IMPACT OF BREXIT ON UK ENERGY SECURITY
ANALYSING THE IMPACT OF DIFFERENT BREXIT SCENARIOS ON THE UK ENERGY SECURITY OF SUPPLY

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Executive Summary

The UK currently operates under common EU energy market rules.

As part of the EU and the Internal Energy Market, the UK energy sector complies with EU-wide rules, such as, unbundling, third party access and limitations on state aid. These rules have been introduced by the three EU energy packages and have a considerable impact on the sector and its customers.

EU rules have a real impact on how the UK fulfils its energy needs today and how it will do so in the future. Being part of the Internal Energy Market, for instance, allows for lower and more stable electricity prices for UK customers by facilitating interconnection to different countries.

Today, the UK is facing the issue of low power capacity margins; it can generate just enough electricity to meet the highest levels of demand. Low capacity margins have a negative impact on the energy security profile of the UK. The term energy security (of supply) is usually used to describe a country’s ability to access energy sources as well as its ability to supply power without disruptions under normal conditions.

To resolve the issue of low capacity margins, fresh investment in new generation capacity is needed. The economic case for this much needed capacity, however, rests on a solid and predictable set of rules that UK regulators have developed throughout the years, established on European guidelines.

A Brexit vote will mean new rules need to be established for the UK to operate in the market

In the event of Brexit the UK will have a two year window during which its political, economic and institutional ties with the EU will be untangled and redefined. As the two parties redefine their ties, existing trade arrangements and the market rules that underpin them will necessarily be abolished or rearranged.

The ultimate result of UK-EU negotiations, will be a new set of trade arrangements and market rules that would define how the UK energy sector operates.

New rule negotiations will take time causing project delays

We expect post-Brexit negotiations to last between 2 years to over a decade. These negotiations will be characterised by a set of heated debates and clashes among EU states who have diverging opinions on this matter. This brings considerable uncertainty; it takes the UK into uncharted waters.

Uncertainty, as is widely recognised, is bad for business. We expect investors and project developers to adopt a ‘wait and see’ approach to Brexit negotiations. This approach can lead to the delay or cancellation of energy infrastructure projects that are being planned or currently developed; not a good outcome for a sector in need of sizeable investment.

For the gas sector Brexit may be easily manageable

The UK gas sector is well positioned to withstand the shock of a Brexit event. Historically, the gas sector has relied on domestic North Sea production; with this area facing a decline in production, imports of gas have become prominent.

We show that the impact of Brexit on access to natural gas would be marginal. Imports are based on long term contracts with EU/EEA countries that rely on already existing pipeline infrastructure.
Furthermore, the UK can count on LNG import terminals that have the capability to process half of yearly national demand. We expect long term import contracts and liquid LNG markets to provide required natural gas supplies without the need for new infrastructure.

The electricity sector will be impacted by Brexit and affect negatively UK energy security

While the gas sector should withstand the impact of Brexit, the same could not be true for the UK electricity sector. Coal-fired power plants, which represent the backbone of the UK generation portfolio, are being decommissioned and new investment is not leading to their replacement. Much emphasis has been given to projects promising to address this issue and provide a stable source of power to the UK. Hinkley Point C is a notorious example.

Declining generation capacity has played a decisive role in low capacity margins on the electricity grid. Low capacity margins give rise to the potential for customer disconnections which, while rare, can impact the wellbeing of consumers and economic activity at large.

As more coal-fired power plants come offline, lower investment in energy infrastructure projects is set to exacerbate the weakening energy security profile of the UK. Interconnection projects are particularly at risk of being cancelled or delayed given their reliance on cross-border regulation.

Interconnecting the UK power system to another country’s is an efficient way to mitigate the issue of low capacity margins. Interconnection projects amounting to 10GW of capacity (on top of the existing 4 GW) are being developed, planned or proposed to connect the UK to evermore countries.

*Figure i* on the right compares the cost, capacity and availability of Hinkley Point C and the planned interconnection projects. We see that the price tag for 10GW of interconnection capacity (£9.6bn) comes at slightly more than half of that for Hinkley Point C (£18bn).2

The third figure, showing availability, measures the percentage of time that Hinkley Point C and Interconnectors produce electricity over a set period of time (i.e. Hinkley Point will produce electricity 81% of the time over a given week/month/year). The 58% availability for interconnection capacity is an average of the availability expected by Ofgem for a range of different projects. Interconnectors with Norway are expected to have an availability factor of 96%, those with Ireland just 23%. This figure is set to improve with the introduction of EU regulation making the flows of electricity more efficient.

One thing is clear, interconnection capacity is a valid alternative to Hinkley Point and many other, more expensive, solutions to low capacity margins.
We have seen that Brexit would limit the development of important energy infrastructure. In this research we set out to answer the following question: How would Brexit impact the energy security of the United Kingdom?

We examined three potential scenarios

We modelled three different outcomes of the referendum to gauge the impact of Brexit on the UK’s energy security:

- **Norway Scenario** – This case hypothesises that the UK will join the EEA after withdrawing its membership to the European Union. We applied the trade and regulatory arrangements that underpin Norway-EU energy trade and applied them to the UK.

- **Switzerland Scenario** – In this case we assume that the UK will leave the EU and rely on bilateral trade arrangement to deal with the Union, just as Switzerland does.

- **No Brexit Scenario** – To deliver a full picture of the possible outcomes we forecasted the UK’s energy security profile should Britons choose to remain in the EU.

As a result of our analysis we have found that:

- **Any scenario of Brexit would not affect the UK’s ability to access primary energy sources, such as natural gas, coal and petroleum products.**

- **Brexit would impact electricity capacity margins. The impact on interconnection investment stemming from cross-border regulatory uncertainty would be a major driver of this problem.**

Brexit would have a negative impact on the energy security profile of the United Kingdom

If Britain was to leave the EU it would no doubt have implications for the energy market and energy security. The uncertainty created by leaving the EU would impact on investor confidence and the funding and development of new electricity projects, particularly interconnectors with Europe, currently in the pipeline. These projects have been in planning for quite some time, are complicated with numerous counter parties, funding arrangements and regulations.

The extent of the impact will be determined by how quickly UK and the EU can agree on new rules and the relevant interconnection project model. Our assessment tell us this is unlikely to be an expedient process. Changes to the UK’s relationship with the EU energy market will be just one of numerous issues which need to be changed in the event of a Brexit vote. The implications are that this will have a negative impact on the UK’s electricity security of supply.

Improving capacity margins will require the continued operation of coal and oil power stations which have been scheduled for decommissioning; this will have an adverse effect on the environment. Alternatively, it will require the usage of expensive emergency measures that limit industrial power consumption; this will have a negative impact on industrial output.

Brexit stalls investment on projects that would otherwise stimulate economic activity, employment and consumer welfare.
List of Conclusions

A Norway-type Brexit would imply a soft landing for the UK energy sector.

- Over a two year period, we expect the EU and UK to rearrange existing ties to match EEA membership requirements.
- The UK would retain access to the IEM. This would imply no-to-little detrimental effect to the UK energy security profile.
- The UK would retain access to PCI funding. It would be set to secure a substantial amount to develop projects improving its energy security profile and access to the IEM.
- Upon joining Norway in the EEA the UK would have to accept all significant internal market legislation.
- There would be uncertainty in the short term around the rules that will govern and regulate UK-EU energy trade.
- We expect investors and developers to adopt a ‘wait and see’ position in case of Brexit. No new interconnection capacity developed for two years after the referendum.
- Norway-type Brexit would weaken the electricity security of supply in the short term but should have no major impact in the medium run.
- Should Brexit not happen de-rated capacity margins would be between 2% to 6% higher by 2020 (with respect to the Norway case).

In the Switzerland scenario the UK’s energy security profile would be heavily impacted throughout the medium term.

- Exclusion from market coupling: renders markets less liquid, yields a non-efficient flow of power lowering economic welfare, and limits downward pressure on wholesale prices.
- Exclusion from cross-border balancing increases costs to consumers and negatively impacts the resilience of the UK system.
- Exclusion of interconnectors from capacity markets weaken the security of supply profile of the UK by excluding a valuable source of supply diversification.
- Foregone benefits: £430m pounds yearly by the early 2020s
- No new interconnection capacity up to 2030, due to uncertainty on cross-border regulation.
- De-rated margins are strongly impacted in the short and medium run. In 2030 margins would be between 5.5% and 11.9% lower with respect to the No Brexit scenario.

By not exiting the European Union the UK will be able to improve, or by the least, not worsen its electricity security of supply profile.

- The most important element of the No Brexit case is the low uncertainty level with respect to the Norway and Swiss scenarios.
- In the No Brexit scenario, spare capacity margins of electricity are between 5.1%-3.4% higher with respect to any Brexit scenario in the short-run
- Spare capacity margins are between 5.5% and 11.9% higher with respect to the Switzerland case by 2030.
Our analysis has shown that a 20% fluctuation in both Risk Free Rates and Expected Market Returns could change an investor’s required return on investment by the following range: -1.84% to +1.78%.

- Changes in required return will impact the realisation of projects depending on the prevailing market dynamics.
- Projects deemed profitable prior to the Referendum could be cancelled or delayed based on a deteriorating economic case. Conversely, should require return decrease, more projects would become economically feasible.
- The financial impact on interconnection investment would impact significantly future interconnection capacity. It would be secondary with respect to the impact of regulatory uncertainty.
Introduction

On June 23 2016, Britons will head to the polls to make one of the most important decisions in the European Union’s 58 year history; will the UK remain as one of the 28 member countries?

Much is being debated by both sides of the argument, the UK Stronger In Europe campaign and their opponents of the Vote Leave campaign, on the potential impact of an independent United Kingdom on the global economic and geo-strategic ‘chess board’. A Financial Times, poll of polls dated May 30 2016 shows that 46% of voters want to Stay in the EU, 43% want to Leave it and that 12% are undecided3. Based on these figures, and on the ever changing balance of the polls, the Brexit referendum is very likely to be a close one. As Brexit is a realistic possibility, it is crucial to understand how this event might impact the UK.

As with nearly every other sector of the UK economy, the future of the Energy sector, will undoubtedly be shaped by the result of this June’s Referendum. This sector is a central part of the country’s economy, a 2013 study has found that it provided a total of 680,000 jobs and contributed as much as 6% to the UK’s GDP4. However, its evident benefits on the labour and capital markets are not the only contributions.

A thriving, well-structured Energy sector coupled with sensible government policy enables a strong energy security of supply profile for the UK. Security of supply, defined by the IEA as “uninterrupted availability of energy sources at an affordable price”5 is a crucial element of a strong economy. It provides security, it fuels economic development, it stimulates the achievement of environmental goals and can be even seen as an element strengthening a country’s foreign policy position.

The objective of this research paper is, then, to assess the impact of Brexit on the energy security profile of the UK market by conducting a scenario analysis in which various forms of potential UK-EU cooperation are taken into account. The paper aims to find out how the access to energy sources will be impacted by the UK decision’s to leave, or to stay, in the Union.

The relevance of the research we hereby present is rooted in two considerations. Firstly, any significant impact on the energy security profile of a major economic and geopolitical party such as the United Kingdom is worthy of careful assessment because of the potential impact it has domestically and on its foreign partners. Secondly, the Brexit Referendum coincides with a delicate time for a specific aspect of the UK’s security of supply, namely, low marginal spare capacity on the electricity network. On the 9th of May 2016 seven power station suddenly came offline, prompting National Grid to request additional supplies and shooting power prices from a summer average of £50/MWh to £1,250/MWh, given the thin margin of supply over demand6. While spikes to this degree are unusual, this instance highlights the practical detriment to consumers as a result of low capacity margins.

While coal, oil and CCGT plants are being decommissioned, following a new direction of UK’s energy policy 1 (encouraged but not mandated by the European Union) the amount of additional renewable capacity coming on stream is struggling to keep up. In 2014, total capacity of all generators was 84,987 MW, down 1.4 per cent from the 86,200 MW installed at the end of 20138. Given uncertainty over the development of additional capacity (see the case of Hinckley point C nuclear plant), the possibility exists for low capacity margins to be a characterising factor of the UK electricity market in the short to medium term.
In order to tackle the uncertainty, a natural result of any immediate post-Brexit scenario, surrounding the shape and form of UK-EU cooperation, we have built three different scenarios, detailed in later chapters, which rely on the existing arrangements in energy cooperation between the EU and various countries.

The Switzerland case lies on one extreme, outside of the EU and relying on Bilateral Agreements to regulate trade; the No Brexit case, which builds onto the status quo towards a more integrated UK in the European Energy market lies on the other. The Norway case lies in between the two latter cases, outside of the EU retaining, however, free access to the bloc’s energy markets.

Overall, the hypothesis that we test by conducting this analysis is that the UK’s access to primary sources of energy would not be significantly impacted by any Brexit scenario, but that restriction of access to the Internal Energy Market for Electricity would lead to a significant weakening of the UK’s electricity security of supply profile.

We recognise that applying the existing arrangements between the EU and external countries does not, in any way, guarantee that a similar arrangement might be applied to the UK. However, we also believe it is the only method of analysis that delivers an indication of the effects of Brexit, minimising uncertainty and relying on certain facts. In other words, analysing the matter under this lens allows us to deliver the most impartial, unbiased view on a much politicised issue.

We have built this research on a solid base of literature review from unbiased sources including but not limited to: industry participants, global think tanks, the UK Energy market regulator Ofgem, international organisations, bodies of the European Union such as ENTSOs and CEF and major publications such as the BBC, the Financial Times and many others.

Furthermore, we at Sia Partners have conducted proprietary analysis on the matter and have created a set of assessments tailored to this topic as well as basing our analysis on the vast amount of Energy Industry experience we retain.

It is important to stress that Sia Partners has no position on the Brexit referendum. This paper has been written for purely informative reasons, is an independent initiative of the author Alessio Villanacci and is intended to inform the Brexit debate on the specific issue of security of supply.

Following this introduction, the paper will go on to illustrate to the reader; the key concepts and topics presented in the research, the relevant definition and the economic concepts that support the analyses carried out to reach a conclusion.

Presentation of key topics

In this chapter we aim to introduce the reader to the topics, the measures and the methods of analysis that are employed later in this paper to assess the impact of Brexit on the energy security profile of the United Kingdom.

In treating a topic such as energy security, diverse issues both technical and economical in nature are taken into consideration. In this section we will introduce the following points:

- Definitions of energy security and the one that we have adopted for this research paper.
- Relevant measures of security of supply and the way in which we have treated them.
- Introducing the Internal Energy Market, its aim and mechanism as well as its ongoing transformation to highlight its importance in bolstering energy security.
• Following the IEM, naturally, we introduce the role of interconnectors in an integrated energy market, their socio-economic and wider benefits and look at how they are funded.
• Finally, but most importantly, equipped with a general understanding of the above-mentioned topics, we introduce the scenarios around which our research revolves.

Definition of Energy Security of Supply

Somewhat different definitions of security of supply exist. The International Energy Agency (IEA) defines security of supply as “uninterrupted availability of energy sources at an affordable price”\textsuperscript{10}. This definition encompasses different aspects depending on the timeframe examined: in the long/medium run it measures the ability of a country to commit and attract investment in energy infrastructure aimed at fuelling economic and societal development as well as meeting environmental needs. In the short term, the IEA definition of energy security is more concerned in assessing a system’s resilience to unexpected supply/demand shocks.

On the other hand, ENTSO-E, the European Network of Transmission System Operators for Electricity, defines security of supply as “ability of a power system to provide an adequate and secure supply of electricity under ordinary conditions”\textsuperscript{11}. This is a more technical and narrow definition which focuses on the technical side of electricity system resilience, also presented in the previous definition, and is based on a static assessment (security at any given moment).

For the purpose of this paper, which is aimed at assessing the impact of Brexit on the short-to-medium term security of supply profile of the UK, we will base our definition of energy security on the IEA version while adopting, the adequacy and security criteria of system resilience (N-0, N-1)\textsuperscript{1} contained in the ENTSO-E definition.

We shall determine the UK’s energy supply is secure if it meets the two following points:

• The UK is able to access plentiful energy resources at an affordable price
• The UK power system is able to provide adequate supply under normal conditions.

Measures of Security of Supply

Security of supply is measured by different methods depending on the nature of the research carried out. A more geo-strategy oriented paper might adopt an HHI-related index highlighting the relative weight of different suppliers in a country’s supply source portfolio (i.e. HHI index is high for Baltic countries who mostly rely on Russia for Natural Gas supplies); a paper focused on consumer welfare might, instead, use a measure indicating the likelihood of controlled disconnections.

In order to assess the UK’s energy security profile and the impact Brexit will have on it we will use the following measures:

• SCI Index\textsuperscript{12} – The country specific supplier concentration index (SCI) builds upon a HHI index but takes into account both diversity of suppliers and the exposure of a country to external suppliers. It is computed as the sum of squares of the quotient of net positive imports ($NPII$) from a partner to an importing country and the gross inland consumption ($C$) of that fuel in the importing country.

\textsuperscript{1} Furthermore, it adds: “Adequacy measures the ability of a power system to supply demand in full, at the current state of network availability; the power system can be said to be in an N-0 state. Security measures the ability of a power system to meet demand in full and to continue to do so under all credible contingencies of single transmission faults; such a system is said to be N-1 secure.”
Ceteri Paribus, a smaller value of SCI indicates more diversification and, consequently, lower security of supply risks. The index adjusts results by political risk and country size, please see source for more details.

\[ SCI = \sum_i \left( \frac{NPI_i}{C} \right)^2 \times 100 \]

- **De-rated capacity margins** - Measuring electricity system resilience to supply/demand shocks – is defined by Ofgem as “… the average excess of available generation over peak demand. De-rated margins are a simple and intuitive way of measuring the risks to security of supply, however they have limitations; specifically they do not reflect the amount of variability associated with them”\(^{13}\). The Capacity Margin is defined as follows:

\[ \text{Capacity Margin(\%)} = \frac{\text{Total available capacity} - \text{Peak Demand}}{\text{Peak Demand}} \times 100\% \]

- **Loss of load expectation (LOLE)** – Measuring electricity system resilience to supply/demand shocks – is the average number of hours in which supply is expected to be lower than demand under normal conditions, for a given year. Unlike de-rated margins the LOLE measure captures the intermittence of renewable generation capacity, important in the UK given the sizeable share of wind generation in the country’s portfolio.

### The Internal Energy Market (IEM)

The development of an Internal Energy Market (IEM) has been an area of focus for the EU since the 1990s. Three legislative packages of measures have been introduced between 1996 and 2009 with the aim of removing various obstacles and trade barriers among national energy markets in order to “ensure a functioning market with fair market access and a high level of consumer protection as well as adequate levels of interconnection and generation capacity”\(^{14}\). The IEM is meant to yield savings for consumers, bolster competition in the energy market, and improve renewable integration on electricity grids as well as being the EU’s ultimate security of supply tool.

The gradual liberalisation of gas and electricity market has brought about the realisation of a more integrated gas and electricity market on a European scale. Some of the benefits it has brought to the UK, will be discussed later when analysing various Brexit scenarios. The following are important features of the IEM:

- **Market Coupling** – In order to reap the benefits of wider market integration, the Transmission System Operators (TSOs) and Power Exchanges of various European member states, including the UK, have coupled (“Synchronised”) their day-ahead markets. Additionally, some of these countries are working on integrating their intra-day market as this document is being written. The primary aim of the mechanism is to improve market liquidity and therefore induce lower and more stable electricity prices. While trading electricity across borders has been happening for some time now, the new market arrangement gives rise to the following advantages:
There is no need for trading parities to acquire transmission capacity rights at each border given that both prices and capacity are simultaneously coordinated by the same pricing algorithm *Euphemia* developed by PCR\(^\text{ii}\) (Price Coupling of Regions)\(^\text{15}\).

Market players do not need to have sites in each country with which they trade, dramatically increasing the number of potential trading partners.

Management of daily cross-border capacity is optimised, increasing market liquidity and levelling out prices throughout coupled markets.

The borders coupled so far comprise of an area covering 20 countries and standing for over 85% of European power consumption. This area is called Multi-Regional Coupling (MRC)\(^\text{16}\).

- **Cross-Border Balancing Market** – A large increase in renewable (and therefore intermittent) generation capacity expected to come online in the next decade poses technical challenges for TSOs in terms of network balancing. The EU aims to integrate national balancing markets as part of the creation of an Internal Energy Market. ACER (the Agency for the Cooperation of Energy Regulators), first introduced Framework Guidelines on Electricity Balancing in September 2012 which set out a common set of rights and obligations to create a more efficient use of balancing reserves on a larger scale\(^\text{17}\).

Following the introduction of Framework Guidelines, Network Codes are being finalised and will soon become part of EU-Law\(^\text{18}\); these codes promote higher uptake of cross-border balancing services and yield large savings for TSOs (translated as savings for consumers) when compared to different, independent, balancing methods.

A 2013 study by Mott Macdonald, finds that “integration of [EU] Balancing Markets and sharing of reserves could achieve operational costs savings of the order of €3bn/year and reduced (up to 40% less) requirements for reserve capacity”\(^\text{19}\) highlighting the benefit of such practices.

As well as the above-mentioned measures adopted by the EU as part of efforts orientated towards the achievement of an IEM, other measures, such as **solidarity mechanisms**\(^\text{20}\) (including mandatory stocks and contingency plans) among member states are being encouraged by the EU in natural gas markets to bolster energy security.

We will see how each scenario impacts the UK’s participation to these measures and will assess quantitatively and qualitatively their impact on its energy security profile.

\(^\text{ii}\) The PCR project is a Market Coupling project, initiative of seven Power Exchanges, which is creating a governance structure based on a Co-Ownership Agreement and Co-Operation Agreement among exchanges with the aim to deliver a common European price coupling solution.” Sia Partners is taking part to this effort by actively supporting PCR in its growth and development.
Interconnectors and their role in Capacity Market

Interconnectors are the key piece of infrastructure that enables transfers of electricity between two national power systems. They lie at the heart of the Internal Energy Market project given their very role as integrators of European power systems. As testified by the Market Coupling efforts, interconnecting various power systems yields a variety of benefits, among which Security of Supply, of electricity in this specific case, is strongly featured. In theory, interconnectors bolster security of supply between two markets in various ways:

- **Spare Electricity Capacity** – provided that there is cross-border capacity available at any given moment, the Interconnector will ensure an additional flow of power into a system characterised by low spare capacity. The supply/demand imbalance gives rise to a price signal which incentivises this flow. Furthermore, additional capacity provides, as mentioned earlier, a more efficient means of balancing the power system for TSOs.

- **Capacity Market Auctions** – the capacity market is a set of auctions tied to capacity obligations; a capacity obligation is a pledge to make available a certain amount of power over a set timeframe (i.e. 2019-2020), on which generators can bid. Tied to each obligation the successful bidders receive a capacity payment, a predictable revenue stream to encourage investment in new or existing projects. The most recent UK Capacity Market auction (2020/2021 which took place in 2015) welcomed, for the first time, interconnectors on the same terms as existing generation capacity\(^{21}\). The inclusion of interconnectors in this market increases security of supply.

Apart from their crucial contribution to bolstering security of supply interconnectors are desirable because of the socio-economic and environmental advantages they present. As mentioned previously, the sizeable expected increase in renewable and intermittent generation capacity puts power systems under stress.

By connecting different countries, with varying renewable generation portfolios (for example hydropower in Norway and wind-based generation in the United Kingdom), interconnectors promote renewable integration. In other words, they allow for the efficient redistribution of intermittent power across countries characterised by diverse price and shape patterns; i.e. extra wind power generated at night time in the UK, while not needed domestically, can be transferred to Norway to activate a pumping station that will allow hydro stations to generate baseload power (for the UK) during the day.

*Figure 2*\(^{22}\) illustrates the net welfare creation (net benefit to society) derived from connecting two markets with different marginal cost profiles (i.e. low cost, Norway, and high cost, UK). Marginal cost profiles are intended to represent the cost of operating the priciest generation unit which meets the maximum amount of energy demanded. Norway, with very significant hydroelectric generation capacity meets maximum demand at a lower price than the UK which makes use of CCGT or other pricier generation options to meet peak demand. The graph shows that upon connecting the two markets, electricity from the low-cost area \((P_A)\) will flow towards the high cost area \((P_B)\), assuming spare generation capacity in the low-cost area.

\(^{21}\) \(P_A\) = Price of electricity in A; \(P_B\) = Price of electricity in B; \(Q_A\) = Quantity supplied in A; \(Q_B\) = Quantity supplied in B; \(Q_A^*\) = Quantity produced in A post interconnection; \(Q_B^*\) = Quantity consumed in A post interconnection; \(Q_B^*\) = Quantity consumed in B post interconnection; \(Q_B^*\) = Quantity produced in B post interconnection. D & S are supply and demand curve characterizing A and B.
It can be observed that consumer welfare (areas c,f,g) is created in the high cost country, derived from lower prices for households and institutional consumers ($P_b^* < P_b$).

Consequently, welfare creation for producers in the low cost country is observed, due to the amount exported at a higher price than that of the domestic market ($P_b^* > P_b$). There is a welfare loss (area e) for producers of electricity in the high-cost area, as interconnectors, supplying lower-cost power, push pricier options out of the market (not profitable at $P_b^*$).

The high-cost area produces more electricity ($Q_{ap}^* > Q_a$) to meet extra demand ($Q_{bc}^* > Q_b$) in the low-cost area that is induced by the, now, lower prices.

Historical analysis of data has suggested that interconnector flows have not performed as expected by economic theory in responding to price signals and has therefore raised questions on the impact of interconnectors on security of supply. Importantly, however, work from the DECC has showed that over the past few years the economic response of interconnectors to price differentials has greatly improved thanks to improved rules on Network Codes and the wider market coupling effort.

Interconnectors operate on one of three business models:

- **Merchant Projects** – Commercial basis for the project is established outside of the regulatory scheme and driven by differences in price shape, level and unpredictability of peaks across markets. Eleclink, connecting France and the UK is an example.
- **Fully Regulated Projects** – The commercial basis for this category of projects is fully covered by the regulated revenue framework.
- **Mixed Projects** – Commercial basis exist given congestion rents between countries involved within limits established by the regulator (Cap & Floor framework adopted by Ofgem limits downside risk by guaranteeing minim repayment but also caps upside on revenues). Brit Ned and Nemo Link are two notable examples of this type of projects.

In all the above mentioned-models, project finance, corporate finance (or corporate guarantees) or a mix of the two are instrumental to the construction of these large scale projects. Stemming from this consideration, variations in cost of debt and equity tied to each investment are important decision points when it comes to reaching a Final Investment Decision (FID). We shall see in this paper the effect of uncertainty on these factors and their impact on planned interconnection capacity between the UK and the EU.

In this paper we will focus on the role that interconnectors play in security of supply and, of course, on what their development is expected to be and what part they will play in the IEM given the diverse scenarios.
Introducing our scenarios

This research paper bases its analysis on the development of three different outcomes of the June 2016 referendum, namely, two Brexit cases, the Norway and Switzerland Scenarios and a No Brexit Scenario.

The table below will illustrate the assumptions which make up each scenario:

<table>
<thead>
<tr>
<th>MODEL ASSUMPTIONS</th>
<th>NORWAY SCENARIO</th>
<th>SWITZERLAND SCENARIO</th>
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<tr>
<td>ACCESS TO PRIMARY ENERGY</td>
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<td>High</td>
<td>High</td>
</tr>
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Explanation of the model assumptions:

- **EU Integration Level** – This assumption indicates, qualitatively the level of buy-in to the European project and strongly influences the other assumptions for each scenario. The No Brexit scenario and Switzerland scenario lay at opposite ends of the EU-integration spectrum with membership to the EEA being a sort of ‘middle ground’ skewed however towards a No Brexit Scenario level of integration.

- **Access to IEM** – This assumption indicates the level of UK access to the Internal Energy Market and all its shared initiatives, introduced earlier such as market coupling, cross-border balancing, solidarity mechanism and adherence to all the Network Codes related to these measures.

- **Tariffs on Energy** – Leaving the EU and common market could result in the re-establishment of import tariffs on products. An alternative is the establishment of bilateral agreements that abolish import tariffs and regulate trade between the now separate entities. It is crucial to note however that wholesale energy trade is not subject to tariffs and that any Brexit case will not see an increase in energy prices strictly due to import tariffs.

- **EU PCI Grants Access** – The European Commission has listed 195 key energy infrastructure projects, known as Projects of Common Interest, essential to complete the IEM. PCIs benefits from accelerated planning and permit granting, a single regulatory counterparty, improved regulatory convictions, increased public participation via consultations and increased visibility to investors as well as financial support. €5.35bn has been earmarked by the Connecting Europe Facility from 2014-2020. All else equal, a project deemed PCI should have a higher likelihood of meeting the FID.
• **Uncertainty Timeframe** – Uncertainty yields risk. As mentioned earlier, given the importance of corporate and project finance in the funding of an interconnector, risk premiums tied to uncertainty have a strong impact on the overall cost of such a large investment. The longer the list of agreements, provisions and regulation to be re-developed and negotiated to carry out UK-EU trade the longer the timeframe of uncertainty and, consequently, the higher the risk premium. We assume the residual instability after a No Brexit case will increase the risk premium slightly.

  o **Norway Scenario** – For this scenario we expect the UK to be able to renegotiate and adapt existing arrangements to fit into the EEA membership agreement in the window provided for by Art. 50 of the Treaty of Lisbon. This article states that “The Treaties shall cease to apply to the State in question from the date of entry into force of the withdrawal agreement or, failing that, two years after the notification [that a Member State has decided to withdraw from the Union]”. The two year limit is crucial as after this threshold general WTO rules apply and the decision to start bilateral negotiations needs to be unanimous on the side of the European Union.

  o **Switzerland Scenario** - Switzerland has been negotiating an electricity agreement with the EU since 2007; the ultimate objective of this is to conclude a comprehensive energy agreement that includes electricity trade (on which the country relies during winter months) but also aspects of energy infrastructure (such as interconnectors), energy efficiency and gas. As reported by the European Commission, Swiss-EU talks were placed on hold following Switzerland’s referendum vote, which curtailed immigration from other EU states into the country. Free movement of people and labour, a founding virtue of the EU, extends to Switzerland by underpinning many of the current CH-EU agreements. As of May 2016, the talks have not resumed. We believe this will prolong negotiations well over the 2 year limit into the medium term.

• **Regulatory Independence** – This assumption is directly tied to the level of EU integration. As part of the EEA agreements, large parts of EU regulation is adopted by the member while in the Switzerland scenario regulatory independence is high and adoption of rules is just restrained to a case-by-case agreement.

• **Access to Primary Energy** – While we will dwell on this topic in the following chapter, we assume that in the short to medium term, any of the scenarios will not impact significantly access to Primary Energy, namely, natural gas, coal, uranium and oil products given the UK’s well diversified mix of suppliers and import infrastructure.

**Assessing the impact on investment in interconnectors**

When it comes to assessing the impact of Brexit on the investment case for much of the future generation capacity in the UK, the picture is obstructed by substantial uncertainty. Energy infrastructure depends on government policy as much as it does on the prevailing domestic market situation. The only certain outcome of Brexit is immediate institutional uncertainty stemming from the need to untangle and redefine all the legislative, economic and political ties that the UK and the EU currently share. **Uncertainty is directly translated by the market into more risk and in turn an increased required return from a given investor.** The economic rationale for this consideration can be found in the Capital Asset Pricing Model, reported below, which demonstrates the ties between risk and required returns and from which, cost of equity, is derived.
\[ Ra = Rf + \beta a(Rm - Rf) \]

Where:

- \( Ra \) = the return required by the investor to undertake a project with a certain level of risk; cost of equity
- \( Rm \) = expected market return
- \( \beta a \) = the beta, which represents the volatility of stock returns
- \( Rf \) = the risk free rate, usually 10 year treasury bonds or a similar measure

As uncertainty grows, an investor will require a higher return to invest in a project versus a risk free asset, such as a 10 Year Treasury bond in the US or a ‘gilt’ bond in the UK.

While seemingly straightforward, assessing the impact of Brexit on investment levels in UK energy infrastructure, particularly interconnectors, presents various obstacles. A quick review of government, media and academia discussions on the topic will soon reveal the breadth of expectations on movement of the markets (FTSE 100 up or down), on the movement of the UK bond markets (yields up or down) and so on.

Given the substantial uncertainty surrounding the topic we approached the analysis of Brexit on investments cost by modelling the required return of investors on UK interconnector projects (based on measures on the Cap & Floor decision document on NEMO by Ofgem\(^29\)) for a set of (arbitrary) changes in \( Rm \) (expected market return) and \( Rf \) (the risk free rate) based on the CAPM.

The results of this analysis will be presented in later chapters.

Assessing the Impact on Security of Supply

In order to assess the effect that different scenarios of Brexit would have on the UK’s security of supply we calculated de-rated capacity margins, introduced above, for each of our scenarios in 2020 and 2030.

To carry out this calculation we had to:

- **Estimate future levels of generation capacity, the generation portfolio and peak demand levels.** We looked at future estimates of installed generation capacity and peak demand for the years 2020 and 2030 under two different scenarios envisaged by the National Grid in their “Future Energy Scenarios” 2015 document. We focused on two diametrically opposite scenarios, “Gone Green” featuring moderate economic growth and a solid drive towards renewable energy and “No Progress” characterised by sluggish growth and little interest in renewable generation\(^30\).

- **Assess future levels of interconnection** in two different timeframes. This figure is the result of our analysis in later chapter and it mirrors differing levels of uncertainty in each scenario.

We de-rated the expected capacity for each generation source to reflect their expected availability at any point in time, using the de-rating factors established by Ofgem\(^31\). By plugging the total amount of de-rated capacity into the capacity margin formula we obtained de-rated capacity margins in 2020 and 2030 for our scenarios. For datasets used and information about de-rating factors please see Annex 4.
The Current State of Energy Security on the UK Market

The role of this chapter is central to analysing the potential impact of Brexit on the energy security profile of the UK. It provides, in fact, a starting point to the discussion and a basis from which the evolution of energy security, shaped by the varying scenarios, stems from.

We will be looking at various measures of energy security to assess the current security profile of the UK market and will then shift our focus to electricity security of supply and consequently assess its current state.

Access to Primary Energy Sources

Access to energy resources, particularly to natural gas, has not been a problem for the United Kingdom historically. The large reserves of gas and oil fields in the North Sea has ensured the country’s access to plentiful energy resources.

In recent years, given various factors such as the slump in oil prices, which has strongly affected a relatively high cost area and the natural decline in reserves (calling for the need of Enhanced Oil Recovery methods which raise costs) has turned the UK from an energy exporter to a net importer.

As can be seen in Figure 3, the country was a net exporter of natural gas as recently as 2004; the extent and pace at which that position has reversed is significant. In 2014 the United Kingdom imported roughly 350 TWh more than it exported.

While this consideration would lead the reader to assume the UK to be characterised by a weak energy security profile, the reality is very different.

The UK’s dependence on imported primary energy products is, in fact, significantly inferior to the average of the 28 EU member states. Additionally, the UK features a diversified composition of suppliers and a vast network of import infrastructure. See Annex 1 for further detail.

Figure 4 shows that the UK relies on imports from Norway, the Netherlands and LNG Markets (mainly Qatar) for 61% of its Natural Gas consumption. As another measure of Security of Supply we can take into consideration the SCI index of natural gas supply for the UK.

As previously mentioned, the SCI index measures market concentration and more specifically in this case if any, particular supplier weighs heavily on the energy imports of the UK. Research by the European Commission indicated an SCI index (measured on a scale 0-100) for the UK between 0 and 5 based on 2012 data, the 6th lowest of a group including EU and EEA members.

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4 1 TWh = 1000 GWh
Security of supply also depends on the resilience of the infrastructure in place to source energy from global and regional markets. A recent study by the UK Government states that "gas supply infrastructure is resilient to all but the most extreme and unlikely combinations of severe infrastructure and supply shocks. The UK N-1 calculation\(^5\) exceeds the target of more than 100% with a score of 112-13%"\(^3\). This calculation includes the three LNG import facilities in the UK that have the capacity to supply 50% of yearly natural gas demand.

The reader might notice that in basing our assessment of security of supply we have only taken into considerations measures of access to Natural Gas and the resilience of infrastructure aimed at transporting and transforming it. The reason is that while coal and petroleum products enjoy the dynamics of a liberalised, global and very liquid market, natural gas (with the partial exception of LNG) is characterised by long-term, oil indexed contracts. Its imports are tied to the development of costly infrastructure which is, in turn, based on cumbersome contractual agreements such as take-or-pay contracts; for these reasons natural gas supplies face a higher degree of potential disruption with respect to other sources of primary energy.

In other words, we expect the UK to be able to access a stable supply of energy sources at an affordable price in any scenario of Brexit. This fulfils half of our definition of security of supply defined at the onset of this document.

The crucial point to be made regarding the UK’s access to primary energy is that whatever the result of the June Referendum will be, the country would still have satisfactory access to energy resources sourced by regional (European) and global, liquid markets in the short-to-medium term. This is a common feature of all the scenarios selected by Sia Partners for this study and underpins the focus of this paper towards electricity security of supply as the area for potential downsides from Brexit scenarios.

Electricity Security of Supply

Spare capacity of electricity generation was at a 7-year low during the 2015/2016 winter\(^3\)\(^6\). To mitigate the danger posed by low capacity margins to consumers and businesses Ofgem approved the Supplemental Balancing Reserve (SBR) and Demand Side Balancing Reserve (DSBR) as additional tools that National Grid could rely on to help balance the system should margins be dangerously low\(^3\)\(^7\).

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\(^{5}\)"The N-1 formula describes the ability of the technical capacity of the gas infrastructure to satisfy total gas demand in the calculated area in the event of disruption of the single largest gas infrastructure during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years. Gas infrastructure includes the gas transmission network including interconnectors as well as production, LNG and storage facilities connected to the calculated area. The technical capacity of all remaining available gas infrastructure in the event of disruption of the single largest gas infrastructure should be at least equal to the sum of the total daily gas demand of the calculated area during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years. The results of the N-1 formula, as calculated below, should at least equal 100 %."
It has been reported that National Grid paid £36m to have various industrial facilities shutdown or move to standby mode over the 2015/16 winter; this measure secured 2.56GW to support capacity margins and avoid emergency situations. That came at a cost of about £1.4\(^6\) on the electricity bill of each UK household\(^6\). Figure 5 shows the impact of SBR and DSBR measures on the expectation of LOLEs (as explained in the methodology section Loss Of Load Expectation).

Similarly, the de-rated margins have also increased from a 1%-4% range to a 3%-10% range.\(^39\)

This urgency and the adoption of these extreme measures indicate issues with electricity security of supply in the UK. Further confirming our analysis, the European Commission, in a UK country report dating from 2014 has stressed concerns about the adequacy of power generation in the mid-term. Furthermore, it has stated its “expectation that generating margins will decrease to historically low levels in the middle of the decade”, pointing to a weak status quo and an uncertain future\(^40\).

Echoing the European Commission’s concerns, Ofgem highlighted issues with capacity margins in the short term. Figure 6\(^4\) shows Ofgem’s expectation that next winter 2016/2017 could see even lower margins before an improvement in capacity due to mothballed plants projected to come online and an expected drop in demand by 2017/2018. Ofgem’s capacity margin projections mentioned above paint a bleak picture for the UK electricity market.

In order to fully gauge the gravity of the issue it is worth understanding how the UK managed to reach such low capacity margins.

It is a mix of ambitious environmental policy choices and planned decommissioning of plants which has led coal generation and nuclear generation to decline in recent years. While planned decommissioning is a structural factor which can be predicted years in advance, energy policy shifts have been, likely, a bigger part of the issue.

Growing concern over environmental issues and climate change has led a policy-driven push to move away from conventional sources of generation, mostly coal power plants that comprise the backbone of the UK generation portfolio, as can be seen in the Figure 7.

\(^6\) Based on 26,473,000 households in the UK
During November 2015, Energy Secretary Amber Rudd announced plans to shut down all coal generation by 2025 and restrict its use by 2030. Policy as such shifts investment away from conventional sources towards renewable and more intermittent sources of power. In the absence of counterbalancing measures, this has impacted negatively on the electricity security of supply profile of the United Kingdom.

The role of Interconnectors

In the wake of low capacity margins on the UK electricity system and given the policy and technical constraints to develop new generation in the short term, imports of electricity gain considerable importance as a tool to balance the system and ensure sufficient supply at all times. Recognising their role as crucial to ensure security of supply, interconnectors were recently allowed to participate in the capacity market auctions to pledge capacity for 2019/20; two interconnectors were successful pledging nearly 1.9 GW (0.5% of total awarded capacity).

*Figure 8* features two scenarios of available generation capacity in 2019, after the coal reduction programme has taken place and 5 to 7 GW of conventional generation capacity is taken offline. The dotted black line, showing expected peak demand levels in the UK, demonstrates that supply barely meets demand in the ‘Outage Scenario’. 

**Interconnection import capacity** (indicated by the segment of black bar in the orange area) can provide a safety buffer to avoid system disruptions, improving, therefore, the UK’s energy of security profile.

Efficiency of electricity flows, of course, is important; should interconnectors be exporting electricity out of the UK electricity’s system during the outage scenario, this would create shortages of power. In 2015, UK interconnection capacity stood at 4GW.
The following is a list of existing interconnectors:

- **IFA** – Connecting France and the UK with a capacity of **2000 MW**
- **Moyle** – Connecting the Irish and UK systems with **500 MW**
- **BritNed** – between the UK and Netherlands systems with **1000 MW**
- **EWIC** – again, between Ireland and the UK system with a capacity of **500 MW**

The current level of interconnections (4.4%) is well short of the 10% (of domestic installed generation) interconnection capacity target set for 2020 by the European Union. Analysis from ENTSO-E has identified an additional 8GW of potential cross border transfer capacities between UK and Continental Europe & Norway. Several interconnection projects have been identified and are being developed between the UK and its neighbours, the following is a list:

<table>
<thead>
<tr>
<th>NAME</th>
<th>CONNECTED MARKET</th>
<th>CAPACITY (MW)</th>
<th>DUE BY</th>
<th>COST (€M)</th>
<th>STATUS AS OF FEB. 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEMO</td>
<td>Belgium</td>
<td>1,000</td>
<td>2019</td>
<td>690</td>
<td>Cap &amp; Floor; Construction</td>
</tr>
<tr>
<td>ELECLINK</td>
<td>France</td>
<td>1,000</td>
<td>2019</td>
<td>400</td>
<td>Exemption; Offering Capacity</td>
</tr>
<tr>
<td>IFA2</td>
<td>France</td>
<td>1,000</td>
<td>2020</td>
<td>690</td>
<td>Cap &amp; Floor; Consultation</td>
</tr>
<tr>
<td>NSN</td>
<td>Norway</td>
<td>1,400</td>
<td>2021</td>
<td>2000</td>
<td>Cap &amp; Floor; Construction</td>
</tr>
<tr>
<td>GREENLINK</td>
<td>Irish SEM</td>
<td>500</td>
<td>2021</td>
<td>560</td>
<td>Cap &amp; Floor</td>
</tr>
<tr>
<td>FAB LINK</td>
<td>France</td>
<td>1,400</td>
<td>2022</td>
<td>750</td>
<td>Cap &amp; Floor; Detailed Surveys</td>
</tr>
<tr>
<td>VIKING LINK</td>
<td>Denmark</td>
<td>1,000</td>
<td>2022</td>
<td>2000</td>
<td>Cap &amp; Floor ; Surveys</td>
</tr>
<tr>
<td>NORTH CONNECT</td>
<td>Norway</td>
<td>1,400</td>
<td>2022</td>
<td>1300</td>
<td>Development Studies</td>
</tr>
<tr>
<td>ICELINK</td>
<td>Iceland</td>
<td>800-1,200</td>
<td>2024</td>
<td>4000</td>
<td>Development Studies</td>
</tr>
<tr>
<td></td>
<td><strong>9.9 GW</strong></td>
<td></td>
<td></td>
<td><strong>€12,390m</strong></td>
<td>Source: Poyry, Sia Partners, 4C Offshore</td>
</tr>
</tbody>
</table>

The investment rationale for interconnectors, as mentioned in previous chapters, rests on price shape and level differential among markets but also, importantly, on regulatory arrangements with the relevant authorities at each end of the cable. In the UK, as the table shows, many of these projects, deemed beneficial for UK customers have been granted Cap & Floor regimes, limiting downside risks and capping profits on the projects at a certain level.

Such regulatory arrangements which set the amounts at which projects are likely to be rewarded, as well as other arrangements such as capacity payments which grant projects with a stable and reliable cash flow, play an important role in the investment decisions of investors and TSOs alike.

The prospect of Brexit and more specifically, the prospect of uncertainty surrounding policy and regulation that underpin many of the investor’s choices when it comes to commit to an interconnector, are a considerable threat to the realisation of a large number of these projects.

Three of the aforementioned projects are in advanced phases of completion, namely Nemo, Eleclink and the NSN interconnectors have already met their Final Investment Decision, have defined regulatory arrangements (Eleclink is purely a merchant interconnector) and are currently being developed. These interconnectors are at risk of being delayed or even being cancelled as a result of differing uncertainty timeframes.
Should the outcome or a Brexit scenario be unfavourable to their development (i.e. no inclusion of interconnectors in capacity markets, requirement to renegotiate regulatory arrangements, withdrawal of PCI status) or should uncertainty linger for an excessive period of time following June’s referendum, these projects might not be completed.

The prospect of limited amounts of interconnection are, as we have seen, detrimental to the security of supply of the UK market and will be closely watched in the analysis of the scenarios. We believe that, along with a broader decrease in energy infrastructure investment and curtailed access to the IEM, the potential withdrawal of projected interconnection capacity is a very significant threat posed by Brexit to the security of supply of the UK.

Having introduced the risk of lower investment in interconnection capacity, let us pay a closer look to how we approached the analysis of the impact Brexit could have on investment levels in interconnection capacity.

Impact of Brexit on Interconnection Investment

The impact of Brexit on interconnection investment will come from two factors, one financial and the other regulatory. While the two are correlated in a way, we have treated them as two separate items, to clearly identify their contribution.

- **Financial factor** – Investment in interconnectors will be impacted because of variations in an investor’s required return caused by shifting market dynamics. Because predicting market shifts stemming from such an uncertain issue is particularly daunting we carried out a scenario analysis where we look at how shifts in risk free rates and expected market returns impact an investor’s required return. From this analysis we are able to understand how shifts in market dynamics impact the profitability of projects, and therefore the likelihood that any given projects might be realized.

- **Regulatory factor** – First and foremost, we believe that uncertainty around rules and regulations regarding the place of the UK in the IEM and how it will trade with its former partners will be the biggest deterrent to investment levels in interconnection. As we have indicated in each case we forecast a period of uncertainty lasting for 2 years in the Norway scenario and throughout the short and medium term in the Switzerland scenario.

We dedicate a separate chapter to this issue because while the regulatory factor plays a different role in our scenarios, our analysis of the financial impact is applicable to the Switzerland, Norway and No Brexit scenarios.

Financial Impact on Interconnection Investment

By utilising the CAPM model shown above we looked at what happened to the return ($R_a$) that investors would require to finance a UK based interconnection project in different cases. The starting point provided by Ofgem was a risk free rate of 1.6% (based on prior regulatory settlements) and an implied expected market return ($R_m$) of 6.8%. We changed both figures on a range spanning from -20% to +20% and plugged each combination of $R_f$ & $R_m$ into the CAPM to estimate the impact on the required returns.
Figure 9 shows the range of required returns for varying levels of expected market return ($R_m$) and a fixed risk free rate ($R_f$).

The analysis (full table and explanation available in Appendix 2) tell us that:

1. **Expected Market Return** is the driver of change in Required Returns ($R_a$) – 100% of the cases in which $R_a$ was modelled with a decrease in Market Returns yielded a lower required return. In other words, **should Market returns decrease as a result of Brexit, the return that investors would require to enter the projects would be lower than the base case.**

2. Out of the total 81 combinations modelled, 28 cases featured a required rate of return that is more than half a percentage point higher than in the base case ($R_a = 8.1\%$). **In other words, in 28 cases the realisation of the project could be placed under review.**

3. **Risk free rates have a marginal impact on the required returns** – mostly given to their traditionally low levels (1% - 2%), an increase of even 20% does not have a substantial weigh on the CAPM formula.

But what does this all mean for investment in UK interconnectors?

It means that, according to economic theory we have showed that expected declining market returns as a result of Brexit, would lower the return that investors would require to fund a given project.

Lower required returns are equivalent to lower cost of equity, which alongside cost of debt provides the discount that investors apply to expected cash flows from projects. By holding cost of debt fixed and lowering cost of equity, the profitability of the project is higher. **For a detailed explanation see Appendix 3.**

In non-economic terms this means that projects which were deemed not profitable, or not profitable enough, might become a viable option with lower required returns. The same holds true for the opposite case, should investor’s required returns increase, projects that were deemed profitable and attractive, might see their economic case slip away.

**Regulatory Uncertainty**

Among various types of electricity infrastructure projects, electricity interconnectors are particularly at risk of being abandoned given the extent of financial and regulatory complexity under which they are conceived; the support of common regulation, grants, streamlined permit pipeline and other benefits that UK interconnector projects today, might be lost. **As long as investors will not benefit from a solid set of agreements on which they can base a Final Investment Decision further investment in electricity interconnectors with mainland Europe will come to a near halt.**

As we mentioned earlier, in the case of a Norway-type Brexit scenario, uncertainty, would be short-lived when compared to a Switzerland case.
We believe that it is feasible to redefine regulatory and institutional ties in the energy sector in a case where many of the EU rules are set in place today, and a large part of current UK membership to EU regulatory bodies would be retained. In practical terms this will yield shorter negotiations and provide a sound set of rules and agreements on which investment decisions on a 20-30 year old asset can be made with confidence.

We expect that FID on a large part of the projects being currently proposed could be delayed by up to two years in a Norway scenario. This analysis is based on the assumption that it will be doable for the UK government to renegotiate a transition to the EEA within the 2 year negotiation window provided by EU law on the matter. In terms of projects in their initial phase of development we assume that these will not be commissioned on-time as developers will adopt a wait and see position. With other factors held constant, this would lead to a prolonged period of thin capacity margins and impact negatively the UK’s electricity security of supply.

In terms of interconnection investment, as for investment in the wider UK energy sector, a Switzerland type Brexit scenario would have a strong negative impact in the short to medium term. The Swiss case shares a high level of uncertainty with the Norway scenario in the months immediately following the June referendum. While in the Norway case, current arrangements could be more quickly organized to match EEA membership requirements, the Swiss case presents a prolonged period of uncertainty that is especially detrimental to interconnection investment. The reason is the particular importance of a solid set of cross-border regulation of flows and remuneration; in the Swiss scenario the development of these arrangements might take anywhere from two years to decades. It suffices to mention that political obstacles have prevented Switzerland and the EU from reaching an energy agreement that is, currently, 10 years in the making. We expect investors to adopt a wait and see strategy.

It was important to introduce, first, the way we assessed the impact of Brexit on interconnection investment for our different cases, as it influences how much interconnection capacity there is in each case, an important factor of security of supply.

Let us now look at our first scenario of Brexit, the Norway scenario.

Brexit Scenario I - Norway

The following is a recap of the Norway Scenario assumptions.

<table>
<thead>
<tr>
<th>EU INTEGRATION LEVEL</th>
<th>ACCESS TO IEM</th>
<th>TARIFFS ON ENERGY</th>
<th>EU PCI GRANTS ACCESS</th>
<th>UNCERTAINTY TIMEFRAME</th>
<th>REGULATORY INDEPENDENCE</th>
<th>ACCESS TO PRIMARY ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORWAY SCENARIO</td>
<td>EEA Member</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Short</td>
<td>Medium/Low</td>
</tr>
</tbody>
</table>

Review of Norway’s arrangements with the EU

EU-Norway relations are governed by the EEA Agreement which includes various key regulations shared with EU member states such as the single market legislation, which includes competition law, public procurement, state aid restrictions and the free movement of goods.
Under the EEA Agreement, Norway is obliged to implement the internal energy market legislation. Through this obligation, the country has closely cooperated with the EU on energy efficiency, renewable energy and new energy technology issues by assisting relevant EU programmes.

Particularly, given its importance to the EU as an external energy supplier, Norway is deeply integrated into the EU-wide energy market. In the specific case of electricity systems, the country is fully integrated in the Nordic electricity market and has interconnection capacity well over the 10% target set by the European Union for 2020.

The Nordic market, including EEA member Norway and EU members Finland and Sweden has been a trailblazer in market coupling efforts (completing price coupling by 2000) and currently serves as an example to other regions being integrated.

Through the EEA agreement, Norway is entitled to cooperate with ENTSOs and ACER, the two European regulating bodies that are instrumental in developing EU wide rules (such as network codes) that promote the realisation of an integrated energy market.

As a result of its adoption of Internal Energy Market legislation and its cooperation with EU-wide regulatory bodies, Norway has access to the range of benefits tied to market coupling.

The country is part of the EU’s Price Coupling of Regions mentioned before and has access to cross-border balancing and capacity markets.

Furthermore, Norway’s integration in the market makes it eligible for receiving funding under various EU investment programmes, notably, the CEF (Connecting Europe Facility) which in 2014 funded 50% (over €31m) of the technical design studies on the NSN interconnector (UK-NO).

While it may seem that Norway’s position is strikingly close to that of a full EU member state, the Nordic country is only consulted during the early stages of legislative processes by the European Commission. It has no vote in the Council of Ministers and the European Parliament, effectively rendering it a rule-taker.

Applying the Norway Scenario to the UK

An analysis of the section above makes it clear that a Norway-type Brexit would imply a soft landing for the UK energy sector, particularly with regards to its electricity security of supply.

Retaining access to the IEM comes with continued participation to the market coupling programme, which as mentioned previously, stabilises electricity prices, optimises cross-border capacity and improves overall security of supply. Given that the UK is currently part of this programme, its continued adherence to it would imply no detrimental effect on its energy security profile. We shall quantify, in the Switzerland scenario, the benefits tied to the adherence to market coupling. For the time being it is worth noting that the benefit is in the neighbourhood of hundreds of millions of UKP yearly. Continued membership to ENTSOs and ACER would ensure the adherence to and co-development of network codes and other EU-wide energy markets regulation.

Another important characteristic of a Norway-type scenario is the continued access to funding from the CEF towards the realisation of PCIs based in or benefitting the UK. As can be seen from the table below, between 2014 and 2015 UK based projects have benefitted from €126m (roughly £100m at 1EUR=.79GBP) in funding on gas and electricity infrastructure projects that aim to strengthen the UK’s security of supply as well as to further integrate the country in the EU energy market.
Most of this funding was geared towards feasibility and development studies that assist project sponsors in securing regulatory approval and facilitate the realisation of a Final Investment Decision. Moreover, CEF funding is particularly relevant in the case of electricity interconnectors (NSN Link, FAB, ElecLink and Greenwire are included in the list above), highlighting the strategic importance of further electricity interconnection both for the UK’s electricity security of supply and to unlock wider benefits from unconstrained market coupling.

While only 7 UK-based projects have received funding from the CEF so far, a total of 26 projects have been deemed as PCIs by the European Commission: 21 of them are electricity projects, 4 are gas projects and the remaining is a smart grid project. In other words, should the UK retain access to PCI funding, it would be set to secure a substantial amount to develop projects improving its energy security profile and access to the IEM.

A significant drawback for the UK under a Norway-type scenario of Brexit would be a more limited regulatory freedom with respect to the current situation. While it might seem odd that leaving the EU might lower regulatory freedom, the UK would, as Norway does today, have to accept all significant internal market legislation. For the energy sector that would translate into adopting competition legislation and state aid rules (the UK would not be able to exclude Interconnectors from capacity markets to preserve domestic generation based on internal market rules).

While the UK, currently, has to abide by these rules, it also retains a voice and a vote to be able to influence present regulation and its future path; by joining Norway in the EEA it will lose this freedom while having to respect (nearly) the same rules as it does currently.

Furthermore, as discussed earlier, the Norway scenario presents an important drawback to investment in interconnection. Regulatory uncertainty around the set of arrangements that will tie EU-UK trade and the latter’s position in the IEM will lead investors and developers to adopt a ‘wait and see’ position that will place most, if not all projects, on hold.
Security of Supply Forecast – Norway Scenario

Having come to the conclusion that uncertainty will slow down or stop investment in interconnection capacity with mainland Europe, we set out to quantify the impact on the UK’s security of supply profile for this scenario.

<table>
<thead>
<tr>
<th>NORWAY</th>
<th>NO PROGRESSION</th>
<th>GONE GREEN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
</tr>
<tr>
<td>DE-RATED CAPACITY MARGINS</td>
<td>5.38%</td>
<td>9.74%</td>
</tr>
</tbody>
</table>

Specifically, for the Norway scenario we excluded any additional interconnection capacity (fixed at 4.4GW) until 2020, and then factored de-rated interconnection capacity in the calculation of margins for the year 2030. The table shows the results of our analysis, and highlights the role of paramount importance that interconnectors play in keeping margins above peak demand. It can be observed that both scenarios see a tight de-rated capacity margin for 2020, $(2020 – \text{No progression} = 5.38\%, \quad 2020 – \text{Gone Green} = 2.15\%)$ which is kept positive by the marginal contribution of de-rated interconnection capacity.

Instead, if we had included the full amount of interconnection capacity forecasted by National Grid, the margins would go up to 7.3% for the No Progression case and to 8.8% for the Gone Green scenario in 2020; this points to a to a significant worsening of the energy security profile of the UK as a result of missed interconnection capacity.

It is crucial to mention that Ofgem de-rates the contribution of interconnectors on a case by case basis; country to country differences are prominent given the different price levels and shape of interconnected market and the characteristics of each national power system.

For the sake of applicability, we de-rated interconnectors with a 58% factor which averages already established factors as used by Ofgem\textsuperscript{55}. For a detailed explanation see Appendix 4.

When including the full forecasted interconnection capacity in the installed capacity for 2030 in both scenarios, the capacity margin looks better. The No Progression scenario features a de-rated capacity margin of 9.7%, the same figure goes up to 19.6% for the Gone Green scenario.

Note that interconnection at early stages of development, like the Nemo and NSN Link interconnectors, which were expected to come online around 2020, are not included in the calculation of the 2020 capacity margin in the Norway case. The rationale for the choice ties back to our expectations that developers, like investors will adopt a ‘wait and see’ approach given regulatory uncertainty.

Conclusion – Norway Scenario

In this chapter we have seen that a Brexit scenario that results in a Norway-style set of agreements between the EU and the UK has a minor negative impact on the energy security profile of the UK. From the analysis of capacity margins we can conclude that a Norway-type Brexit will weaken the electricity security of supply in the short term (should Brexit not happen, de-rated capacity margins would be between 2% to 6% higher) but should have no major impact in the medium run.
The UK, will be able to retain its access to the IEM and PCI grants that not only benefit consumers, but also improve liquidity of markets, provide balancing options to increase the resilience of the power system and support the realization of further interconnections that diversify the UK’s supply of electricity by connecting it to lower cost markets.

Brexit Scenario II – Switzerland

The following table contains a summary of the Switzerland case’ assumptions.

<table>
<thead>
<tr>
<th>SWISS SCENARIO</th>
<th>EU INTEGRATION LEVEL</th>
<th>ACCESS TO IEM</th>
<th>TARIFFS ON ENERGY</th>
<th>EU PCI GRANTS ACCESS</th>
<th>UNCERTAINTY TIMEFRAME</th>
<th>REGULATORY INDEPENDENCE</th>
<th>ACCESS TO PRIMARY ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral Agreements</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Long</td>
<td>High</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

Review of Swiss arrangements with the EU

Despite its position at the heart of Europe, Switzerland is not part of the EU nor part of the European Economic Area. Instead, the country bases its relationship with the European Union on a set of bilateral arrangements, drafted and agreed upon over decades.

Focusing on the energy sector, Switzerland has been negotiating an electricity agreement with the EU since 2007; the ultimate objective of this is to conclude a comprehensive energy agreement that includes electricity trade (on which the country relies during winter months) but also aspects of energy infrastructure (such as interconnectors), energy efficiency and gas56.

The absence of an overarching agreement on energy issues excludes Switzerland from the Internal Energy Market, and as a consequence, from the Market Coupling project. In 2013, Swissgrid, the Swiss TSO, reportedly gathered support from the political establishment and the wider energy sector to drive the introduction of market coupling with neighbouring countries recognising its benefits.

The company ensured technical and operational readiness for coupling by the end of 2014, however, “actual market coupling – i.e. commercial coupling – can only take place when Switzerland and the European Commission have reached the appropriate political agreements”57. Further emphasising the need for a political agreement the EU has stated “The Union single day-ahead and intraday coupling may be opened to market operators and TSOs operating in Switzerland on the condition that the national law in that country implements the main provisions of Union electricity market legislation and that there is an intergovernmental agreement on electricity cooperation between the Union and Switzerland.”58
In absence of market coupling, along with its mechanisms to couple prices and capacity simultaneously at European borders, electricity trade between Switzerland and the EU functions as shown in Figure 10:

- Swiss electricity traders purchase from and sell electricity to foreign electricity traders.
- Both parties inform their respective TSOs.
- The TSOs create aggregated schedules to monitor capacity at borders and oversee the transaction.

The acceptance of basic EU virtues such as the free movement of people and labour takes us to analyse the regulatory freedom of Switzerland, which is considerably higher than other EU member states.

Switzerland does not accept EU competition law and state aid rules (apart from the aviation sector)\(^\text{60}\). In the energy sector this translates to more freedom for the country to subsidise certain types of generation among other things.

Last, but certainly not least, notwithstanding the geographical position of Switzerland at the centre of Europe, the country does not have access to PCI grants and funds from the Connecting Europe Facility. It profits from the development of infrastructure that benefits other EU member states, but is not entitled directly to receive funds for the development of projects that promote security of supply or welfare generation\(^\text{61}\).

Applying the Switzerland Scenario to the UK

A UK outside of the EU, relying on the (lengthy) establishment of bilateral agreements is a country outside the IEM. By losing access to the Internal Energy Market, the UK would have to forgo benefits stemming from market coupling, balancing services and could possibly face loss of benefit from exclusion of interconnectors in capacity market auctions.

A study commissioned by the National Grid dating back to end of March 2016 puts a figure on these foregone benefits: £420m pounds yearly by the early 2020s\(^\text{62}\). See Figure 11.

- **Exclusion from market coupling - £160m loss.** Exclusion from the IEM and the relinquished membership to ACER and ENTSO-E will imply the UK’s exclusion for developments on network codes and price coupling advancements. The loss stems from sub-optimal interconnector flows and higher wholesale prices.
- **Exclusion from cross-border balancing - £80m** by early 2020s. Because of exclusion from market coupling and the various issues mentioned above the UK would have to resort to more expensive system balancing options.
- **Exclusion of interconnectors from Capacity Market - £20m** by early 2020s. The current inclusion of interconnectors in the UK Capacity Market is driven by EU competition rules\(^\text{63}\). Excluding interconnectors from Capacity Markets (the initial decision of the UK this issue) would result in more expensive security of supply options.

In a Swiss case scenario, it is clear that the country would be negatively impacted under a security of supply point of view.

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\(^{\text{60}}\) See Figure 10- SWISS ELECTRICITY TRADING SCHEME

Source: Swissgrid

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\(^{\text{62}}\) See Figure 11
• Exclusion from market coupling renders markets less liquid, yields a non-efficient flow of power lowering economic welfare and weakens the downward pressure on wholesale prices that market coupling brings.

• Exclusion from cross-border balancing increases costs and negatively impacts the resilience of the UK system.

• Exclusion of interconnectors from capacity markets weaken the security of supply profile of the UK by excluding a valuable source of supply diversification.

As shown in the Norway case, should the United Kingdom exit the EU they would have to forgo sizeable grants for the development of infrastructure, mostly interconnectors that promote the development of an integrated market and increase security of supply as part of the PCI framework.

It is worth reminding that in the past two years the UK have been granted over €64 m (assuming a 1.27 €-£ exchange rate) by the Connecting Europe Facility to develop such infrastructure and that many more projects are set to receive funding as part of this program.

In terms of interconnection investment, as for investment in the wider UK energy sector, a Switzerland scenario would have a strong negative impact in the short to medium term. Forgone benefits from interconnection investment have also been estimated by the same study mentioned above. An undermined business case for FAB Link, IFA2 and Viking Link (3.4 GW) would yield a welfare loss of £160m per year in the 2020s.

Security of Supply Forecast – Switzerland Scenario

We used the same approach shown in the Norway scenario to obtain the expected de-rated capacity margin of the UK. For a Swiss-type case, we want to reflect our belief that this scenario will imply longer periods of uncertainty and therefore stifle investment in the short-to-medium term.

Here we will see how UK capacity margins look without any additional investment in interconnection capacity from 2016 onwards. In the Norway case we had modelled capacity margins by the including the full expected amount of interconnection capacity by 2030. When modelling margins with no new interconnection capacity in the medium term, we see margins decrease from 9.7%, observed in the first case, to 4.2% in the 2030 - No Progression case and from 19.6%, in the Norway case, to 7.7% in the 2030 - Gone Green case.

<table>
<thead>
<tr>
<th>SWITZERL.</th>
<th>NO PROGRESSION</th>
<th></th>
<th>GONE GREEN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
<td>2020</td>
</tr>
<tr>
<td>DE-RATED</td>
<td>5.38%</td>
<td>4.24%</td>
<td>2.15%</td>
</tr>
<tr>
<td>CAPACITY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MARGINS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Sia Partners Analysis
Again, as was true for the *Norway scenario*, interconnection at early stages of development, like the Nemo and NSN Link interconnectors, expected to come online in the coming decade, are not included in the calculation of the 2020 and 2030 capacity margin in the *Switzerland case*. The rationale for the choice ties back to our expectations that developers, like investors will adopt a ‘wait and see’ approach given regulatory uncertainty.

**Conclusion – Switzerland Case**

As was the case for Norway we can conclude that no investment in further interconnection capacity from 2016 levels will result in a weaker short-term energy security profile. **Additionally, given the longer period of uncertainty which characterises the Swiss-type case, the UK’s energy security profile could be heavily impacted in the medium term.**

As we have seen in this chapter a Brexit scenario based on the Swiss arrangements with the EU would be seriously detrimental to the security of supply profile of the UK as well as implying sizeable forgone benefits from market integration.

A summary of the conclusions follows:

<table>
<thead>
<tr>
<th>CAUSE</th>
<th>MARKET COUPLING</th>
<th>BALANCING SERVICES</th>
<th>CAPACITY MARKETS</th>
<th>FEWER INTERCONNECTORS</th>
<th>NO ACCESS TO PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UK Leaves IEM, ENTSO-E and ACER</td>
<td>UK Leaves IEM, ENTSO-E and ACER</td>
<td>UK Leaves EU and does not have to adopt its regulation</td>
<td>Increased risk and no EU financial and regulatory support</td>
<td>UK leaves the EU</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EFFECT</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less liquid market</td>
<td>Negative impact on system resilience</td>
<td>Diminished diversity of supply</td>
<td>Diminished diversity of supply yielding higher prices</td>
<td>Limited interconnection capacity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COST</th>
<th>MARKET COUPLING</th>
<th>BALANCING SERVICES</th>
<th>CAPACITY MARKETS</th>
<th>FEWER INTERCONNECTORS</th>
<th>NO ACCESS TO PCI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>£160m/y</td>
<td>£80m/y</td>
<td>£20m/y</td>
<td>£160m/y</td>
<td>£10m /y^7</td>
</tr>
</tbody>
</table>

**TOTAL**

£ 430m/y

**Brexit Scenario III – No Brexit**

The table below shows a summary of the *No Brexit* Scenario assumptions.

<table>
<thead>
<tr>
<th>EU INTEGRATION LEVEL</th>
<th>ACCESS TO IEM</th>
<th>TARIFFS ON ENERGY</th>
<th>EU PCI GRANTS ACCESS</th>
<th>UNCERTAINTY TIMEFRAME</th>
<th>REGULATORY INDEPENDENCE</th>
<th>ACCESS TO PRIMARY ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREXIT SCENARIO</td>
<td>EU Member</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>None</td>
<td>Low</td>
</tr>
</tbody>
</table>

Should the UK vote to remain as part of the EU in the June Referendum, the future of the UK’s energy industry, like the future energy security profile of the country, will depend on a variety of factors.

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^7 Sia Partners estimation based on the 26 PCI projects sponsored by the UK government and spread equally over 15 years. The current average funding for UK PCI is €11.45m. The total yearly figure is based on the 15 of the 26 PCI projects based in the UK that have not been funded yet. We divided the unfunded amount of €172m and spread it over 15 years.
The future extent of integration of the IEM, along with the UK’s domestic energy policy objectives will be crucial factors in shaping energy security.

The National Grid attempts to estimate future scenarios in the Future Energy Scenario document, which was last published in 2015. This document looks at the future under the lens of four different scenarios of varying economic growth levels and ambitiousness of energy policy objectives.

Notwithstanding the large difference among the scenarios in terms of generation mix, government policy and social behaviour all of them forecast an increase in interconnection capacity, recognising its important contribution to security of supply. See Figure 12.

The realisation of further interconnection projects with mainland Europe would be supported by all of the benefits that derive from membership to the IEM, collaboration with ACER and ENTSO-E, and economic support from the Connecting Europe Facility for PCI projects. All of these benefits have been discussed extensively in previous chapter and will not be reported in this chapter.

The UK is envisaged to remain a net electricity importer in three of the four scenarios. In the gone green scenario (after 2035), however, National Grid expects the country to become a net exporter of electricity given the decrease of wholesale energy cost relative to neighbouring countries.

We believe the most important element of the No Brexit case is the low uncertainty level relative to the Norway and Swiss cases. Low uncertainty keeps investment cost low, does not require investors and regulators to revise current plans and ensures from the day following the Referendum, a stable and reliable set of rules that supports the development of energy infrastructure.

Based on this scenario we should be able to see increased levels of generation around the turn of the decade with projects such as NSN and Nemo coming online, bringing interconnection capacity to around 6 GW. Should further interconnection capacity levels materialise as early as 2020s, de-rated capacity margins would benefit sharply. Based on the analysis presented in previous chapter we can conclude that, including further levels of interconnection the capacity margins will look like this:

<table>
<thead>
<tr>
<th></th>
<th>NO BREXIT</th>
<th>NO PROGRESSION</th>
<th>GONE GREEN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
<td>2020</td>
</tr>
<tr>
<td>DE-RATED MARGINAL CAPACITY</td>
<td>7.28%</td>
<td>9.74%</td>
<td>8.76%</td>
</tr>
</tbody>
</table>

We can observe that capacity margins benefit from further interconnection both in the short term (2020s) and in the medium term (2030s). Based on the latter consideration we believe that by not exiting the European Union the UK will be able to improve, or by the least, not worsen its electricity security of supply profile.
Conclusion

As this research comes to a conclusion it is time to summarise our findings.

We have been satisfied to conclude that many of the analyses on the impacts of different scenarios of Brexit on the UK’s energy security confirmed our hypothesis. We expected to see that a UK as a member of the EU would have a stronger security of supply profile while a Swiss-type Brexit scenario would lie at the opposite end of the spectrum; this conclusion is supported by our findings.

The conclusions are summarised in the following table:

<table>
<thead>
<tr>
<th>FORGONE INTEGRATION BENEFITS</th>
<th>NORWAY SCENARIO</th>
<th>SWITZERLAND SCENARIO</th>
<th>NO BREXIT SCENARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 DE-RATED CAPACITY MARGINS</td>
<td>£0/year</td>
<td>£430m/year</td>
<td>£0/year</td>
</tr>
<tr>
<td>2.15% - 5.38%</td>
<td>7.28% - 8.76%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030 DE-RATED CAPACITY MARGINS</td>
<td>9.74% - 19.7%</td>
<td>4.24% - 7.73%</td>
<td>9.74% - 19.7%</td>
</tr>
<tr>
<td>INTERCONNECTION CAPACITY CANCEL OR DELAY RISK⁸</td>
<td>2.2-6.4 GW</td>
<td>5.4-13.3 GW</td>
<td>0 GW</td>
</tr>
</tbody>
</table>

We expected to find stronger evidence of an increased investment cost because of greater uncertainty tied to the two Brexit scenarios; this was not the case, at least in part. We have found, in fact, that cost of capital may both, decrease or increase, depending on movements in the risk free rate but particularly the expected market returns. We have not found any compelling evidence to suggest that either of these might move in a predictable way and have therefore explored a portfolio of 81 cases in order to understand the issue. As predicted by the CAPM, movements in expected market returns will be a determining factor in the evolution of cost of capital.

⁸ The amount of interconnection capacity at risk of being cancelled or delayed does not reflect the exact list of proposed interconnection projects presented earlier. Instead, it is based on the interconnection levels forecasted by the Future Energy Scenarios document by National Grid. The difference shown is what we expect to be commissioned between 2020 and 2030 and what the FES document had initially estimated. See Annex 4 for more detail.
Finally, based on our findings we conclude that remaining one of the 28 EU members will allow the UK to develop a stronger energy security profile, particularly under the electricity point of view.

A Switzerland type scenario lies at the opposite end of the spectrum, given the long uncertainty timeframe that accompanies it, during which integration benefits will be lost, the UK will suffer from a weaker security of supply profile and investment will be placed on hold or cancelled altogether.

We thank you for your attention and hope that you have found this paper insightful.

Next Steps
An interesting development based on the material presented in this research would be an assessment of the impact of varying values of cost of equity (referencing to the cases of required returns modelled in this paper) on the Cap and Floor regime awarded by Ofgem.

As Ofgem has suggested in the Cap & Floor decision document for the Nemo interconnector, the Cap and Floor will be calculated using the CAPM model, also presented in this paper. We expect important variations in the values for both the cap and floor, which will impact the economic case of interconnection project.

Limitations
We hereby present the limitation of analysis techniques used in this research document:

- **DCF & IRR** – These two investment decision measures, while widely used because of their applicability and comparability, are used to benchmark mutually exclusive projects. They do not offer a comprehensive view of the value of a project.

- **De-rating factors** – We estimated the de-rating factor of solar to 15%, in an arbitrary fashion, given that Ofgem has not released their view on this source of generation. Furthermore, these de-rating factors were applied over the next 20 years, this may result in incongruences given changing technology levels that should improve the availability and efficiency of these sources.

- **De-rated capacity margin** – As stated by Ofgem, de-rated capacity margins “… do not reflect the amount of variability associated with [generation sources]” and “de-rated margins do not directly represent the risk of customers being disconnected.”

- This paper does not weight the political feasibility of each scenario. For example, entering the EEA might not be politically feasible should a Brexit campaign win. In fact, should the UK decide to impose controls on EU migrants, it would almost certainly lose preferential access to the single market. Moreover, by entering the EEA it would have to unconditionally accept most of the rules and regulations that apply to EU businesses, defeating the purpose of leaving the bloc to gain more independence.
IMPACT OF BREXIT ON UK ENERGY SECURITY

June 2016

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The UK Energy Team supports clients with services ranging from Business Transformation to operational and regulatory Due Diligence studies. Clients include energy and water market regulators, major suppliers, distributors and transmission operators in both electricity and gas markets as well as prominent global investment funds.

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ANNEX # 1 – Net trade balance of energy products - % of GDP

This graphs maps the net trade balance of all energy products as a percentage of GDP on each of the 28 EU member states as well as including the EU Average (-2.62%). This measure for the UK stands at a relatively high -0.6% indicating a low impact of energy imports on the negative current account balance of the UK, one of the highest in the whole EU.

![Net trade balance of energy products - % of GDP](image)

Source: eurostat

ANNEX # 2 – Required Return Scenario Analysis

The table below shows the 81 scenarios modelled using the Capital Asset Pricing Model. The Beta in this model is fixed at 1.25 (based on the beta of generation company Drax, as determined by Ofgem in the Nemo Cap & Floor decision document).

The 🟢 sign indicates all the cases (41) for which the required rate of return by investors “Ra”, as derived by the Capital Asset Pricing Model, is lower than in the base case scenario (Lower than 8.1%) indicating, a lower cost of capital and consequently indicating a higher likelihood that a given project might be deemed profitable (holding cash flows fixed). The 🟡 sign indicates the cases (12) for which Ra is .5% higher than in the base case scenario and the symbol 🟡 indicates those scenarios (28) for which the profitability is in danger (Ra > 8.6%).

<table>
<thead>
<tr>
<th>Value</th>
<th>Rm</th>
<th>Rm +5%</th>
<th>Rm +10%</th>
<th>Rm +15%</th>
<th>Rm +20%</th>
<th>Rm -5%</th>
<th>Rm -10%</th>
<th>Rm -15%</th>
<th>Rm -20%</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ra</td>
<td>6.80%</td>
<td>7.14%</td>
<td>7.48%</td>
<td>7.82%</td>
<td>8.16%</td>
<td>6.46%</td>
<td>6.12%</td>
<td>5.78%</td>
<td>5.44%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rf</td>
<td>1.60%</td>
<td>8.10%</td>
<td>8.53%</td>
<td>8.95%</td>
<td>9.38%</td>
<td>9.80%</td>
<td>7.68%</td>
<td>7.25%</td>
<td>6.83%</td>
<td>6.40%</td>
<td>9.80%</td>
</tr>
<tr>
<td>Rf +5%</td>
<td>1.68%</td>
<td>8.08%</td>
<td>8.51%</td>
<td>8.93%</td>
<td>9.36%</td>
<td>9.78%</td>
<td>7.66%</td>
<td>7.23%</td>
<td>6.81%</td>
<td>6.38%</td>
<td>9.78%</td>
</tr>
<tr>
<td>Rf +10%</td>
<td>1.76%</td>
<td>8.06%</td>
<td>8.49%</td>
<td>8.91%</td>
<td>9.34%</td>
<td>9.76%</td>
<td>7.64%</td>
<td>7.21%</td>
<td>6.79%</td>
<td>6.36%</td>
<td>9.76%</td>
</tr>
<tr>
<td>Rf +15%</td>
<td>1.93%</td>
<td>8.02%</td>
<td>8.44%</td>
<td>8.87%</td>
<td>9.29%</td>
<td>9.72%</td>
<td>7.59%</td>
<td>7.17%</td>
<td>6.74%</td>
<td>6.32%</td>
<td>9.72%</td>
</tr>
<tr>
<td>Rf +20%</td>
<td>2.11%</td>
<td>7.97%</td>
<td>8.40%</td>
<td>8.82%</td>
<td>9.25%</td>
<td>9.67%</td>
<td>7.55%</td>
<td>7.12%</td>
<td>6.70%</td>
<td>6.27%</td>
<td>9.67%</td>
</tr>
<tr>
<td>Rf -5%</td>
<td>1.52%</td>
<td>8.12%</td>
<td>8.55%</td>
<td>8.97%</td>
<td>9.40%</td>
<td>9.82%</td>
<td>7.70%</td>
<td>7.27%</td>
<td>6.85%</td>
<td>6.42%</td>
<td>9.82%</td>
</tr>
<tr>
<td>Rf -10%</td>
<td>1.44%</td>
<td>8.14%</td>
<td>8.57%</td>
<td>8.99%</td>
<td>9.42%</td>
<td>9.84%</td>
<td>7.72%</td>
<td>7.29%</td>
<td>6.87%</td>
<td>6.44%</td>
<td>9.84%</td>
</tr>
<tr>
<td>Rf -15%</td>
<td>1.36%</td>
<td>8.16%</td>
<td>8.59%</td>
<td>9.01%</td>
<td>9.44%</td>
<td>9.86%</td>
<td>7.74%</td>
<td>7.31%</td>
<td>6.89%</td>
<td>6.46%</td>
<td>9.86%</td>
</tr>
<tr>
<td>Rf -20%</td>
<td>1.28%</td>
<td>8.18%</td>
<td>8.61%</td>
<td>9.03%</td>
<td>9.46%</td>
<td>9.88%</td>
<td>7.76%</td>
<td>7.33%</td>
<td>6.91%</td>
<td>6.48%</td>
<td>9.88%</td>
</tr>
<tr>
<td>Min</td>
<td>-</td>
<td>7.97%</td>
<td>8.40%</td>
<td>8.82%</td>
<td>9.25%</td>
<td>9.67%</td>
<td>7.55%</td>
<td>7.12%</td>
<td>6.70%</td>
<td>6.27%</td>
<td>-</td>
</tr>
<tr>
<td>Max</td>
<td>-</td>
<td>8.18%</td>
<td>8.61%</td>
<td>9.03%</td>
<td>9.46%</td>
<td>9.88%</td>
<td>7.76%</td>
<td>7.33%</td>
<td>6.91%</td>
<td>6.48%</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Sia Partners

The Min and Max show the range of required returns (Ra) for each individual scenario.
ANNEX #3 – Explaining the impact of a lower required return on investment

As we have seen in Annex #2, fluctuations in risk free rates ($R_f$) and market expected returns ($R_m$) can impact the return that an investor will require to fund a specific project (as calculated by the CAPM model, included in the body of the text).

**Required return, is another, more intuitive name for cost of equity.** Along with cost of debt (the effective rate that a company has to pay on the debt it has issued), cost of equity makes up the capital structure of a company.

Cost of equity and of capital are merged into the Weighted Average Cost of Capital (WACC) to get a single figure representing how much a company will have to pay to obtain the funds that it used to finance its activities. It is “weighted” because cost of capital and of debt are multiplied by the proportion of debt and equity as a share of total financing.

$$WACC = \left( \frac{E}{V} \times Ra \right) + \left( \frac{D}{V} \times Rd \right) \times (1 - Tc)$$

Where:

- $E/V$ = Percentage of equity in total financing
- $D/V$ = Percentage of debt in total financing
- $Ra$ = Cost of Equity
- $Rd$ = Cost of Debt
- $Tc$ = Corporate tax rate

In our analysis we focused on $Ra$, the cost of equity. **Computing the WACC formula with a different cost of equity yields a different WACC** which, in turn, will play an important factor in shaping an investor’s decision. The ways this happens are varied, we will look at two of them.

- **Discounted Cash Flow analysis** – this is a popular method of valuing a project. It takes all the future cash flows that a specific project is expected to generate and discounts (divides) them by the cost of capital, WACC. The result yields the present value of all future cash flows and shows the value added that a project will yield. If it is positive the project should be accepted. Assuming fixed cash flows, *if the WACC increases the value added of a project will decrease, if the WACC decrease the value of the project will increase.*

- **IRR** – Internal Rate of Return. The IRR shows the discount rate that is needed to make all cash flows expected by the project yield a return of exactly 0. In other words, it can be seen as the “WACC” needed for a project to break even. *If the WACC of a specific project is smaller than the IRR then the project should generally go ahead because of its added value, and vice-versa.*

We have calculated the WACC in **four scenarios of varying cost of equity ($Ra$)** which resulted from our previous analysis. By holding Ofgem’s $69$ cost of debt, the tax rate, and notional gearing (proportion of debt and equity in financing) constant we see significant swigs in WACC.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost of Debt</th>
<th>Tax Rate</th>
<th>Notional Gearing</th>
<th>Cost of Equity</th>
<th>WACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.25%</td>
<td>20%</td>
<td>50%</td>
<td>8.1%</td>
<td>4.55%</td>
</tr>
<tr>
<td>2</td>
<td>1.25%</td>
<td>20%</td>
<td>50%</td>
<td>6.40%</td>
<td>3.70%</td>
</tr>
<tr>
<td>3</td>
<td>1.25%</td>
<td>20%</td>
<td>50%</td>
<td>9.80%</td>
<td>5.40%</td>
</tr>
<tr>
<td>4</td>
<td>1.25%</td>
<td>20%</td>
<td>50%</td>
<td>6.27%</td>
<td>3.64%</td>
</tr>
</tbody>
</table>

Source: Sia Partners Analysis

While each project will have its own IRR and DCF calculations, we have explained why, changes in the required return ($Ra$), can strongly impact the Final Investment Decision on a given project.
ANNEX #4 – De-rated margin calculation

We hereby present the data used to calculate de-rated margins for 2020 and 2030 under two different scenarios “Gone Green” and “No Progression” as presented by the National Grid’s Future Energy Scenarios.

<table>
<thead>
<tr>
<th>No Progression</th>
<th>Gone Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020 Capacity (GW)</td>
<td>2030 Capacity (GW)</td>
</tr>
<tr>
<td>Nuclear</td>
<td>9</td>
</tr>
<tr>
<td>Coal</td>
<td>10.4</td>
</tr>
<tr>
<td>Gas</td>
<td>30.9</td>
</tr>
<tr>
<td>CCS</td>
<td>0</td>
</tr>
<tr>
<td>CHP</td>
<td>4.6</td>
</tr>
<tr>
<td>Onshore Wind</td>
<td>11.3</td>
</tr>
<tr>
<td>Offshore Wind</td>
<td>8.1</td>
</tr>
<tr>
<td>Solar</td>
<td>8.6</td>
</tr>
<tr>
<td>Renewable Other</td>
<td>6</td>
</tr>
<tr>
<td>Conventional Other</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Interconnectors: 6 9.8 10.8 17.7

<table>
<thead>
<tr>
<th>Derating Factors</th>
<th>Nuclear</th>
<th>81%</th>
<th>Derating Factors</th>
<th>Interconnectors</th>
<th>France</th>
<th>44%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>88%</td>
<td></td>
<td>Gas</td>
<td>85%</td>
<td>Ireland</td>
<td>23%</td>
</tr>
<tr>
<td>CCS</td>
<td>85%</td>
<td></td>
<td>CHP</td>
<td>85%</td>
<td>Netherlands</td>
<td>70%</td>
</tr>
<tr>
<td>Onshore Wind</td>
<td>20.50%</td>
<td></td>
<td>Offshore Wind</td>
<td>20.50%</td>
<td>Belgium</td>
<td>55%</td>
</tr>
<tr>
<td>Solar</td>
<td>15%</td>
<td></td>
<td>Renewable Other</td>
<td>96%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional Other</td>
<td>87%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where the Capacity Margin is defined as follows:

\[
\text{Capacity Margin(\%)} = \frac{\text{Total available capacity} - \text{Peak Demand}}{\text{Peak Demand}} \times 100\%
\]

These are the de-rating factors used for the de-rated capacity margin calculation. In order to get de-rated capacities for each generation source it suffices to multiply the de-rating factor by the total available capacity.