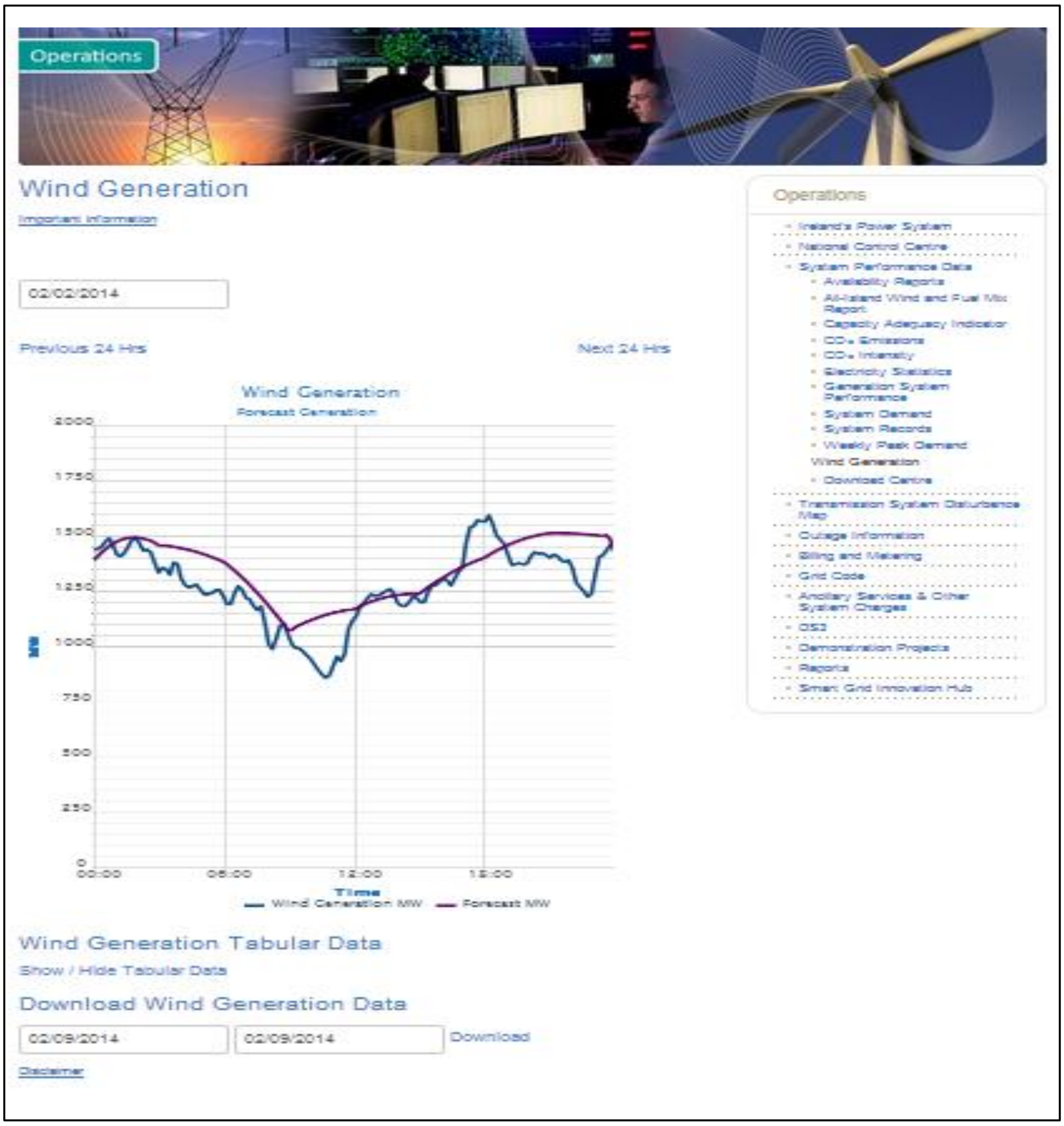


Figure 5.5 Screenshot of the location from which wind forecast and generation data was obtained from the apx EirGrid website

5.1.2 Collating Data Sources

In order to analyse the data listed above, it had to first be collated –this was primarily done by time interval or Unit ID.

While all SEMO and APX data employed was given in half hour intervals, these time intervals were presented in different formats for different data sets.

For example, SEMO sometimes present time intervals in two columns, one for date in the form dd/mm/yyyy and one for time in the form hh:mm.

Other times, SEMO presented time intervals in the form of delivery date, delivery hour, and delivery interval; with delivery hour being represented by an integer from 1 to 24 and delivery interval being either 1 or 2 to represent respectively the first and second half hour period.

Where this format is used, sometimes delivery hour 1, delivery interval 1 represents the period from 01:00 hours to 01:30 GMT.

Other times, (1,1) represented the period from 07:00 – 07:30 GMT , the first half hour of the SEMO trading day which runs from 7am to 7am.

There are also instances where delivery hour 1, interval 1 refers to the time period from 00:00 to 00:30.

As the protocol being used for each set of SEMO data is not clarified, the datasets had to be graphed and a knowledge of daily patterns used to determine which protocol was being used.

Collating data according to Time Interval

In order to combine and compare different variables, a uniform means of expressing date and time in one column had to be determined.

This was achieved by calculating date in dd/mm/yyyy format and time in hh/mm format, and combining them to produce a unique decimal number representing that date and time.

This requires a knowledge of how excel represents dates and times.

Excel represents all dates relative to 01/01/1990. So 01/01/1990 equals 1 when converted to 'general' format. 01/01/2014 converts to 41,640 –the number of days since 01/01/1990.

Time in hh/mm format will convert to number of minutes since 00:00 when converted to general format. So 08:30 will produce 510 when converted to general form.

With this knowledge, date and time, regardless of how they were presented in any number of columns could be converted to a single cell entry in the form 'dd/mm/yyyy hh:mm' allowing different data sets to be combined.

Table 5.1 illustrates how this method is used to convert delivery date, hour and interval to a single 'Time Code'.

- First, time interval is converted to minutes using an 'if' statement (if delivery hour is equal to 1 return 0, if it is equal to 2 return 30). The time in minutes is calculated by multiplying the delivery hour by 60 and adding column 4, to produce column 5
- To represent this in time format in excel, this figure must be divided by 1440 (the number of minutes in one day) and the format converted to 'time'. See column 6.
- Delivery date and time in hh:mm format are added in column 7.
- Column 8 represents the values in column 7 in 'general' format.

For the case of apx data where time was expressed as hh:mm – hh:mm, the data had to be first split into separate columns and the second time removed before time could be converted to minutes.

When this figure had been calculated for each time period for each set of data, a Vlookup was used to combine the three sets accurately.

Table 5.1 Example of how uniform 'Time Code' was calculated to combine data sets

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Delivery Date	Delivery Hour	Delivery Interval	Delivery Interval represented in minutes	Real time in minutes	Minutes / 1400 to convert to excel time format	Delivery Date plus 'real time' combined	Time Code – Delivery date and time as a decimal
31/05/2014	7	1	0	420	07:00:00	31/05/2014 07:00	41790.2916666667
31/05/2014	7	2	30	450	07:30:00	31/05/2014 07:30	41790.3125
31/05/2014	8	1	0	480	08:00:00	31/05/2014 08:00	41790.3333333333
31/05/2014	8	2	30	510	08:30:00	31/05/2014 08:30	41790.3541666667

Collating Data according to Participant ID, Unit ID or Account Name

By separating data into columns and using a series of Vlookups, the Registered Generator Unit dataset and the data from SEMO's Registered Capacity report were combined to create a comprehensive dataset on registered participants and their associated units.

This could then be used in combination with the vlookup function to enrich datasets that included minimal information on the interconnector user associated with the entry.

5.1.3 Data Analysis

Once datasets had been collated as described above, Excel 'Pivot Tables' were employed to add, compare and graph variables. Figure 5.6 illustrates a section of a pivot table. Figure 5.7 illustrates how data from that table is converted to a pivot chart. Each column from the pivot table is represented in the menu to the right of the pivot chart and variables can be added, removed and manipulated.

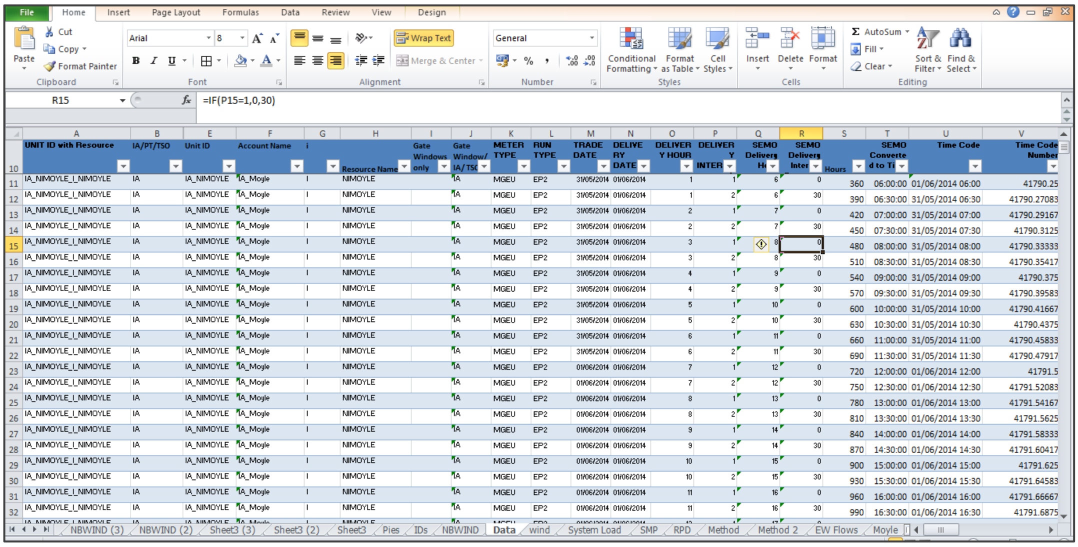


Figure 5.6 Screenshot of a Pivot Table

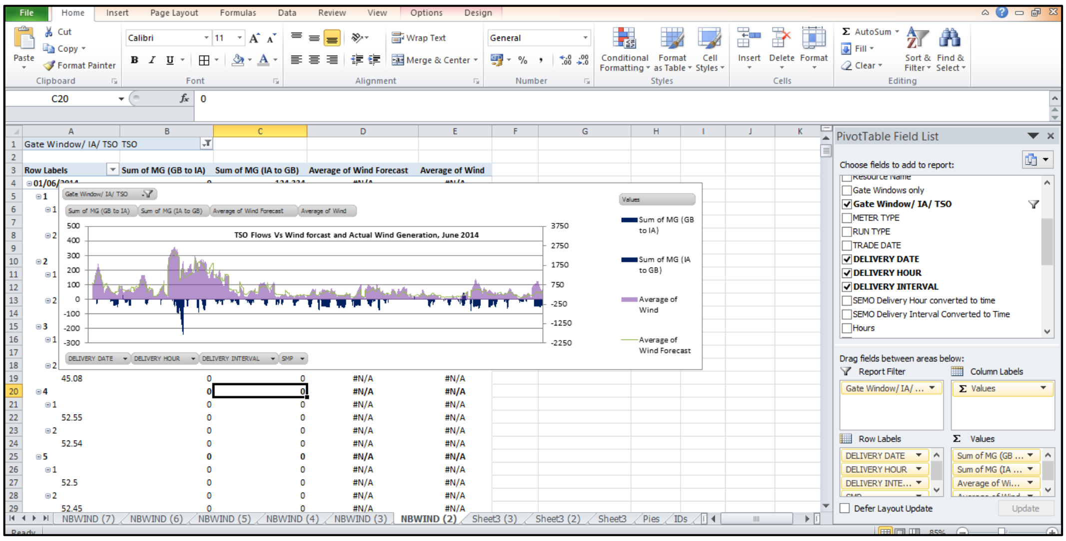


Figure 5.7 Screenshot of a Pivot Chart being created from the data in the Pivot Table in Figure 5.4

5.1.4 Compiling and comparing Interconnector Flows and influencing factors; Methodology

This section of the analysis required the collation of a number of data sets. Given the volume of data involved and the time constraints, it was decided that just one month would be analysed. June 2014 was selected as, at the time, this was the most recently available data and would produce the most up to date results.

Firstly, to represent the correlation between interconnector flows and other factors; Interconnector Flow, All Island System Load, Wind Generation, APX RPD and SMP data were graphed for one month. These data sets were correlated by time using the method described in section 5.1.2.

The results could then be graphed using a pivot table, as described in section 5.1.2 and compared. The pivot table allowed different variables to be added or removed to identify their relative weighting and facilitate closer inspection. Moyle and EWIC were found to display similar characteristics and so were graphed as a single line for clarity of visual inspection.

Next, in order to understand better how the interconnector is being used, MIUN data for one full year (June 2013 – June 2014) was compiled and cumulative flows for each gate window in both the SEM to BETTA and BETTA to SEM direction were calculated. The results were presented in tabular, pie chart and bar chart form to illustrate clearly the overall distribution and trends emerging over time.

The results were then presented for just one representative week so that daily trading patterns could be identified.

Next, each MIUN value was matched with its associated Interconnector User. This was achieved by comparing Unit ID columns in the MIUN data set with those in the Registered Units dataset and employing a Vlookup.

Using the filtering feature available in excel Pivot Tables, the Modified Interconnector Unit Nomination (MIUN) data for each Interconnector User over the full year could be presented separately allowing trading patterns to be identified.

5.1.5 Approximating the Welfare Benefits of the Interconnector; Methodology

In order to illustrate the welfare benefits of the interconnector to Irish consumers, a simplified analysis comparing the estimated cost of net energy imports for June 2014 with the theoretical amount it would have cost us to produce this energy at home were the interconnectors not available.

First net commercial imports had to be derived from MIUN Data which is available from SEMO's dynamic report database. MIUN was used because it excludes IA and TSO trades which allows us to examine just commercial trades and ignore balancing and counter trading.

MIUN MW data is categorised by participant name, resource name, run type, trade date, delivery date, and delivery hour and delivery interval when downloaded from the SEMO website. As such, the data had to be sorted and all participant trades totalled for each time period. Different numbers of IUs participated in the various trading intervals so two sorting columns were created to gather and total entries associated with each time period using 'if' statements in excel.

SMP data was also downloaded from the SEMO Dynamic Reports database.

As previously discussed, Power Exchange data from the UK can be used an approximate for GB wholesale price. '[APX Power UK RPD historical data]' was downloaded from the APX Group website for the month of June.

The three data sets were collated by 'Time Code' as described in section 5.2.

As SMP and APX RPD data are given in €/MW and £/ MW, MIUN values were not converted to MWh. This is allowable because the same time periods are used across all data sets, but it means we must examine proportional differences rather than actual values.

Net imports could then be multiplied by the approximated value for GB wholesale electricity price for each time period. The cumulative total of these values is an estimate of the cost of net imports for that month.

Net imports were then multiplied by SMP values to represent what the cost of producing this electricity at home would have been. It should be noted that this represents an estimation, not an actual figure, as we would expect SMP for these periods to have been higher were the interconnector not in place. Additionally, the SMP does not include capacity or constraint payments.

5.1.6 Are the Interconnectors helping us to achieve our Renewable Targets; Methodology

This section of the data analysis was again limited to one month; June 2014. Unlike previous sections that exclusively looked at commercial flows, this section of the report included Transmission System Operator and Interconnector Administrator Flows in an attempt to quantify the impact of EirGrid Counter Trading on the facilitation of wind.

Firstly cumulative flows for the month were compared to determine the overall volume and net direction of TSO trades. Next, TSO counter flows were graphed against actual and forecast wind data obtained from EirGrid and SONI as described above.

5.2 Part II: Qualitative Analysis; Literary Review and Interviews

5.3 Literature Review

In addition to the published reports and analyses reviewed as part of Chapter 2, a wide range of EU, Ofgem, SEM, CER and Utility Regulator and Eirgrid published regulations, consultation documents and associated responses, final decision papers and conference proceedings were reviewed and critically analysed.

5.4 Semi Structured Interviews

Semi Structured interviews, as defined by Robson (Robson, 2002) refer to interviews which have predetermined questions, but the order can be modified based upon the interviewer’s perception of what seems most appropriate. Question wording can be changed and explanations given; particular questions which seem inappropriate with a particular interviewee can be omitted, or additional ones included.

Once an initial appreciation of the processes involved in interconnection and the key issues had been determined, semi-structured interviews were completed with energy traders based in Ireland who participate in purchasing and selling capacity and energy across the interconnector. In addition to enquiries regarding specific points that required clarification on account of contradictions within the literature, these interviews involved a number of open ended questions which allowed the interviewees to highlight the most important material that the interviewer may otherwise not have been aware of.

The interviewees and the companies for whom they work have been kept confidential for the sake of commercial sensitivity.

5.5 Critical Analysis of EirGrid Study; Methodology

A critical analysis of EirGrid's 2014 study (Campbell, 2014) is undertaken in Chapter 6. This was informed by the following sources;

- EWIC Impact to SEM; Explanation of Analysis (Campbell, 2014)
- Information Note on the East West Interconnector (EirGrid, 2014)
- CER Decision CER/13/191 'Accessing Tariffs and Financing the Gas Transmission System; Consultation Process (CER, 2013) and Decision Paper (CER, 2013) and published industry responses to the new regulation.
- Solver Choice in the SEM: A Comparative Study of Lagrangian Relaxation vs. Mixed Integer Programming (Eirgrid, SONI, 2010)
- Interviews with market participants.

6 Results and Discussion

6.1 Introduction

Delivery of the objectives listed in chapter 1, part 3 is reported in this chapter which is divided as follows.

In section 6.2, the prevailing trends in direction and volume of interconnector flows are presented. This sets the basis for section 6.3, which attempts to ascertain how the interconnector is being used and what the motivating factors for trading across the interconnector are. This study would assert that an understanding of these factors is a vital prerequisite to determining the best regulatory measures to optimise welfare.

In section 6.4 and 6.5, the performance of the interconnectors with respect to reducing the price of electricity and facilitating renewable generation is assessed.

A final conclusion on the results is presented in Chapter 7.

6.2 Interconnector Flows; Trends in Volumes and Direction

Based on the theory of Interconnection outlined in Chapter 1, and the body of research presented in the literature review, one might expect to see a close correlation between SEM-BETTA wholesale price differences and Interconnector Flows.

The data sample presented in figure 6.1 would indicate otherwise. Figure 6.1 compares the combined net interconnector flows of Moyle and EWIC with price differences between the SEM and BETTA (where AI prices are represented by SMP and GB prices represented by APX RPD data) for one week in June 2014, AI total system load and wind generation for one week are also graphed. Price Differences have been scaled by 10 to allow more accurate visual inspection –as we are examining proportional differences not actual values this is acceptable.

This comparison indicates that for Interconnection between AI and GB the correlations between price difference, wind and interconnector flows that one would expect based on the theory are not reflected in the real data. Indeed, interconnector flows are almost exclusively from GB to AI in this sample despite clear instances of lower wholesale prices in AI.

Interconnector flows are at their highest during the day when demand in Ireland is greatest and while net flows drop to zero or below (ie. net exporting is occurring) nightly in response to the predictable nightly drop in SMP, they do not appear to respond in any substantial way to arbitrage opportunities or instances of high volumes of wind on the SEM as they occur throughout the day.

The following sections will examine why this is happening.

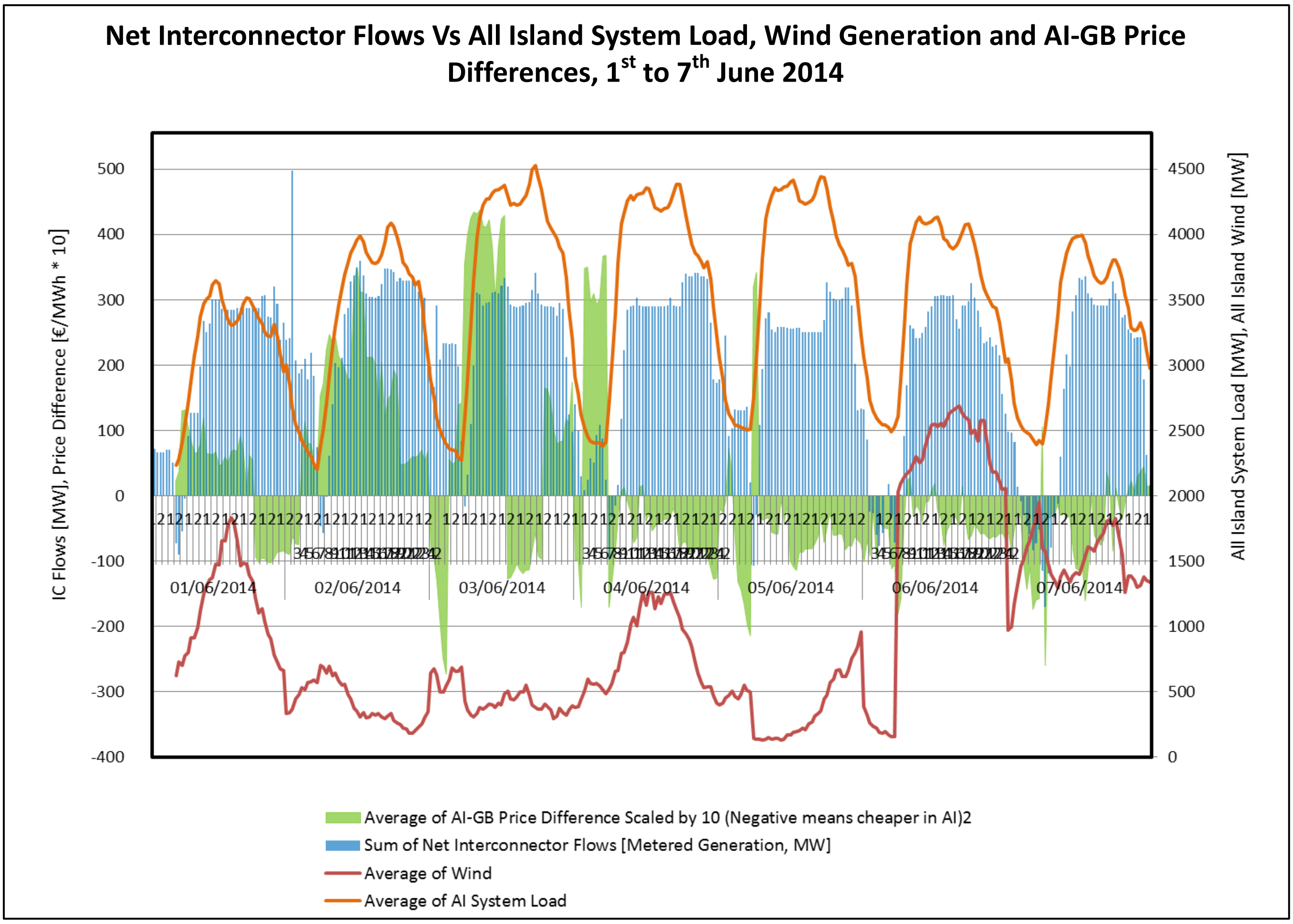


Figure 6.1 All Island System Load, Wind Gen, IC Flows and Price Difference with UK apx rpd. for June 1-7th 2014

As outlined in chapter 3 part 4, EA modified interconnector unit nominations represent energy flows associated with capacity which has been bought at long term 'explicit' auctions, be they annual auctions, seasonal, quarterly, monthly or daily. EA2 and WD1 MIUNs on the other hand represent energy and capacity purchased at implicit auctions. The EA2 bidding window closes at 11:30 on the day prior to delivery and the auction covers the full SEM trading day (06:00 – 06:00). The bidding window for the WD1 auction closes at 07:00 on the day of delivery and the auction covers a twelve hour period within the SEM trade day (18:00 – 06:00).

Where these auctions fit into the SEMO timescale is summarised below.

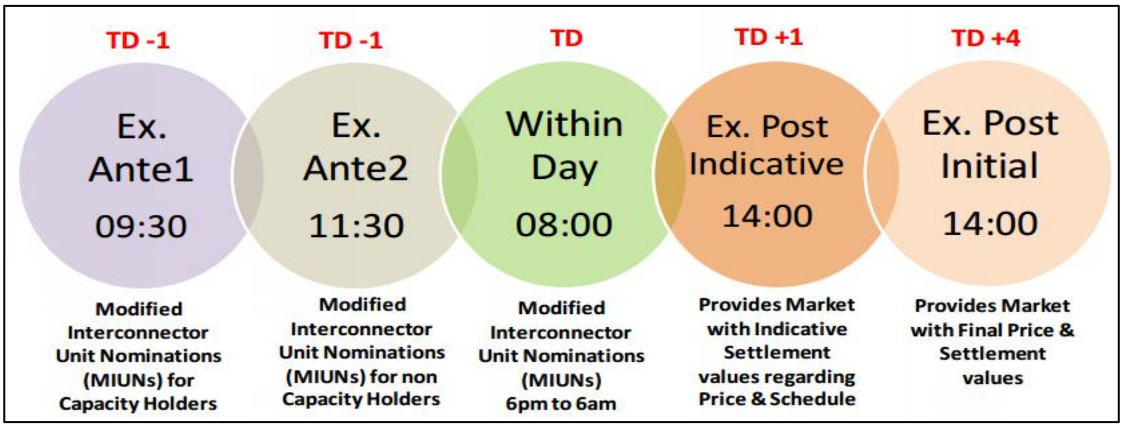


Figure 6.2 Cycle per trading day graphic, Source (SEMO, 2013)

With this knowledge, we can interpret MIUN data available from the SEMO database to gain a basic understanding of the type of trades the interconnectors are predominantly being used for. Table 6.1 and Figure 6.3 present a breakdown of interconnector flows by flow direction and auction type for the year long period from the 1st June 2013 to the 2nd of June 2014. Figure 6.4 illustrates the breakdown by month.

Table 6.1 Figure 3 Breakdown of total AI GB Interconnector Flows by Direction and Auction Type, June 2013 – End May 2014. Note these figures do not include TSO or IA trades

Row Labels	Sum of EA +	Sum of EA -	Sum of WD1 +	Sum of WD1 -	Sum of EA2 +	Sum of EA2 -
I_NIMOYLE	3061910.605	-171782.106	96251.822	-15472.639	64353.951	-271279.178
I_ROIEWIC	6637735.849	-379123.656	89963.371	-51290.243	52200.109	-357674.647
Grand Total	**9699646.454**	**-550905.762**	**186215.193**	**-66762.882**	**116554.06**	**-628953.825**

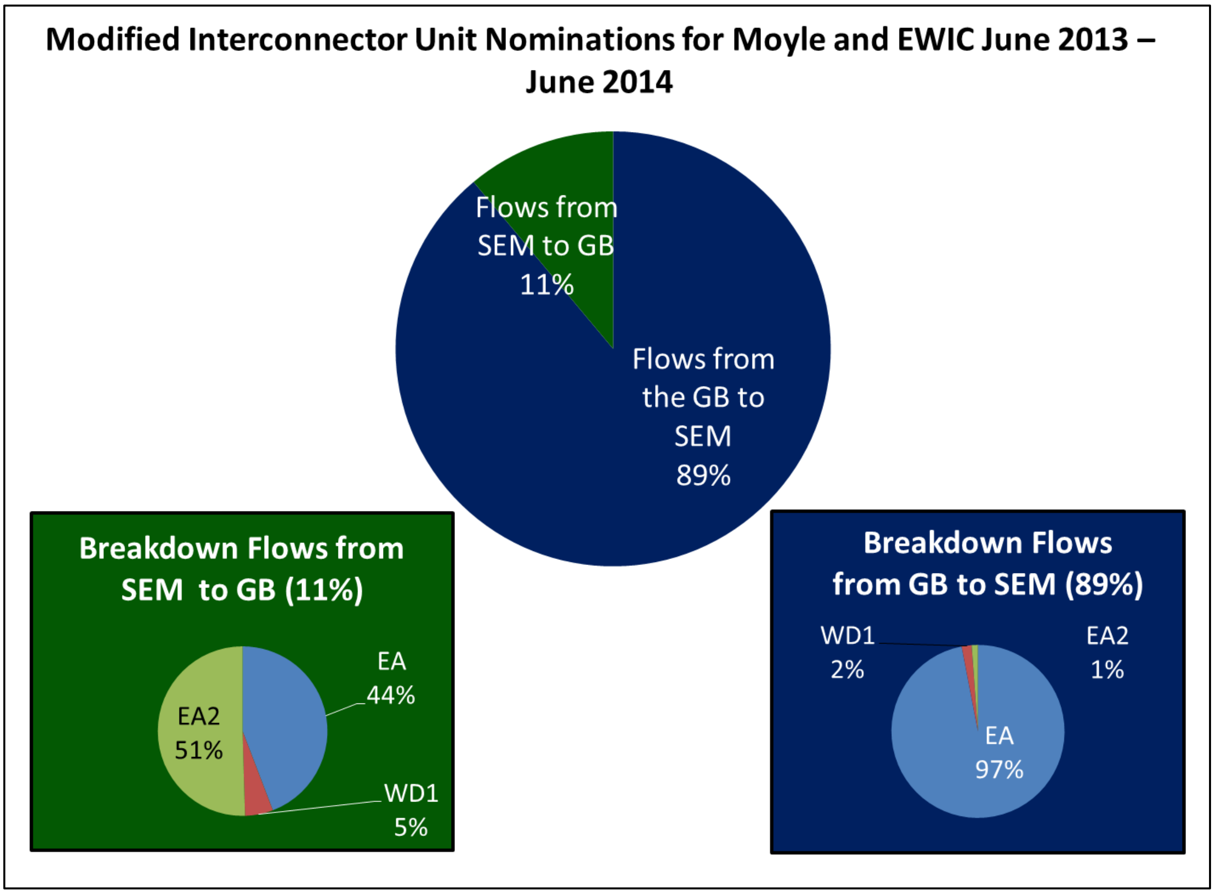


Figure 6.3 Graphical representation of breakdown of total AI GB Interconnector Flows by Direction and Auction Type, June 2013 – June 2014. Note these figures do not include TSO or IA flows

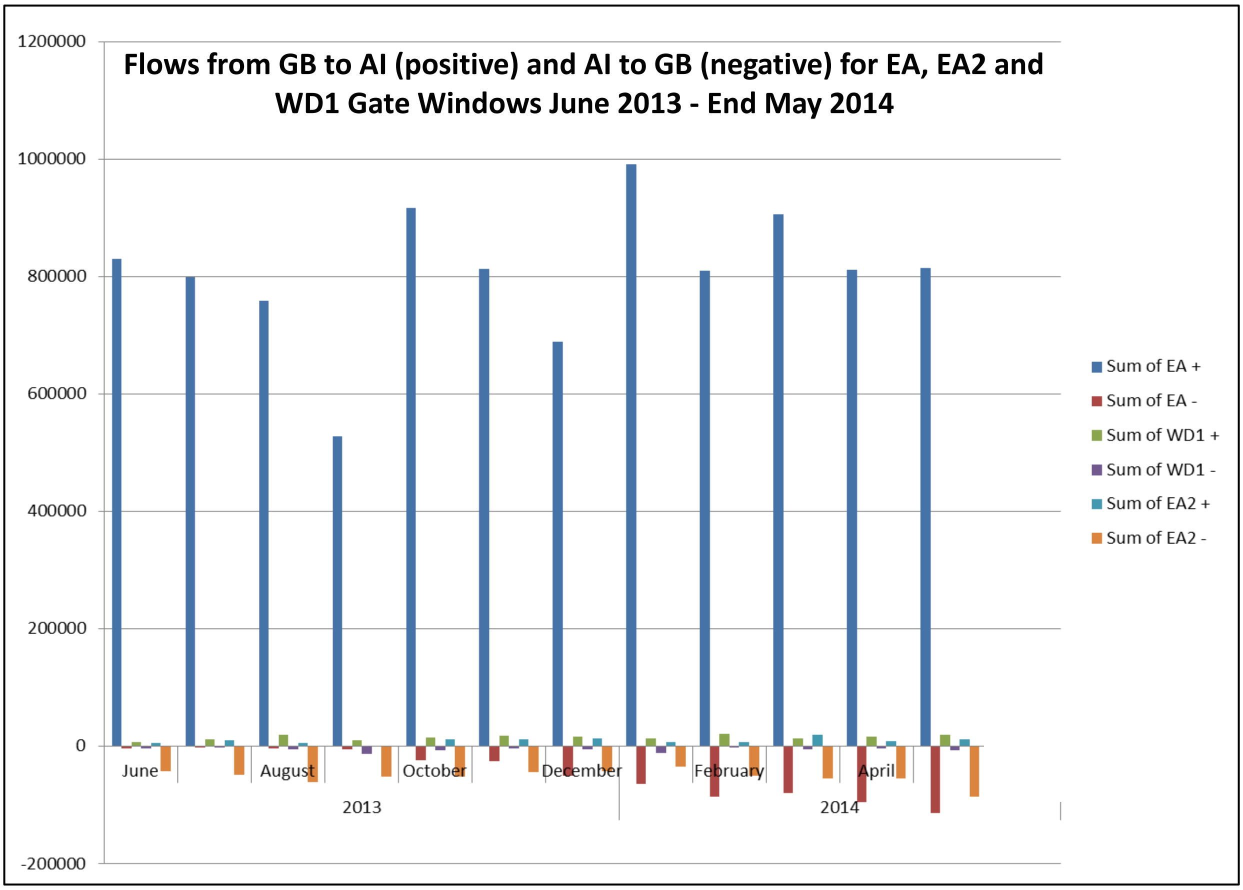


Figure 6.4 Flows from GB to AI (positive) and AI to GB (negative) for EA, EA2 and WD1 Gate Windows June 2013 - End May 2014

From this data we can ascertain that the bulk (89%) of flows across the Interconnectors from June 2013 to the end of May 2014 were from GB to AI and a staggering 97% of these imported flows were secured in advance via explicit auction. It is not surprising then that Figure 6.1 shows little response to short term price differentials – since the vast majority of energy flowing across the interconnector was secured in advance, traders could not possibly predict hour to hour to hour price differentials.

Exports include a higher percentage of implicit auctions; trades associated with the EA2 gate window represent 51% and WD1 trades represent 5% of exports during this period.

By examining flows again over a sample week long period, and this time breaking them down into their constituent EA, EA2 and WD1 MIUNs, a clear pattern can be identified.

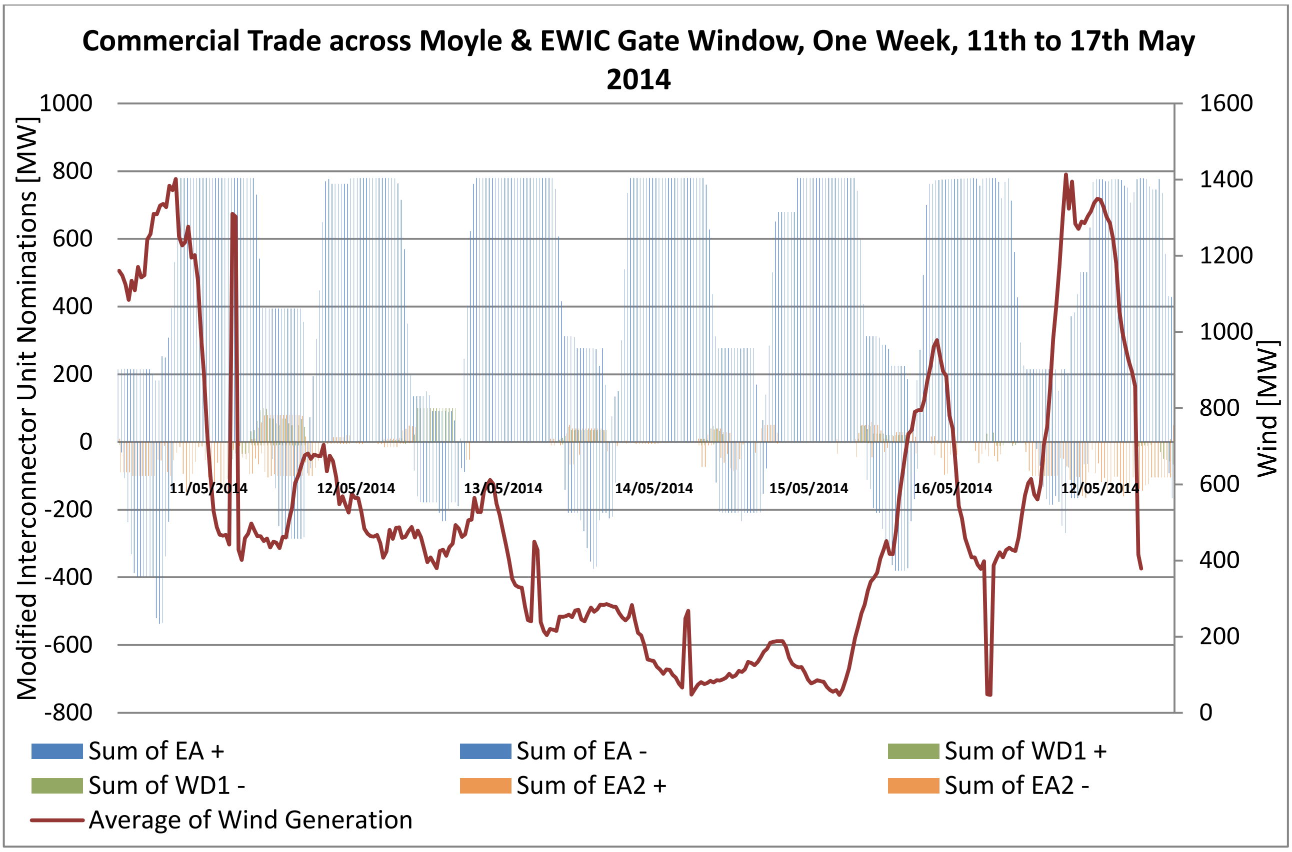


Figure 6.5 Trading across EWIC, breakdown by Gate Window for 11th to 17th May 2014

The EA flows from GB to AI demonstrate a distinct ‘blocky’ pattern which reinforces the idea that the capacity and energy associated with these flows has been purchased ‘in bulk’. As outlined in Chapter three, capacity is purchased for a period of time and the associated energy is then bought for intervals during that time (ie. there are times when the capacity which has been purchased will not be used because it is uneconomic to do so) –here, EA import capacity appears to be used during the day from approximately 09:00 to 23:00 but is used to a much lesser extent at night. In discussion with a representative from a company which trades across the interconnector, it was explained that this is because, on average, SMP falls closer to, and sometimes below, the price of electricity in GB during these hours. Therefore it does not make economic sense to import energy during these hours. Exports too appear to be dominated by EA MIUNs for the week examined above; however from figure 6.3 we can see that over the course of the year, EA2 MIUNs accounted for 51% and EA for 44% of commercial trades.

In the next section of this report, we will break down these results further, this time by Interconnector Participant. This will allow us to identify the different trading strategies that make up net interconnector flows.

6.3 Trading Across the Interconnector; Three Strategies

Who is using the Interconnectors, how are they using them and why?

Details of all registered Interconnector Users who secured commercial capacity on the Moyle and/ or East West Interconnectors from June 2013 to End May2014 have been compiled from a SEMO list of registered generator units and matched against MIUN data. These details are tabulated below with their associated parent companies. Note Cenergise and Endesa are registered on both Moyle and EWIC but only traded across EWIC for the duration of this analysis.

Table 6.2 Details of active registered commercial Interconnector Users

Parent Company	Trading across MOYLE		Trading across the EWIC	
	User ID	User Name	User ID	User Name
SSE Airtricity	PT_500 021	Airtricity Energy Supply NI Ltd Generation	PT_400021	Airtricity Ltd (Generation)
ESB Group	PT_500 024	Coolkeeragh ESB Ltd (Generation)	PT_400030	ESB PGEN
Viridian Group	PT_500 031	Viridan Energy Supply Ltd	PT_400100	Viridian Energy Supply Limited
Bord Gáis Éireann	PT_500 037	Bord Gais Interconnector (NI)	PT_400099	Bord Gais
Danske Commodities	PT_500 070	Danske Commodities A/S	PT_500070	Danske Commodities A/S
ElectroRoute	PT_500 069	ElectroRoute Energy Trading	PT_400096	ElectroRoute Energy Trading
RWE Group	PT_500 058	RWE Supply and Trading GmbH	PT_400113	RWE Supply & Trading GmbH

Endesa Ireland Ltd.	PT_500 071	Endesa Generación	PT_400114	Endesa Generación
Cenergise Ltd.	PT_500 075	Cenergise Limited	PT_400136	Cenergise Limited

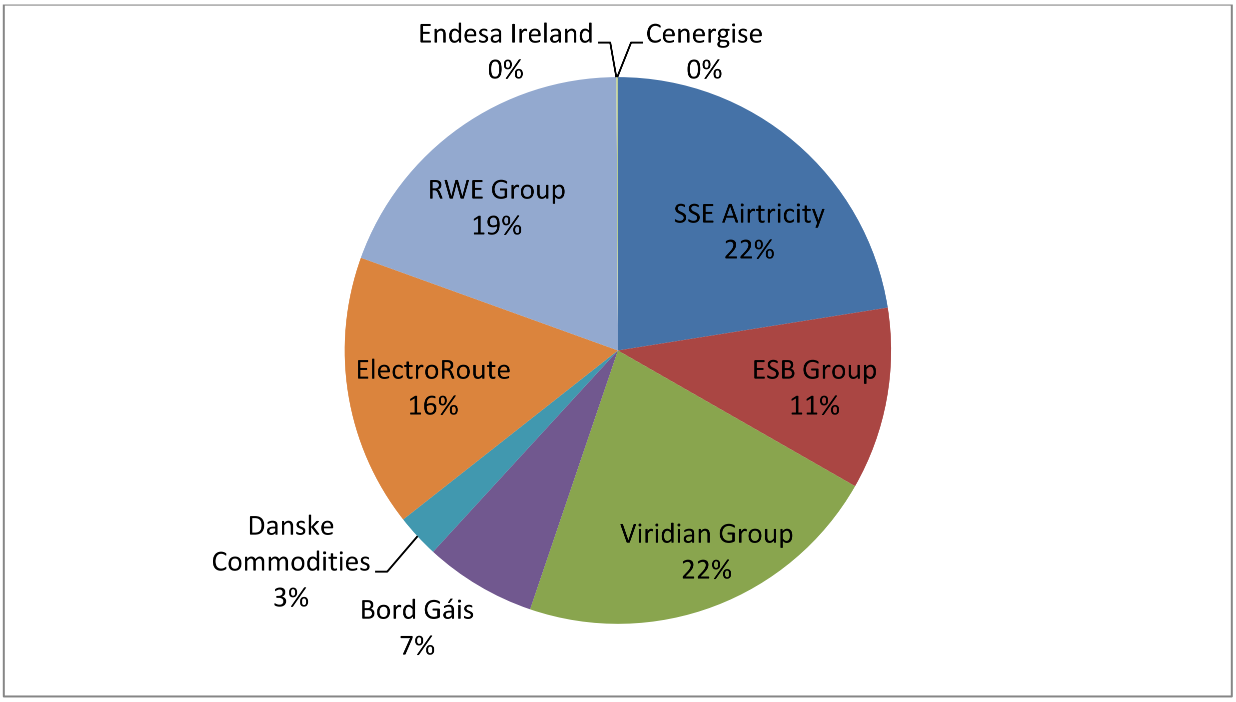


Figure 6.6 Breakdown of Total volumes commercially traded across Moyle & EWIC combined by Interconnector User (June 2013 - End May 2014)

The following analysis shows that the companies listed here differ in their use of the interconnector, not just in terms of volumes traded but in total trading strategy. Using SEMO data, three distinct trading patterns have been identified and will be explored in the following sections.

6.3.1 Hedging via the Interconnectors; 'Bulk Buying' Energy

The trading behaviour of Bord Gáis is typical of how most large companies in Ireland have historically used the AI-GB interconnectors.

Total energy traded across the interconnector by Bord Gáis for the period from June 2013 to June 2014 is presented in Figure 6.7. The data illustrates that Bord Gáis have almost exclusively purchased capacity at explicit auction.

In discussion with a representative from a large energy company, this strategy was explained as follows; Supply Company X wishes to hedge their portfolio and so they enter into a Contract for Difference with a registered interconnector User. In AI, the suppliers and registered interconnector users entering into this kind of arrangement are most commonly from the same company or group –the company or group will generally also have a generation portfolio.

The Interconnector User then submits bids via the Auction Management Platform to secure long term import capacity to meet their contractual obligation. If they are successful in the capacity auction, they then purchase the associated energy either via a direct bilateral contract with a GB generator or trader or, more commonly, via a GB Energy Exchange. Using their knowledge of average AI-GB price differences though they will only purchase energy during the day when it is on average more profitable and they will forego their capacity at night.

In this way, the supply company secures a guaranteed volume of energy to meet future demand at a fixed price that they expect will be on average lower than SMP for that period of time. It is important to note that they are interested in the average savings as opposed to taking advantage of price differences as they arise. The Interconnector User must also receive their share for conducting the trade.

This behaviour is considerably different to the 'optimal' trading that was used to create the models to predict interconnector impact and justify its construction as described in the literature review.

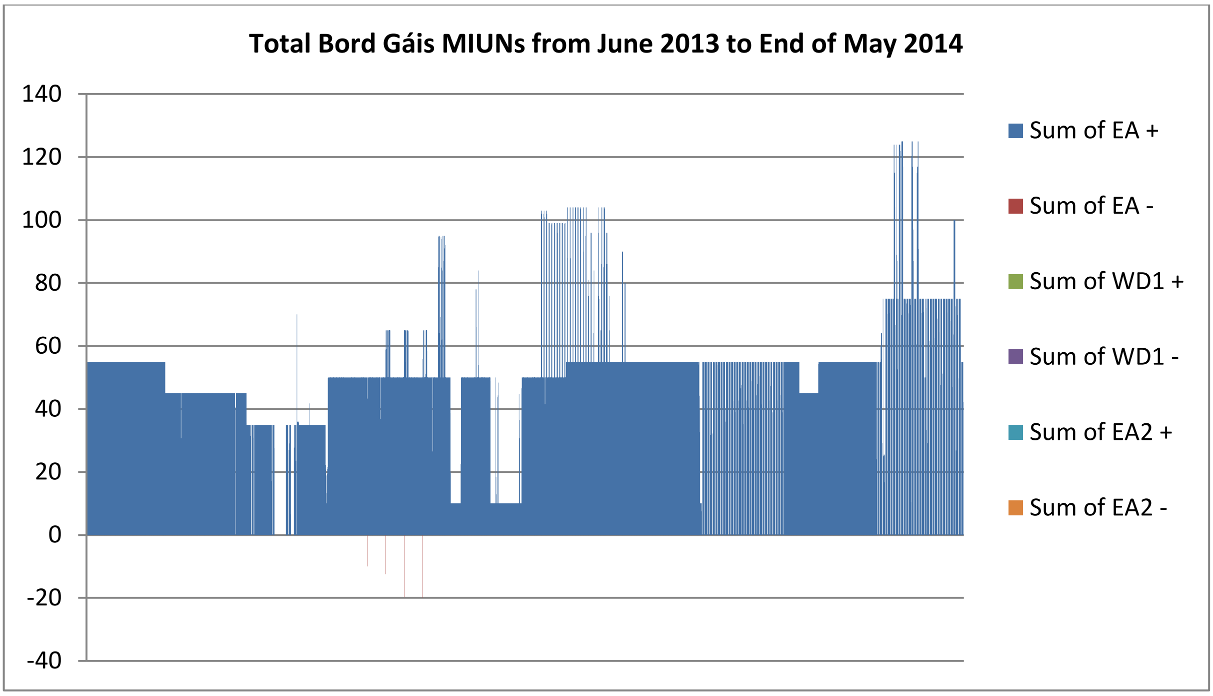


Figure 6.7 Bord Gáis trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

Broadly speaking, *RWE Supply and Trading GmbH* traded in a similar manner for the period studied –with the exception of the high volumes exported nightly from the 2nd to the 8th of October.

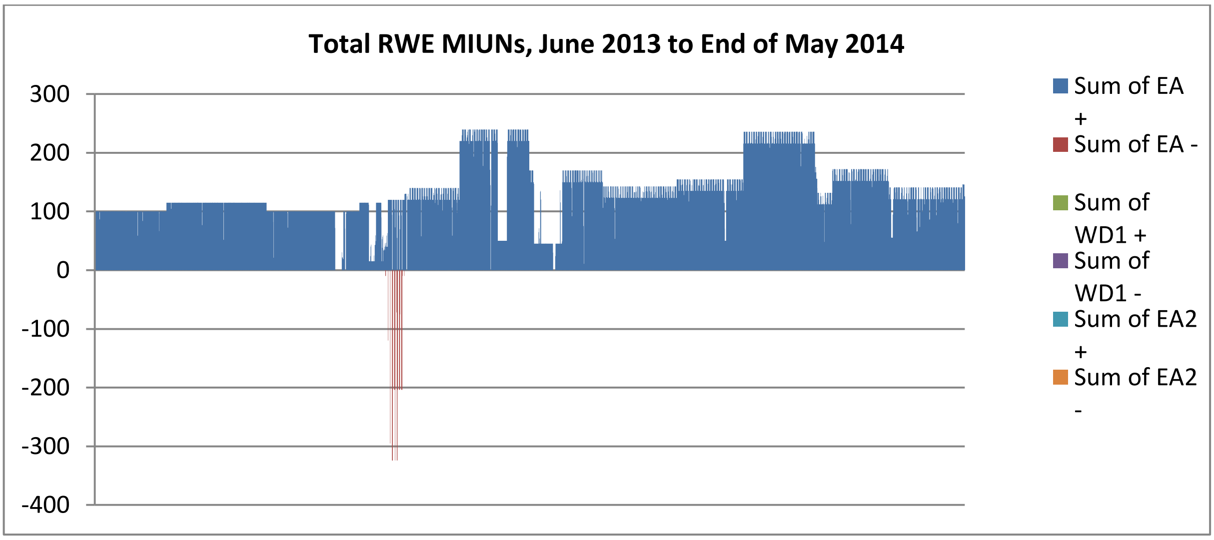


Figure 6.8 RWE trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

6.3.2 Proprietary Traders –Capturing arbitrage opportunities

At other end of the spectrum we have the companies whose strategies are characterised by arbitrage or proprietary trading, i.e. their trading strategies are designed to take advantage of price discrepancies through the purchase and sale of capacity and energy. These companies trade to profit from the market.

Electroroute and Cenergise are two new companies based in Ireland who appear to be utilising the interconnector in this manner. According to the data collected here, these are currently the only two companies trading in this way. As illustrated in figure 6.9 and 6.10, the trading behaviour of these companies is markedly different to those described in section 6.3.1.

Electroroute was established in 2011 and as illustrated in Figure 6.6 accounted for 16% of total commercial energy traded across the interconnector during the year long period studied. Cenergise commenced operation less than a year ago and represented just 0.09% of energy traded during the period studied. Cenergise exclusively traded across EWIC for the period studied but are registered to trade on Moyle.

The financial success of these companies in their use of the interconnectors in this manner is unknown due to the commercially sensitive nature of this information. The rate of expansion of Electroroute as a company however would tend to suggest the strategy is proving profitable.

The redistribution of 'welfare gains' (as described in section 1.1) from this type of trading is also unknown. This thesis would propose that further study comparing the distribution of welfare gains from this type of trading; with the distribution of welfare gains modelled by early studies (particularly those justifying EU support of interconnection infrastructure) would be merited.

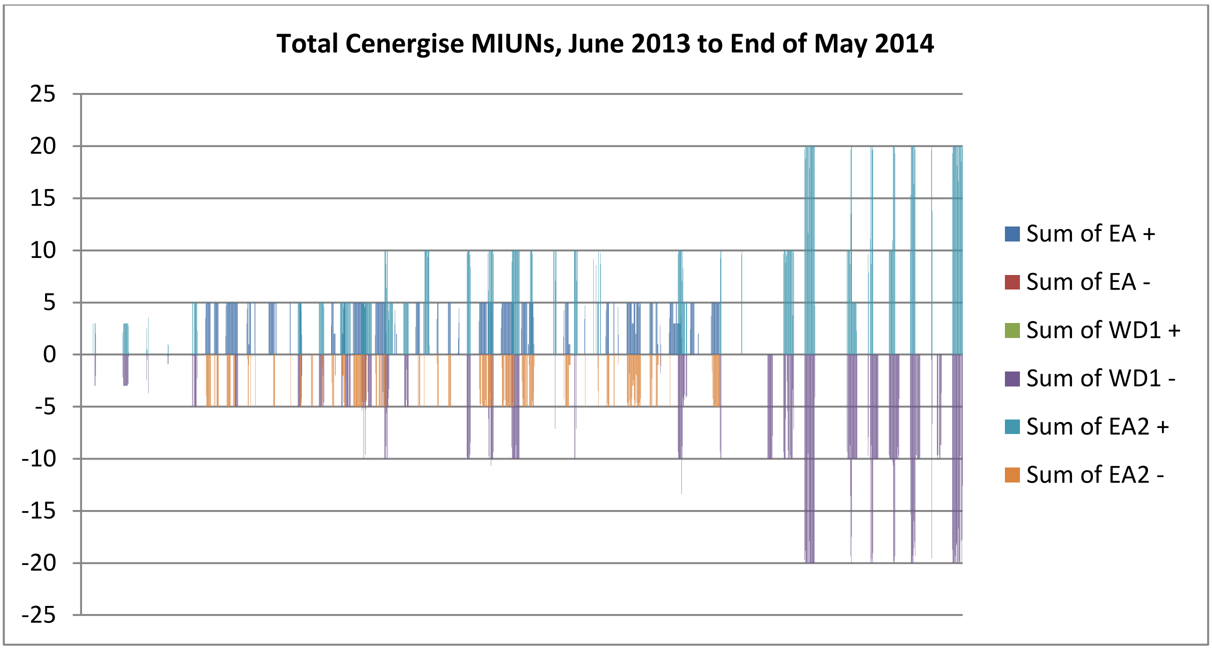


Figure 6.9 Cenergise trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

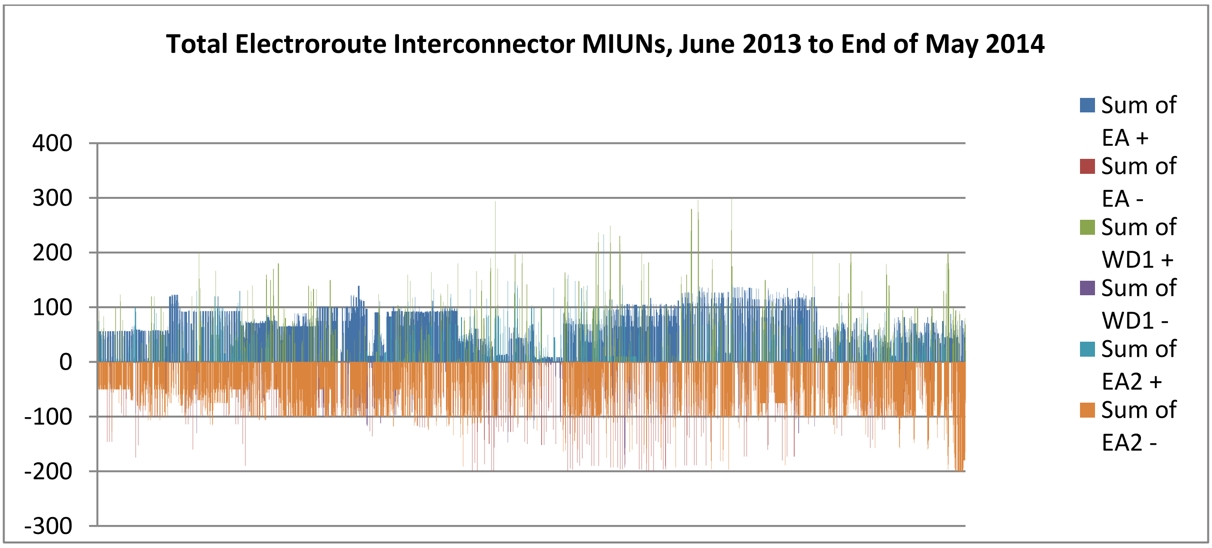


Figure 6.10 Electroroute trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

6.3.3 Optimising Trades; A growing trend

One of the most interesting trends to emerge from the data relates to a development in the trading behaviour of companies who traditionally would have taken a similar approach to Bord Gáis. This trend involves a growing pattern of exporting at night to capture price differentials

ESB and Airtricity, who together made up a third of energy traded across the Interconnectors during the period studied, have been the pioneers of this approach. As with Bord Gáis and RWE, ESB and Airtricity's trading entities enter contracts for difference with their associated supply companies and purchase the energy to meet those contracts from GB, importing across the interconnectors.

However, it appears that since November 2013, these two companies have begun to explore opportunities for arbitrage trading at night when SMP drops; at present, this is primarily taking the form of EA exports (purchasing from the SEM pool to sell in GB) in addition to some WD1 and EA2 trades in both directions.

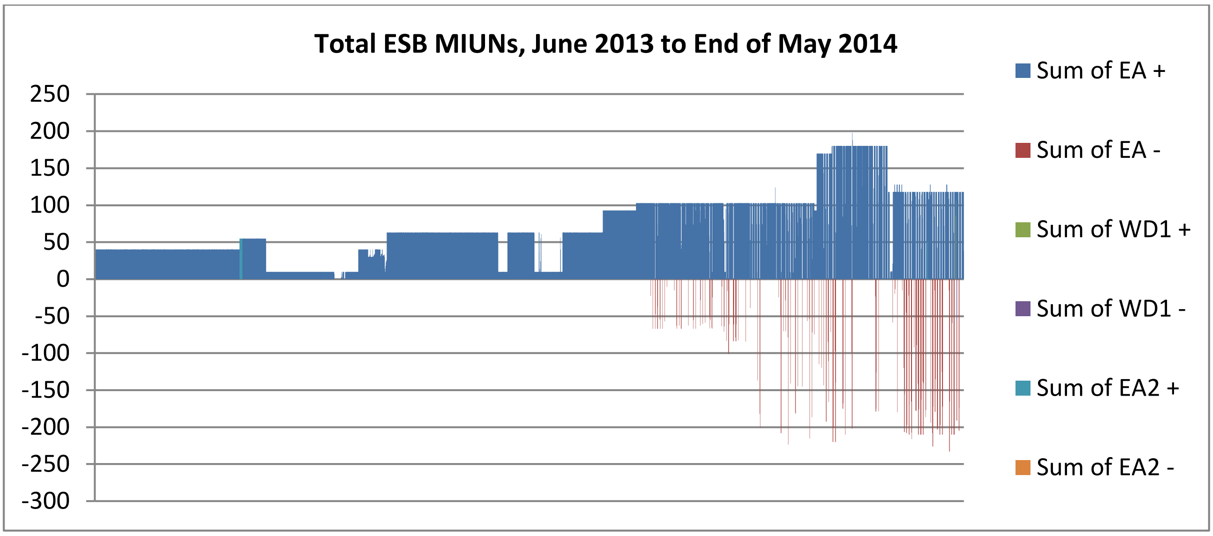


Figure 6.11 ESB Interconnector trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

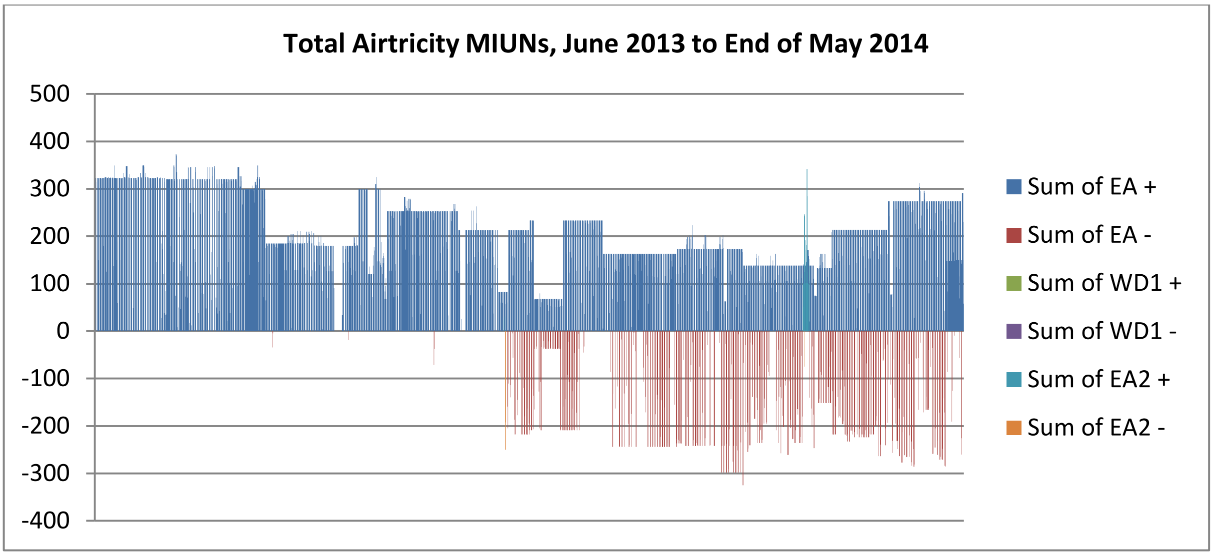


Figure 6.12 Airtricity trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

Viridian Energy Supply Ltd. who traded a full 22% of the energy traded across the interconnector during the period studied have also begun to engage with EA exports at night, however on a much smaller scale than ESB and Airtricity.

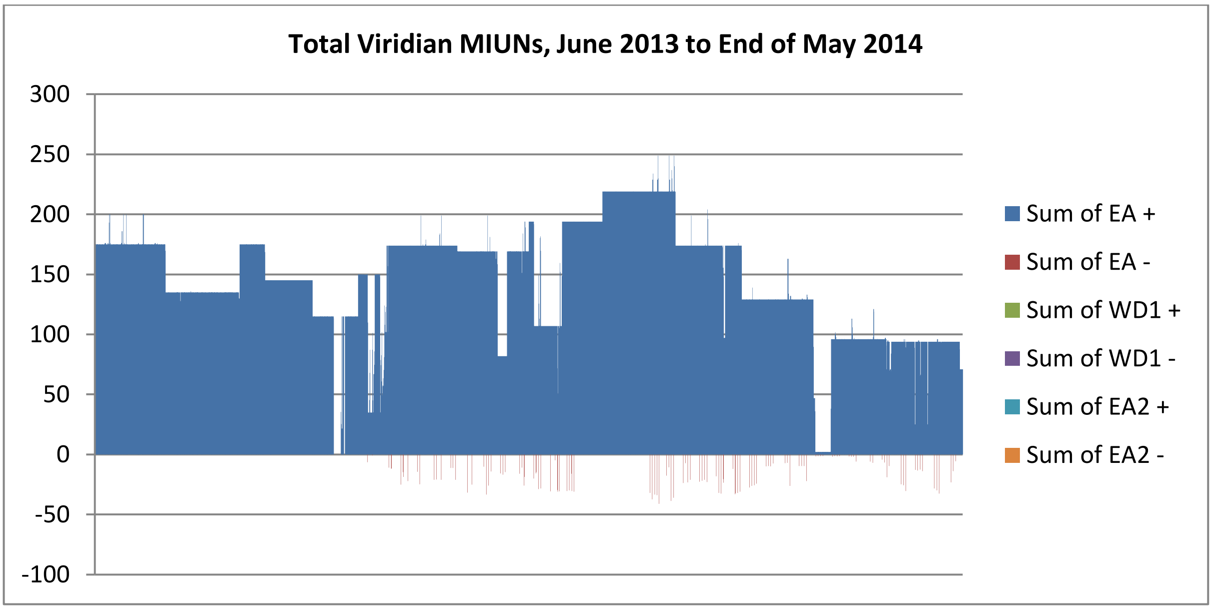


Figure 6.13 Viridian Energy trade across the Moyle and East West Interconnectors from June 2013 to End of May 2014

The significance of this change in behaviour of two key market participants is illustrated in the following graph of EA AI to GB trades.

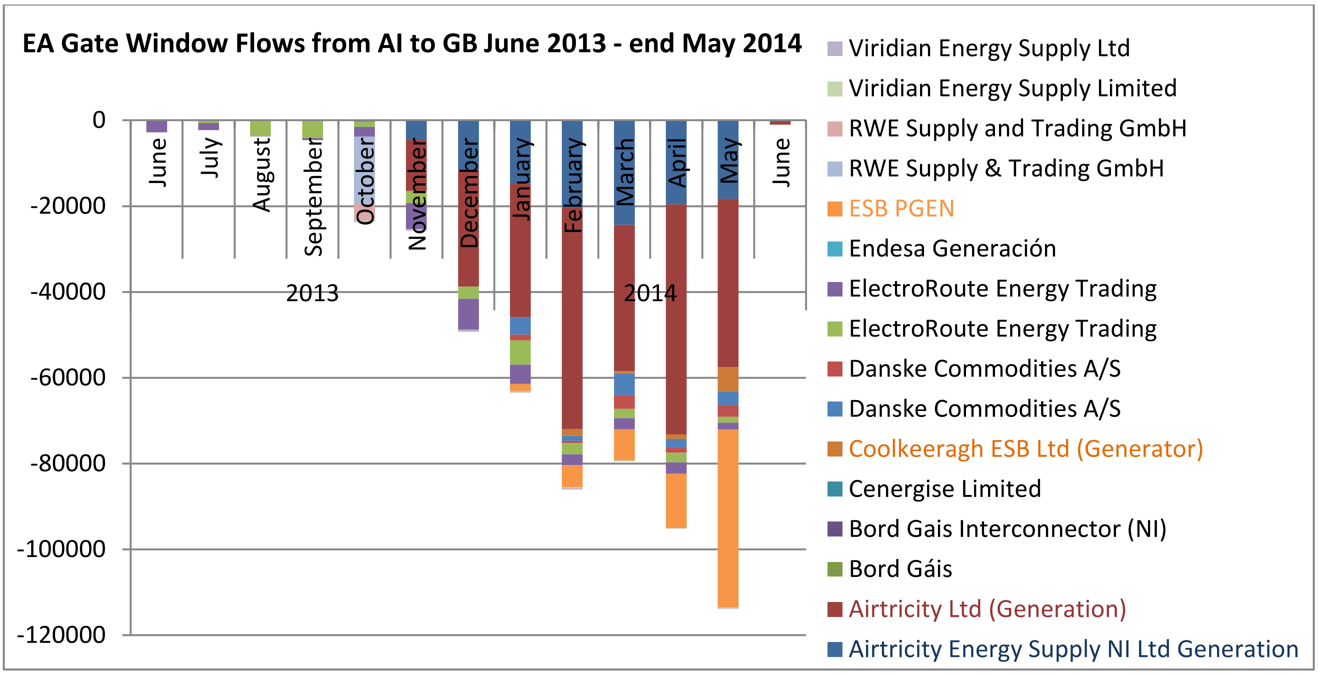


Figure 6.14 EA MIUNs from AI to GB June 2013.

6.3.4 Trading Trends Conclusion

The trends identified in the above sections demonstrates clearly that despite the introduction of an intra-day trading window in 2011 (WD1), Energy associated with explicit capacity constitutes the vast bulk of flows across the Interconnector. This presents a new perspective on the concept of welfare gains given that it is evidently not possible to optimally respond to short term price differences using this approach, however, average price differences over a long term period can be captured.

Given the relatively new phenomenon of arbitrage trading by Cenergise and Electroroute, it is difficult to determine what the impact of this will be. Whether or not these companies will help reduce the final price of electricity for consumers (which will depend on the volumes traded and degree of rent capture) they do seem to be impacting the trading behaviour of well established companies who are now exploring a more dynamic approach to trade across the interconnectors. Ultimately the degree of profitability will determine the extent to which this trading approach will grow. The resistance of Bord Gáis to adopt to this approach to date raises some questions, however their response to the latest I-SEM Consultation paper which argues 'Only large portfolio players such as ESB Group are in a position to arbitrage portfolio bids to the detriment of the competitiveness of smaller players.' would suggest it is a matter of resources.

6.4 Is trade across the Interconnectors reducing the Price of Electricity in Ireland?

This section contains two parts, in the first; a simplistic analysis of the impact of Interconnection is undertaken using real data for the month of June 2014. In the second part, a critical analysis of EirGrid's more detailed analysis is undertaken.

6.4.1 SMP Vs APX RPD; What does the Data Say?

In this section, an analysis is undertaken to compare an estimated value for the cost of net energy imported during the month of June with a theoretical value of what it would have cost to produce this energy in each market.

A comparison of SMP and RPD for the month of June is illustrated in Figure 6.15 and 6.16. The data is graphed once for the full month, and once from the first to the 28th to remove the extreme peak and allow closer inspection. The blue entry represents price difference (SMP – APX RPD). Positive values indicate the SMP is higher than the APX price, values below the zero axis indicate price in the GB is higher.

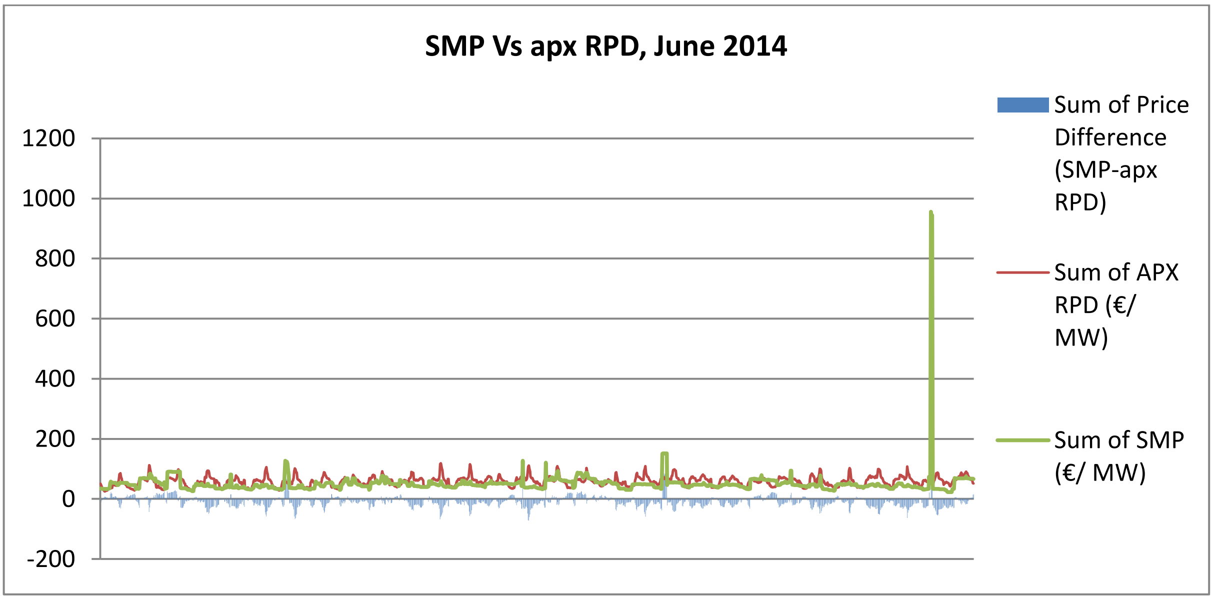


Figure 6.15 SMP Vs apx RPD, June 2014

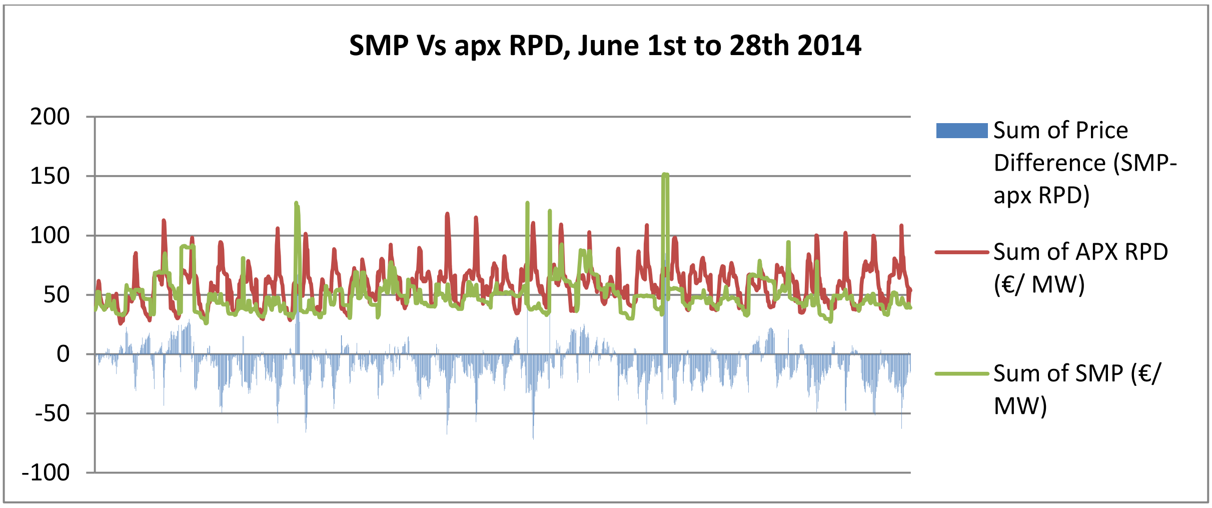


Figure 6.16 SMP Vs apx RPD, June 1st to 28th 2014

Contrary to what was expected, the average reference price for GB at 58.97 €/MW was higher by 15% than SMP (at 51.21 €/MW) for this period.

Despite this, flows were predominantly in the GB -> AI direction.

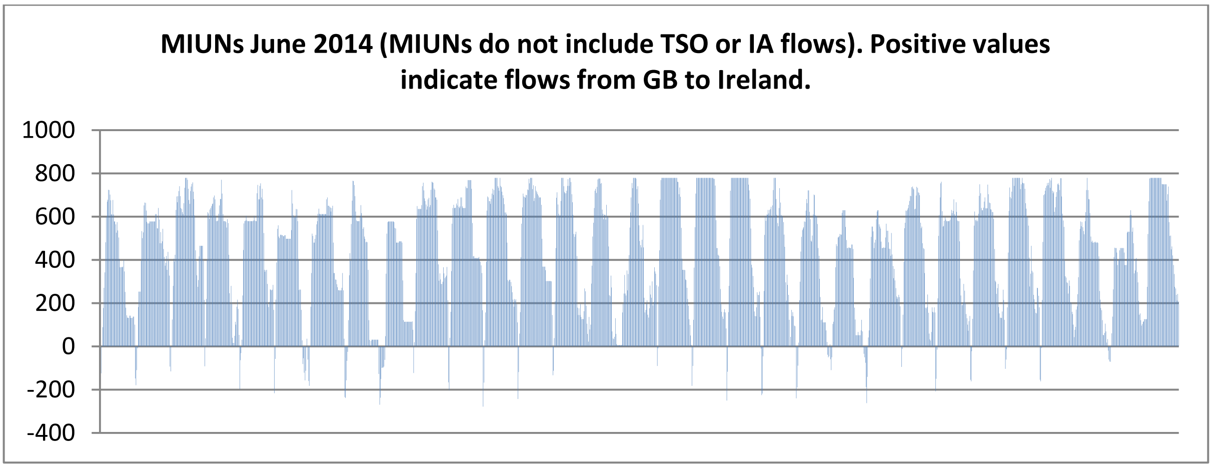


Figure 6.17 MIUNs June 2014 (MIUNs do not include TSO or IA flows). Positive values indicate flows from GB to Ireland.

The following graph compares an estimated value for the cost of net energy imported during this period with a theoretical value of what it would have cost to produce the energy in country. The data is presented from the 1-28th as the extreme peak on the 29th changes the scale and makes visual inspection of the results more difficult.

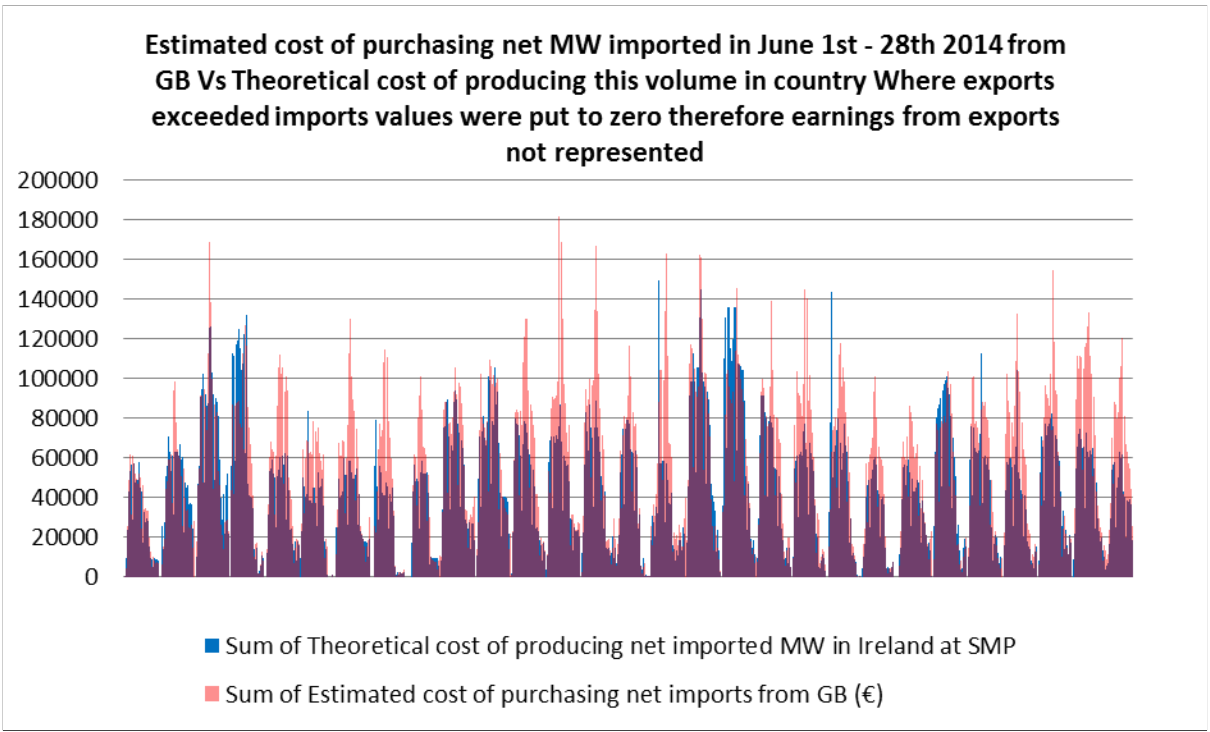


Figure 6.18 Estimated cost of purchasing net MW imported in June 1st - 28th 2014 from GB Vs Theoretical cost of producing this volume in country Where exports exceeded imports values were put to zero therefore earnings from exports not represented

The results indicated the theoretical cost of purchasing net imports from GB in June 2014 was, over the course of the month, 18% higher than the estimated cost of producing in Ireland.

These results are contrary to what would be expected based on the theory and literature review. What does this mean?

Firstly, there are a number of assumptions which influence the margin of error that should be considered;

1. As previously discussed, APX RPD is only an approximation for GB wholesale price. The actual prices secured by interconnector users importing energy to Ireland are confidential.
2. Secondly, SMP does not include capacity or constraint payments.
3. SMP would of course be different if indigenous generators were bidding into the SEM as opposed to the energy being imported across the interconnector. The studies outlined in the Literature Review indicate it would be higher without the interconnector.

Despite these assumptions, these results are still interesting as they suggest potential uneconomic use of the indicator which raises the possibility that systemic barriers to efficient trade exist.

One factor to consider here is the extent to which capacity payments may have changed these results. As discussed in Chapter 3, Interconnector users importing into the SEM receive SMP and Capacity Payments based on flows. Interconnector Users exporting out from SEM pay SMP and Capacity Payments based on flows. If capacity payments were responsible for traders importing to the SEM when the price in GB was lower, this would constitute an inefficient use of the interconnector. The above results suggest that further investigation into whether these payments are potentially encouraging import flows where they are not economical would be merited.

A second factor to consider is the changing dynamics in prices between the SEM and BETTA as discussed in the Literature review. The latest Regulatory Regular SEM Price Report (SEM-13-070) covering the period May - August 2013 Inclusive indicated that UK prices remained lower, but noted that other markets listed did not include all energy and capacity costs in the same manner as the SEM and as a result, the comparison may not be completely accurate.

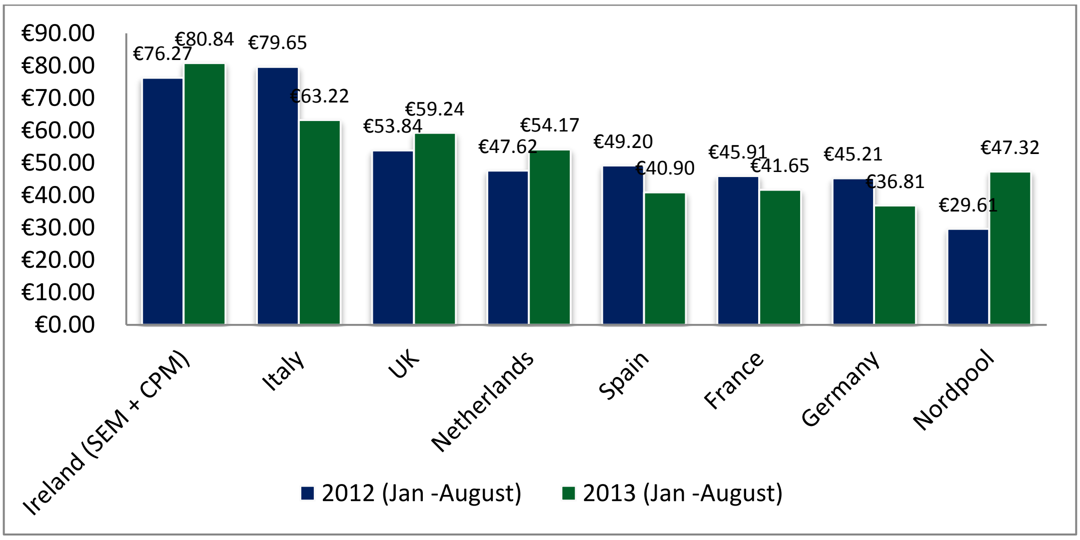


Figure 6.19 Wholesale price per MW paid to generators across Europe, Source (CER & Utilit Regulator, 2013)

The results presented in this section would suggest that close attention should be paid to any changes in the wholesale price differential between GB and

Ireland in the next report, and into the future, particularly as reforms are introduced to BETTA as part of the programme of Electricity Market Reform.

This thesis would hold that the low levels of flows from AI to GB, despite clear arbitrage opportunities merits close attention.

In a 2009 response to a SEM Consultation Paper (Moyle Interconnector Ltd, 2009), Moyle Interconnector Limited found that one of the major problems non SEM traders identified with the SEM (and barriers to them entering SEM) was the lack of an ex ante price in the market. It was noted that they would expect this to be provided through a healthy liquid market for CFD's but this did not exist.

In discussion with Irish market traders as part of the research process for this thesis, the SEM SMP was described as being 'notoriously difficult to predict'. Given this level of uncertainty, users are not prepared to take the increased risk of trading higher volumes. This was presented as a fundamental reason why more arbitrage opportunities are not being captured.

6.4.2 Critical Analysis of EirGrid Published Results

As outlined in the literature review, in April 2014 EirGrid published the results of an analysis of EWIC's impact on overall production costs and SMP. The study found that for the duration of their analysis (1st May 2013 – 30th April 2014) EWIC had had the effect of reducing the SMP by 9%. While conducting a sufficiently detailed independent analysis with the same goal was beyond the scope of this thesis, the methodology and assumptions of the EirGrid study will be analysed here with a view to determining the possible margin of error for their results.

The analysis was based on the comparison of a base case 'EWIC ON' scenario representing EWIC being fully available from May 1st 2013 to April 1st 2014 with an 'EWIC OFF' scenario representing an unconnected AI market for the same period. In order to model the Interconnector Off scenario, EirGrid replaced the interconnector with an equivalent sized gas generator and assumed the same bidding behaviour.

This study found that three of the assumptions upon which this analysis was based do not reflect the current reality. Correcting these assumptions would have cumulatively had the effect of lowering resulting percentage impact of the EWIC interconnector on SMP.

1. *Assumptions surrounding Bidding Behaviour*

EirGrid's study assumed that market participants would adopt the same bidding behaviour with and without the interconnector.

This assumption did not factor in the effect of a regulatory change to gas transmission tariffs which came into effect in October 2013, as per the CER Decision CER/13/191 of 21 August 2013.

These changes provided for the removal of secondary gas capacity transfers at the exit and effectively meant that generators lost the flexibility to adjust their capacity to match their usage on a daily basis.

This change was seen as a necessary response to under recovery of revenues by Bord Gáis which was a result of the reduction in domestic demand for baseload gas brought about by the introduction of the interconnector. The change in booking gas capacity was intended to deliver more certainty in relation to cost recovery for the gas transmission line owner. According to one industry response (Fullam, 2013) to CER/13/112, the CER's consultation document on this issue, the cumulative effect of changes in gas transmission tariffs for 2013 was a 35.8% increase in transmission tariffs over 2012 levels and had 'adversely impacted the cost competitiveness of Irish business'.

Had EirGrid factored into their analysis that if the EWIC were not in place, Bord Gais would have continued to recover revenues sufficiently and the old regulations would have held, the EWIC OFF scenario would have returned lower SMPs than were predicted.

The impact of this change in assumptions on the final results could be estimated by looking at the difference between baseload, mid merit and peaking gas plant pre October 2013 and then again post 2014. Unfortunately this was beyond the scope of this project due to time constraints.

2. *Solver Choice*

This software used to solve SEM problems in the SEM is largely seen as 'black box' technology where commercial and technical data of participating generators is input and market schedules and prices are output.

The Lagrangian Relaxation (LR) method is most commonly applied to solve unit commitment problems in the SEM. However SEMO have also developed a secondary solver for determining the Market Schedules and SMPs known as Mixed Integer Programming (MIP). MIP was originally designed as a back-up for LR and produces slightly different results –with the trend being that MIR returns slightly lower SMPs

For simplicity, LR was applied uniformly when building the EWIC OFF model. This however does not reflect the reality where MIP solving is being used more and more frequently due to the increasingly complex nature of the market.

Had MIP been factored in for a number of the days we can assume that the EWIC OFF scenario would have yielded slightly lower results for SMP and the measured impact of the Interconnector would have been slightly lower.

3. *Time Weighted Vs Volume Weighted.*

Energy prices are normally quoted as time weighted figures in the market. This study calculated volume weighted SMP which can vary slightly from time weighted SMP (sometimes higher, sometimes lower). This factor may have had a minor impact on the accuracy of results and is not the standard quote of energy price in the market.

In summary, EirGrid's conclusion that the EWIC has reduced the wholesale price of electricity in Ireland appears to be correct however, when the assumptions are considered more closely, particularly with respect to the bidding pattern of generators, it becomes clear that the extent to which it is doing so (9%) may be over-estimated.

6.5 Are the Interconnectors helping us to achieve our Renewables Targets?

As discussed in the literature review, the majority of reports pre EWIC and many reports post EWIC, indicated that a key benefit of increased interconnection would be increased utilisation of wind. Whereby increased interconnection would allow Ireland to export wind during high wind periods and import power from Britain when wind levels were low; 'In order to ensure wind is not unduly curtailed off the system, interconnection is of vital importance' (Gorecki, 2011).

As illustrated in section 6.2, actual commercial interconnector flows have not been responsive to wind.

Additionally, European Legislation requires that Interconnection 'should be facilitated as far as possible' as not to do so could otherwise constitute an obstacle to trade. This means that Interconnector schedules are not re-optimised by the TSOs i.e. consideration is not given to security of supply or transmission constraint requirements with respect to the interconnector (EirGrid, 2014). In certain circumstances this may lead to constraint of wind generators in favour of imported electricity. The wind industry has registered their discontent with this, claiming that 'An interconnector should be treated as a conventional generator, i.e. the priority dispatch of renewables should result in the "bumping" off of an importing interconnector (Irish Wind Energy Association, 2009).'

To counteract this effect, the Transmission System Operator has intervened by engaging in 'Counter Trading' across Moyle and EWIC as described in Section 3.4.4.

Cumulative TSO Flows as a percentage of Total Interconnector Flows are illustrated in Figure 6.18.

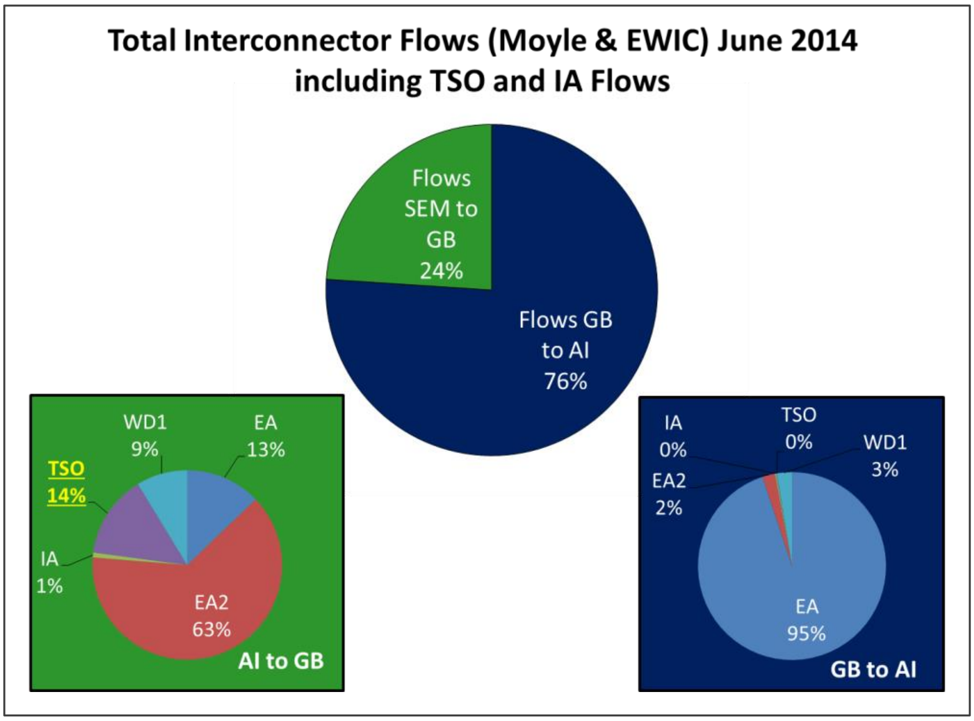


Figure 6.20 Breakdown of Total Interconnector Flows for June 2014

As shown, Interconnector Flows corresponded to 14% of exports from the SEM and just 0.08% of imported flows. By graphing wind data against TSO Counter trades (Figure 6.21) we can see where the Transmission System Operator utilised this option.

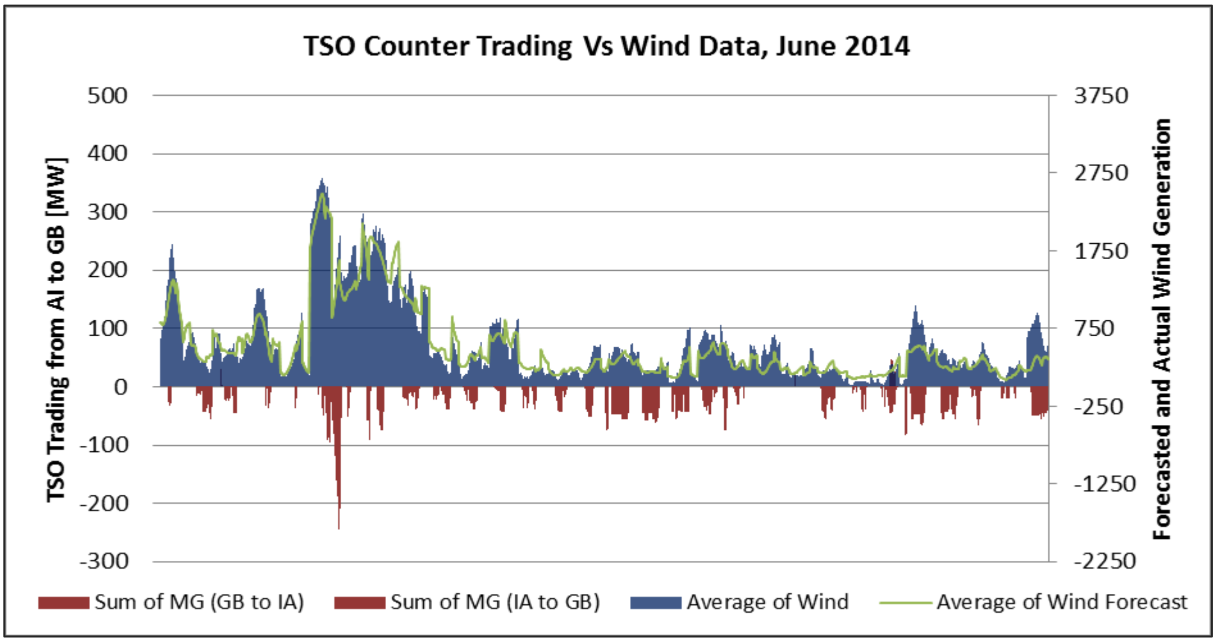


Figure 6.21 TSO Counter Flows Vs Wind Forecast and Actual Wind Generation, June 2014. Note, a filter has been applied to illustrate just TSO Metered Generation, thus 'Sum of Metered Generation' refers to these flows only.

When we factor in price differentials between GB and AI, as illustrated in Figure 6.22, we see that TSO exports often occurred when the prices in the SEM were lower. The fact that these opportunities were not captured by commercial Interconnector Users and intervention was required by the TSO to prevent curtailment suggests again that trading is not optimal.

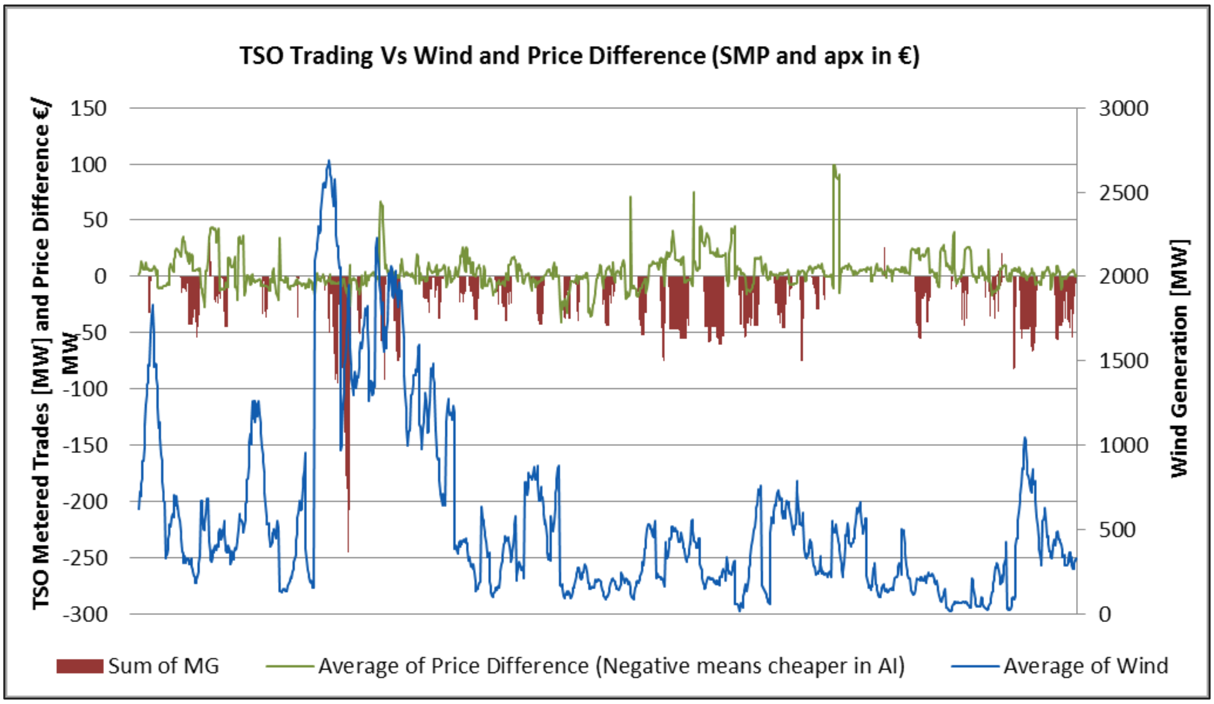


Figure 6.22 TSO Trading Vs Wind and Price Difference (SMP and apx in €)

7 Conclusion

In this final chapter, the research findings described in Chapter 6 are summarised, limitations are listed and recommendations for further research are presented.

7.1 Research Findings

Taking account of the results and discussion presented in Chapter 6, and the qualifications applying to the assumptions made, the conclusions of this study, which contribute to the aims and objectives listed in Chapter 1 are that;

1. Assumption around economic trading across electricity interconnectors do not reflect the behaviour in the real market to date.
2. There are a number of reasons for this, related to other risks to which the market participants are exposed; in particular, with regard to uncertainty around the firmness of price in real time in the SEM.
3. The East West Interconnector has reduced System Marginal Price in the SEM but this study indicates it may not have done so to the extent reported by EirGrid in their 2014 analysis.
4. The TSO has resorted to proxy trading to facilitate renewable generation in the absence of the commercial incentives to do so. This could be interpreted as a symptom of uneconomic use of the interconnector and an indication of potential barriers to efficient trade.
5. The redesign of SEM to comply with the European Target Model risks further distortion to trading if the lessons from experience to date are not adequately addressed in this process.

7.2 Limitations

As discussed in section 1.4, and throughout Chapter 6, this thesis was constrained by a number of limitations with respect to time, software, data availability and number of interviews undertaken.

With regard to software, use of the market modelling package PLEXOS would have enabled more detailed analysis.

In relation to data, assumptions had to be made to derive wholesale price; in the case of the SEM, the final wholesale prices including constraints and capacity payments were not available. GB prices had to be determined by reference to a price exchange.

As outlined in section 1.4, the sample of interviews taken was not fully representative of all parties associated with the interconnector. As a result they had the potential to be biased although enquires were constructed to minimise this possibility.

7.3 Recommendations for Future Research

Chapter 6 clearly indicates that there is scope for future research to obtain a more in-depth understanding of trading behaviours across the Interconnector and barriers to its efficient utilisation with a view to identifying the best solutions to implement as part of I-SEM.

This may include but are not limited to;

- Undertaking a more comprehensive stakeholder survey to assess the motivation behind current trading strategies and the resistance or willingness to engage in arbitrage trading.
- Updating the EirGrid Analysis based the recommendations regarding assumptions in sections 6.4.1
- Utilisation of Plexos to assess interconnector flows in response to more accurate estimations of price differentials between GB and the SEM.

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Appendix A : Registered Interconnector Units as of 05/07/2014

Associated Account	Unit ID	Unit Name	Unit Type
IA_NIMOYLE_Interconnector Administrator	IA_NIMOYLE_I_NIMOYLE	Moyle Interconnector Error Unit	Interconnector Error Unit
IA_RIEWIC_EirGrid PLC_Interconnector Administrator	IA_RIEWIC_I_RIEWIC	EWIC Interconnector Error Unit	Interconnector Error Unit
IA_NIMOYLE_Interconnector Administrator	IA_NIMOYLE_I_NIMOYLE_IRCU	Moyle Interconnector Residual Capacity Unit	Interconnector Residual Capacity Unit
TSO_EIRGRID	IA_RIEWIC_I_RIEWIC_IRCU	EWIC Interconnector Residual Capacity Unit	Interconnector Residual Capacity Unit
PT_400021_Airtricity Ltd (Generation)	PT_400021_I_RIEWIC	Airtricity Limited	Interconnector Unit
PT_500021_Airtricity Energy Supply NI Ltd Generation	PT_500021_I_NIMOYLE	Interconnector Unit	Interconnector Unit
PT_400099_Bord Gáis	PT_400099_I_RIEWIC	Bord Gáis	Interconnector Unit
PT_500037_Bord Gais Interconnector (NI)	PT_500037_I_NIMOYLE	Interconnector Unit	Interconnector Unit
PT_500024_Coolkeeragh ESB Ltd (Generator)	PT_500024_I_NIMOYLE	Interconnector Unit	Interconnector Unit
PT_400030_ESB PGEN	PT_400030_I_RIEWIC	ESB PGEN EWIC	Interconnector Unit
PT_500026_ESB Independent Energy NI Interconnector	PT_500026_I_NIMOYLE	Interconnector Unit	Interconnector Unit
PT_500027_NIE Power Procurement Business	PT_500027_I_NIMOYLE	Interconnector Unit	Interconnector Unit
PT_500034_NIE Supply Generation	PT_500034_I_NIMOYLE	Interconnector Unit	Interconnector Unit
PT_500031_Viridian Energy Supply Ltd	PT_500031_I_NIMOYLE	Interconnector Unit	Interconnector Unit

PT_400115_Viridian Energy Supply Limited	PT_400115_I_RIEWIC	Viridian Eeergy Supply Limited - EWIC	Interconnector Unit
PT_500042_Scottish Power Energy Management Ltd	PT_500042_I_NIMOYLE	Scottish Power Energy Management Ltd	Interconnector Unit
PT_500051_SSE Generation Ireland Limited - Interconnector	PT_500051_I_NIMOYLE	Endessa Interconnector Unit	Interconnector Unit
PT_500072_SSE Generation Ireland Limited - Interconnector	PT_500072_I_NIMOYLE	SSE Generation Ireland Limited - Interconnector Unit	Interconnector Unit
PT_400096_ElectroRoute Energy Trading	PT_400096_I_RIEWIC	ElectroRoute Energy Trading	Interconnector Unit
PT_500059_ElectroRoute Energy Trading	PT_500059_I_NIMOYLE	ElectroRoute Energy Trading Ltd	Interconnector Unit
PT_500069_ElectroRoute Energy Trading	PT_500069_I_NIMOYLE	ElectroRoute Energy Trading Ltd	Interconnector Unit
PT_400113_RWE Supply & Trading GmbH	PT_400113_I_RIEWIC	RWE Supply & Trading GmbH	Interconnector Unit
PT_500058_RWE Supply and Trading GmbH	PT_500058_I_NIMOYLE	RWE Supply & Trading GmbH	Interconnector Unit
PT_400114_Endesa Generación	PT_400114_I_RIEWIC	Endesa Generación EWIC	Interconnector Unit
PT_500071_Endesa Generación	PT_500071_I_NIMOYLE	Endesa Generación MOYLE	Interconnector Unit
PT_400108_Danske Commodities A/S	PT_400108_I_RIEWIC	Danske Commodities A/S	Interconnector Unit
PT_500070_Danske Commodities A/S	PT_500070_I_NIMOYLE	Danske Commodities A/S	Interconnector Unit
PT_400136_Cenergise Limited	PT_400136_I_RIEWIC	Cenergise Limited - EWIC	Interconnector Unit
PT_500075_Cenergise Limited	PT_500075_I_NIMOYLE	Cenergise Ltd MOYLE	Interconnector Unit

Appendix B : Overview of I-SEM Options, Source (SEM Committee, 2014)

			Adapted Decentralised Market	Mandatory ex-post Pool for Net Volumes	Mandatory Centralised Market	Gross Pool - Net Settlement Market
Participation in European markets for trading of energy in DA and ID timescales	DA	Portfolio vs. unit bidding	Gross portfolio bidding	Portfolio bidding	Unit bidding	Portfolio bidding
		Mandatory vs. voluntary	Voluntary participation [plus specific liquidity promoting measures]	Voluntary participation [with volume limitation measures]	Mandatory participation	Voluntary participation
		Bid format	Simple, block (or sophisticated unit) bids	Simple, block (or sophisticated unit) bids	Simple, block or sophisticated bids	Simple, block (or sophisticated unit) bids
	ID	Portfolio vs. unit bidding	Gross portfolio bidding	Unit bidding	Unit bidding	Unit bidding
		Exclusive vs. Non-exclusive	Non-exclusive	Non-exclusive [with same volume limitation measures]	Exclusive	Non-exclusive
		Bid format	Simple, block [or sophisticated] bids	Simple, block [or sophisticated] bids	Simple, block [or sophisticated] bids	Simple, block [or sophisticated] bids
Process for reaching feasible dispatch position		Starting point of dispatch	- DA nomination is the starting point (updated in the IDM) - Maintaining absolute priority dispatch	- DA nomination is the starting point (updated in the IDM) - Maintaining absolute priority dispatch	- DA nomination is the starting point (updated in the IDM) - Maintaining absolute priority dispatch	- IC volumes determined by DAM and IDM - Maintaining absolute priority dispatch
		Bids to the TSO for balancing and dispatch	Voluntary Inc's and dec's up to IDM GC (mandatory Inc's and dec's for generating units after IDM GC)	Mandatory net (+/-) complex bids for generating units	Mandatory Inc's and dec's for generating units	Mandatory complex bids for generating units
		Timing of bid submission	At DA and then updated continuously	At DA and then updated continuously	At DA and then updated continuously	At DA and then updated at specific windows
Imbalance/Pool settlement			Marginal imbalance price applied to all market participants based on (+/-) energy balancing actions	Net ex-post unconstrained market schedule to minimise production cost that determines the ex-post prices paid to/by all market participants (prices may vary by direction)	Marginal imbalance price applied to all market participants based on (+/-) energy balancing actions	Full ex-post unconstrained market schedule to minimise production cost that results in a single marginal price paid for all scheduled volumes
Arrangements for long-term trading		Internal	Both physical and financial trading	Both physical [with volume limitation measures] and financial trading	Financial trading	Financial trading
		Cross-border	PTRs to support bids for interconnector capacity	PTRs to support bids for interconnector capacity	FTRs to support bids for interconnector capacity	FTRs to support bids for interconnector capacity

Appendix C : Thesis Aims, Objectives and Methodology

Aims	Objectives	Methodology
1. Examine interconnector flows between the SEM/All-island (AI) and BETTA markets	**1a.** Collect, organise and analyse SEMO Interconnector Flow Data to identify trends in volumes and direction over time and by type of trade.	**1a i.** All Island System Load, Wind Generation, Interconnector Flow, APX RPD and SMP data for June 2014 were graphed over time using a pivot chart and analysed.
		1a ii. MIUN data for one full year (June 2013 – June 2014) was compiled and cumulative flows for each gate window in both the SEM to BETTA and BETTA to SEM direction were calculated. The results were presented in tabular, pie chart and bar chart form to illustrate clearly the overall distribution and trends emerging over time.
	1b. Identify trading patterns and strategies of Interconnector Users	**1b i.** Each MIUN value was matched with its associated Interconnector User. This was achieved by comparing Unit ID columns in the MIUN data set with those in the Registered Units dataset and employing a Vlookup. Using the filtering feature available in excel Pivot Tables, the Modified Interconnector Unit Nomination (MIUN) data for each Interconnector User over the full year could be presented separately allowing trading patterns to be identified.

2. Determine whether the actual utilisation of the interconnectors; corresponds with pre-interconnector delivery projections;	**2a.** Compare findings with assumptions underpinning previous studies.	**2a i.** Compare results with findings from literature **review.**
	2b. Assess whether EWIC is reducing SMP	**2b i.** A simplified analysis was designed to compare the estimated cost of net energy imports for June 2014 with the theoretical amount it would have cost us to produce this energy at home were the interconnectors not available.
		2b ii. The margin of error for EirGrid's 2014 analysis was estimated by examining the assumptions and determining their accuracy via literature review and interviews with market participants.
	2c. Assess whether EWIC is helping us to achieve renewable targets	**2c i.** Using findings from the analysis of Interconnector User behaviour, responsiveness to wind could be determined. The impact of TSO counter trades was determined by comparing TSO counter flows with wind data
3. Consider the reasons for any variances that have arisen under the current SEM market	**3a.** Analyse results and determine whether there is a connection between the difference	**3a i.** Compare results with findings from literature review.

arrangements and what lessons can be provided in terms of developing the revised I-SEM market	in assumed trading patterns and the differences in results.	