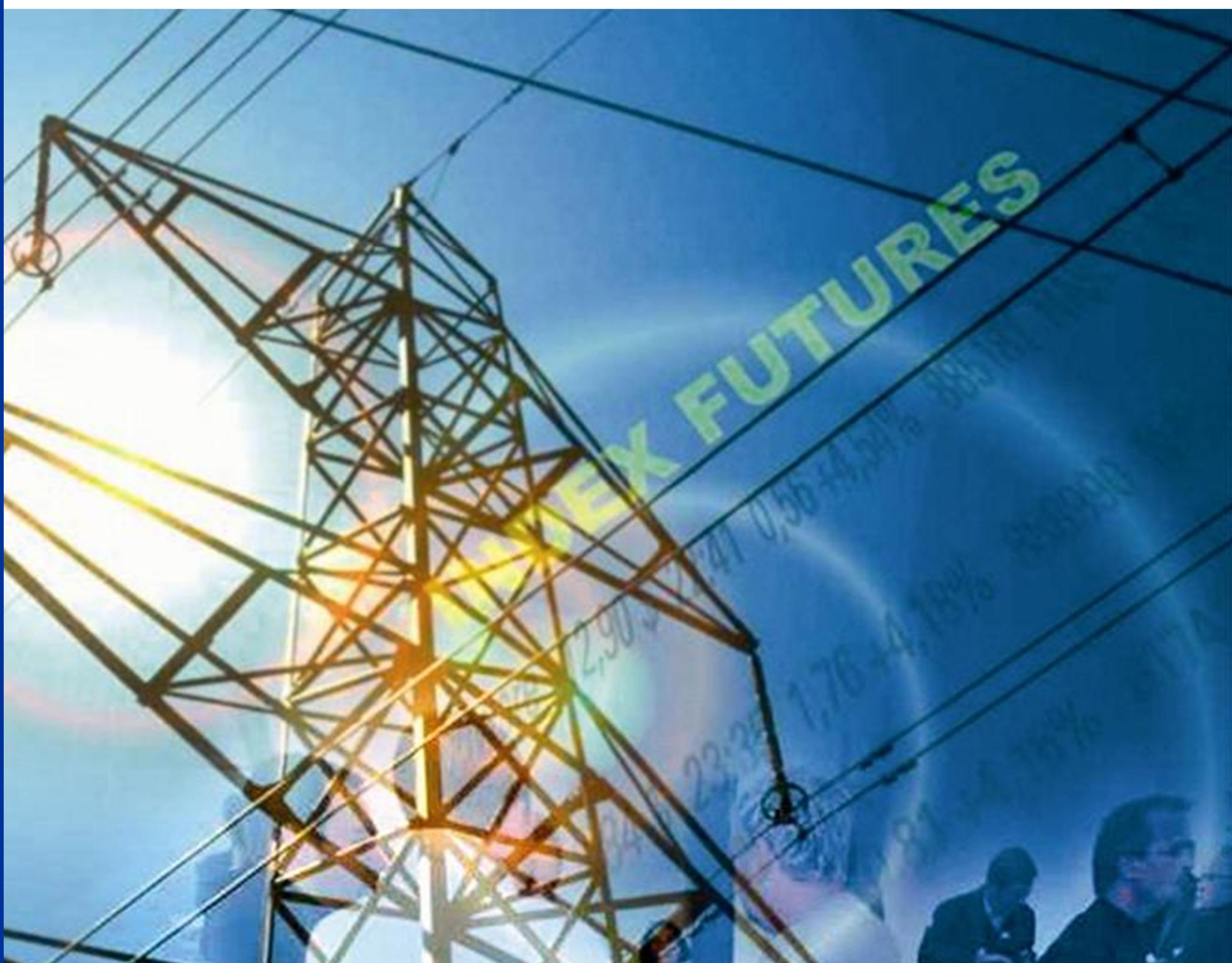
PÖYRY

ANALYSIS OF THE CORRELATION OF STRESS PERIODS IN THE ELECTRICITY MARKETS IN GB AND ITS INTERCONNECTED SYSTEMS

A report to Ofgem

March 2013



ANALYSIS OF THE CORRELATION OF STRESS PERIODS IN THE ELECTRICITY MARKETS IN GB AND ITS INTERCONNECTED SYSTEMS

Contact details

Name	Email	Telephone
Anser Shakoor	anser.shakoor@poyry.com	01865 812 267
Mike Wilks	mike.wilks@poyry.com	01865 812 251

Pöyry is an international consulting and engineering company. We serve clients globally across the energy and industrial sectors and locally in our core markets. We deliver strategic advisory and engineering services, underpinned by strong project implementation capability and expertise. Our focus sectors are power generation, transmission & distribution, forest industry, chemicals & biorefining, mining & metals, transportation, water and real estate sectors. Pöyry has an extensive local office network employing about 7,000 experts. Pöyry's net sales in 2012 were EUR 775 million and the company's shares are quoted on NASDAQ OMX Helsinki (Pöyry PLC: POY1V).

Pöyry Management Consulting provides leading-edge consulting and advisory services covering the whole value chain in energy, forest and other process industries. Our energy practice is the leading provider of strategic, commercial, regulatory and policy advice to Europe's energy markets. Our energy team of 200 specialists, located across 14 European offices in 12 systems, offers unparalleled expertise in the rapidly changing energy sector.

TABLE OF CONTENTS

[This page is intentionally blank]

EXECUTIVE SUMMARY

Objectives

The objective of the work presented in this report is to inform Ofgem's analysis of the contribution of cross-border interconnection flows in the context of assessing the risks for security of supply in GB electricity market. This is achieved through addressing the following two questions:

- What are the drivers for hours of relatively tight capacity margins in GB electricity system and interconnected systems?
- What is the impact of the identified drivers on cross-border interconnection flows between GB and interconnected systems?

Scope of work

As agreed with Ofgem, the analysis was based on key system parameters (demand, availability of conventional generation, wind and solar, and interconnector flows) of GB and its directly interconnected systems; Ireland (Republic of Ireland and Northern Ireland combined), France and the Netherlands. Germany and Spain were also included in the analysis due to large growth of renewables in these system and their potential impact on interconnector flows to France and GB.

Other factors could also impact the historical available capacity margins in GB and other systems such as; regulatory considerations, market development and its coupling, coordination of transmission system operators on the two sides of the interconnectors and impact of electricity price differentials. However, analysis of these factors was beyond the scope of this project.

Furthermore, the entire analysis was based on historical data (and necessary assumptions regarding any unavailable data as agreed with Ofgem) and did not include the impact of future evolution of; generation mix, interconnector growth, markets or any cross-border trading arrangements.

Approach to work

In order to address the above mentioned questions our overall approach was based on statistical correlation analysis which included the following main assessments:

- correlation analysis[1] of key system parameters; demand, available conventional capacity, wind and net flows, between GB and interconnected systems;
- computation of historic capacity margins in GB and other systems and analysis of their mutual correlations; and
- correlation analysis of hourly capacity margin in GB with its own and other system's parameters.

1 All correlations were assessed by calculating the correlation coefficient 'r' of relevant data sets. The coefficient 'r' can take values from –1.0 to +1.0. The sign of 'r' indicates whether the correlation is positive or negative i.e. whether the two variables are moving in the same (+) or opposite (-) direction. The magnitude (absolute value) of 'r' indicates the strength of the correlation.

The correlation assessments were performed based on hourly data for annual, seasonal, peak winter and during low capacity margin hours with the key focus being on GB.

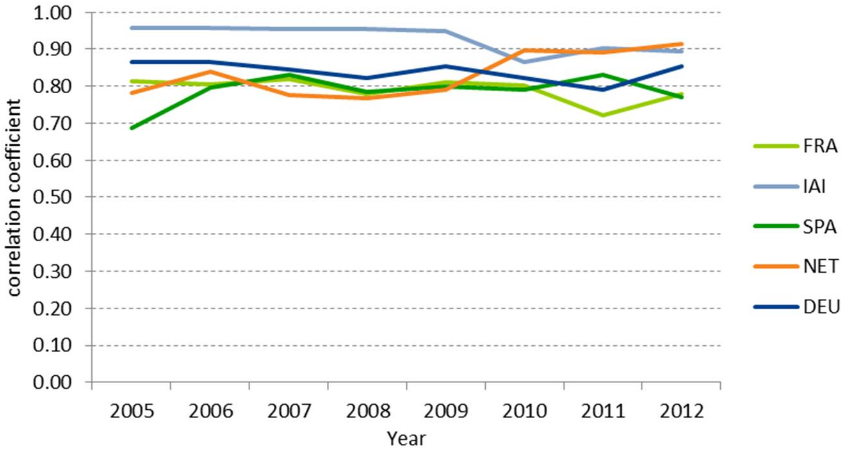
The historical data related to demand, available conventional generation and interconnector flows was mainly collected from respective Transmission System Operators (TSOs), Power Exchanges and European Network of Transmission System Operators for Electricity (ENTSO-E). Wind and solar data was prepared based on Anemos wind speed atlas and Transvalor radiation data respectively.

Demand correlations

We computed the correlations of hourly demand in GB with the hourly demand in other systems as shown in Figure 1. GB hourly demand has a very high correlation with the hourly demand of other systems included in this study.

Strong weather correlations between GB and Ireland and same time zone results in significant synchronisation of demand behaviour in the two systems resulting in very high positive correlation between their concurrent hourly demand.

Figure 1 – Correlation of hourly annual demand in GB and interconnected systems



Note: IAI represents Republic of Ireland and Northern Ireland as a combined system.

Furthermore, the correlations of peak demand (7am-9pm during business days) between GB and other systems were found to be relatively less high compared to the annual correlations although peak demand correlations between GB and Ireland remained very high. Higher year to year variability of correlation was also noticed for the peak demand correlations. Both annual and peak demand correlations were found to be statistically significant (at a significance level of 95%)[2].

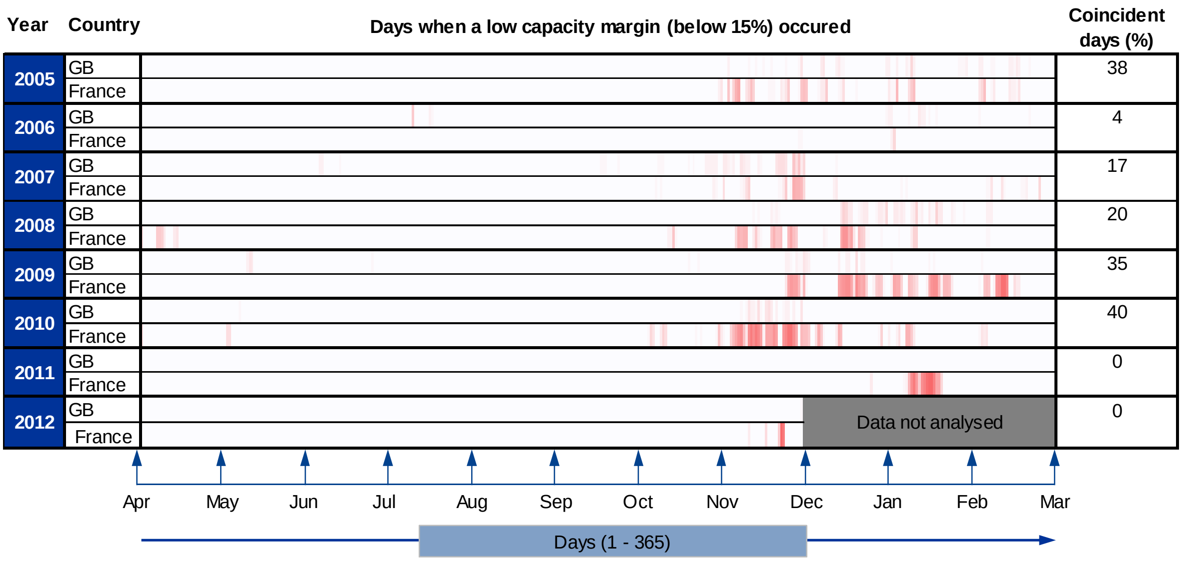
Among all the system parameters that have been analysed for their correlations, demand is found to be the most correlated parameter between GB and other systems.

2 Significance of a correlation is a statistical measure to test the likelihood of a computed correlation based on the magnitude of correlation coefficient, size of the data sample and the significance level criterion.

Capacity margin correlations

The occurrence of low capacity margin hours varies significantly across different days from one year to the other in GB as well as in other systems. For example, analysis of the distribution of below 15% capacity margins, across different days of a given historical year (April-April), in GB and France is presented in Figure 2 where each vertical red line indicates a day when a low capacity margin hour(s) occurred.

Figure 2 – Distribution of low (<15%) capacity margins across different days in GB and France (without interconnector flows)

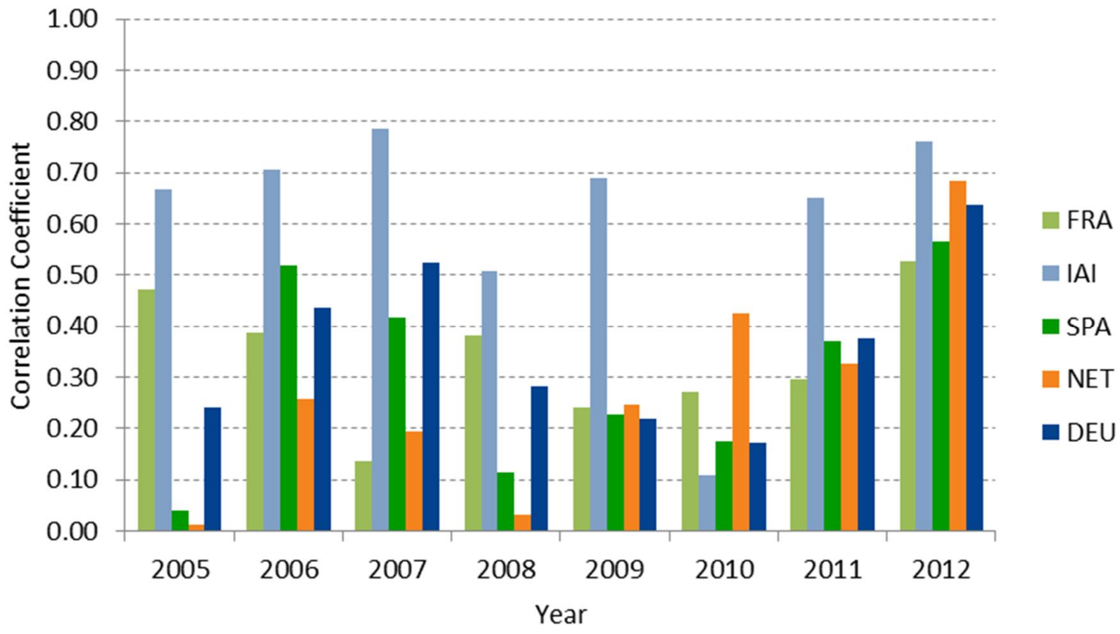


The following two observations arise from our review of timing of market stress hours:

- an inconsistent distribution (appearance) of low capacity margin hours existed across the 365 days among different years for each system; and
- whilst the majority of low capacity margins appear in winter, their coincidence (occurrence on the same day) varied significantly between the two systems for a given year.

Correlations of hourly capacity margins between GB and all other systems were also determined. As shown in Figure 3, capacity margins during peak demand hours in GB have been highly correlated with concurrent capacity margins in Ireland followed by medium level of correlation with France. These correlations are significant (at a significance level of 95%). However, substantial year to year changes in the magnitude of these correlations have been found for all systems.

Figure 3 – Correlations of GB capacity margins with other systems during peak demand hours (without interconnector flows)



Impact of Interconnector flows on GB capacity margins

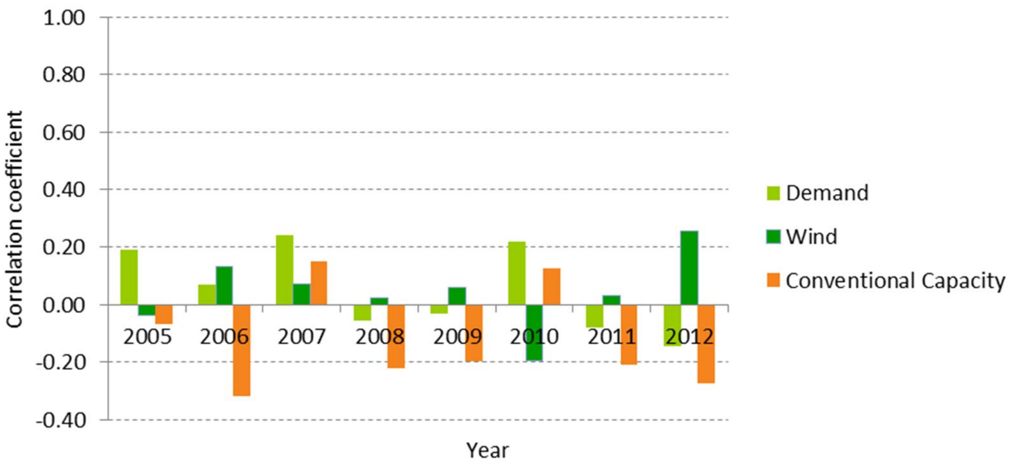
Comparison of low capacity margins in GB with and without interconnector flows (as shown in Table 1) indicates that interconnectors broadly help to reduce the number of low capacity margin hours however, specifically for small (less than 10%) capacity margins, the contribution of interconnector flows varies across different years. For example in 2005, net flows (imports) have resulted in reducing the number of less than 10% capacity margin hours. While in 2007 during the system stress hours net flows (exports) from GB (mainly to France) increased the number of less than 10% capacity margin hours in GB.

Table 1 – Impact of interconnector flows on number of hours within a specific capacity margin range in GB, increase (+ve)/decrease (-ve)

Year	0%-5%	5%-10%	10%-15%	15%-20%	20%-25%	25%-30%
2005	0	-20	-78	-74	-141	-149
2006	0	-2	-18	-87	-94	-88
2007	0	8	-40	-129	-42	-59
2008	0	0	-2	-38	-179	-182
2009	0	2	6	55	39	7
2010	0	-1	4	2	11	-15
2011	0	0	0	0	-14	-39
2012	0	0	-10	-45	-132	-304
Overall Avg.	0	-2	-17	-40	-69	-104

The correlation of net interconnector flows with the key GB system parameters i.e. demand, availability of conventional capacity and wind output during peak winter hours is shown in Figure 4. It was found that these correlations remain low (weak) and even turn from a positive correlation to a negative correlation across different years. However, the significance test of these correlations (at a significance level of 95%) revealed that the net flows correlation with demand as well as conventional capacity was significant for all years (with the exception of demand correlation in 2009). Considering both the magnitude of these correlations and their statistical significance it can be concluded that the historical net flows to GB have not been strictly dependent on GB system parameters.

Figure 4 – Correlation of GB net flows with GB system parameters (winter peak hours)



Furthermore, the capacity margin correlation with net flows into GB was predominantly negative. However, the magnitude of the correlation (annual as well as for below 10% and below 20% levels) remained mainly low (with few exceptions) and highly variable from one year to the other as shown in Table 2.

Table 2 – Correlation of capacity margins with net interconnector flows (capacity margins without interconnector flows)

	Correlation coefficient			Significance (p-vlaue)		
Year	**Annual**	**<10%**	**<20%**	**Annual**	**<10%**	**<20%**
2005	0.00	-0.35	-0.10	0.89	0.99	0.97
2006	-0.01		-0.12	0.57		0.91
2007	-0.03	0.00	-0.10	0.02	0.90	0.53
2008	0.04	-0.20	-0.05	0.00	0.84	0.41
2009	-0.18		-0.72	0.00		0.00
2010	-0.08	0.03	-0.28	0.00	0.86	0.37
2011	0.00			0.66		
2012	-0.17		-0.11	0.00		0.10

Note: Empty cells in the table indicate absence of relevant data in the corresponding capacity margin range.

The negative correlation between capacity margins and net interconnector flows broadly indicated that there were relatively more hours when low GB margins were associated with higher imports or when high GB margins were associated with higher exports.

However, the significance test (at a significance level of 95%) has indicated that these evaluated correlation coefficients are not consistently significant, being significant for five years out of eight years for annual correlations. On the other hand, for below 10% and 20% capacity margin hours all correlations were found to be insignificant (with the exception of 2009 correlation of below 20% capacity margin). Based on the strength of these correlations and their significance it was therefore not statistically possible to draw robust conclusions regarding the support by interconnector imports to GB during low capacity margin periods.

Conclusions

The findings of this analysis can be summarised as following:

- Historical demand of all analysed systems has shown a high correlation with GB demand.
- GB low capacity margins (below 20%) show a medium level of correlation with low capacity margins in Ireland and France. On the other hand, very low capacity margins (below 10%) in GB do not show a definite correlation with any of the other systems.
- Comparison of low capacity margins in GB, with and without interconnector flows, indicates that interconnector flows have broadly helped to reduce the number of low capacity margin (below 20%) hours in a year. However, for hours of highest GB system stress (i.e. where capacity margins are below 10%) interconnector flows have not consistently helped or worsen the capacity margin conditions in GB.
- GB capacity margin correlation with net interconnector flows to GB is predominantly negative, low, statistically insignificant and highly variable from one year to the other.

Thus in considering the role of interconnectors in contributing to GB security of supply we conclude that:

- Historical net interconnector flows to GB have not been driven by system parameters in GB or other included systems and could have been influenced by a number of co-occurring system (and/or market) conditions in GB and Europe.
- Under current market conditions, GB interconnector flows may either make the GB capacity margin situation better or worse and hence cannot be relied upon to support GB security of supply at times of GB system stress hours in particular when capacity margins are below 10%.

1. INTRODUCTION

This report provides analysis of the drivers of conditions when the margin between available supply and demand is tightest during a year in GB and its interconnected systems i.e. France, the Netherlands and Ireland (Republic of Ireland and Northern Ireland combined) and as well as in Germany and Spain. Statistical historical correlations of capacity margins and key system parameters (demand, available conventional capacity and wind) are evaluated for all systems considered in this analysis. This is to provide an independent analysis to Ofgem on the contribution of interconnector flows in the context of assessing the risks for security of supply in GB electricity market.

1.1 Context

Section 47ZA of the Electricity Act 1989, as amended, imposes an obligation on GEMA to prepare a report to the Secretary of State for Energy and Climate Change with an Electricity Capacity Assessment report every year. As part of the preparation of the 2013 report Ofgem is evaluating the contribution of interconnector flows to the security of supply risks in GB as measured in Ofgem's 2012 Electricity Capacity Assessment report.

The analysis of hours where the margin between available supply and demand is the tightest during a year (April to April) in the electricity markets in GB and its interconnected systems will be used to inform the evaluation of this contribution. Therefore Ofgem has sought specialist advisory support from Pöyry to investigate the system stress hours in GB and connected systems through statistical analysis of the historical correlations of system stress hours, winter demands, daily peak times, conventional plant outages and wind generation availabilities as well as an assessment of the likely direction and level of interconnector flows under existing market conditions.

1.2 Objectives

The objective of the work presented in this report is to inform Ofgem's analysis of the contribution of cross-border interconnection flows in the context of assessing the risks for security of supply in GB electricity market. This is achieved through addressing the following two questions:

- What are the drivers for hours of relatively tight capacity margins in GB electricity system and interconnected systems?
- What is the impact of the identified drivers on cross-border interconnection flows between GB and interconnected systems?

1.3 Scope of work

As agreed with Ofgem, the analysis was based on key parameters (demand, availability of conventional generation, wind and solar, and interconnector flows) of GB and its directly interconnected systems; Ireland (Republic of Ireland and Northern Ireland combined), France and the Netherlands. Germany and Spain were also included in the analysis due to large growth of renewables in these system and their potential impact on interconnector flows to France and GB.

Other factors could also impact the historical available capacity margins in GB and other systems such as; regulatory considerations, market development and its coupling, coordination of transmission system operators on the two sides of the interconnectors and impact of electricity price differentials. However, analysis of these factors was beyond the scope of this project.

Furthermore, the entire analysis was based on historical data (and necessary assumptions regarding any unavailable data as agreed with Ofgem) and did not include the impact of future evolution of; generation mix, interconnector growth, markets or any cross-border trading arrangements.

1.4 Approach to work

In order to address the above mentioned questions our overall approach was based on statistical correlation analysis which included the following main assessments:

- correlation analysis of key system parameters; demand, available conventional capacity, wind and net flows, between GB and interconnected systems;
- computation of historic capacity margins in GB and other systems and analysis of their mutual correlations; and
- correlation analysis of hourly capacity margin in GB with its own and other system's parameters.

The correlation assessments were performed based on hourly data for annual, seasonal, peak winter and during low capacity margin hours with the key focus being on GB. All capacity margin calculations are based on static capacity margins.

The historical data related to demand, available conventional generation and interconnector flows was mainly collected from respective Transmission System Operators (TSOs), Power Exchanges and European Network of Transmission System Operators for Electricity (ENTSO-E). Wind and solar data was prepared based on Anemos wind speed atlas and Transvalor radiation data respectively.

1.5 Structure of this report

This report details our methodology, nature and sources of data and key assumptions as applied in the study. All key findings of the overall analysis are presented in this report. Any other necessary and relevant information is included in the form of annexes. The remainder of this report is structured as follows:

- Chapter 2 describes the details of our methodology, input data and assumptions;
- Chapter 3 provides the results of statistical correlation analysis;
- Chapter 4 presents the results of the interconnector flow assessment; and
- Annex A provides charts and tables for additional correlation analysis while Annex B provides an introduction to Ilex energy reports.

1.6 Conventions

Throughout this report all annual data relates to years running from April to April, unless otherwise identified.

1.6.1 Sources

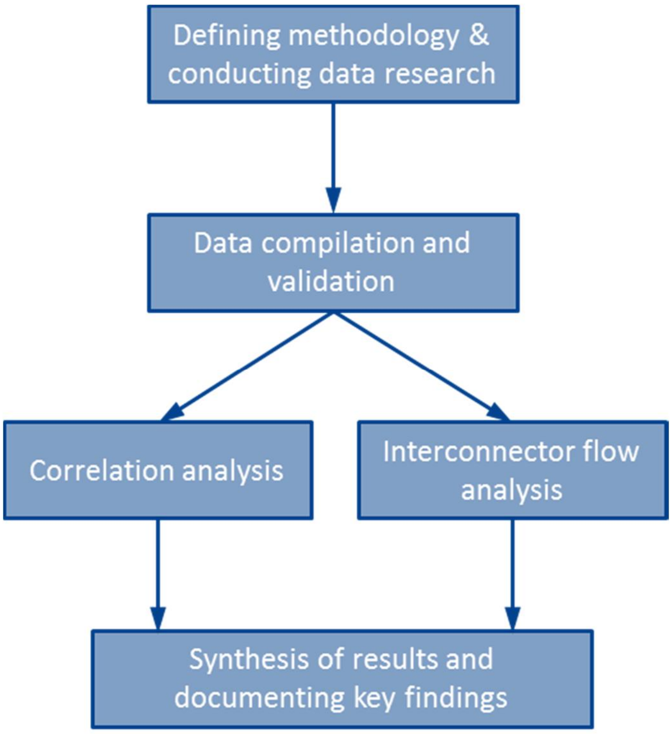
Unless otherwise attributed the source for all tables, figures and charts is Pöyry Management Consulting.

2. METHODOLOGY

2.1 Introduction

This chapter provides details of our methodology, key data requirements with sources and assumptions. An overview of our overall approach is depicted in Figure 5 below.

Figure 5 – Overview of overall approach



Following sections describe the details of our methodology as applied in this project.

2.2 Data compilation

Most of the relevant data for this project was already available in Pöyry's in-house databases which have been developed through years of research and are updated quarterly as part of our European Electricity Market reporting service, which is provided to a wide range of clients internationally.

The main data requirements for this analysis and their main relevant sources are given in Table 3. We have compiled the relevant data at hourly time resolution and for eight historical years i.e. 2005 to 2012. Eight recent years were chosen as the main renewables growth has taken place in the last 8 years which therefore makes these years relevant for the assessment of security of supply situation under existing market conditions. Furthermore, the availability of consistent relevant data sets before eight years was limited.

Table 3 – Relevant data and key sources

Data type	2005	2006	2007	2008	2009	2010	2011	2012	Key sources
Demand	✓	✓	✓	✓	✓	✓	✓	✓	Pöyry. ENTSOE, TSOs
Wind	✓	✓	✓	✓	✓	✓	✓	✓	Anemos, Pöyry
Solar	✓	✓	✓	✓	✓	✓	✓	✓	Transvalor, Pöyry
Conventional gen. availability	✓	✓	✓	✓	✓	✓	✓	✓	Pöyry, Power exchanges
Flows (physical)	☑	☑	☑	☑	☑	☑	✓	✓	ENTSOE, National TSOs

✓ Compiled

☑ Data for all relevant interconnectors not available

All data was obtained according to respective system's time zones for example, data for France, Germany, Spain and the Netherlands was collected according to Central European Time (CET), while data for Great Britain and Ireland was in Greenwich Mean Time (GMT). All data time series were finally converted into a uniform GMT time stamp. For the sake of consistency among all investigated years, data for 29th February was removed from leap years.

All data series prepared for this study formed a consistent set of key system parameters to compute internally consistent statistical correlations. Also all assessments were based on hourly data resolution. Details of individual data elements are provided in the following sections.

2.2.1 Demand data

Pöyry's in-house databases contain hourly demand data from 2005 to 2012 with hourly resolution for all relevant systems compiled through research carried out for several projects over the last years. This is based on historical demand levels. This demand represents gross consumption and includes grid losses. However, it does not include generation station's own demand. The key sources of our demand database have been European Network of Transmission System Operators for Electricity (ENTSO-E)[3] and national Transmission System Operators (TSOs) in respective systems which include:

- Great Britain – National Grid UK;
- France – RTE;
- The Netherlands – TenneT;
- Single Electricity Market (Ireland and Northern Ireland) – EirGrid/SONI;
- Spain – Red Electrica; and
- Germany – TenneT, Amprion, TransnetBW and 50 hertz.

The prepared demand series represents the power consumed by the network including the network losses but excluding the consumption for pumped storage and excluding the consumption of generating auxiliaries.

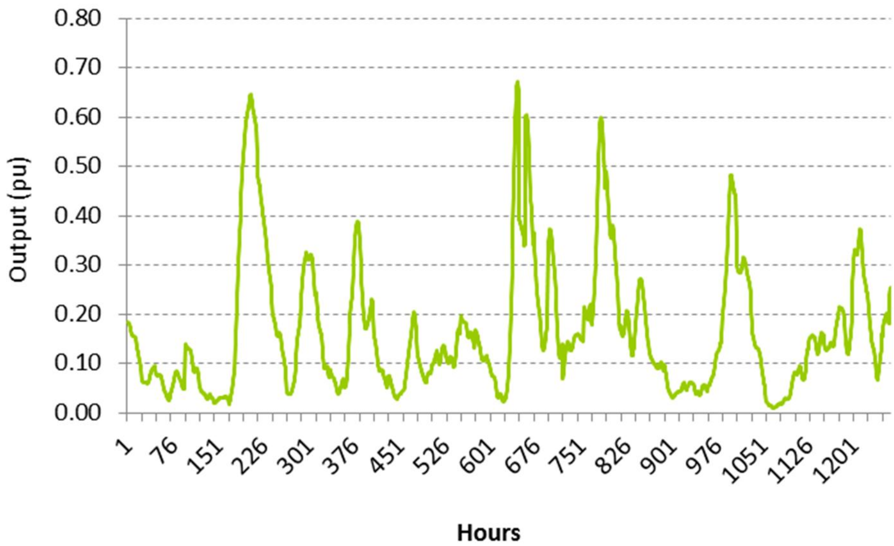
3 http://www.entsoe.net/default.aspx(needs user account to access the data)

2.2.2 Wind data

We have compiled the hourly wind load factor data for all relevant systems for 2005 to 2012. These load factors are based on wind speed data (based on Anemos[4] wind atlas) with appropriate turbine/wind farm output curves corresponding to the geographical locations of wind farms in respective systems and calibrated according to historical wind outputs. This data is converted into MW values based on the average quarterly installed capacity of wind during each year in respective systems because wind installed capacity has varied significantly in some systems within a given historical year.

We have deployed our Anemos wind data as it has been validated and provides internal consistency with the rest of the required data (e.g. with demand) that has been compiled for this study. Anemos wind data applied for this study was for a 20km grid and 80m height. An example of computed wind output series is provided in Figure 6 below.

Figure 6 – An example of wind output profile based on Anemos wind speed data for Germany (January-February 2010)



2.2.3 Solar data

Solar generation growth has started in the last few years in selected systems mainly in Spain, and especially rapidly in Germany but also recently in France and GB. We have applied hourly solar radiation data from Transvalor[5] to prepare annual solar load factors at system level based on our knowledge of solar generation locations in respective systems.

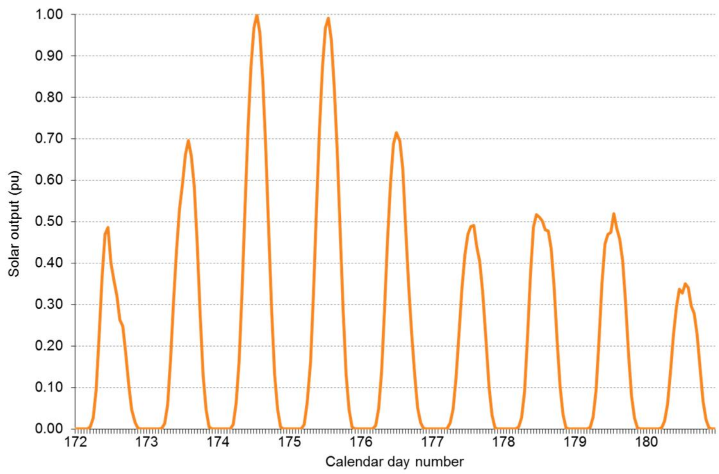
The hourly load factors were converted into solar power output based on installed solar capacity in each capacity. Similar to wind, solar installed capacity has been changing significantly within year in recent years. Therefore, we have applied average quarterly solar installed capacity to build annual solar output time series in respective systems.

4 For information about the Anemos Wind Atlas see: http://www.anemos.de

5 http://www.soda-is.com

We have prepared 2005-2012 solar radiation data and corresponding computed output time series. An example of computed solar output series is provided in Figure 7.

Figure 7 – An example of solar output profile based on Transvalor radiation data for Germany (summer week, 2011)



2.2.4 *Conventional capacity and availability data*

Our desk based research in the last several years has resulted in compiling conventional (thermal) generation installed capacity and seasonal availability data of all plants (>50MW) across all Europe. This data includes the historical capacity additions, retirements, historic load factor information and technical availability profiles of all existing technologies. By applying technical availabilities of technologies along with the respective installed capacity we have computed the hourly availability of all conventional generation aggregated at individual system level.

An accurate computation of available capacity margins in GB is critical in this project therefore we have applied relatively detailed data regarding historical technical availabilities of conventional plants in GB. For example, we hold GB conventional capacity availability data (by technology) at half-hourly resolution (mainly sourced from ELEXON[6]) which (converted to hourly hours) was best suited for this study compared to using average seasonal (winter/summer) availabilities.

For other systems the conventional thermal plant availability was not available at hourly levels. Our earlier research has compiled monthly availability profiles at individual system level of all thermal technologies (including nuclear) further characterized by business and non-business day availabilities in each month. These were applied respectively for all systems other than GB.

2.2.5 *Interconnector (physical) flow data*

The main sources of GB interconnector flows data (hourly) include; National Grid (UK), ELEXON and Mutual Energy[7] (for Moyle interconnector data). Most of the Interconnector

---

6 https://www.elexonportal.co.uk/ (requires user account for accessing data)

7 http://www.mutual-energy.com/The_Moyle_Interconnector/Index.php

flows data (hourly physical flows) for other systems was acquired from ENTSO-E which provides data for last two years on a rolling basis.

Hourly data for all GB interconnectors was compiled for 2005-2012 while interconnector flows data relevant for other systems was available for 2010-2012.

2.3 Correlation analysis

For assessment of the drivers attributing to relatively tight capacity margins in the Great Britain electricity market and adjacent interconnected systems, detailed statistical correlation analysis was performed.

For evaluations of various correlations following key statistical measures were applied:

Correlation coefficient

Correlation coefficient is a quantitative measure of the mutual relationship between two variables. The coefficient 'r' can take values from –1.0 to +1.0. The sign of r indicates whether the correlation is positive or negative i.e. whether the two variables analysed are moving in the same (+) or opposite (-) direction. The magnitude (absolute value) of r indicates the strength of the correlation i.e. both variables move in the same proportion (strong correlation) or they move with different orders of magnitude (weak correlation).

Significance of correlation coefficient

Significance of a correlation coefficient is a statistical measure to test the likelihood of a computed correlation based on the magnitude of correlation coefficient, size of the data sample and the significance level criterion.

We have applied 't test' to assess the hypothesis of no correlation against the hypothesis of the correlation coefficient being the calculated value. The value of 't' is computed based on the following formula:

$$t = r\sqrt{(n-2)}/\sqrt{(1-r^2)}$$

Where 'r' is the sample correlation coefficient, and 'n' is the size of the sample (the number of data pairs). The value of 't' is applied to determine the p-value i.e. the significance of the correlation. This tells how unlikely a given correlation coefficient, r, will occur given no relationship in the data. The smaller the p-level, the more significant the relationship will be.

In order to guide the interpretation of results we have applied a rule that all correlations above p-value of 0.05 (i.e. at a significance level 95%) will be considered insignificant.

While describing the strength of a correlation in all assessments we have applied a consistent interpretation[8] of the magnitude of a correlation as given in Table 4, which would be applicable for both positive and negative correlations. This was based on observing the broad distribution of computed correlation coefficients as observed in various assessments.

8 Although this provides a consistent description and comparison of various correlations evaluated in this study however, due to significant inter-year variations of a given type of correlation it was not always possible to describe precisely a given correlation which fluctuates significantly across several years.

Table 4 – Interpretation of the magnitude (absolute value) of a correlation coefficient

Correlation Level	Range of correlation coefficient Min. (≥)	Max (<)
Weak	0	0.2
Medium	0.2	0.5
High	0.5	0.8
Very High	0.8	1

2.3.1 *Assessment of capacity margins and their correlations*

Available capacity margin during individual hours for each system was based on the concurrent generation and demand conditions as well as the net aggregated flow through all the interconnectors to the respective system as shown by the following expression.

System margin = Total available generation (conventional + renewables) + Net flows - Demand

However, for those assessments involving capacity margins without interconnector flows, net flows were not included while computing the capacity margins.

Having determined the capacity margins in each hour for all historical years we have evaluated their correlations specifically focusing on the hours where the margin between available supply and demand is the tightest during a year (April to April).

In order to understand the correlations among the key system parameters we have determined the matrices of correlations of key system parameters i.e. demand and net demand among different systems.

Following list provides key correlations that have been performed in this analysis:

- capacity margin correlations – GB vs. other systems;
  - annual, peak, seasonal, winter peak and during low capacity margins hours
- correlations of capacity margins with system parameters for each system;
  - annual and during low capacity margin hours
- GB capacity margins correlations with demand of other systems;
  - annual and peak demand
- demand correlations – GB vs. other systems;
  - annual, peak, seasonal, winter peak and during hours of low capacity margin hours
- net Demand correlations – GB vs. other systems;
  - annual and peak
- wind generation correlations – GB vs. other systems; and
  - annual, seasonal and winter peaks.

The above mentioned correlations have been performed keeping in view that the focus of this analysis is GB security of supply.

2.4 Interconnector flow analysis

A qualitative assessment of interconnector behaviour under existing market conditions was performed. It is based on how GB interconnector flows have historically interacted with various system parameters in GB and other systems across the year and during peak winter conditions.

Our assessment of GB interconnectors' behaviour was built on various correlations analysis which includes:

- impact of interconnectors on number of hours of low capacity margins in GB;
- correlation of net flows into GB with GB system parameters (wind, demand, conventional generation availability);
- correlation of GB imports with GB demand; and
- correlation of net flows into GB with capacity margins in GB.

By analysing the above historical correlations we have provided our view of the degree of reliance on interconnector flows for security of supply in GB.

[This page is intentionally blank]

3. CORRELATION ANALYSIS

3.1 Introduction

In this chapter the results of our analysis based on computation of capacity margins and various statistical correlations are presented.

In order to understand the drivers of low capacity margin hours in GB and their interaction with neighbouring systems we have performed various assessments which include:

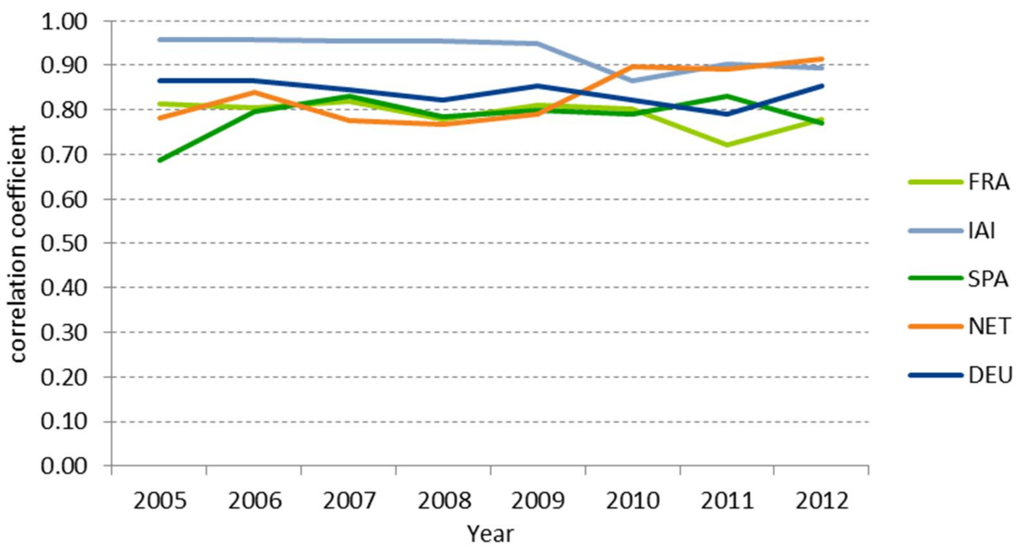
- correlation analysis of key system parameters (demand, available conventional capacity, wind and net flows) between GB and interconnected systems;
- computation of historic capacity margins in GB and other systems and analysis of their mutual correlations; and
- correlation analysis of hourly capacity margin hours in GB with its own and other system's parameters.

3.2 Demand correlations

We have computed the correlations of hourly demand in GB with the hourly demand in other systems as shown in Figure 8. Historical demand in all systems has shown a high degree of correlation with GB demand. However, year to year variations in correlation have also been observed which are relatively high for GB-Spain and GB-Netherland demand.

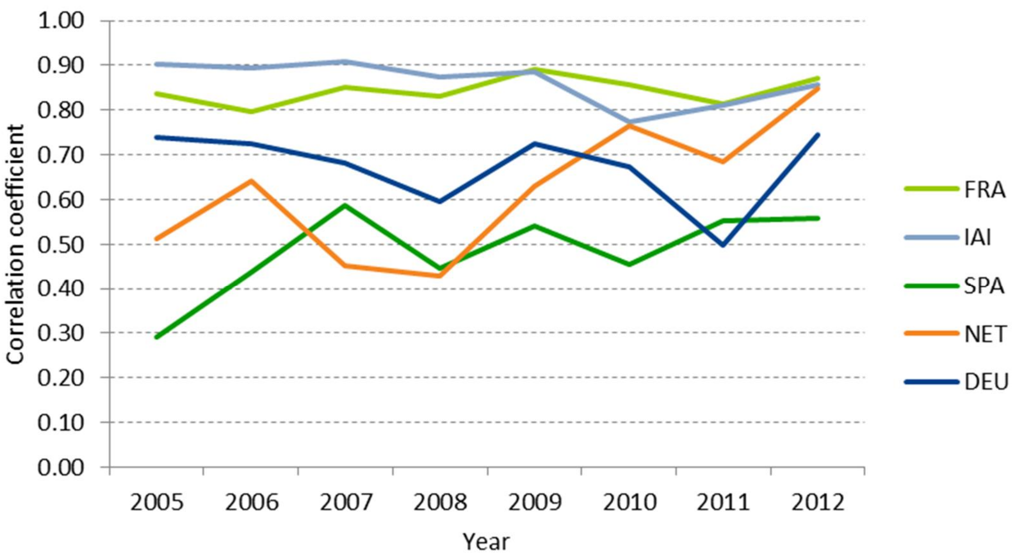
Strong weather correlations between GB and Ireland as well as same time zone results in significant synchronization of demand behaviour in the two systems resulting in very high positive correlation between their concurrent hourly demand.

Figure 8 – Correlation of GB demand with demand of other systems (hourly demand across entire year)



Furthermore, the correlations of peak demand (7am-9pm during business days) between GB and other systems as presented in Figure 9 were found to be relatively less high compared to the annual correlations although peak demand correlations between GB and Ireland remained very high. Higher year to year variability of correlation was also noticed for the peak demand correlations. Both annual and peak demand correlations were found to be statistically significant (at a significance level of 95%)[9].

Figure 9 – Correlation of peak demand between GB and other systems (demand during 7am-9pm GMT)



The variation of GB demand correlations for a given system across different years is linked to the changes in both the gross annual demand and its distribution across different seasons and peak/off-peak during each season. On the other hand correlation of GB-Netherlands peak demands vary significantly across different years due to significant inter-year changes in the electricity demand for transport and agriculture in the Netherlands.

Among all the system parameters that have been analysed for their correlations, demand is found to be the most correlated parameter between GB and other systems.

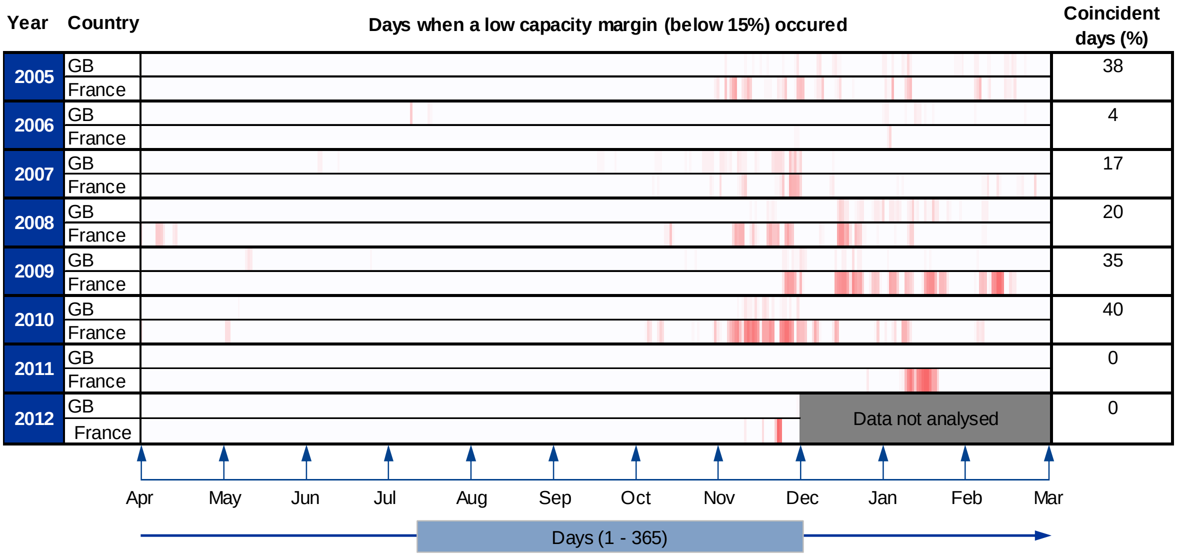
3.3 Historic capacity margins

The occurrence of low capacity margin hours varies significantly across different days from one year to the other in GB as well as in other systems. For example, analysis of the distribution of below 15% capacity margins, across different days of a given historical year (April-April), in GB and France is presented in Figure 10 where each vertical red line indicates a day when a low capacity margin hour(s) occurred.

---

9 Significance of a correlation is a statistical measure to test the likelihood of a computed correlation based on the magnitude of correlation coefficient, size of the data sample and the significance level criterion.

Figure 10 – Distribution of low (<15%) capacity margin hours (without interconnector flows)



The following two observations arise from our review of timing of market stress hours:

- an inconsistent distribution (appearance) of low capacity margin hours existed across the 365 days among different years for each system; and
- whilst the majority of low capacity margins appear in winter, their coincidence (occurrence on the same day) varied significantly between the two systems for a given year.

Furthermore, the comparison of low capacity margins in GB with and without interconnector flows (as shown in Table 5) indicates that interconnectors broadly help to reduce the number of low capacity margin hours however, specifically for small (less than 10%) capacity margins, the contribution of interconnector flows varies across different years. For example in 2005, net flows (imports) have resulted in reducing the number of less than 10% capacity margin hours. While in 2007 during the system stress hours net flows (exports) from GB (mainly to France) increased the number of less than 10% capacity margin hours in GB.

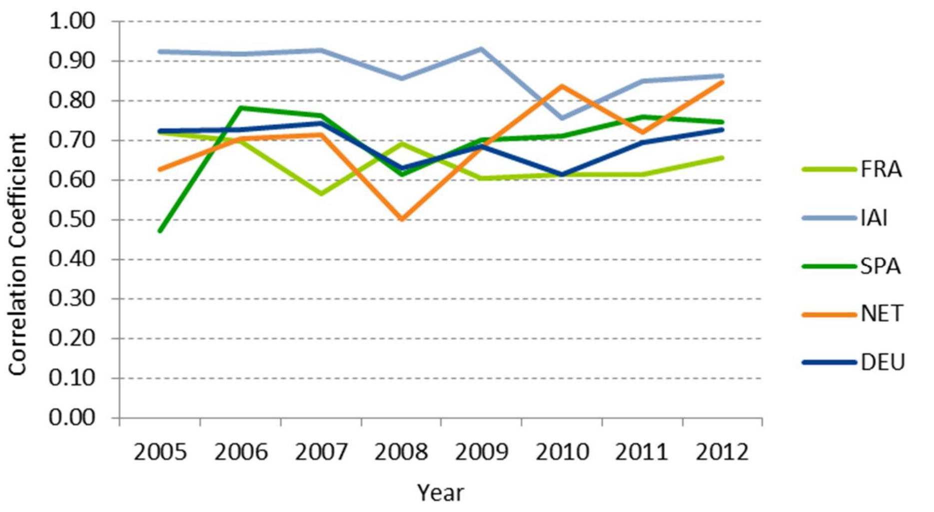
Table 5 – Impact of interconnector flows on number of hours within a specific capacity margin range in GB, increase (+ve)/decrease (-ve)

Year	0%-5%	5%-10%	10%-15%	15%-20%	20%-25%	25%-30%
2005	0	-20	-78	-74	-141	-149
2006	0	-2	-18	-87	-94	-88
2007	0	8	-40	-129	-42	-59
2008	0	0	-2	-38	-179	-182
2009	0	2	6	55	39	7
2010	0	-1	4	2	11	-15
2011	0	0	0	0	-14	-39
2012	0	0	-10	-45	-132	-304
Overall Avg.	0	-2	-17	-40	-69	-104

3.4 Correlations of capacity margins

We have assessed various correlations of GB capacity margins with the capacity margins of other systems in order to understand the mutual interactions. Figure 11 shows the correlation of all capacity margins across the entire year (without interconnector flows) between GB and its surrounding systems. Very high positive correlations of capacity margins are observed between GB and Ireland. This is primarily linked to very high demand correlations (as shown earlier in Figure 8) between the two systems.

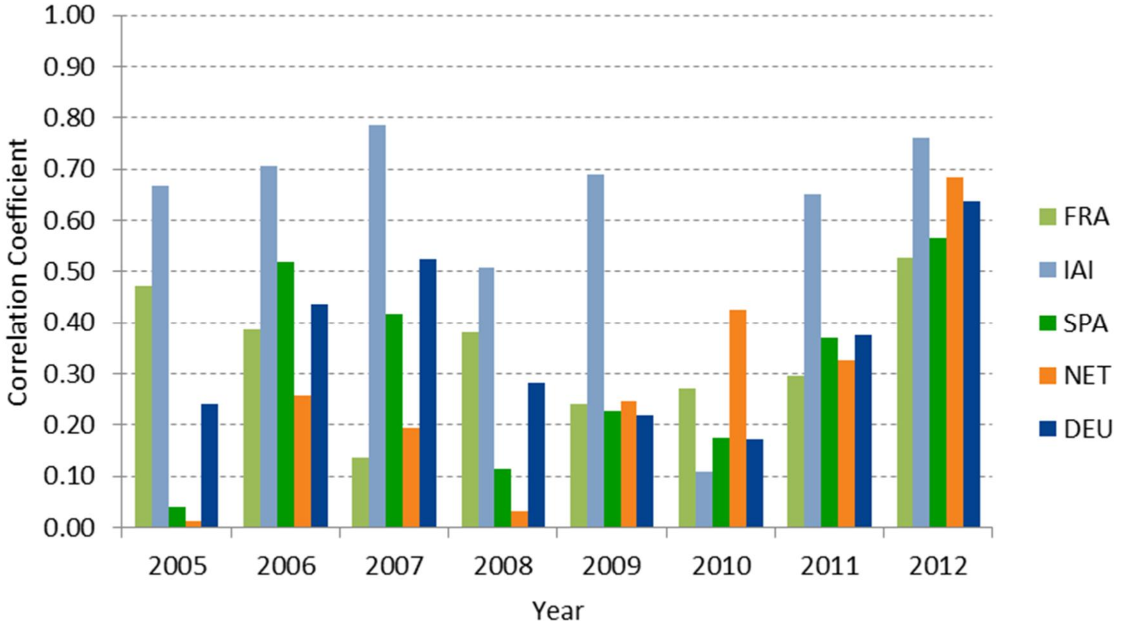
Figure 11 – Correlations of GB capacity margins with other systems (annual, without interconnector flows)



The annual capacity margin correlations; GB-France and GB-Germany, were also high while other systems exhibit significant variation in the capacity margin correlations with GB across different years. The year-to-year variations are linked to changes in annual gross demand and distribution of demand across a given year for individual systems.

Correlations of hourly capacity margins between GB and all other systems were also determined. As shown in Figure 12, capacity margins during peak demand hours in GB have been highly correlated with concurrent capacity margins in Ireland followed by medium level of correlation with France. These correlations are significant (at a significance level of 95%). However, substantial year to year changes in the magnitude of these correlations have been found for all systems.

Figure 12 – Correlations of GB capacity margins with other systems during peak demand hours (without interconnector flows)



For those hours when capacity margins are very low (below 10% capacity margins) in GB, the corresponding correlations with concurrent capacity margins of other systems are provided in Table 6. Due to significantly small number of hours in this capacity margin range, the corresponding correlations with all other systems remain insignificant.

Table 6 – Correlation of low (below 10%) capacity margins in GB with concurrent capacity margins in other systems (without interconnector flows)

	Correlation coefficient					Significance of correlation (p-value)				
Year	FRA	IAI	SPA	NET	DEU	FRA	IAI	SPA	NET	DEU
2005	0.42	0.13	-0.39	0.43	-0.44	0.06	0.57	0.08	0.05	0.04
2006										
2007	0.54	0.38	0.47	0.29	0.40	0.01	0.06	0.02	0.16	0.05
2008	0.26	0.26	-0.22	0.40	0.07	0.20	0.19	0.28	0.04	0.74
2009										
2010	0.33	0.54	0.37	0.41	0.06	0.43	0.17	0.37	0.31	0.89
2011										
2012										

Note: Empty cells in the table indicate absence of hours below 10% capacity margin range.

For low capacity margins (below 20% capacity margins), GB correlations with Ireland and France vary from low to medium level and are generally significant with few exceptions as shown in Table 7.

Table 7 – Correlation of low (below 20%) capacity margins in GB with concurrent capacity margins in other systems (without interconnector flows)

	Correlation coefficient					Significance of correlation (p-value)				
Year	FRA	IAI	SPA	NET	DEU	FRA	IAI	SPA	NET	DEU
2005	0.43	0.34	-0.05	-0.07	0.15	0.00	0.00	0.27	0.09	0.00
2006	0.25	0.18	0.16	0.09	0.17	0.00	0.00	0.00	0.09	0.00
2007	0.39	0.48	0.41	-0.07	0.18	0.00	0.00	0.00	0.10	0.00
2008	0.35	0.40	0.12	0.06	0.21	0.00	0.00	0.02	0.19	0.00
2009	-0.07	0.09	-0.25	0.23	0.02	0.28	0.15	0.00	0.00	0.72
2010	0.31	0.56	-0.06	-0.09	0.13	0.00	0.00	0.50	0.26	0.12
2011										
2012	0.05	0.19	-0.10	-0.04	-0.09	0.64	0.06	0.36	0.69	0.37

Note: Empty cells in the table indicate absence of hours below 20% capacity margin range.

3.5 Correlations of GB capacity margins with its key system parameters

The capacity margins in GB were analysed for their correlation with its key system parameters i.e. with demand, net demand (demand – intermittent generation), wind and available conventional thermal capacity. These correlations are shown in Figure 13 below. Hourly capacity margins in GB have high negative correlation with concurrent demand. All of these correlations were statistically significant.

GB capacity margins show a medium level of positive correlation with the availability of conventional thermal capacity in GB as low capacity margin hours could also be triggered by low availability of conventional thermal capacity as well as higher availability of thermal capacity leads to larger capacity margins. A relatively weak but positive correlation of GB capacity margins with available wind output was also observed which is attributed to GB experiencing high wind speeds during winter when demand is also high.

As currently there is not a large amount of intermittent generation in GB therefore, net demand also follows about the same correlation level with capacity margins as demand.

Figure 13 – Correlations of GB capacity margins with GB system parameters (without interconnector flows)

An assessment of the correlation of low capacity margin hours with GB system parameters is presented in Table 8 (for below 10% capacity margins) and Table 9 (for below 20% capacity margins). Significant changes in the direction and magnitude of the correlation coefficient of all system parameters across different years and their statistical insignificance (particularly for below 10% capacity margins) indicate that a single parameter was not consistently responsible for low capacity margin hours in GB. For example in one year outages of thermal units could lead to low capacity margin hours while in another year large demand swings (rise) resulted in low capacity margin hours.

Table 8 – Correlations of below 10%capacity margins with system parameters in GB (without interconnector flows)

	Correlation coefficient				Significance of correlation (p-value)			
Year	Demand	NetDemand	Wind	Conv Thermal Cap	Demand	NetDemand	Wind	Conv Thermal Cap
2005	0.46	0.41	0.06	0.62	0.04	0.07	0.81	0.00
2006								
2007	-0.40	-0.51	0.36	-0.07	0.05	0.01	0.08	0.73
2008	-0.23	-0.35	0.35	0.20	0.25	0.08	0.08	0.32
2009								
2010	-0.37	-0.52	0.31	0.05	0.37	0.19	0.45	0.91
2011								
2012								

Note: Empty cells in the table indicate absence of hours below 10% capacity margin range.

Table 9 – Correlations of low (below 20%) capacity margins with system parameters in GB (without interconnector flows)

	Correlation coefficient				Significance of correlation (p-value)			
Year	Demand	NetDemand	Wind	Conv Thermal Cap	Demand	NetDemand	Wind	Conv Thermal Cap
2005	-0.06	-0.10	0.21	0.21	0.17	0.02	0.00	0.00
2006	0.63	0.59	0.52	0.73	0.00	0.00	0.00	0.00
2007	0.24	0.21	0.39	0.44	0.00	0.00	0.00	0.00
2008	-0.17	-0.20	0.15	0.20	0.00	0.00	0.00	0.00
2009	0.73	0.73	0.03	0.82	0.00	0.00	0.65	0.00
2010	-0.04	-0.05	0.03	0.26	0.60	0.58	0.76	0.00
2011								
2012	0.46	0.47	0.01	0.64	0.00	0.00	0.95	0.00

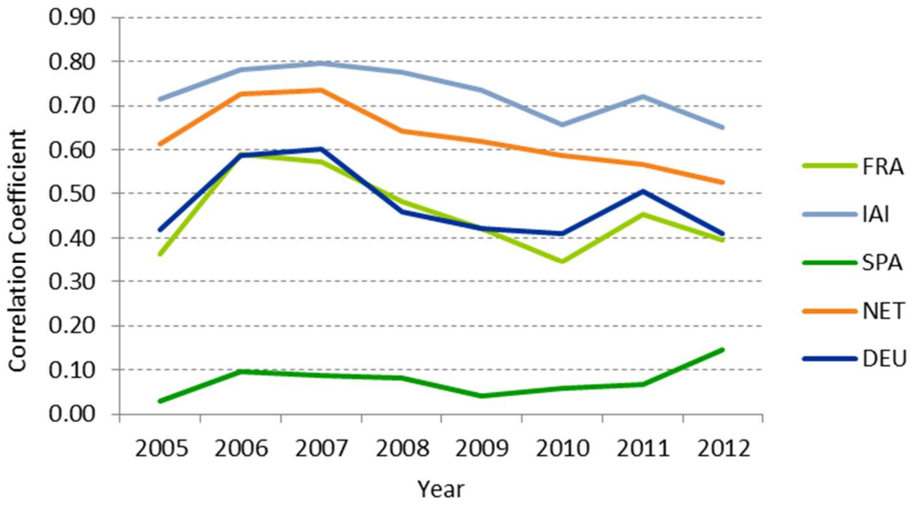
Note: Empty cells in the table indicate absence of hours below 20% capacity margin range.

3.6 Wind output correlations

As the amount of wind generation is rapidly increasing in GB and surrounding systems it is likely to influence the available capacity margins in respective systems. An important feature of wind in the GB security of supply context would be the extent to which wind output is correlated between GB and other systems which are directly or indirectly connected to GB. The inter-system wind output correlation would impact the corresponding interconnector flows particularly when the wind volume becomes substantial in a system such as more recently in the case of Germany.

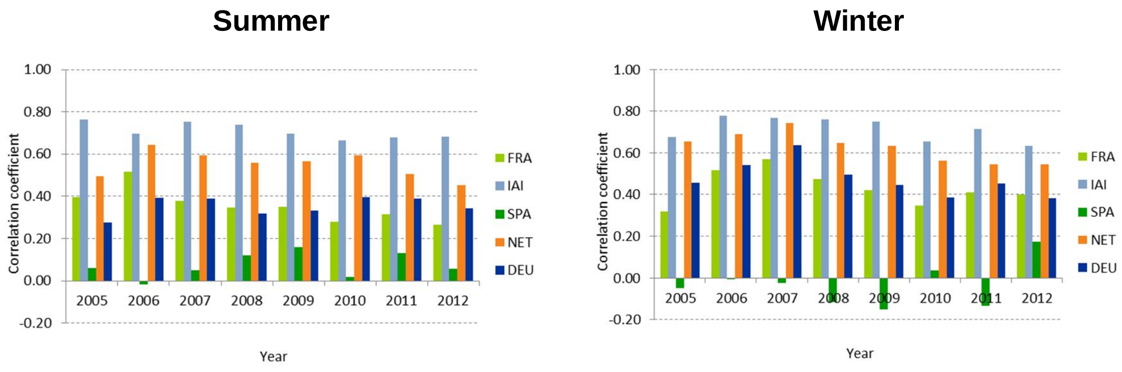
We have assessed the hourly correlation of wind power availability in GB and other systems across the entire year as shown in Figure 14. High (positive) and statistically significant wind correlations were found between GB-Ireland followed by GB-Netherlands. On the other hand GB wind was very weakly correlated with wind in Spain, primarily due to significant difference in the geographical locations of the two systems.

Figure 14 – Correlation of wind output in GB with other systems (annual)



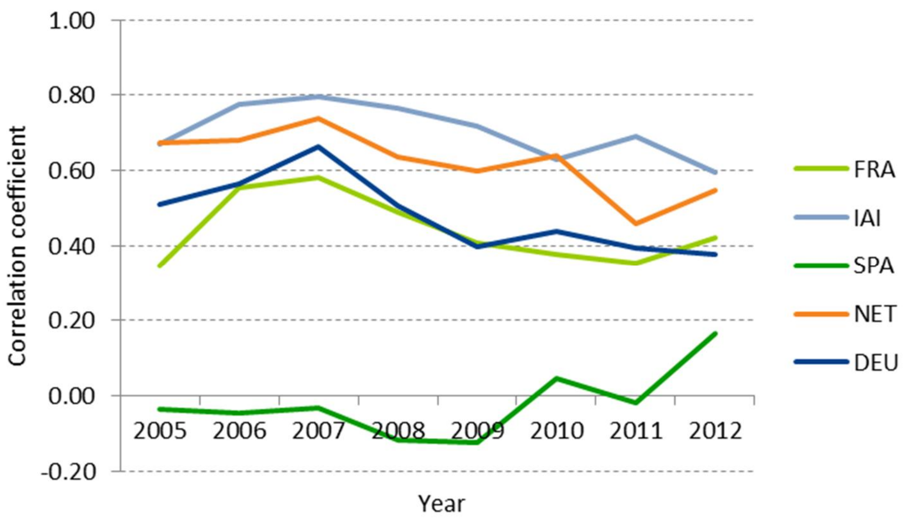
Assessment of seasonal wind correlation between GB and other systems, as shown in Figure 15, also revealed that winter correlations were relatively stronger (with the exception of Spain) than the summer correlations. It is related to the greater winter weather correlations across Europe which is often associated with relatively high wind speeds compared to the summer season. The computed correlations for both summer and winter were statistically significant.

Figure 15 – Correlation of wind output in GB with other systems (seasonal)



Since the likelihood of the appearance of low capacity margins in GB is high during winter peak demand hours therefore, we have analysed the behaviour of GB wind during these hours in terms of its correlation with other systems. Again with the exception of Spain all systems have shown a medium to high degree of positive and statistically significant wind correlations across the winter peak period.

Figure 16 – Correlation of wind output in GB with other systems (winter peak)



Existence of a good level of positive correlation in wind output between GB and other systems (in particular with connected systems during peak winter hours) means that the degree of reliance on wind generation will be more onerous. As when GB experiences a low capacity margin hour associated with low availability of wind output, other systems would potentially experience the same wind conditions during such hours.

3.7 Conclusions

The findings of the correlation analysis can be summarised as following:

- Historical demand of all analysed systems has shown a high correlation with GB demand.
- GB low capacity margins (below 20%) show a medium level of correlation with low capacity margins in Ireland and France. On the other hand, very low capacity margins (below 10%) in GB do not show a definite correlation with any of the other systems.
- Comparison of low capacity margins in GB, with and without interconnector flows, indicates that interconnector flows have broadly helped to reduce the number of low capacity margin (below 20%) hours in a year. However, for hours of highest GB system stress (i.e. where capacity margins are below 10%) interconnector flows have not consistently helped or worsen the capacity margin conditions in GB.

4. QUALITATIVE ASSESSMENT OF INTERCONNECTOR FLOWS

4.1 Introduction

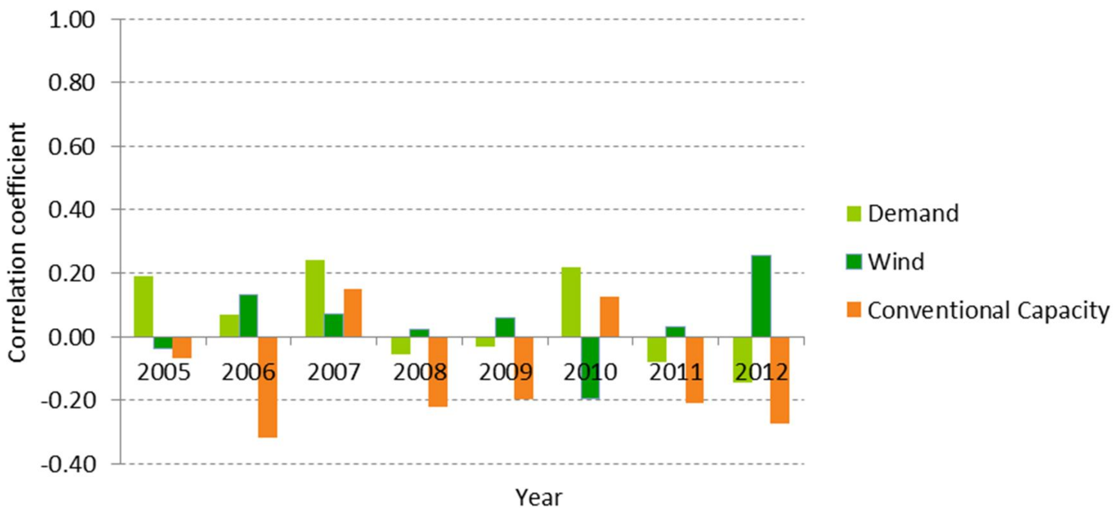
This chapter provides the results of our assessment of interconnector behaviour under existing market conditions. It is based on how GB interconnector flows have been interacting with key system parameters in GB and other systems during GB peak winter conditions in the past and provides an indication of reliance for GB security of supply in 2013 on interconnector imports.

The various correlations presented in here were based on historical data of physical flows and do not take into account the influence of market behaviour on interconnector imports or exports to/from GB.

4.2 Correlations of GB interconnector flows with its key system parameters

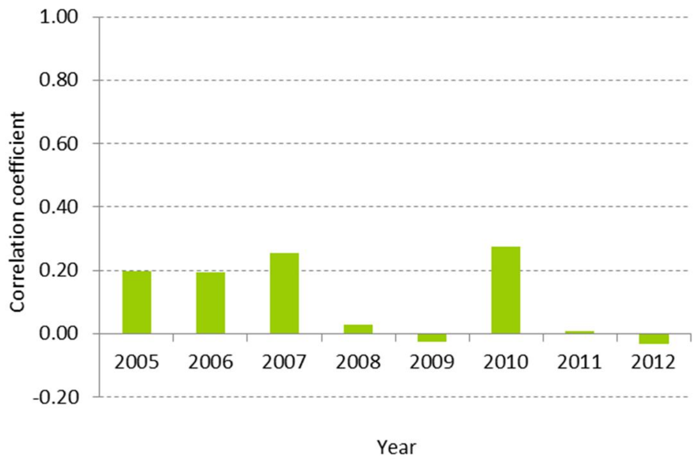
We have determined the correlation of aggregated interconnector flows of GB with its key system parameters i.e. demand, availability of conventional capacity and wind during peak winter hours as shown in Figure 17. It was found that these correlations remain low (weak) and even turn from a positive correlation to a negative correlation across different years. Although, the correlations of flows with demand and available conventional capacity remain statistically significant with the exception of flows-demand correlation for 2009, the historical net interconnector flows to GB have not been strictly dependent on GB system parameters.

Figure 17 – Correlation of aggregated GB interconnector flows with GB system parameters (winter peak hours)



We have further investigated the correlation of GB imports only with the key driver of GB capacity margins i.e. system demand, as shown in Figure 18, which also depicts a low correlation between these two. This means that there were very few hours during winter peak when GB demand was high and it was importing. Four of the eight years have indicated near zero correlation of demand with imports during winter peak times and these correlations have also been statistically insignificant.

Figure 18 – Correlation of GB imports with GB demand (winter peak hours)



Furthermore, the capacity margin correlation with net flows into GB was predominantly negative. However, the magnitude of the correlation (annual as well as for below 10% and below 20% levels) remained mainly low (with few exceptions) and highly variable from one year to the other as shown in Table 10.

However, the significance test (at a significance level of 95%) has indicated that these evaluated correlation coefficients are not consistently significant, being significant for five years out of eight years for annual correlations. On the other hand, for below 10% and 20% capacity margin hours all correlations were found to be insignificant (with the exception of 2009 correlation of below 20% capacity margin). Based on the strength of these correlations and their significance it was therefore not statistically possible to draw robust conclusions regarding the support by interconnector imports to GB during low capacity margin periods.

Table 10 – Correlation of capacity margins with net interconnector flows (capacity margins without interconnector flows)

	Correlation coefficient			Significance (p-vlaue)		
Year	Annual	<10%	<20%	Annual	<10%	<20%
2005	0.00	-0.35	-0.10	0.89	0.99	0.97
2006	-0.01		-0.12	0.57		0.91
2007	-0.03	0.00	-0.10	0.02	0.90	0.53
2008	0.04	-0.20	-0.05	0.00	0.84	0.41
2009	-0.18		-0.72	0.00		0.00
2010	-0.08	0.03	-0.28	0.00	0.86	0.37
2011	0.00			0.66		
2012	-0.17		-0.11	0.00		0.10

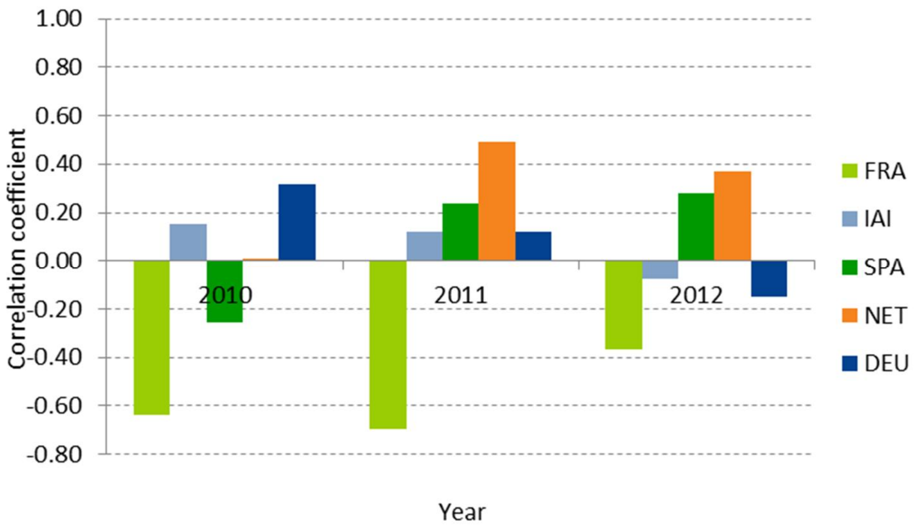
Note: Empty cells in the table indicate absence of hours in the corresponding capacity margin range.

4.3 Correlations of GB interconnector flows with parameters of other systems

The net interconnector flows into GB were analysed for their correlation with the net flows of all other systems during winter peak hours. Figure 19 shows the correlations of GB net flows to the net flows of other systems. Due to unavailability of flow data for all systems this analysis was limited to 2010-2012.

It is clear that net flows of France have a medium level of negative correlation with GB flows i.e. France has been exporting when GB was importing during peak winter demand hours. For other systems no clear trend can be established due to limited number of years that have been investigated.

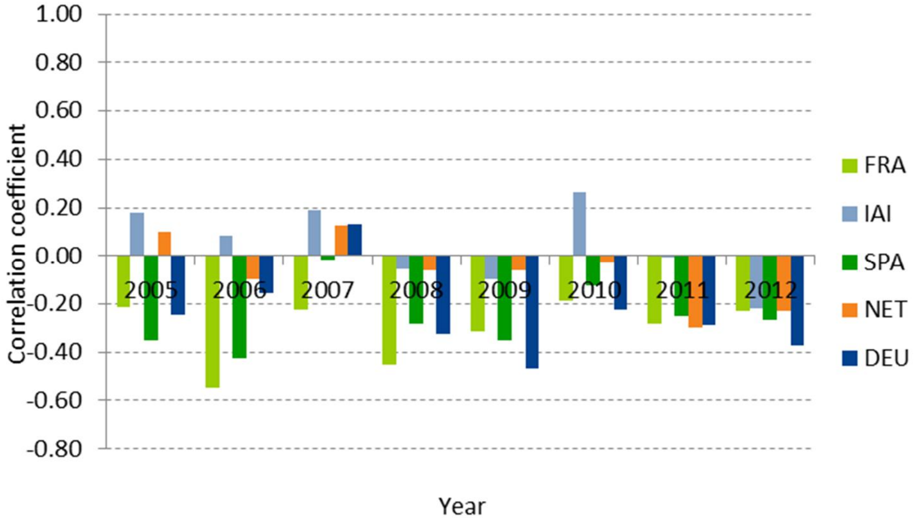
Figure 19 – Correlation of aggregated GB interconnector flows with net flows in other systems (winter peak hours)



We have further investigated the interaction of GB net flows with demand in other systems as given by their correlations in Figure 20. Although the magnitude of correlation coefficient is relatively small however, the predominant negative correlation with most of the systems across different years indicates that there were relatively more hours during winter peak when a); other systems had low demand and GB imports were high or, b) other systems had high demand and GB imports were low.

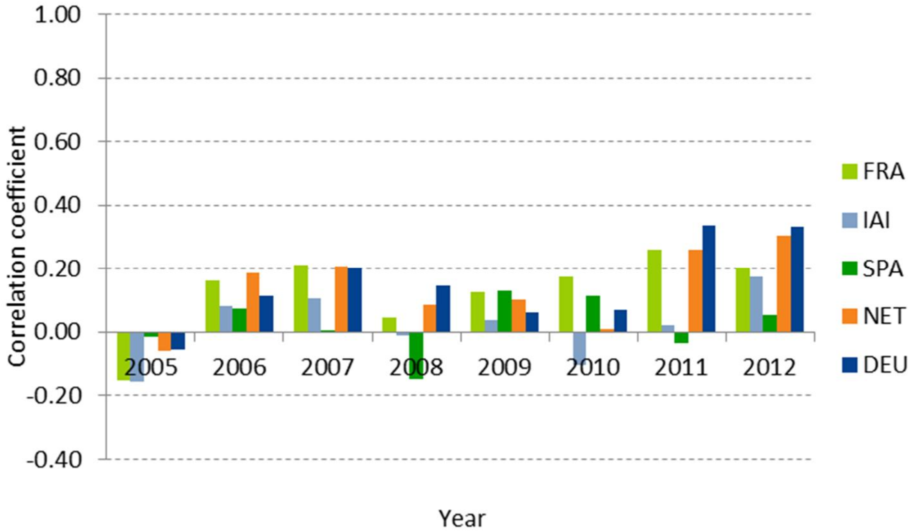
A slightly different trend can be observed for Ireland in which case the positive correlation for at least four years suggests that GB was exporting when Irish demand was high or vice versa.

Figure 20 – Correlation of aggregated GB interconnector flows with demand in other systems (winter peak hours)



A correlation assessment was made of the net flows into GB with the wind power availability in other systems as shown in Figure 21. It can be observed that GB net flows have an evolving positive correlation with the wind output in all systems. In particular during the last two years these correlations have been rising with France, Germany and the Netherlands.

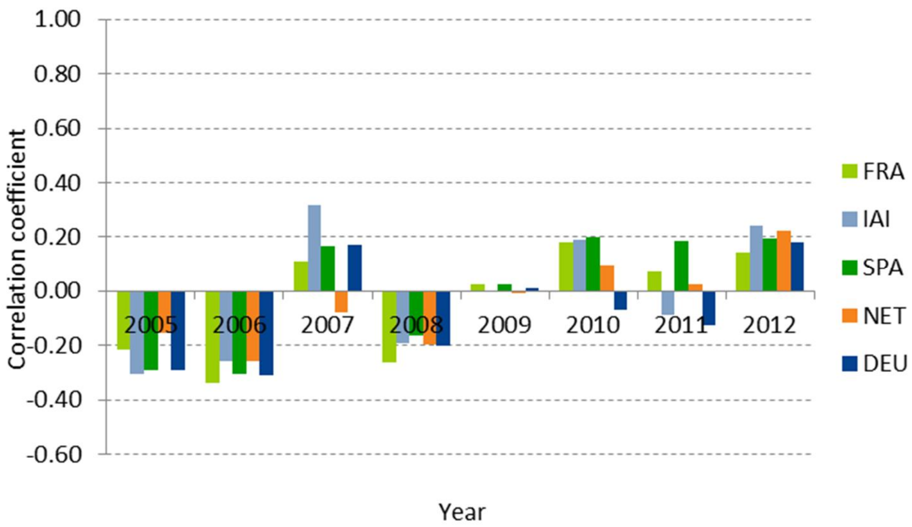
Figure 21 – Correlation of aggregated GB interconnector flows with wind in other systems (winter peak hours)



A correlation of another key system parameter i.e. available conventional capacity with GB net flows is shown in Figure 22 below. With the exception of 2007, the broad trend of the correlations of GB flows with the available conventional capacity has been reversed from a negative correlation (2005-2006) to a positive correlation (2011-2012).

The correlations are relatively weak however it shows that in the past, during winter peak hours, there were more hours when GB was exporting during low available conventional generation conditions in other systems while in the last two years (particularly 2012) GB had been importing during low available conventional generation in other systems.

Figure 22 – Correlation of aggregated GB interconnector flows with available conventional capacity in other systems (winter peak hours)



4.4 Conclusion

In considering the role of interconnectors in contributing to GB security of supply we conclude that:

- GB capacity margin correlation with net interconnector flows to GB is predominantly negative, low, statistically insignificant and highly variable from one year to the other.
- Historical net interconnector flows to GB have not been driven by a single system parameter in GB or other included systems and could have been influenced by a number of co-occurring system (and/or market) conditions in GB and Europe.
- Under current market conditions, GB interconnector flows may either make the GB capacity margin situation better or worse and hence cannot be relied upon to support GB security of supply at times of GB system stress hours in particular when capacity margins are below 10%.

[This page is intentionally blank]

ANNEX A – CORRELATION CHARTS

A.1 Demand and net demand correlations

The correlations of concurrent demand with low capacity margin hours (below 10% capacity margin), as given in Table 11, indicate that the demand in GB was highly correlated with France and Ireland when correlation coefficients were also statistically significant.

Table 11 – Correlations of GB demand during hours of low (below 10%) capacity margins with concurrent hours demand in other systems

	Correlation coefficient						Significance of correlation (p-value)				
Year	FRA	IAI	SPA	NET	DEU	Year	FRA	IAI	SPA	NET	DEU
2005						2005					
2006						2006					
2007	0.61	0.46	0.78	0.69	0.40	2007	0.00	0.02	0.00	0.00	0.05
2008	0.70	0.70	0.08	0.67	0.40	2008	0.00	0.00	0.68	0.00	0.04
2009						2009					
2010	0.09	0.80	-0.16	0.78	0.22	2010	0.82	0.02	0.71	0.02	0.60
2011						2011					
2012						2012					

Note: Empty cells in the table indicate absence of hours below 10% capacity margin range.

Demand correlations for below 20% capacity margin hours (Table 12) in GB tend to converge more towards the annual demand correlations and were predominantly significant with the exception of Spain during two years (2005 and 2006).

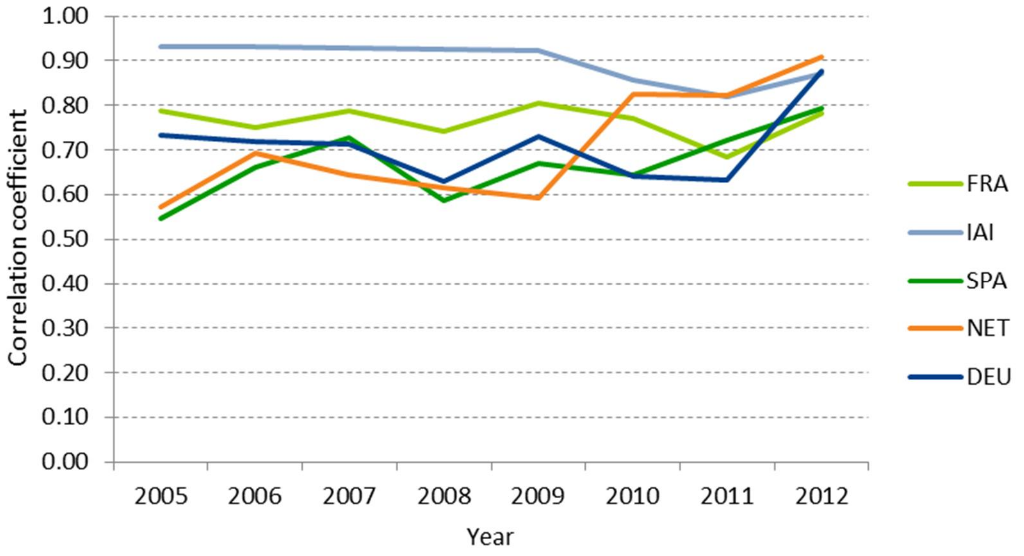
Table 12 – Correlations of GB demand during hours of low (< 20%) capacity margins with concurrent hours demand in other systems

	Correlation coefficient						Significance of correlation (p-value)				
Year	FRA	IAI	SPA	NET	DEU	Year	FRA	IAI	SPA	NET	DEU
2005	0.85	0.89	0.09	0.15	0.70	2005	0.00	0.00	0.03	0.00	0.00
2006	0.93	0.94	0.03	0.41	0.84	2006	0.00	0.00	0.61	0.00	0.00
2007	0.92	0.93	0.83	0.29	0.63	2007	0.00	0.00	0.00	0.00	0.00
2008	0.55	0.82	0.50	0.25	0.52	2008	0.00	0.00	0.00	0.00	0.00
2009	0.96	0.95	0.70	0.51	0.79	2009	0.00	0.00	0.00	0.00	0.00
2010	0.88	0.93	0.45	0.80	0.72	2010	0.00	0.00	0.00	0.00	0.00
2011						2011					
2012	0.92	0.86	0.80	0.89	0.75	2012	0.00	0.00	0.00	0.00	0.00

Note: Empty cells in the table indicate absence of hours below 10% capacity margin range.

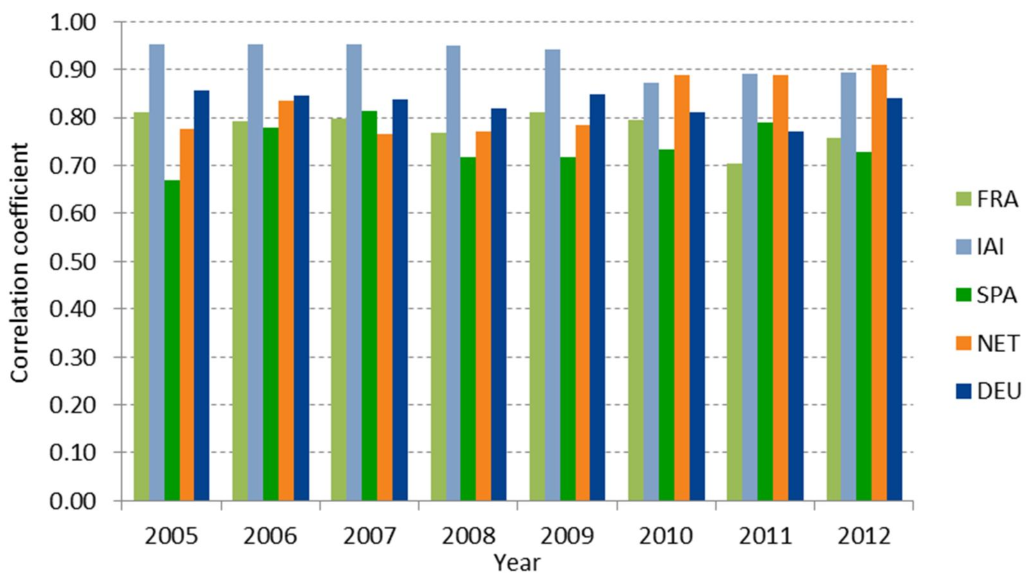
Annual (hourly) off-peak demand in GB also shows a high degree of correlation with demand in neighbouring systems as given in Figure 23. Similar to peak demand, off-peak demand in GB is also very high correlated with Ireland followed by France. Significant changes in the Netherlands transport and agriculture related electricity demand in the last few years has also resulted in significant change in their aggregated off-peak demand correlation with GB.

Figure 23 – Off-peak demand correlations, GB vs. other systems



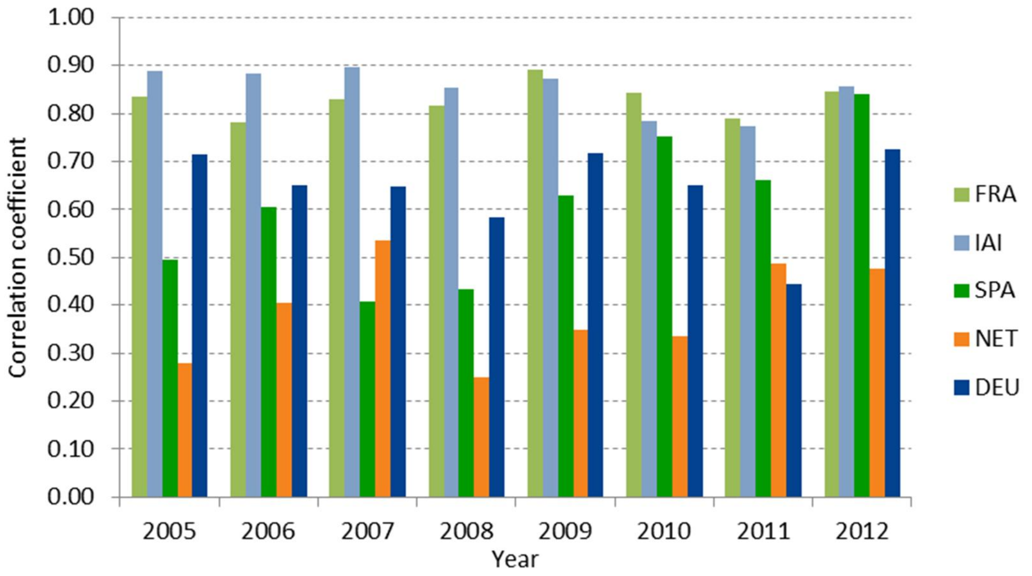
In order to understand the impact of intermittent renewables the correlations of net demand (i.e. gross demand minus wind and solar generation) between GB and its neighbouring systems was also determined. However, no significant deviation of net demand correlations relative to the demand correlations was observed. Annual (hourly) net demand correlations remain high (very high for Ireland) with all systems as shown in Figure 24.

Figure 24 – Correlation of GB net demand with net demand of other systems (annual)



Peak net demand correlations (as shown in Figure 25) also remain very high for GB-Ireland and GB-France. Greater year-to-year changes in Peak net demand correlations were observed for GB-Germany and GB-Spain due to significant penetration of wind and solar in these Germany and Spain.

Figure 25 – Net demand correlations, GB vs. other systems (during peak time in GB)



A.2 Capacity margins correlations with system parameters for other systems

In order to have a more general understanding of the key drivers of capacity margins, correlations of capacity margins with key system parameters of all systems included in this analysis were also determined.

These correlations are provided in Figure 26 for France, Figure 27 for Ireland, Figure 28 for the Netherlands, Figure 29 for Germany and Figure 30for Spain. Several common trends are observed for all systems as summarized below:

- Capacity margins in each system have very high negative correlations with demand and net demand across all investigated years. Some year-to-year variations exist for all systems due to inter-year changes in overall demand as well as in demand distribution across the year.
- Capacity margins correlations with available conventional capacity vary between low to medium range and remain positive for all systems except France. Negative correlation of French capacity margins (annual) with conventional thermal capacity is due to larger drop of demand compared to available conventional (nuclear) capacity during summer and off peak hours.
- Correlation of capacity margins with wind remain low on the average across different years however in most cases these are positively correlated with capacity margins due to generally higher wind speeds in winter compared to summer in North West Europe.
- Correlations of capacity margins with solar output remain low and negative in respective systems.

Figure 26 – Correlations of capacity margins with system parameters (France, without IC Flows)

Figure 27 – Correlations of capacity margins with system parameters (Ireland, without IC Flows)

Figure 28 – Correlations of capacity margins with system parameters (The Netherlands, without IC Flows)

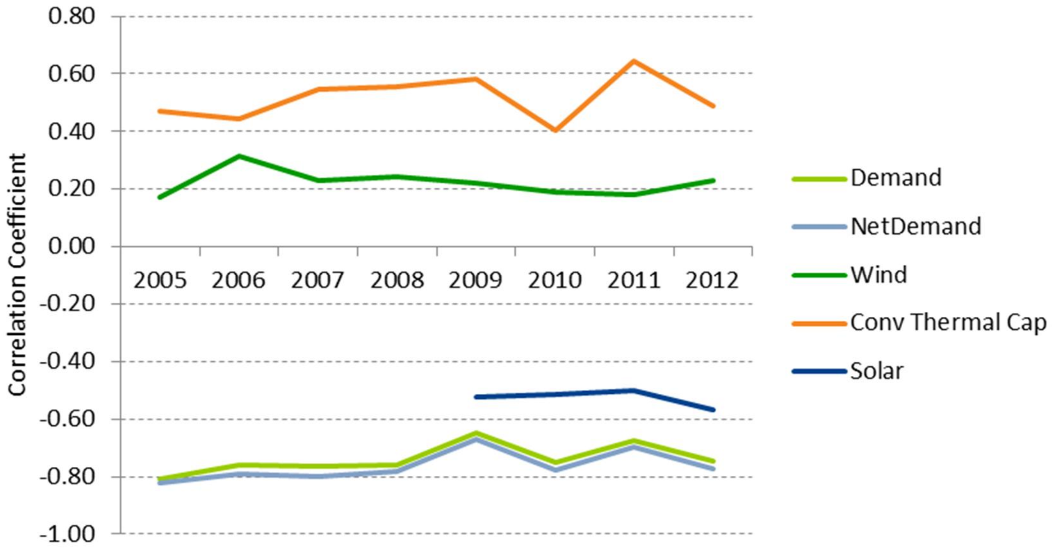


Figure 29 – Correlations of capacity margins with system parameters (Germany, without IC Flows)

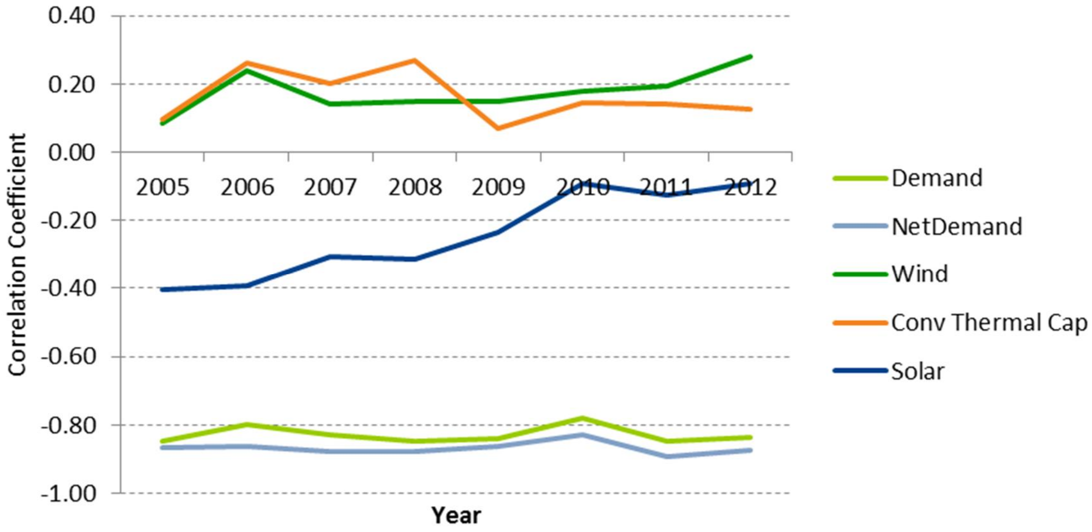
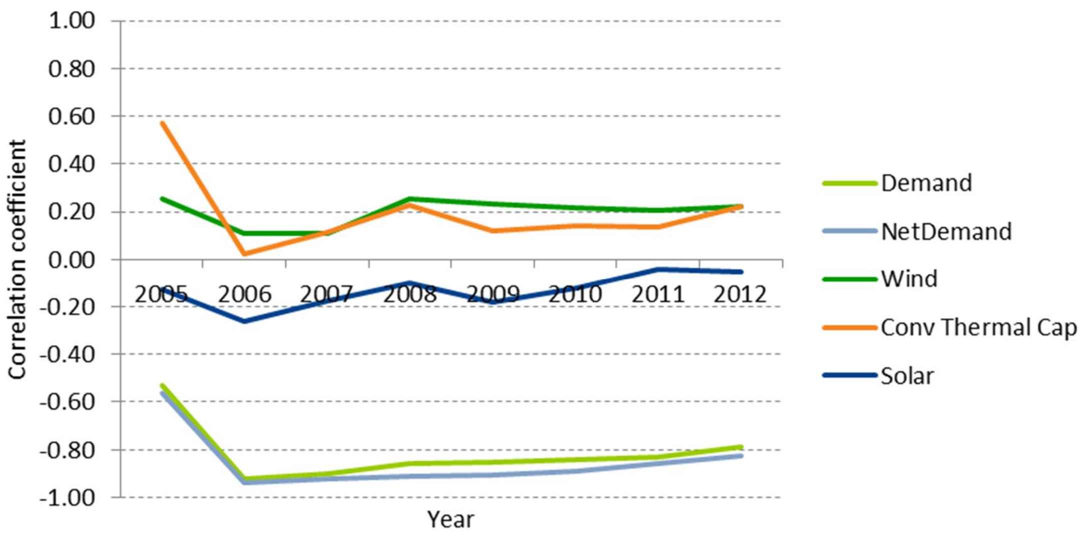


Figure 30 – Correlations of capacity margins with system parameters (Spain, without IC Flows)



ANNEX B – ILEX ENERGY REPORTS

Pöyry produces the renowned ILEX Energy Reports. ILEX Energy Reports provide detailed descriptions of European energy markets coupled with market-leading price projections for wholesale electricity, gas, carbon and green certificates. ILEX Energy Reports and price projections are currently available for the:

- electricity and/or gas markets including the following markets:
  - Belgium
  - Bulgaria
  - Cyprus
  - France
  - Germany
  - Great Britain
  - Greece
  - Ireland
  - Italy
  - the Netherlands
  - Poland
  - Romania
  - South East Europe
  - Spain
  - Switzerland
  - Turkey
- renewables markets in:
  - Italy
  - Poland
  - Romania
  - Spain
  - United Kingdom
- the biofuels market in Europe.

In addition to ILEX Energy Reports, Pöyry also produces a number of other reports, including electricity reports for Norway, Sweden and Finland, a renewables report for Sweden, and a report of the EU Emissions Trading Scheme with carbon price projections.

[This page is intentionally blank]

QUALITY AND DOCUMENT CONTROL

Quality control		Report's unique identifier: **2013/XXX**
Role	Name	Date
Author(s):	Anser Shakoor	March 2013
Approved by:	Mike Wilks	March 2013
QC review by:		March 2013

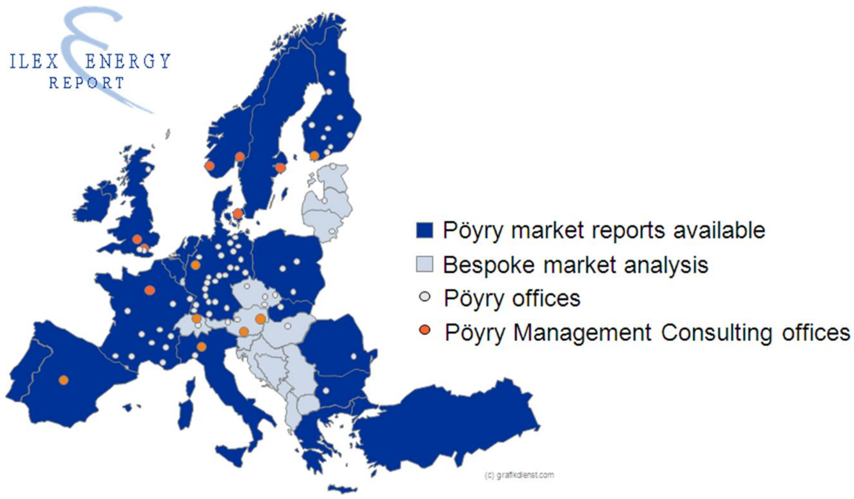
Document control			
Version no.	Unique id.	Principal changes	Date
v1_0	2013/XXX		March 2013

Pöyry is a global consulting and engineering firm.

Our in-depth expertise extends across the fields of energy, industry, transportation, water, environment and real estate.

Pöyry plc has c.7000 experts and a local office network in 50 systems and net sales of EUR 775 million (2012). The company's shares are quoted on NASDAQ OMX Helsinki (Pöyry PLC: POY1V).

Pöyry Management Consulting provides leading-edge consulting and advisory services covering the whole value chain in energy, forest and other process industries. Our energy practice is the leading provider of strategic, commercial, regulatory and policy advice to Europe's energy markets. Our energy team of 200 specialists, located across 14 European offices in 12 systems, offers unparalleled expertise in the rapidly changing energy sector.



Pöyry Management Consulting

King Charles House
Park End Street
Oxford, OX1 1JD
UK

Tel: +44 (0)1865 722660
Fax: +44 (0)1865 722988
www.poyry.co.uk
E-mail: consulting.energy.uk@poyry.com

PÖYRY

Pöyry Management Consulting (UK) Ltd, Registered in England No. 2573801
King Charles House, Park End Street, Oxford OX1 1JD, UK