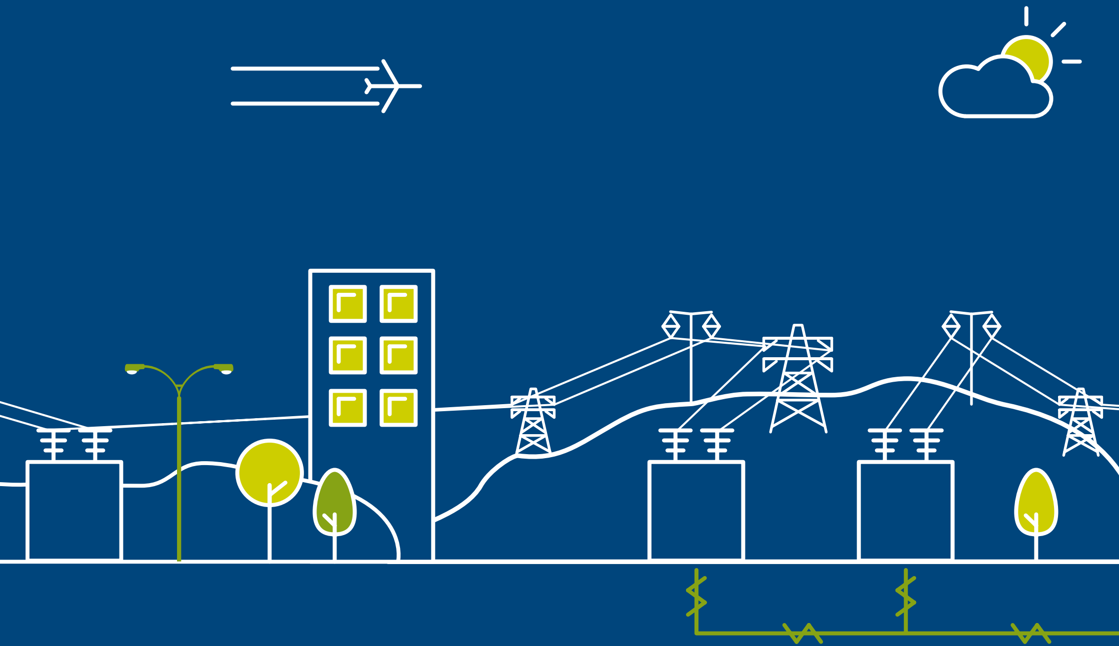
national**grid**

Network Options Assessment 2016/17

UK electricity transmission



JANUARY 2017

How to use this interactive document

To help you find the information you need quickly and easily we have published *NOA* as an interactive document.

Home

This will take you to the contents page. You can click on the titles to navigate to a section.

Arrows

Click on the arrows to move backwards or forwards a page.

A to Z

You will find a link to the glossary on each page.

Hyperlinks

Hyperlinks are highlighted in bold throughout the report. You can click on them to access further information.

We are in the midst of an energy revolution. The economic landscape, developments in technology and consumer behaviour are changing at an unprecedented rate, creating more opportunities than ever for our industry.

Our *Network Options Assessment (NOA)* publication, along with our other future energy System Operator publications, aims to encourage and inform debate, leading to changes that ensure a secure, sustainable and affordable energy future.

Your views, knowledge and insight have shaped the publication, helping us to better understand the future of energy. Thank you for this valuable input over the past year.

Now our 2016 analysis is complete, we have been able to look holistically at the results. They point to some important themes and messages.

As highlighted in our *Electricity Ten Year Statement (ETYS)* 2016 we continue to see increasing new low-carbon generation together with fossil fuelled plant closures and increasing interconnector activity putting additional stress on the network. Our role is to maintain an efficient and economic balance between investing in further infrastructure and constraining the use of the system when necessary – striking a balance between the risk of stranding assets from investing too early; and the potential high costs of constraints from investing too late. Getting this balance right will deliver the best value for consumers.

We will achieve this through our *Network Options Assessment (NOA)*. The *NOA* aims to make sure that the transmission system is continuously developed in a timely, economic and efficient way, providing value for our customers. The results from *ETYS* 2016 have fed into *NOA* 2016/17 to provide the required transmission capabilities.

To conduct the *NOA*, we asked each of the Transmission Owners in GB (SHE Transmission, SP Transmission and the TO business within National Grid) to identify investment options, timings and costs to improve the capability of a number of stressed system boundaries that we had identified during the *ETYS* process.

I hope that you find this document, along with our other System Operator publications, useful as a catalyst for wider debate. For more information about all our publications, please see page 7–8.

Please share your views with us; you can find details of how to contact us on our website **http://www.nationalgrid.com/noa**.

Richard Smith
Head of Network Capability (Electricity)

Contents

Executive summary

Using the 2016 *Future Energy Scenarios (FES)* and *ETYS 2016*, the System Operator (SO) recommends the options which the GB Transmission Owners should invest in for the upcoming year. Below, we present a summary of the key points from our economic analysis.

Key points

- The SO recommends investment of £83m in 2017/18 across fourteen projects to maintain the option to deliver projects worth almost £3.8bn. This year's investment will allow us to manage the capability of the GB transmission networks against the uncertainty of the future. This will make sure that the networks can continue supporting the transition to the future energy landscape in an efficient, economical and coordinated way.
- As the energy landscape is uncertain, the SO must make certain that all investment is truly necessary. We performed analysis of over 80 different investment options proposed by the GB Transmission Owners. We identified 32 options where no decision was yet required, allowing the SO to delay the recommendation to a later investment year. This ensures that we never make an investment recommendation for an option earlier than necessary. Where the decision cannot be delayed any further, our economic analysis assesses the cost impact of not investing in this financial year. As a result of this analysis, the SO recommends to delay spend of over £2.5m on three options for this investment year. The table below is an overview of the *NOA* 2016/17 investment recommendations where the decision must be made this year.
- Our Interconnection analysis has demonstrated that the planned first window Cap and Floor interconnection will be beneficial for GB consumers under all *FES* energy scenarios and will provide benefit to GB and European markets. The SO's analysis suggests a total interconnection capacity between 14.8 to 17.3GW between GB and European markets by 2030 would provide optimal benefit.

£83m
Investing £83 million

14
Through 14 options

17.3GW
Up to 17.3GW interconnection

Executive summary

Option	EISD	Optimal Delivery Date						Last Year's Recommendation	2016/17 Recommendation	Reasons for Change
		Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted			
BBNO[1] New Beauly to Blackhillock 400kV double circuit	2025	N/A	N/A	N/A	N/A	N/A	N/A	**Delay**	**Do not Proceed**	Not optimal at this time
LDQB Lister Drive quad booster	2020	2020	2020	2020	2021	N/A	N/A	No Decision Required	**Proceed**	Reinforcement is required due to heavy constraint build up in early years on B7a
WHTI[2] Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit	2020	2020	2020	2020	2020	N/A	N/A	Proceed	**Proceed**	No Change
LNRE Reconductor Lackenby to Norton single 400kV circuit	2022	2022	2022	N/A	N/A	N/A	N/A	No Decision Required	**Delay**	Regret analysis gave a recommendation to delay this year
MRUP Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV	2023	2023	2023	2023	2026	N/A	N/A	N/A	**Proceed**	Generation background change has made this reinforcement viable
OENO Central Yorkshire reinforcement	2024	2024	2025	2024	2024	N/A	N/A	N/A	**Proceed**	This reinforcement is new for *NOA* 2016/17 as a 4GW net reduction of power on the west of the country in some scenarios changes the power flow balance between east and west
E4DC Eastern subsea HVDC Link from Peterhead to Hawthorn Pit	2024	2024	2024	2024	2026	N/A	N/A	Proceed	**Proceed**	No Change
E2DC Eastern subsea HVDC Link from Torness to Hawthorn Pit	2024	2024	N/A	N/A	N/A	N/A	N/A	No decision required	**Proceed**	Coordination between reinforcements in the North make this reinforcement viable

[1] The new Beauly to Blackhillock 400kV double circuit (BBNO) was critical in *NOA* 2015/16 but recommended to delay. For *NOA* 2016/17, BBNO is now considered not optimal and therefore we recommend 'Do Not Proceed' at this time.

[2] WHTI is a modified version of ELEU which was presented in last year's *NOA*.

Option	EISD	Optimal Delivery Date: Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted	Last Year's Recommendation	2016/17 Recommendation	Reasons for Change
NOR1 Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit	2022	2025	2023	2022	2026	N/A	N/A	No Decision Required	**Proceed**	Reinforcement has become critical this year
TLNO Torness to North East England AC reinforcement	2028	N/A	N/A	2028	N/A	N/A	N/A	N/A	**Proceed**	Low cost reduces the regret of proceeding
WEOS Western HVDC Link fast de-load scheme	2019	2023	2025	2025	2024	N/A	N/A	Proceed	**Delay**	Driven by changing generation patterns in north west England
BMMS 225MVAr MSCs at Burwell Main	2023	2024	2028	2026	2023	2023	N/A	No Decision Required	**Proceed**	Reinforcement has become critical this year
SCRC South East coast reactive compensation	2018	2018	2018	2018	2018	2018	2018	Proceed	**Proceed**	No Change
FLRE Fleet to Lovedean reconductoring	2020	2020	2020	2020	2020	2020	2020	Proceed	**Proceed**	No Change
KLRE Kemsley to Littlebrook circuits uprating	2021	2021	2021	2021	2021	2021	2021	Proceed	**Proceed**	No Change
SEEU Reactive compensation protective switching scheme	2021	2021	2021	2021	2021	2021	2021	N/A	**Proceed**	Reinforcement is required due to the large number of interconnectors connecting in the region
WYTI Wymondley turn-in	2020	2029	2024	2030	2020	2029	2029	Delay	**Delay**	
HSNO Hinkley Point to Seabank new double circuit	2023	2026	2027	2031	2034	2024	N/A	Proceed	**Proceed**	No Change. We recommend proceeding with the SWW project based on the contracted connection date
WPNO Wylfa to Pentir second double circuit	2024	2030	2030	2029	N/A	2025	N/A	Delay	**Proceed**[3]	Proceed because of customer agreement

[3] Work on the Wylfa to Pentir second double circuit has already started, and should continue due to a local customer agreement in place.

Executive summary

It is important to recognise that these recommendations represent the best view at a snap-shot in time. Investment decisions taken by any business should always consider these recommendations in the light of subsequent events and developments in the energy sector.

The project options we have recommended in this *NOA* 2016/17 will make sure that the GB transmission network can continue supporting the transition to the future energy landscape in an efficient, economical and coordinated way.

This year NOA recommends the options that meet the Ofgem criteria for onshore competition. These can be found in Chapter 5 section 5.

We welcome your views

Our customers and stakeholders have contributed to the production of this *NOA* publication from the very beginning, by being involved in Ofgem's Integrated Transmission Planning and Regulation project and shaping our Future Energy Scenarios.

We want to evolve this process and report, year on year, to better serve your interests. So we'd welcome your views on the content and scope of this year's document and would like to know what changes you'd like us to make to future versions. There are five ways to tell us what you think:

- Customer seminars.
- Operational forums.
- Email us at **transmission.etys@nationalgrid.com**
- Feedback via survey at **https://www.surveymonkey.com/r/2016-17NOA**
- Bilateral stakeholder meetings.

The Stakeholder Engagement chapter sets out further information on our 2016 *ETYS* and *NOA* stakeholder activities programme. Your continuing support and feedback on our Future of Energy processes and documents are important to us. Please get in touch.

Continuing the conversation

Future energy publications
National Grid has an important role to play in leading the energy debate across our industry and working with you to make sure that together we secure our shared energy future. As System Operator (SO), we are perfectly placed as an enabler, informer and facilitator. The SO publications that we produce every year are intended to be a catalyst for debate, decision making and change.

The starting point for our flagship publications is the *Future Energy Scenarios (FES)*. The *FES* is published every year and involves input from stakeholders from across the energy industry.

These scenarios are based on the energy trilemma (security of supply, sustainability and affordability) and provide supply and demand projections out to 2050. We use these scenarios to inform the energy industry about network analysis and the investment being planned, which will benefit our customers.

For short-term challenges around gas and electricity transmission, we produce the *Summer* and *Winter Outlook Reports* every six months. We publish them ahead of each season to provide a view of gas and electricity supply and demand for the coming summer or winter. These publications are designed to support and inform your business planning activities and are complemented by summer and winter consultations and reports.

We build our long-term view of the gas and electricity transmission capability and operability in our *Future Energy Scenarios (FES)*, *Ten Year Statements (ETYS* and *GTYS)*, *Network Options Assessment (NOA)*, gas *Future Operability Planning (FOP)* and electricity *System Operability Framework (SOF)* publications. To help shape these publications, we seek your views and share information across the energy industry that can inform debate.

The *Gas Ten Year Statement (GTYS)* describes in detail what and where entry and exit capacity is available on the gas National Transmission System (NTS). The *GTYS* provides an update on projects we are currently working on. It also provides our view of the capability requirements and network development decisions that will be required for the NTS over the next ten years. If you are interested in finding out more about the longer-term view of gas capability and operability, please consider reading our *Future Energy Scenarios (FES)*, and gas *Future Operability Planning (FOP)* publications.

The *Electricity Ten Year Statement (ETYS)* applies Future Energy Scenarios to network models and highlights the capacity shortfalls on the GB National Electricity Transmission System (NETS) over the next ten years. You can find out more about the longer-term view of electricity capability and operability by reading our *Future Energy Scenarios (FES)* and *System Operability Framework (SOF)* publications.

Executive summary

Our gas *Future Operability Planning (FOP)* publication describes how changing requirements affect the future capability of the NTS beyond 2050. It also considers how these requirements may affect NTS operation and our processes. The *FOP* may highlight a need to change the way we respond to you or other market signals. This, in turn, may lead us to modify our operational processes and decision making. This publication helps to make sure we continue to maintain a resilient, safe and secure NTS now and into the future. If you are interested in finding out more about the longer-term view of gas capability and operability, please consider reading our *Future Energy Scenarios (FES)* and *Gas Ten Year Statement (GTYS)*.

The *System Operability Framework (SOF)* uses the *Future Energy Scenarios* to examine future requirements for the operability of GB electricity networks. It describes developments in operational needs and provides information that can help towards developing new technology, codes and solutions that improve system operability. If you are interested in finding out more about the longer term view of electricity capability and operability, please consider reading our *Future Energy Scenarios (FES)*, *Electricity Ten Year Statements (ETYS)* and *Network Options Assessment (NOA)* publications.

Chapter one

Aim of the report

1.1 Introduction

This chapter introduces the *NOA* and explains how it works with the publications that National Grid produces as the System Operator (SO).

The *Network Options Assessment (NOA)* 2016/17 is the second to be published. It's produced for you, our stakeholders, and we'll use what you tell us to develop it further.

The *NOA* is the driver for developing an efficient, coordinated and economic system of electricity transmission, consistent with the national electricity transmission system security and quality of supply standard. **Its purpose is to make recommendations to the Transmission Owners (TOs) across Great Britain as to which projects to proceed with to meet the future network requirements as defined in the *Electricity Ten Year Statement (ETYS)*. A key aim is also to recommend to Ofgem which of the projects might be suitable for competition.**

This report is one of the publications underpinned by our *Future Energy Scenarios (FES)*. This means that the *NOA* and the *ETYS* have a consistent base for assessing the potential development of both the gas and electricity transmission networks. When read together, the *ETYS* and *NOA* give the full picture of requirements and potential options for the National Electricity Transmission System (NETS).

The *NOA* 2016/17 was published in January 2017 and is based on *FES* 2016.

1.2
How the *NOA* fits in with the *FES* and *ETYS*

The SO produces a suite of publications on the future of energy for Great Britain (see page 7–8). These aim to inform the whole energy debate through addressing specific issues in each document. The *FES*, *ETYS* and *NOA* can be read together to form an evolutionary and consistent voice in the development of GB's electricity network.

Future Energy Scenarios
July 2016

Electricity Ten Year Statement
November 2016

Network Options Assessment
January 2017

We use the *FES* to assess the network requirements for power flows across the GB NETS. These requirements were published in the *ETYS* in November 2016 and the TOs responded with options for reinforcing the network. Our economic analysis of these options then forms the foundation for the *NOA* publication. Further explanation of this process and each of the publications can be found in Chapter 2 – Methodology.

In the *NOA*, we summarise each reinforcement option and our cost–benefit analysis of those options. The report also identifies our recommended option or options for each region of the GB network, based on the cost–benefit analysis. For some options, we have included a summary of the Strategic Wider Works (SWW) analysis in this document.

It's important to note that while we recommend options to meet system needs, the TOs or other relevant parties will ultimately decide on what, where and when to invest.

Some of the alternative options we have evaluated are reduced build options as explained in Chapter 2 – Methodology. The *NOA* emphasises reinforcing the network and we are keen to embrace innovative ways to do so.

Aim of the report

1.3 What *NOA* can do

- *NOA* can recommend how, where and when the TOs should invest in their transmission networks to manage risk in an uncertain world.
- *NOA* can recommend whether TOs should delay or continue current projects to make sure they are completed at a time that will deliver the most benefit.
- *NOA* can indicate the optimum level of interconnection to other European electricity grids in order to maximise socio-economic welfare based on market-driven analysis.
- *NOA* can indicate to TOs whether they should begin developing the needs case for SWW options.
- *NOA* can indicate to Ofgem whether options are eligible for onshore competition.

1.4
What *NOA* cannot do

- *NOA* cannot insist that options be pursued. We can only recommend based upon our analysis. The TOs are ultimately responsible for how, when and where they invest in their networks.
- *NOA* cannot comment on options' specific details, such as how they are planned or delivered. It is the TOs who decide how they implement their options.
- *NOA* cannot evaluate options' specific designs such as the choice of equipment, route or environmental impacts. These types of decisions can only be made by the TOs when the options are in a more advanced stage.
- *NOA* cannot assess network maintenance projects or individual customer connections.
- *NOA* cannot list all of the options that the TOs develop as some reach only a low level of maturity and are discarded early. It is for the TOs to develop options and consult with stakeholders on variations on options.
- *NOA* cannot evaluate the network and technical challenges of possible interconnectors. It can only evaluate the socio-economic welfare a completed interconnector would provide.
- *NOA* cannot forecast or recommend future interconnection levels. It indicates the optimum level of interconnection.

Aim of the report

1.5
The *NOA* Report methodology

The *NOA* Report methodology sets out how the *NOA* process should work and establishes the finer detail. We started the *NOA* Report methodology in early 2016, working with the onshore TOs and Ofgem. The initial draft of the methodology for *NOA* 2016/17 was published on our website in May 2016 and, after more discussions and refinement, the methodology was published in July 2016.

We describe the methodology further in Chapter 2 – Methodology.

1.6
Navigating through the document

We have structured the *NOA* document in a logical manner to help you understand how we reach our recommendations and conclusions.

Chapter **two**

Methodology page 19
Chapter 2 describes the *NOA* process and the economic theory behind it. This is a good overview if you are unfamiliar with *NOA* or if you'd like to understand more about how we perform the cost–benefit analysis of options.

Chapter **three**

Boundary descriptions page 35
Chapter 3 describes how we divide the GB network into boundaries for analysis and gives a description of each boundary as well as an overview of the types of generation you can find within each boundary. This is a good introduction if you'd like to improve your understanding of the GB network.

Chapter **four**

Proposed options page 65
Chapter 4 introduces and describes the reinforcement options which can increase the National Electricity Transmission Systems' (NETS's) capability. This is a good description of the types of options being proposed by the TOs.[1]

Chapter **five**

Investment recommendations page 83
Chapter 5 presents our investment recommendations for 2017/18. This is an important chapter if you are interested in whether we recommend options to be proceeded for this investment year.

Chapter **six**

Interconnection analysis page 103
Chapter 6 presents our interconnection analysis results. We describe the optimum levels of European interconnection between GB and European markets and explain the economic theory behind interconnector benefit to the consumer. This is an important chapter if you are interested in the future of European interconnection.

Chapter seven

Stakeholder engagement page 117
Chapter 7 discusses how we can work with you to improve the *NOA* in future publications. This is a useful chapter if you'd like to see how you can give us your feedback and opinion.

[1] Some options are not in our *NOA* process analysis but are described in Chapter 4 – Proposed Options. Chapter 2 – Methodology covers why these other options are kept separate from our analysis.

Aim of the report

1.7 What's new?

Acting on stakeholder feedback, we continue to evolve and improve the *NOA* together. The following areas are new additions for the *NOA* 2016/17:

1.7.1 Interconnection analysis

This year we have included our interconnection assessment as part of the *NOA*. This was previously a separate report titled '*NOA* for Interconnectors' but now forms Chapter 6 – Interconnection analysis. This chapter will evaluate the future optimum interconnection capacity between GB and European markets for each of our four scenarios, and the ideal timing of any capacity increase. This facilitates the development of interconnector capacity as part of an efficient, coordinated and economical system of electricity transmission.

1.7.2 Detailed explanation of our economic analysis

In order to make our analysis and results even clearer, Chapter 2 – Methodology now has a clearer description of our wider works cost–benefit analysis and how we assess the value delivered by proposed reinforcements from an economic perspective.

1.7.3 Onshore competition

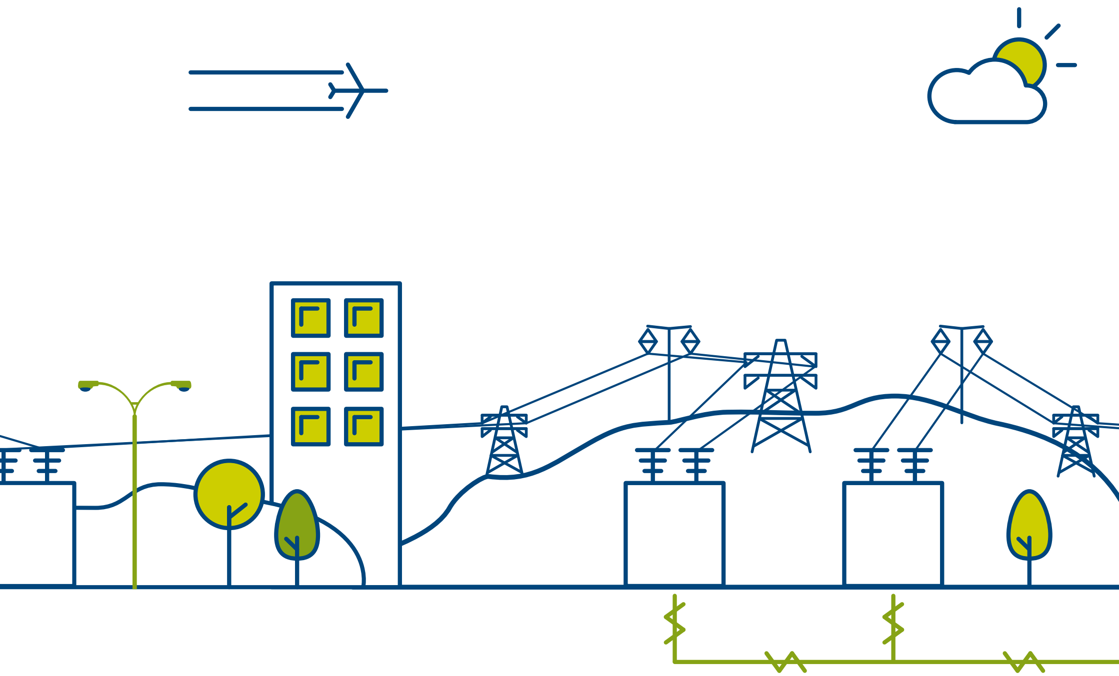
Chapter 5 – Investment recommendations lists the options we recommend to proceed this year. In addition, we will also evaluate these options against the competition criteria provided by Ofgem. This means that some options may go through a competitive tender process to decide which party will deliver the project.

We always want to hear suggestions on how we can continue improving the *NOA* so don't hesitate to let us know how we can further develop it to meet your needs.

1.8 Stakeholder engagement and feedback

Feedback isn't limited to the questions we've included in this publication and we'd be delighted to hear from you by any appropriate means. We are also keen to know how you'd prefer to share your views and help us develop the *NOA*. Please see Chapter 7 – Stakeholder engagement for more information.

To help encourage your feedback, you will see that we've included prompts such as this for engagement throughout the publication and these highlight areas in each section where we'd like your views.



Chapter two

Methodology

2.1 Introduction

This chapter highlights the methodology used for the *NOA* and explains the economic theory behind our analysis. It also explains how *NOA* ties in with the SWW process.

2.2
NOA process

The *NOA* methodology describes how we assess Major National Electricity Transmission System (NETS) reinforcement options to meet the requirements that the SO finds from its analysis of the *FES*. We have published this year's methodology on our website. It also includes the methodologies for interconnectors and SWW. As the NOA is derived from the Network Development Policy (NDP), the two methodologies are similar. You can find a copy of our original NDP methodology alongside the *NOA* methodology on our website below:

www2.nationalgrid.com
> UK Sites > Industry Information (more information) > Future of Energy > Network Options Assessment

www2.nationalgrid.com
/WorkArea/DownloadAsset.aspx?id=8589936185

www2.nationalgrid.com
/WorkArea/DownloadAsset.aspx?id=34153

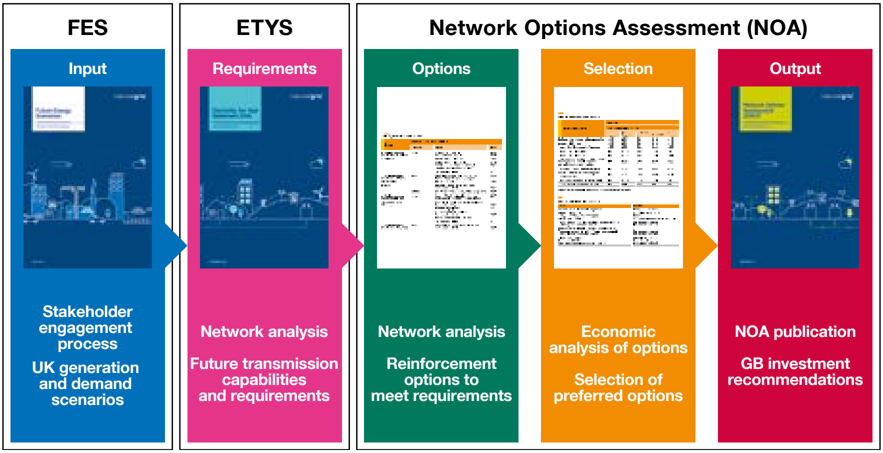
> In accordance with our licence condition, Major National Electricity Transmission System reinforcements are defined in Paragraph 21 of the *NOA* methodology. We define them as:
> "a project or projects in development to deliver additional boundary capacity or alternative system benefits, as identified in the *Electricity Ten Year Statement* or equivalent document."

Some users' connection agreements have major reinforcements as their enabling works. This means that the *NOA* may recommend a change to the delivery of these works. If this happens, we will work with those stakeholders and keep them informed.

Figure 2.1 shows the steps we take to produce the *NOA*. It follows the five stages of the *NOA* Report process.

Methodology

Figure 2.1
NOA process



2.2.1
Future Energy Scenarios

The *NOA* process for the NETS planning starts with the *FES*. They are a plausible range of future background conditions to assess against and form the foundation for our studies and economic analysis. The four scenarios are:

- **Gone Green.**
- **Slow Progression.**
- **No Progression.**
- **Consumer Power.**

For more information on our *FES* and how they are created, please see the *FES* 2016, which you can find at:

nationalgrid.com

fes.nationalgrid.com
> *FES* document.

2.2.2
Electricity Ten Year Statement

The *ETYS* is the second stage in the *NOA* process. We apply the *FES* to transmission system models and calculate the power flow requirements across the transmission network. To do this we have developed the concept of boundaries. Boundaries don't exist physically but are instead a conceptual split of the network into two adjacent parts. As power transfers between these areas, we can see which parts of the network are under the most stress and where network reinforcement would be most suitable. The capability of the network and its future requirements are published in *ETYS* 2016, which you can find at:

nationalgrid.com

www.nationalgrid.com/etys

2.2.3
Network Options Assessment

In order to create an electricity transmission network fit for the future, TOs propose options to meet the reinforcement needs outlined by *ETYS*. We encourage a range of options that include upgrading existing assets or creating new assets in order to ensure that we have a strong selection of options from which to assess.

As well as these build options, both the TOs and SO can propose opportunities for reduced build options. Reduced build options are solutions that require very little build and instead maximise use of existing assets often in innovative ways. You can find a full list of the options that we analysed in Chapter 4 – Proposed options.

With this varied list of options, we move onto the fourth stage of the *NOA* process 'Selection'. We use our understanding of constraint costs to carry out a cost–benefit analysis of all the options. This narrows the list of proposed options into a list of our preferred options, which we believe are the best ones at the time that provide the most benefit for GB consumers. You can find the full list of our recommended options in Chapter 5 – Investment recommendations. How we perform the cost–benefit analysis is described in greater detail in the following section.

Methodology

2.3
Economic analysis

2.3.1
Theory

To understand our investment recommendations, we must first understand why we recommend the TOs to invest in their networks.

The transfer of energy across our network boundaries occurs because generation and demand are typically situated in different locations. When the power required across a transmission system boundary is above that boundary's capability, the SO's control room must reduce the power transfer to avoid dangerously overloading the transmission assets. This limiting of power transfer is referred to as 'constraining' the network.

When we constrain the network, we ask generators within the affected area to limit their output. In order to maintain an energy balance, we replace this energy with generation in an unconstrained area of the network. Balancing the network by switching generation on and off costs money, and if we are constraining the network by large amounts regularly then these constraint costs begin to accumulate.

Assessment of these future constraint costs is an important factor in our decision-making process when we're assessing whether we should invest in the network, such as creating new overhead lines and underground cables. We refer to these potential investments as 'options' and although they cost money they also raise the capability of the network meaning that more power can be transferred without the need to constrain. The SO and TOs work together to upgrade the transmission networks at the right time in the right places in order to find the best balance between investing in the network and constraining it.

2.3.2
Optimum years

In order to maximise benefit to the consumer, we must recommend to the TOs to invest in the right options at the right time. However, it takes time for the TOs to upgrade the network with some options taking longer to implement than others. The earliest year that an option can be delivered is an important factor in our analysis. It's called the 'earliest in service date' (EISD) and an option cannot be delivered earlier than its EISD. We need to take this into account when we're considering the optimal timing of options. We don't want to unnecessarily invest too early, nor incur potentially high constraint costs by investing too late. Getting this balance right will achieve the best value for consumers. Consequently, each option has an optimum year of delivery that realises the most benefit, and we aim to time an option to be delivered in its optimum year.

If an option's optimum year of delivery is later than its EISD, then no decision on whether to proceed with the option needs to be made yet. However, if an option's optimum year is the same year as its EISD then the decision cannot be delayed any longer without risking the option missing its optimum year. Because the decision must be made this year, these options are considered 'critical'. These critical options are entered into our single year least regret analysis where we ultimately decide the investment recommendation for this year.

2.3.3
Single year least regret analysis

The uncertainty of the future means that the optimum year of delivery for an option will likely not be the same for each of the energy scenarios. Therefore we must understand the risk between recommending the TOs to proceed a critical option so it may be delivered on its EISD or delaying it so it may be delivered closer to its optimum year.

Table 2.1
Example of a critical option's optimum years of delivery

	EISD	Optimum Year of Delivery			
		Scenario A	Scenario B	Scenario C	Scenario D
Critical Option	2019	2019	2019	2020	2021

In the above example, the earliest year that the option can be delivered is 2019. The optimum year of delivery varies across the scenarios, but for Scenarios A and B it's also 2019 therefore this is a critical option. For those scenarios, the right recommendation would be for the TOs to proceed this option to maintain its EISD of 2019. However, for scenarios C and D the right recommendation would be to not proceed with this option and allow its EISD to slip back to 2020. To make a recommendation to the TOs, we must analyse the potential regret of making one recommendation and not the other.

As we are only interested in making investment recommendations for critical options, we utilise 'single year regret' analysis. As each critical option can either be recommended to 'proceed' or 'delay', there are a number of courses of action we could recommend. For example, two critical options in the same region would produce four different possible courses of action as demonstrated in Table 2.2.

Chapter two

Methodology

Table 2.2
Possible courses of action for two critical options in a region

Course of action 1	Proceed both Options A and B
Course of action 2	Proceed Option A but delay Option B
Course of action 3	Proceed Option B but delay Option A
Course of action 4	Delay both Options A and B

In order to balance the level of investment and exposure to risk, we utilise the concept of economic regret.

Single year least regret analysis allows us to recommend to the TOs to invest just the right amount so an option can be progressed forward by one year and maintain its EISD. As our energy landscape is changing, our recommendations for an option may adapt accordingly. This means that an option that we recommended to proceed last year may be recommended to be delayed this year and vice versa. The robustness of the single year least regret analysis is that an ongoing project is revaluated each year to ensure that its planned completion date remains best for the consumer.

2.3.4 Economic regret

All investment options will have a cost associated with their construction or implementation. Once the relevant project is complete, we will begin to see savings in constraint costs due to the additional capability it brings to the network. Therefore the benefit the option brings over its lifetime can be viewed as the difference between the cost of implementation and the consequent savings in constraint costs. The following description is closer to lifetime regret than single year however it explains the concept of regret. The table below demonstrates the costs and benefits of three example options.

Table 2.3
Example of the costs (investment and savings) each option provides

	Option 1	Option 2	Option 3
Initial investment cost	- £75m	- £90m	- £50m
Consequent reduction in constraint costs	£45m	£130m	£75m
Gross benefit	- £30m	+ £40m	+ £25m
Regret	£70m	£0m	£15m

In economic analysis, an option's 'regret' is defined as the difference in benefit for that option against the benefit of the best option. Therefore the best option will have a regret of zero, and the other options will have different levels of regret depending how they compare to the best option. In table 2.3, Option 2 is the best option, so there is no regret in choosing it. If we were to select Option 3 we would see a cost saving of £25 million which is almost as good, but we would regret the decision as we didn't select Option 2 which is £15 million better. Clearly, choosing the option with least regret makes economic sense.

However, as we face an uncertain future we must consider the regret of our investments across each of the four energy scenarios. The same option won't always deliver the same value across every scenario, so it will have more regret in some scenarios and less in others. As a result, the best option for one scenario might not be the best option for another scenario. Table 2.3's regret results were for just one scenario. We cannot predict the future, so we analyse an option's regret across all four credible scenarios and note the worst regret we could potentially incur by selecting that option.

Table 2.4
Example of least regret analysis with option 3 having the least regret

		Option 1	Option 2	Option 3
Regret	Scenario A	£70m	£0m	£15m
	Scenario B	£0m	£185m	£45m
	Scenario C	£20m	£100m	£0m
	Scenario D	£10m	£0m	£45m
Worst regret		£70m	£185m	£45m

The preferred option is selected based upon which option has the smallest worst regret. In the above example, each scenario has a best choice and a worst choice. Option 2 may be the best choice for Scenarios A and D, but would be a much poorer choice under either of the other two scenarios. Least regret analysis shows that Option 3 minimises regret across all four scenarios, as regret will be no more than £45 million. This approach provides a more stable and robust decision against the range of uncertainties, and minimises exposure to significant regret.

Methodology

2.3.5 Economic tools

We use a constraint costs assessment tool to analyse and establish the benefits to consumers of the different options. Historically, we've used the Electricity Scenario Illustrator (ELSI) to determine these costs. In March 2016 we purchased a new economic tool, BID3, from Pöyry Management Consulting. We began using it from 2016/17 for econometric analysis work. It forecasts the costs of constraints, which are an important factor in the full cost–benefit analysis of the *NOA*. We use this information to help us decide on the best course of action for the next year, taking into account all the future energy scenarios that we described in Chapter 2 of *ETYS* 2016.

To ensure a successful transition to BID3, the model has been extensively benchmarked against ELSI and two independent reviewers (Professor Keith Bell, University of Strathclyde and Dr Iain Staffell, Imperial College London) were appointed to review our work, BID3 configuration and benchmarking.

The future energy landscape is uncertain, so the information we use in our cost–benefit analysis changes over time – we revisit our data, assumptions and analysis results every year to make sure that the preferred strategy is still the best solution. So, when we respond to market or policy-driven changes, this approach allow us to be flexible in our investment decision-making, while also keeping the cost associated with this flexibility to the minimum.

Figure 2.2
BID3 tool inputs

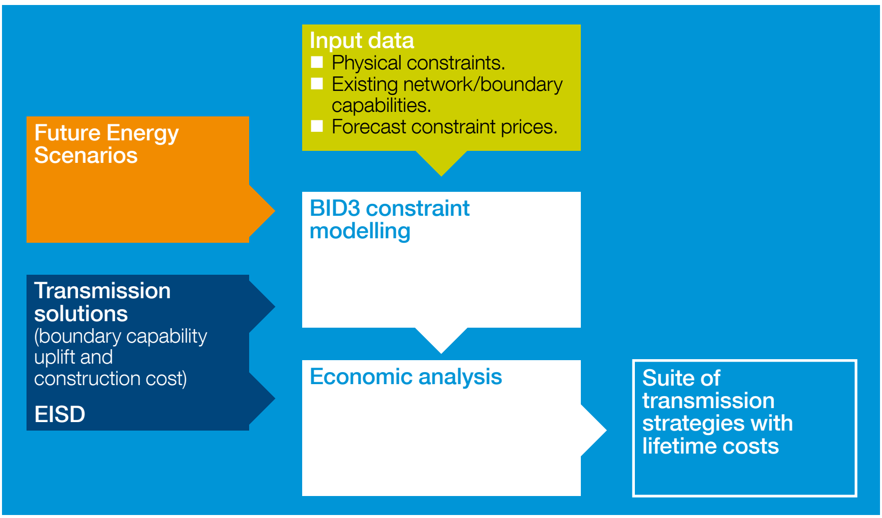


Figure 2.2 shows the various inputs to BID3. The inputs fall broadly into three categories:

Existing boundary capabilities and their future development – these were calculated using a separate power system analysis package. BID3 is the tool for calculating the market driven flow across the boundaries and takes capabilities as an input. The input to BID3 includes the increase in capability that the option provides, its capital cost and the EISD.

Future Energy Scenarios – BID3 assesses all options for network reinforcements against each of the detailed Future Energy Scenarios. The resulting analysis takes us up to 2036 (the values from 2037 are extrapolated from 2036 forecasts so we can estimate full lifetime costs).

Assumptions – BID3's other input data takes account of fuel cost forecasts, plant availabilities and prices in interconnected European member states.

If you want to know more about BID3, there are a number of resources available on our website. A copy of the independent reviewers' report is available, as well as our *Long Term Market and Network Constraint Modelling Report*, which provides further information on why we selected BID3, what we will use it for and more detail on the inputs to BID3. The reports are available at the main *NOA* webpage.

nationalgrid.com/noa

Methodology

2.4
How the *NOA* connects to the SWW process

We use the *NOA* process to look at the costs and benefits of potential options, and put forward our recommended options. If an option is recommended but it involves large infrastructure that satisfies one of the criteria shown below, then this option is referred to as SWW. SWW are led by the TOs, who develop the needs case for such an option. An option in England and Wales needs to meet at least one of the criteria below to be considered as SWW. All costs are in 2009/10 prices:

- The option has a forecast cost of more than £500 million.
- The option has a forecast cost of between £100 million and £500 million, is supported by only one customer, and is not required in most scenarios.
- The option has a forecast cost of less than £100 million, is supported by only one customer, and is not required in most scenarios, but would require consents.

An option in Scotland needs to meet all of the criteria shown below. Once again, all costs are in 2009/10 prices:

- The option has total delivery costs of more than £50 million for SHE Transmission and £100 million for SPT.
- The output will deliver additional cross-boundary (or sub-boundary) capability or wider system benefits.
- Costs cannot be recovered under any other provision of the TO's price control settlement.

It's important to note that the relevant TO leads on developing needs cases for SWW projects, but the SO supports the TO with the economic analysis. The TO initiates the needs case work for SWW projects depending on certain factors, including the forecast costs and whether they trigger the SWW funding formula. Another important factor is the time taken to deliver the option.

This, combined with the date at which the option is needed in service, determines when to start building. The closer this date is the sooner the TO needs to pursue the detailed analysis to justify the SWW's funding.

We have published our methodology for the SO process for input into TO-led SWW needs case submissions on our website. Below is a link to the methodology:

nationalgrid.com

www2.nationalgrid.com
> UK Sites > Industry Information (more information) > Future of Energy > Network Options Assessment

www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589936185

2.4.1
Summary of SWW economic analysis methodology

When an option is deemed to be SWW, cost–benefit analysis examines the economic benefit of a range of reinforcement options against the base network across their lifetimes. The base is usually ‘do nothing’ or ‘do minimum’ and has no associated capital costs. Constraint costs are forecast for the base and each network option across all scenarios.

We calculate the present value of constraint savings compared to the base for each network solution. These are then subtracted from the present value (PV) of capital expenditure associated with each network option, giving a net present value (NPV) for each of the network options. Taking these NPVs, we use lifetime least regret analysis to determine a preferred network option and an optimal delivery year. The results are analysed to determine how changing project capital costs and constraint savings would affect the conclusions.

The Joint Regulators Group on behalf of the UK’s economic and competition regulators recommend a discounting approach that discounts all costs (including financing costs as calculated based on a weighted average cost of capital or WACC) and benefits at HM Treasury’s social time preference rate (STPR). This is known as the Spackman approach and is used for all our reinforcements.

We may vary the process where modelling the base network is not straightforward. Such variations are assessed, case by case, with Ofgem.

Methodology

2.5
Interaction between *NOA* results and *FES*

In the *NOA*, the SO sets out its vision for the future of the electricity transmission networks and European interconnection. Chapter 5 – Investment recommendations explains the SO's recommended options for onshore reinforcements, based on providing the maximum benefit for GB consumers, and Chapter 6 – Interconnection analysis describes the future optimum interconnection capacity between GB and European markets. The analysis for these two chapters is done in parallel, so one set of results does not drive the other. It's important to do this so they can be derived from credible assumptions and are not dependent upon one another. Both sets of results will influence our 2017 *FES* analysis and will therefore contribute to the credible assumptions for 2017/18 *ETYS* and *NOA*. We've described the methodology for interconnection analysis in Chapter 6 – Interconnection analysis.

2.6
Other options

2.6.1
Excluded options

While this report looks at options that could help meet major NETS reinforcement needs, it doesn't include:

- projects with no boundary benefit (unless they are specifically included for another reason, such as links to the Scottish islands that trigger the SWW category)
- options that provide benefits, such as voltage control over the summer minimum, but no boundary capability improvement (this is an area where we would welcome your feedback)
- analysis of options where, by inspection, the costs for the expected benefits would be prohibitive
- options that are more than twenty years in the future, referred to as long-term conceptual options.

We will include a summary of results in the *NOA* for projects where the TO has started the SWW Needs Case process, even though they won't provide boundary capability.

The following projects to connect the Scottish islands are in this category:

- Western Isles.
- Shetland Isles.
- Orkney Isles.

The North West Coast Connection project is driven by a customer.

Methodology

2.6.2
Long-term conceptual options

Through the *NOA* process, the SO states its recommended options for the upcoming investment year, and optimum delivery dates for options over the next twenty years. This process provides a long-term strategy through which the TOs are able to constantly evolve and develop their electricity transmission networks to deliver the best value for consumers.

For this, the SO receives a wide range of options provided by the TOs for analysis and comparison, which the SO assesses for benefit and cost. Development of reinforcement in the network will be a continuous process that will continue long after these twenty years, although the designs and costs for such reinforcements so far in the future are unknown. In order to represent these long-term eventual reinforcements in our cost–benefit analysis, the TOs also provide the SO with more conceptualised reinforcements to support the long-term future network.

Chapter three

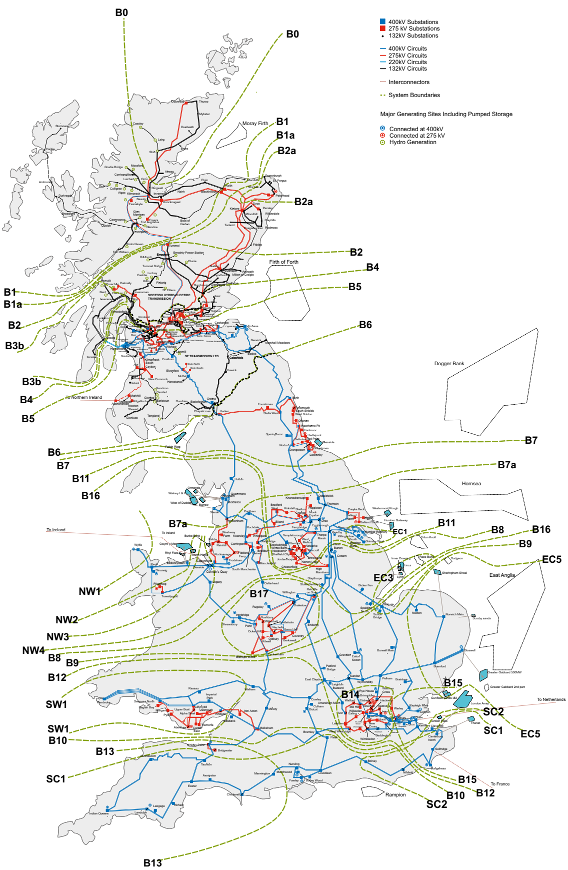
Chapter three

Boundary descriptions

3.1
Introduction

This section provides a short introduction to the boundaries on the NETS. You'll find a fuller description in this year's *ETYS*. Figure 3.1 shows all the boundaries we have considered for this year's analysis.

Figure 3.1
ETYS GB boundaries



3.2
North

3.2.1
Introduction

The following section describes the NETS in Scotland and Northern England. The onshore transmission network in Scotland is owned by SHE Transmission and SP Transmission but is operated by National Grid as SO.

The following boundary information, which relates to potential reinforcements that can improve boundary capability, has been provided by the two Scottish transmission owners and National Grid. In combination a reinforcement might affect other boundaries.

Table 3.1
Effective reinforcement options

Unique reference	Reinforcement title	Boundaries affected
DSNO	Dounreay to Orkney, Bay of Skaill subsea link	radial
GSNO	Gills Bay to Orkney, South Ronaldsay subsea link	radial
DHNO	Dounreay to Orkney, South Hoy subsea link	radial
D2NO	Dounreay to Orkney, Bay of Skaill and Dounreay to Orkney, South Hoy subsea link	radial
BLR1	Beauly to Shin to Loch Buidhe 132kV double circuit reconductoring	B0
FBRE	Beauly to Fyrish 275kV double circuit reconductoring and generation connection reconfiguration	B0
BLR2	Beauly to Loch Buidhe 275kV double circuit reconductoring and generation connection reconfiguration	B0
BDRE	Beauly to Loch Buidhe and Loch Buidhe to Dounreay 275kV double circuit reconductoring	B0
BLN2	New Beauly to Loch Buidhe 275kV double circuit	B0
TURC	Reactive compensation at Tummel	B1, B1a
TMRC	Reactive compensation at Tummel and Melgarve	B1, B1a
B1RC	Reactive compensation at Tummel and Melgarve and inter-bus Transformers at Fort Augustus	B1, B1a
BKNO	New Beauly to Kintore 400kV double circuit	B1, B1a
BBNO	New Beauly to Blackhillock 400kV double circuit	B1

Boundary descriptions

Unique reference	Reinforcement title	Boundaries affected
BLQB	New 275kV phase shifting transformers at Blackhillock on the circuits from Knocknagael	B1
NEEU	North east 400kV and 275kV network reinforcement	B2a
RKEU	Rothienorman substation with reconductoring of the 275kV Rothienorman to Kintore circuit	B2a
ECU2	East Coast onshore 275kV upgrade	B1, B1a, B2, B4, B5
ECUP	East Coast onshore 400kV incremental reinforcement	B1, B1a, B2, B4
ECU4	East Coast onshore 400kV reinforcement	B1, B1a, B2, B4, B5
WLTI	Windyhill to Lambhill to Longannet 275kV circuit turn in to Denny North 275kV substation	B5
DWNO	Denny to Wishaw 400kV reinforcement	B4, B5, B6
E2DC	Eastern subsea HVDC Link from Torness to Hawthorn Pit	B5, B6, B7, B7a, B8
TLNO	Torness to North East England AC reinforcement	B6, B7, B7a
E4DC	Eastern subsea HVDC Link from Peterhead to Hawthorn Pit	B1, B1a, B2, B2a, B4, B5, B6, B7, B7a
WHTI	Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit	B6, B7, B7a
WOSR	Deploy FACTS device on West Boldon to Offerton circuit	B6, B7
WBQB	Install quad booster in West Boldon to Offerton circuit	B6, B7
HAEU	Harker SuperGrid Transformer 6 replacement	B6
LNRE	Reconductor Lackenby to Norton single 400kV circuit	B7
NOR1	Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit	B6, B7, B7a
NOR2	Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit	B7
NOR3	Norton to Osbaldwick 400kV double circuit – reconductor full length of circuits	B6, B7, B7a
NOHW	Thermal uprate 55km of the Norton to Osbaldwick 400kV double circuit	B7
HPNO	New east–west circuit between the north east and Lancashire	B6, B7, B7a, B8

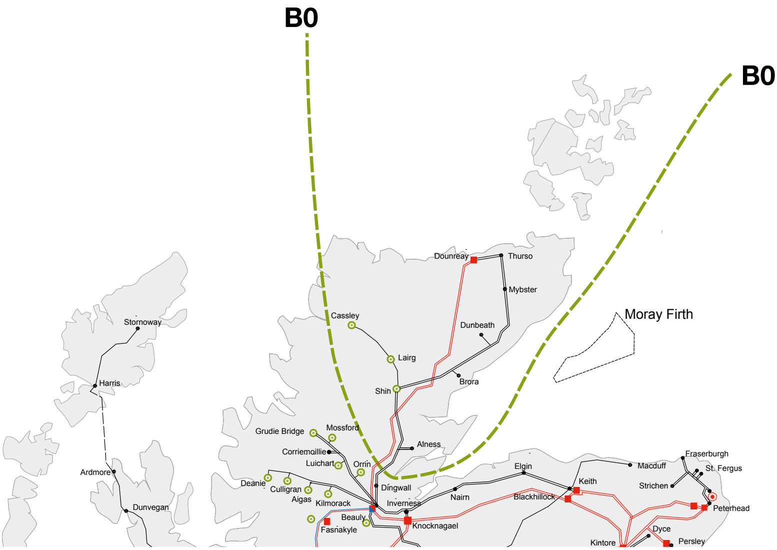
Unique reference	Reinforcement title	Boundaries affected
NPNO	New east–west circuit between the north east and Lancashire	B6, B7, B7a
LTR1	Lackenby to Thornton double circuit – uprate cable and thermal uprate overhead line sections	B7
LTR2	Lackenby to Thornton double circuit – uprate cable section and reconductor sections	B6, B7
OTHW	Osbaldwick to Thornton 1 circuit thermal upgrade	B6
LDQB	Lister Drive quad booster	B7a
MRUP	Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV	B7a
OENO	Central Yorkshire reinforcement	B6, B7, B7a, B8
THS1	Install series reactors at Thornton	B6, B7, B7a, B8 and B9
THS2	Install series reactors at Thornton	B6, B7, B7a, B8 and B9
TDRE	Reconductor Drax to Thornton double circuit	B6, B7, B7a, B8
GKRE	Reconductor Garforth Tee to Keadby leg of the Creyke Beck to Keadby to Killingholme Circuit	B7, B7a, B8
DERE	Drax to Eggborough 1 circuit – reconductor and replace cable section	B6, B7a
DREU	Generator circuit breaker replacement to allow Thornton to run two-way split	B7, B8, B9
WHRE	West Burton to High Marnham circuit – complete gantry works to match circuit rating	B8
KCRE	Reconductor the Keadby to Cottam 400kV circuits	B7a, B8
WEOS	Western HVDC Link fast de-load scheme	B8
TCRE	Treuddyn Tee to Connah's Quay reconductoring	B8
TLH1	Treuddyn Tee to Legacy thermal upgrade	B8

Note that the unique reference code applies only to this year's document.

Boundary descriptions

3.2.2
Boundary B0 – Upper North SHE Transmission

Figure B0.1
Geographic representation of boundary B0

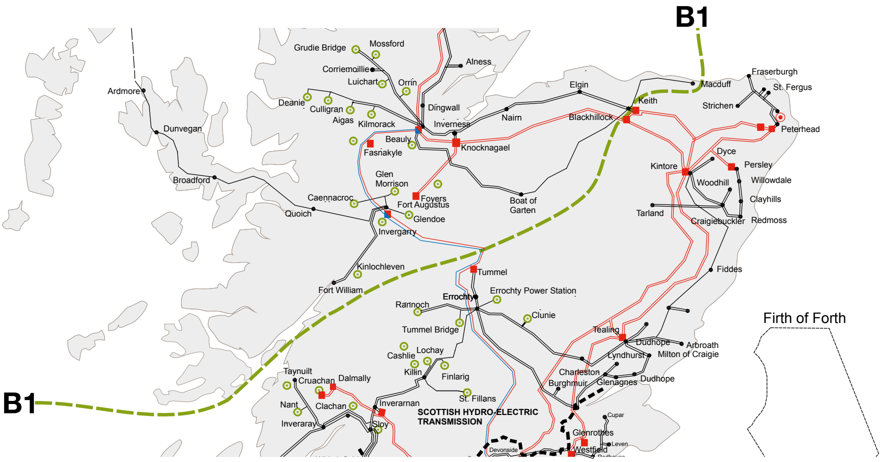


Boundary B0 separates the area north of Beauly, comprising north Highland, Caithness, Sutherland and Orkney. The existing transmission infrastructure north of Beauly is relatively sparse.

The boundary cuts across the existing 275kV double circuit and 132kV double circuit overhead lines extending north from Beauly. The 275kV overhead line takes a direct route north from Beauly to Dounreay, while the 132kV overhead line takes a longer route along the east coast and serves the local grid supply points at Alness, Shin, Brora, Dunbeath, Mybster and Thurso. Orkney is connected via a 33kV subsea link from Thurso. High renewables output causes high transfers across the B0 boundary.

3.2.3
Boundary B1 – North West SHE Transmission

Figure B1.1
Geographic representation of boundary B1



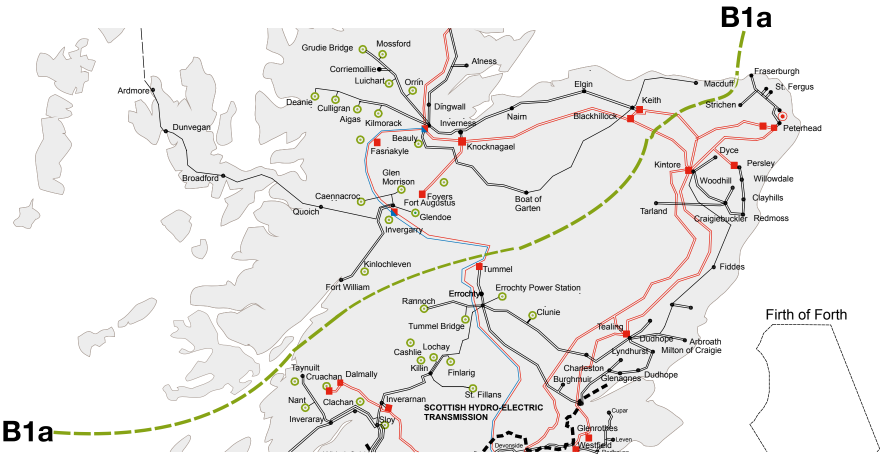
Boundary B1 runs from the Moray coast near Macduff to the west coast near Oban, separating the North West of Scotland from the southern and eastern regions. The boundary crosses the 275kV double circuit running eastwards from Knocknagael to Blackhillock, the 275/132kV interface at Keith and the 275/400kV double circuit running south from Fort Augustus. High renewables output causes high transfers across this boundary.

Boundary descriptions

Chapter three

3.2.4
Boundary B1a – North West 1a SHE Transmission

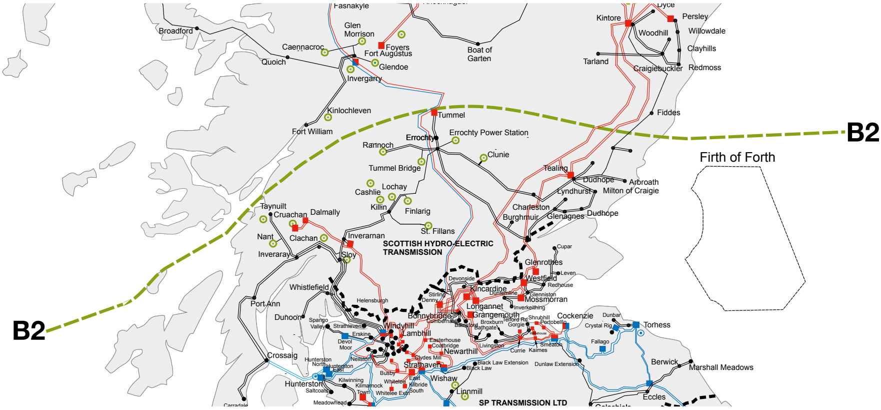
Figure B1a.1
Geographic representation of boundary B1a



Boundary B1a runs from the Moray coast near Macduff to the west coast near Oban, separating the North West of Scotland from the southern and eastern regions. The boundary crosses the 275kV double circuit running eastwards from Blackhillock to Kintore on a direct route and another 275kV double circuit running eastwards from Keith to Peterhead and Kintore and the 275/400kV double circuit running south from Fort Augustus. High renewables output causes high transfers across this boundary. Boundary B1a was introduced in *ETYS* 2016, published in November 2016, specifically to consider the critical circuits between Blackhillock and Kintore. Additional generation between boundaries B1 and B1a drive the requirement for transmission reinforcement across B1a.

3.2.5
Boundary B2 – North to South SHE Transmission

Figure B2.1
Geographic representation of boundary B2

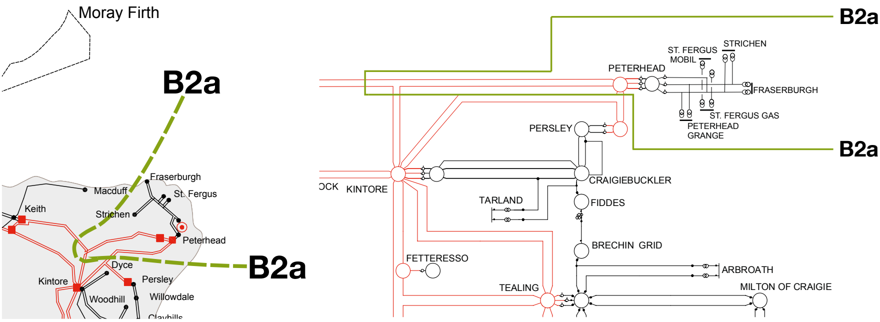


Boundary B2 cuts across the Scottish mainland from the east coast between Aberdeen and Dundee to near Oban on the west coast. The boundary cuts across the two 275kV double circuits and a 132kV single circuit in the east as well as the 275/400kV double circuit overhead line running south from Fort Augustus. As a result it crosses all the main north–south transmission routes from the North of Scotland. High renewables output causes high transfers across this boundary.

Boundary descriptions

3.2.6
Boundary B2a – Peterhead

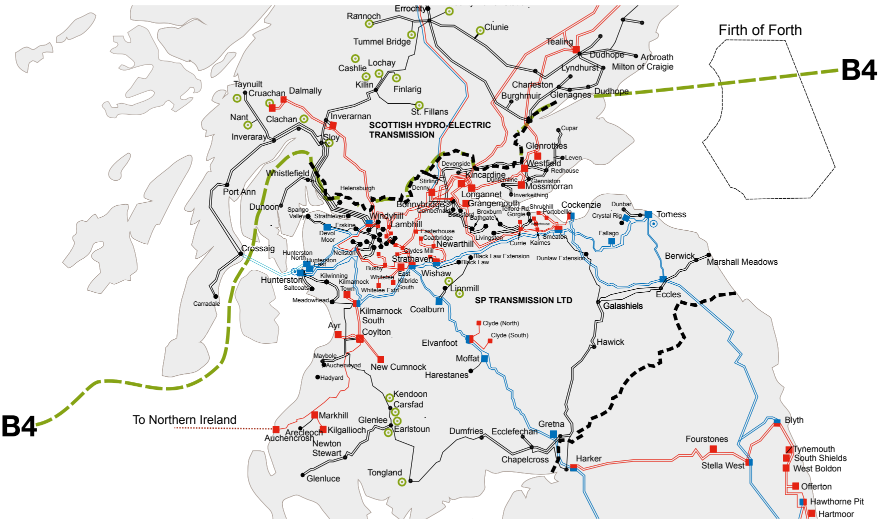
Figure B2a.1
Geographic and single-line representation of boundary B2a



Boundary B2a is a local boundary enclosing Peterhead, New Deer and Rothienorman where the overhead lines from Keith, Peterhead and Kintore converge. The boundary cuts across the 275kV double circuit overhead lines from Peterhead to Kintore via Persley, Kintore towards Rothienorman and Blackhillock towards Rothienorman. Peterhead power station is connected in this area. In addition, future developments such as Moray Offshore windfarm and the North Connect Interconnector are contracted to connect in this area. There is limited capacity on the existing 275kV circuits to accommodate this and other generation connected to the 132kV network in this area.

3.2.7
Boundary B4 – SHE Transmission to SP Transmission

Figure B4.1
Geographic representation of boundary B4



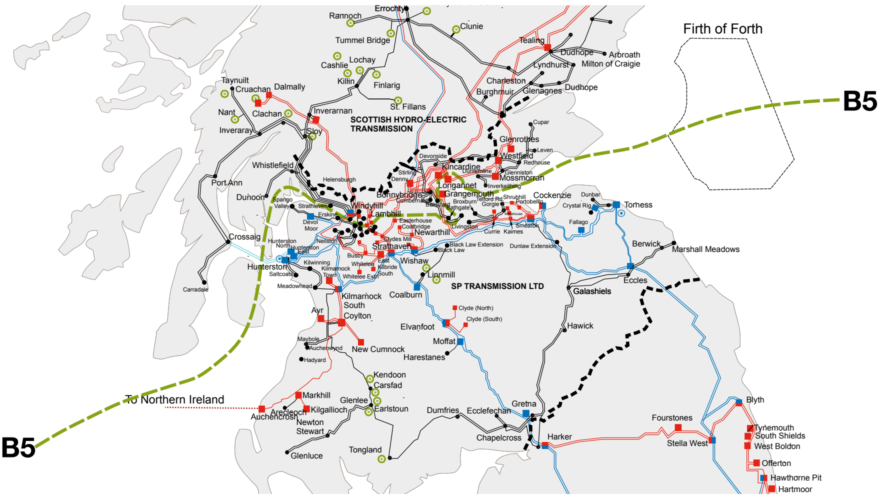
Boundary B4 separates the transmission network at the SP Transmission and SHE Transmission interface running from the Firth of Tay in the east to near the head of Loch Long in the west. The boundary is crossed by 275kV double circuits to Kincardine and Westfield in the east and two 132kV double circuits from Sloy to Windyhill in the west, as well as the 220kV cables from Crossaig to Hunterston, the 275/400kV double circuit overhead line into Denny North and the 275/132kV interface at Inverarnan. High renewables output causes high transfers across this boundary.

Chapter three

Boundary descriptions

3.2.8
Boundary B5 – North to South SP Transmission

Figure B5.1
Geographic representation of boundary B5

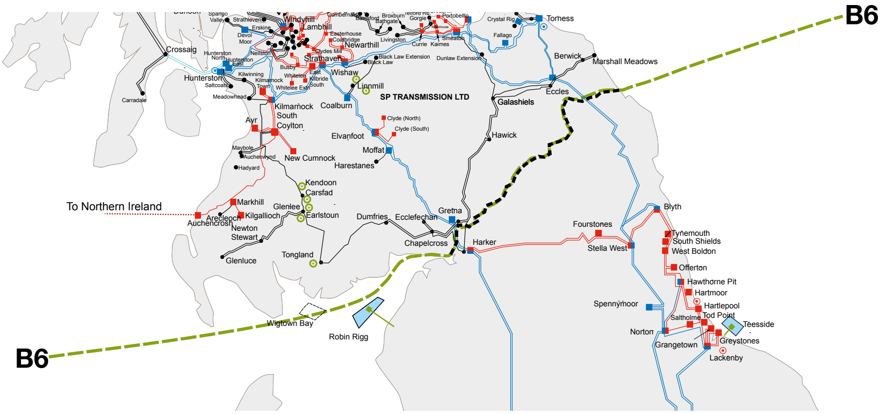


Boundary B5 is internal to the SP Transmission system and runs from the Firth of Clyde in the west to the Firth of Forth in the east. The pumped storage station at Cruachan, together with the demand groups served from Windyhill, Lambhill, Bonnybridge, Mossmorran and Westfield 275kV substations are located between B4 and B5.

The existing transmission network across the boundary comprises three 275kV double circuit routes: one from Windyhill 275kV substation in the west, and one from each of Kincardine and Longannet 275kV substations in the east. The 220kV cables between Crossaig and Hunterston also cross the boundary.

3.2.9
Boundary B6 – SP Transmission to NGET

Figure B6.1
Geographic representation of boundary B6

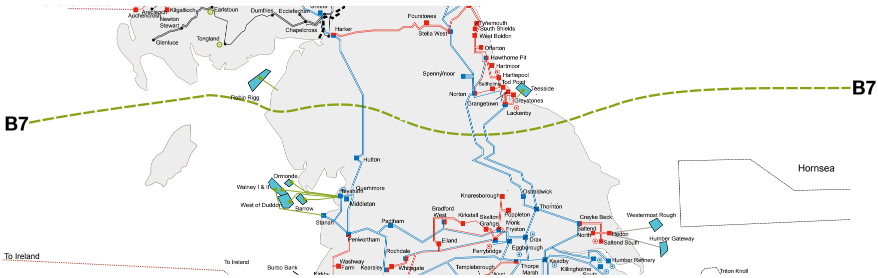


Boundary B6 separates the SP Transmission and the National Grid Electricity Transmission (NGET) systems. The existing transmission network across the boundary primarily consists of two double-circuit 400kV routes. There are also some limited capacity 132kV circuits across the boundary. The key 400kV routes are from Gretna to Harker and from Eccles to Blyth/Stella West. Scotland contains significantly more installed generation capacity than demand, increasingly from wind farms. Peak power flow requirements are typically from north to south at times of high renewable generation output while large south to north power flows can occur during periods of low renewable generation output.

Boundary descriptions

3.2.10
Boundary B7 – Upper North

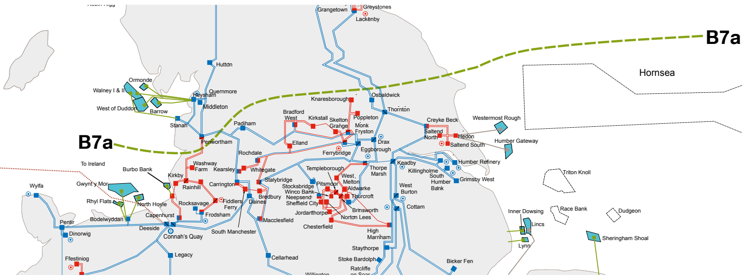
Figure B7.1
Geographic representation of boundary B7



Boundary B7 bisects England south of Teesside, cutting across Cumberland. It is characterised by three 400kV double circuits: two in the east and one in the west. Net generation output from between the B6 and B7 boundaries is small, so north to south exports across B7 tend to be driven by renewables output in Scotland.

3.2.11
Boundary B7a – Upper North

Figure B7a.1
Geographic representation of boundary B7a



Boundary B7a bisects England south of Teesside, across Lancashire and into the Mersey Ring area. It is characterised by three 400kV double circuits (two in the east, one in the west) and one 275kV circuit.

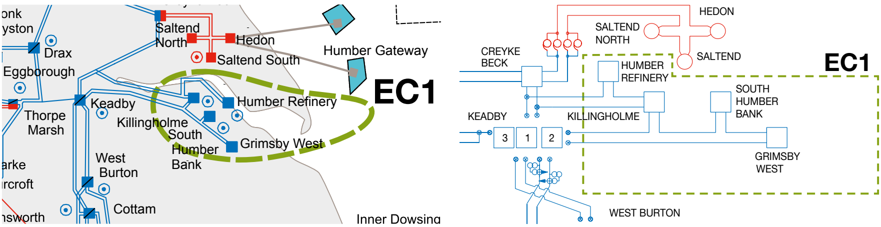
B7a is a modified version of B7 in which the west side is brought south to below Penwortham. This move puts the group of generation around Heysham north of the boundary and allows closer monitoring of the circuit heading south from Penwortham.

Chapter three

Boundary descriptions

3.2.12
Boundary EC1 – Humber

Figure EC1.1
Geographic and single-line representation of boundary EC1

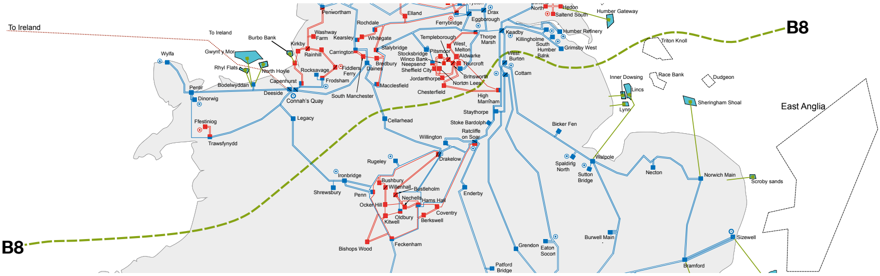


Boundary EC1 is an enclosed local boundary consisting of four 400kV circuits that export power west to Keadby substation. The boundary encloses an area of high generation.

Chapter three

3.2.13
Boundary B8 – North to Midlands

Figure B8.1
Geographic representation of boundary B8

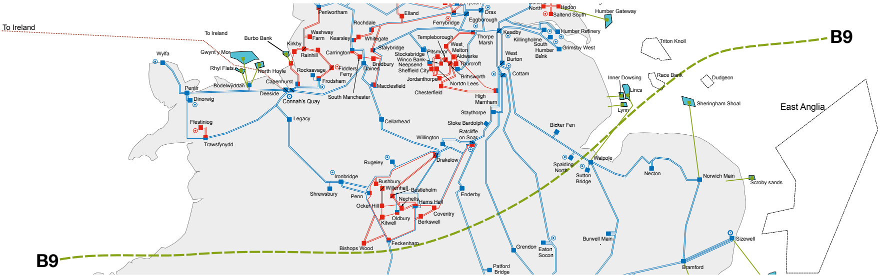


The North to Midlands boundary B8 is one of the wider boundaries that intersects the centre of Great Britain, separating the northern generation zones including Scotland, Northern England and North Wales, from the Midlands and southern demand centres. The boundary crosses four major 400kV double circuits, with two of these passing through the East Midlands and the other two passing through the West Midlands, and a limited 275kV connection to South Yorkshire.

Boundary descriptions

3.2.14
Boundary B9 – Midlands to South

Figure B9.1
Geographic representation of boundary B9



The Midlands to South boundary B9 separates the northern generation zones and the Midlands from the southern demand centres.

The boundary crosses five major 400kV double circuits, transporting power from the north over a long distance to the southern demand hubs, including London.

3.3
East

3.3.1
Introduction

The East region includes the counties of Norfolk and Suffolk. The transmission boundary EC5 covers the transmission network in the area. This boundary is considered local, based on the generation and demand currently connected.

Table 3.2
Effective reinforcement options

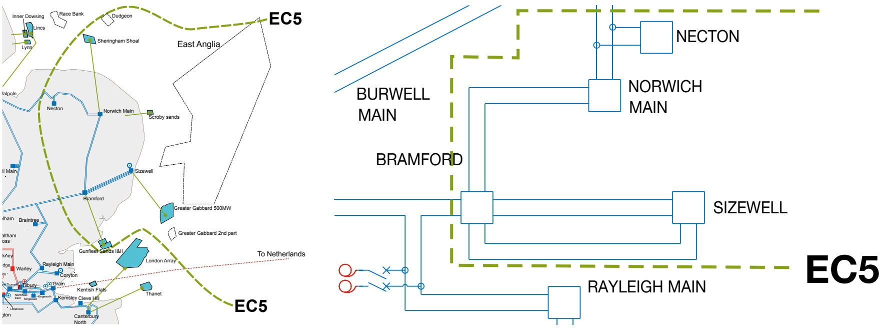
Unique reference	Reinforcement title	Boundaries affected
BMMS	225MVAr MSCs at Burwell Main	EC5
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route	EC5
NBRE	Reconductor Bramford to Norwich double circuit	EC5
BTNO	A new 400kV double circuit between Bramford and Twinstead	EC5
SGDC	South east to East Anglia HVDC link	EC5
CTRE	Reconductor remainder of Coryton South to Tilbury circuit	EC5
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit	EC5
RBRE	Reconductor newly formed second Bramford to Braintree to Rayleigh Main circuit (following Bramford to Twinstead new double circuit)	EC5
PRRE	Reconductor newly formed second Bramford to Pelham circuit (following Bramford to Twinstead new double circuit)	EC5
BPEU	Uprate non-conductor components of Bramford to Pelham double circuit (following Bramford to Twinstead new double circuit)	EC5
RMEU	Uprate non-conductor components of newly formed Bramford to Braintree to Rayleigh Main double circuit (following Bramford to Twinstead new double circuit) at Rayleigh Main	EC5

Note that the unique reference code applies only to this year's document.

Boundary descriptions

3.3.2
Boundary EC5 – East Anglia

Figure EC5.1
Geographic and single-line representation of boundary EC5



Boundary EC5 is a local boundary enclosing most of East Anglia with 400kV substations at Norwich, Sizewell and Bramford. It crosses four 400kV circuits that mainly export power towards London.

The coastline and waters around East Anglia are attractive for the connection of offshore wind projects, including the large East Anglia Round 3 offshore zone that lies directly to the east.

The existing nuclear generation site at Sizewell is one of the approved sites selected for new nuclear generation development.

3.4 South

3.4.1 Introduction

The South region stretches from London across to Devon and Cornwall. It has a high concentration of power demand and generation, with much of the demand found in London and generation in the Thames Estuary. Interconnection to continental Europe is present on the south coast and influences power flows in the region by being able to import and export power with Europe. The South region includes boundaries B13, B14, SC1 and SC2.

Table 3.3
Effective reinforcement options

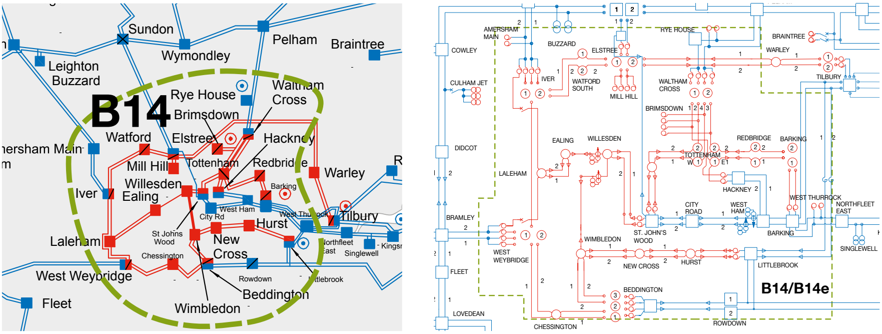
Unique reference	Reinforcement title	Boundaries affected
BFHW	Bramley to Fleet circuits thermal uprating	SC1
SCRC	South East coast reactive compensation	SC1, SC2, B15
BNRC	Bolney and Ninfield additional reactive compensation	SC1, SC2
SEEU	Reactive compensation protective switching scheme	SC2
LNHW	Lovedean to Ninfield thermal uprate	SC1, SC2
SCN1/SCN2/SCN3	New 400kV transmission route between South London and the south coast (there are three alternative designs for this option)	SC1, SC2
FLRE	Fleet to Lovedean reconductoring	SC1
KLRE	Kemsley to Littlebrook circuits uprating	SC1, B15
HSNO	Hinkley Point to Seabank new double circuit	SC1, B13
THRE	Reconductor Hinkley Point to Taunton double circuit	SC1
ATHW	Alverdiscott to Taunton double circuit thermal uprating	SC1
WYTI	Wymondley turn-in	B14e
WYQB	Wymondley quad boosters	B14e
WEC1	Willesden to Wimbledon 275kV cable Ealing diversion	B14e

Note that the unique reference code applies only to this year's document.

Boundary descriptions

3.4.2
Boundary B14 – London

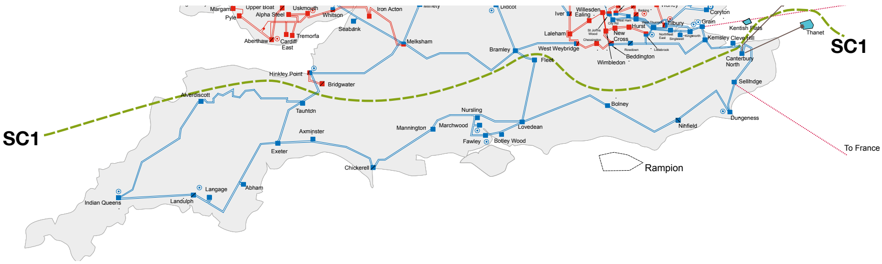
Figure B14.1
Geographic and single-line representation of boundary B14



Boundary B14 encloses London and is characterised by high local demand and a small amount of generation. The circuits entering from the north can be heavily loaded during winter peak conditions. The circuits are further stressed when the European interconnectors export to the continent.

3.4.3
Boundary SC1 – South Coast

Figure SC1.1
Geographic representation of boundary SC1



The south coast boundary SC1 runs parallel with the south coast of England between the Severn and Thames estuaries. At times of peak winter GB demand, the power flow is typically north to south across the boundary.

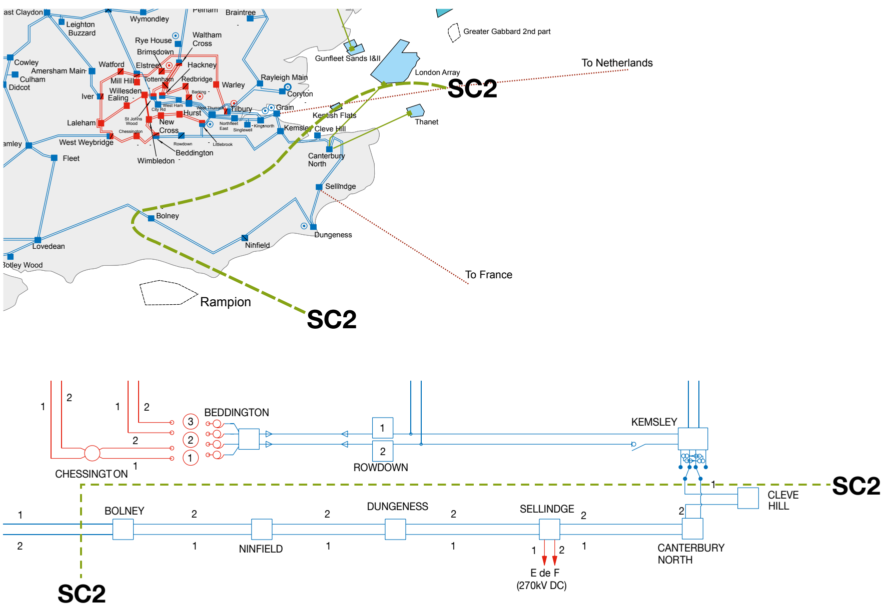
Interconnector activity significantly influences boundary power flow. Crossing the boundary are three 400kV double circuits with one in the east, one in the west and one midway between Fleet and Bramley.

Boundary descriptions

Chapter three

3.4.4
Boundary SC2 – South East Coast

Figure SC2.1
Geographic and single-line representation of boundary SC2

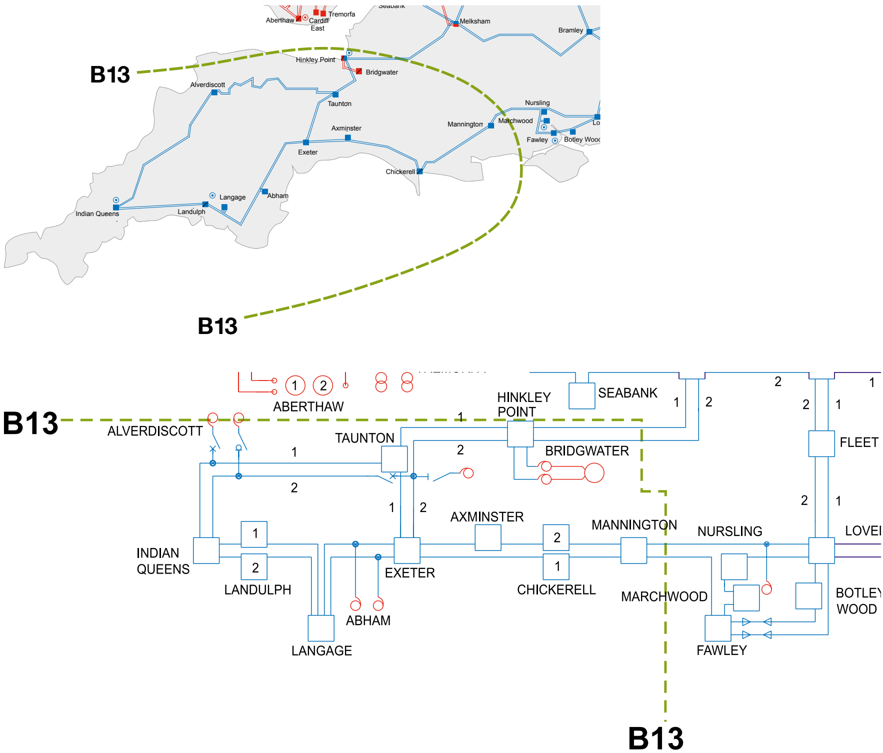


The south coast boundary SC2 takes in Kent and Sussex. At its east end, it cuts the double circuit route between Kemsley and Cleve Hill and at its west end between Bolney and Lovedean. At times of peak winter GB demand, the power flow is typically south to north across the boundary.

Interconnector activity significantly influences boundary power flow.

3.4.5
Boundary B13 – South West

Figure B13.1
Geographic and single-line representation of boundary B13



Wider boundary B13 is defined as the southernmost tip of Great Britain, below the Severn Estuary, encompassing Hinkley Point in the south west and stretching as far east as Mannington. The boundary crossing circuits are the Hinkley Point to Melksham 400kV double circuit and the 400kV circuits from Mannington to Nursling and Fawley.

Boundary descriptions

3.5 West

3.5.1 Introduction

The West region covers the remaining boundaries on the system including Wales, the Midlands and the South West. Some of the boundaries are closely related, such as those for North Wales, but the region also covers large wider boundaries such as B17.

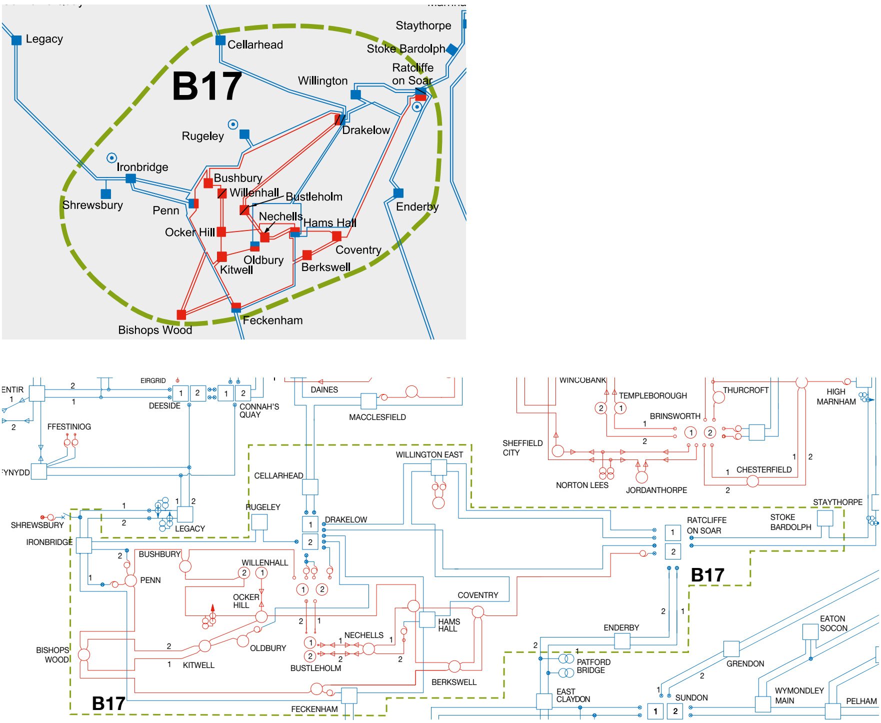
Table 3.4
Effective reinforcement options

Unique reference	Reinforcement title	Boundaries affected
WPNO	Wylfa to Pentir second double circuit route	NW1
WPDC	North Wales to South Wales HVDC Link	SW1, NW2, NW3
BCRE	Reconductor the Connah's Quay legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits	NW2, NW3
PBRE	Reconductor Pentir legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits	NW2
PTNO	Pentir to Trawsfynydd second circuit	NW2
PTC1	Pentir to Trawsfynydd 1 cable replacement – single core per phase	NW2
PTC2	Pentir to Trawsfynydd 1 and 2 cables – second core per phase and reconductor of an overhead line section on the existing Pentir to Trawsfynydd circuit	NW2
PTRE	Pentir to Trawsfynydd circuits – reconductor the remaining overhead line sections	NW2
HCC1	Cowley to Minety and Cowley to Walham cables (Hinksey cables) upgrade	SW1
SEC1	Severn Tunnel 400kV cable circuit uprate	SW1
PWTI	Pembroke to Walham circuit turn-in to Swansea North	SW1
CIQB	Quad booster installation at Cilfynydd	SW1

Note that the unique reference code applies only to this year's document.

3.5.2
Boundary B17 – West Midlands

Figure B17.1
Geographic and single-line representation of boundary B17



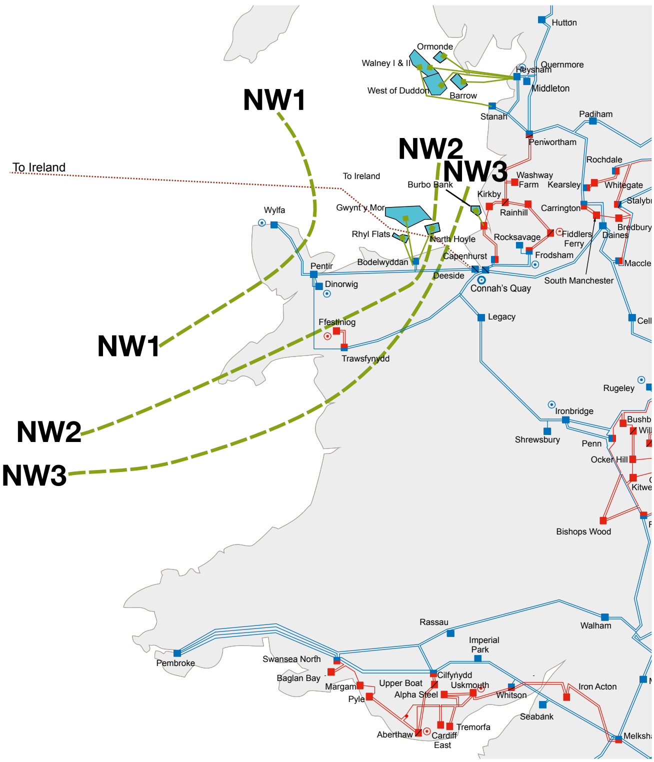
Enclosing the West Midlands, boundary B17 is heavily dependent on importing power from the north because of insufficient local generation. Boundary B17 is crossed by five 400kV double circuits but internally the circuits in and around Birmingham are mostly 275kV.

Chapter three

Boundary descriptions

3.5.3
Boundary NW1, NW2 and NW3 North Wales

Figure NW.1
Geographic representation of North Wales boundaries NW1, NW2 and NW3



The onshore network in North Wales comprises a 400kV circuit ring that connects Pentir, Deeside and Trawsfynydd substations. A short 400kV double-circuit cable spur from Pentir connects Dinorwig pumped storage power station.

Pentir and Trawsfynydd are within the Snowdonia National Park and are connected by a single 400kV circuit, which is the main limiting factor for capacity in this area. The three 'NW' boundaries are local boundaries.

Chapter three

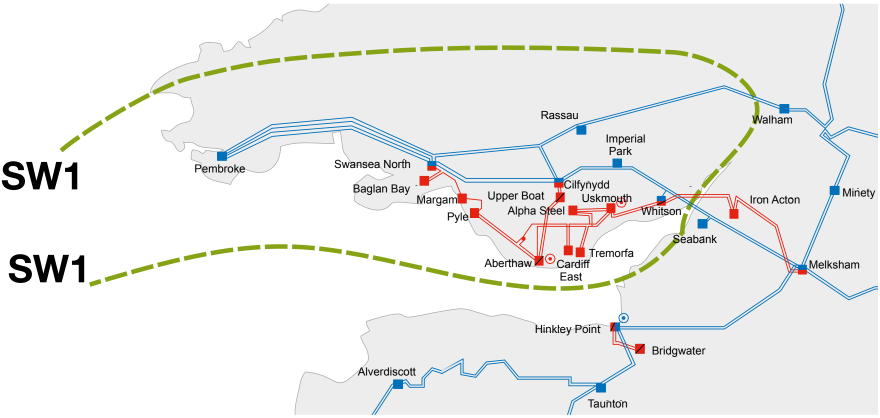
Boundary NW1 – Anglesey
Boundary NW1 crosses the 400kV double circuit that runs along Anglesey between Wylfa and Pentir substations.

Boundary NW2 – Anglesey and Caernarvonshire
Boundary NW2 bisects the North Wales mainland close to Anglesey. It crosses through the Pentir to the Deeside 400kV double circuit and the Trawsfynydd 400kV single circuit.

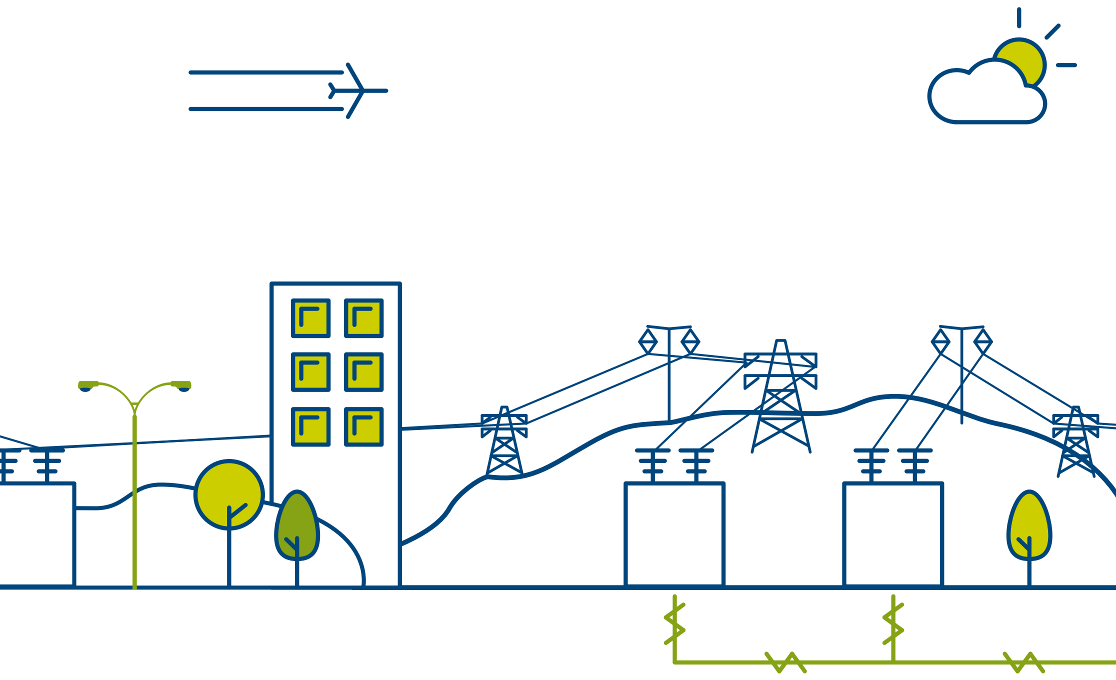
Boundary NW3 – Anglesey, Caernarvonshire and Merionethshire
Boundary NW3 provides capacity for further generation connections, in addition to those behind boundaries NW1 and NW2. It is defined by a pair of 400kV double circuits from Pentir to Deeside and from Trawsfynydd to the Treuddyn Tee.

3.5.4
Boundary SW1 – South Wales

Figure SW1.1
Geographic representation of boundary SW1



Boundary SW1 encloses South Wales and is considered a local boundary. Within the boundary are a number of thermal generators. Some of the older power stations are expected to close in the future but significant amounts of new generation capacity are expected to connect, including generators powered by wind, gas and tidal.



Chapter four

Proposed options

4.1
Introduction

This chapter lists the reinforcement options that could increase NETS capability as part of network planning.

The options for connecting the Scottish islands are radial rather than benefiting particular boundaries but we've included them because they are SWW. For each option we have included the status of the option, whether it is build or reduced-build, and some background.

Depending on the status of offshore connections, the SO can also provide offshore options that can interconnect offshore generation and provide boundary capability. Offshore options rely on emerging technology and usually incur higher costs and risks. This year no offshore options have been identified: however we have drafted the methodology for the SO's assessment of Offshore Wider Works (OWW) and it is available for viewing and comment alongside the *NOA* methodology.

nationalgrid.com

www2.nationalgrid.com
> UK Sites > Industry Information (more information) > Future of Energy > Network Options Assessment

www2.nationalgrid.com
/WorkArea/DownloadAsset.aspx?id=8589936186

4.2
Reinforcement options – Scotland and North of England

Dounreay to Orkney, Bay of Skaill subsea link Status: Optioneering Boundary affected: Radial	Install a 220kV 200MW AC subsea cable between Dounreay, on the north coast of Caithness, and a new substation at Bay of Skaill on the west coast of the Orkney Islands.
Gills Bay to Orkney, South Ronaldsay subsea link Status: Optioneering Boundary affected: Radial	Install a 220kV 220MW AC subsea cable between Gills Bay, on the north east coast of Caithness, and a new substation on the east coast of South Ronaldsay on the Orkney Islands.
Dounreay to Orkney, South Hoy subsea link Status: Optioneering Boundary affected: Radial	Install a 220kV 220MW AC subsea cable between Dounreay, on the north coast of Caithness, and a new substation at the south of Hoy on the Orkney Islands.
Dounreay to Orkney, Bay of Skaill and Dounreay to Orkney, South Hoy subsea link Status: Optioneering Boundary affected: Radial	Install a 220kV AC subsea cable from Dounreay, on the north coast of Caithness, to a new substation at Bay of Skaill on the west coast of the Orkney Islands, and from Dounreay to a new substation at the south of Hoy on the Orkney Islands. The cable to Bay of Skaill would be rated at 200MW and the cable to Hoy would be rated at 220MW.
BLR1 **Beauly to Shin to Loch Buidhe 132kV double circuit reconductoring** Status: Scoping Boundary affected: B0	Reconductor the existing 132kV double circuit overhead line between Beauly, Shin and Loch Buidhe (substation under construction) with a higher rated conductor. Replace the existing phase shifting transformers (PSTs) at Beauly 132kV substation with higher capacity PSTs.
FBRE **Beauly to Fyrish 275kV double circuit reconductoring and generation connection reconfiguration** Status: Scoping Boundary affected: B0	Reconductor the existing 275kV double circuit overhead line between Beauly and Fyrish (substation under construction) with a higher rated conductor. Reconfigure generation connections between Loch Buidhe (substation under construction) and Dounreay to release capacity on the 275kV circuits between the two substations.

Proposed options

BLR2 **Beauly to Loch Buidhe 275kV double circuit reconductoring and generation connection reconfiguration** Status: Scoping Boundary affected: B0	Reconductor the existing 275kV double circuit overhead line between Beauly and Loch Buidhe (substation under construction) with a higher rated conductor. Reconfigure generation connections between Loch Buidhe and Dounreay to release capacity on the 275kV circuits between the two substations.
BDRE **Beauly to Loch Buidhe and Loch Buidhe to Dounreay 275kV double circuit reconductoring** Status: Scoping Boundary affected: B0	Reconductor the existing 275kV double circuit overhead line between Beauly and Loch Buidhe and between Loch Buidhe and Dounreay with a higher rated conductor.
BLN2 **New Beauly to Loch Buidhe 275kV double circuit** Status: Planning Boundary affected: B0	Construct a new 275kV double circuit between Beauly and Loch Buidhe (substation under construction) and transfer Fyrish substation (under construction) onto the new line. On completion of the works, decommission the 132kV double circuit line between Beauly and Shin and the two phase shifting transformers at Beauly.
TURC **Reactive compensation at Tummel** Status: Optioneering Boundaries affected: B1, B1a	Establish a 275kV double busbar at Tummel substation and install shunt reactive compensation.
TMRC **Reactive compensation at Tummel and Melgarve** Status: Scoping Boundaries affected: B1, B1a	Establish a 275kV double busbar at Tummel substation and install shunt reactive compensation. Install shunt reactive compensation at Melgarve on the 132kV double busbar.
B1RC **Reactive compensation at Tummel and Melgarve and inter-bus Transformers at Fort Augustus** Status: Optioneering Boundaries affected: B1, B1a	Establish a 275kV double busbar at Tummel substation and install shunt reactive compensation. Install shunt reactive compensation at Melgarve on the 132kV double busbar and install two 400/275kV inter-bus transformers at Fort Augustus.
BKNO **New Beauly to Kintore 400kV double circuit** Status: Optioneering Boundaries affected: B1, B1a	Establish a 400kV double busbar at Kintore substation and construct a new 400kV double circuit between Beauly and Kintore. Once the new 400kV double circuit has been built, dismantle the 132kV double circuit line from Beauly to Knocknagael.

BBNO **New Beauly to Blackhillock 400kV double circuit** Status: Optioneering Boundary affected: B1	Construct a new 400kV double circuit between Beauly and Blackhillock. Once the new 400kV double circuit has been built, dismantle the 132kV double circuit line from Beauly to Knocknagael.
BLQB **New 275kV phase shifting transformers at Blackhillock on the circuits from Knocknagael** Status: Scoping Boundary affected: B1	Install two new 275kV phase shifting transformers with bypass circuits at Blackhillock substation on the existing 275kV circuits from Knocknagael.
NEEU **North east 400kV and 275kV network reinforcement** Status: Optioneering Boundary affected: B2a	Establish new 400kV substations at Rothienorman and Peterhead and re-insulate the existing 275kV circuits between Blackhillock and Rothienorman, Peterhead and Rothienorman, and Rothienorman and Kintore substations to 400kV operation. The option would also re-profile the existing 275kV double circuit line between Peterhead and Persley, and Persley and Kintore.
RKEU **Rothienorman substation with reconductoring of the 275kV Rothienorman to Kintore circuit** Status: Optioneering Boundary affected: B2a	Establish a new 275kV substation at Rothienorman and reconductor the 275kV double circuit overhead line from Rothienorman to Kintore with a higher rated conductor.
ECU2 **East Coast onshore 275kV upgrade** Status: Optioneering Boundaries affected: B1, B1a, B2, B4, B5	Establish new 275kV substations at Alyth and Fiddes, re-profile the 275kV circuits between Kintore, Alyth and Kincardine and uprate the 275kV circuits between Alyth, Tealing, Westfield and Longannet. Install two phase shifting transformers at Fiddes on the 275kV circuits from Kintore to Tealing and install shunt reactive compensation at the new Alyth substation.

Proposed options

ECUP **East Coast onshore 400kV incremental reinforcement** Status: Optioneering Boundaries affected: B1, B1a, B2, B4	The option builds on the East Coast onshore 275kV upgrade (ECU2) by upgrading the 275kV infrastructure along the Blackhillock–Rothienorman–Kintore–Alyth–Kincardine route on the east coast to operate at 400kV. Establish new 400kV substations at Rothienorman and Kintore, and uprate Alyth substation (proposed under the East Coast 275kV Upgrade) for 400kV operation. Re-insulate the 275kV circuits between Blackhillock, Rothienorman, Kintore, Fetteresso, Alyth and Kincardine for 400kV operation. Install phase shifting transformers with bypass circuits at Blackhillock on the 275kV circuits from Knocknagael and 275/400kV transformers at Kincardine, Alyth, Kintore and Rothienorman.
ECU4 **East Coast onshore 400kV reinforcement** Status: Optioneering Boundaries affected: B1, B1a, B2, B4, B5	Upgrade the 275kV infrastructure on the east coast for 400kV operation by creating new 400kV substations at Rothienorman, Kintore and Alyth and re-insulating the 275kV circuits between Blackhillock, Rothienorman, Kintore, Fetteresso, Alyth and Kincardine to 400kV. Install phase shifting transformers at Blackhillock on the 275kV circuits from Knocknagael and 275/400kV transformers at Kincardine, Alyth, Kintore and Rothienorman. Re-profile the 275kV circuits between Tealing, Westfield and Longannet as well as uprate the cable sections at Longannet to match the enhanced rating.
WLTI **Windyhill to Lambhill to Longannet 275kV circuit turn in to Denny North 275kV substation** Status: Design Boundary affected: B5	Turn the Windyhill to Lambhill to Longannet 275kV circuit into Denny North 275kV substation. This would create a 275kV Windyhill to Lambhill to Denny North circuit and a second Denny North to Longannet 275kV circuit.
DWNO **Denny to Wishaw 400kV reinforcement** Status: Design Boundaries affected: B4, B5, B6	A new 400kV double circuit overhead line from Bonnybridge towards Newarthill. The project would also reconfigure associated sites to establish a fourth north-to-south double circuit route through the Scottish central belt. One side of the new overhead line route would operate at 400kV, the other at 275kV.

E2DC **Eastern subsea HVDC Link from Torness to Hawthorn Pit** Status: Scoping Boundaries affected: B5, B6, B7, B7a, B8	Construct a new offshore 2GW HVDC subsea link from the Torness area to Hawthorn Pit to provide additional transmission capacity. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Torness and Hawthorn Pit.
TLNO **Torness to North East England AC reinforcement** Status: Scoping Boundaries affected: B5, B6, B7, B7a	This option provides additional transmission capacity by installing a new double circuit from a new 400 kV substation in the Torness area to a suitable connection point in North East England.
E4DC **Eastern subsea HVDC Link from Peterhead to Hawthorn Pit** Status: Scoping Boundaries affected: B1, B1a, B2, B2a, B4, B5, B6, B7, B7a	Construct a new offshore 2GW HVDC subsea link from Peterhead in the north east of Scotland to Hawthorn Pit in the north of England. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Peterhead (refer to north east 400kV and 275kV network reinforcement – NEEU) and Hawthorn Pit.
WHTI **Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit** Status: Scoping Boundaries affected: B6, B7, B7a	Turn in the West Boldon to Hartlepool circuit which currently passes the Hawthorn Pit site to connect to it. This would create new West Boldon to Hawthorn Pit and Hawthorn Pit to Hartlepool circuits. This would ensure better load flow sharing and increased connectivity in the north east 275kV ring.
WOSR **Deploy FACTS device on West Boldon to Offerton circuit** Status: Scoping Boundaries affected: B6, B7	This would use novel technology to actively control the power flows on this circuit and prevent it overloading thermally during system faults.
WBQB **Install quad booster in West Boldon to Offerton circuit** Status: Project not started Boundary affected: B6	Install a quad booster into this circuit to control the power flows within it.
HAEU **Harker SuperGrid Transformer 6 replacement** Status: Project not started Boundary affected: B6	Replacing an existing transformer at Harker substation with a new one of higher rating to prevent it overloading following transmission system faults.
LNRE **Reconductor Lackenby to Norton single 400kV circuit** Status: Project not started Boundary affected: B7	Replace the conductors in the Lackenby to Norton single circuit with higher rated conductor, and replace the cable with larger cable of higher rating, to increase the circuit's thermal rating.

Proposed options

NOR1 **Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit** Status: Project not started Boundaries affected: B6, B7, B7a	Replace some of the conductors in the Norton to Osbaldwick double circuit with higher rated conductor to increase the circuits' thermal rating.
NOR2 **Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit** Status: Project not started Boundary affected: B7	Replace some of the conductors in one of the Norton to Osbaldwick circuits with higher rated conductor to increase the circuit's thermal rating.
NOR3 **Norton to Osbaldwick 400kV double circuit – reconductor the rest of the circuits** Status: Project not started Boundaries affected: B6, B7, B7a	Replace the rest of the conductors in the Norton to Osbaldwick double circuit with higher rated conductor to increase the circuits' thermal rating.
NOHW **Thermal uprate 55km of the Norton to Osbaldwick 400kV double circuit** Status: Project not started Reduced build option Boundary affected: B7	Thermal upgrade of the Norton to Osbaldwick circuits to allow them to operate at higher temperatures, and increase their thermal rating.
HPNO **New east–west circuit between the north east and Lancashire** Status: Project not started Boundaries affected: B6, B7, B7a, B8	Construct a new 400kV double circuit in the north of England, to increase power export capability from the north of England into the rest of the transmission system. At this time the exact landing points are to be determined. This is the first of two outline options.
NPNO **New east–west circuit between the north east and Lancashire** Status: Project not started Boundaries affected: B6, B7, B7a	Construct a new 400kV double circuit in the north of England, to increase power export capability from the north of England into the rest of the transmission system. At this time the exact landing points are to be determined. This is the second of two outline options.
LTR1 **Lackenby to Thornton double circuit – uprate cable and thermal uprate overhead line sections** Status: Project not started Boundary affected: B7	Thermal uprate of sections of the Lackenby to Thornton double circuit to allow them to operate at higher temperatures, increasing their thermal rating.

LTR2 **Lackenby to Thornton double circuit – uprate cable section and reconductor sections** Status: Project not started Boundaries affected: B6, B7	Replace some of the conductors in the Lackenby to Thornton double circuit with higher rated conductor and replace the cable sections with new higher rated cable. These two activities would increase the circuits' thermal rating.
OTHW **Osbaldwick to Thornton 1 circuit thermal upgrade** Status: Project not started Reduced build option Boundary affected: B6	Thermal upgrade of the Osbaldwick to Thornton 1 circuit to allow it to operate at higher temperatures, increasing its thermal rating.
LDQB **Lister Drive quad booster** Status: Project not started Boundary affected: B7a	Replacing the series reactor at Lister Drive with a quad booster to allow better control of power flows through the single cable to Birkenhead and avoid thermal overloads in the Mersey Ring area.
MRUP **Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV** Status: Project not started Boundary affected: B7a	Reinsulate the Penwortham to Washway Farm to Kirkby double circuit to allow operation at 400kV. Other associated works are at Kirkby substation to transform voltage from 400kV to 275kV and replace the Washway farm 275/132kV transformers with 400/132kV transformers. The option would prevent thermal overloads on these circuits.
OENO **Central Yorkshire reinforcement** Status: Project not started Boundaries affected: B6, B7, B7a, B8	Construct a new 400kV double circuit in central Yorkshire to facilitate power transfer requirements across the relevant boundaries. Substation works might be required to accommodate the new circuits.
THS1/THS2 **Install series reactors at Thornton** Status: Project not started Boundaries affected: B6, B7, B7a, B8 and B9	Install series reactors at Thornton substation which would connect the parts of the site operated disconnected from one another for fault level reasons through a high impedance path. This would allow some flow sharing between the different parts of the site and reduce thermal overloads on connected circuits.
TDRE **Reconductor Drax to Thornton double circuit** Status: Project not started Boundaries affected: B6, B7, B7a, B8	Replace the conductors in the Drax to Thornton double circuit with higher rated conductor to increase the circuits' thermal rating.

Proposed options

GKRE **Reconductor Garforth Tee to Keadby leg of the Creyke Beck to Keadby to Killingholme Circuit** Status: Project not started Boundaries affected: B7, B7a, B8	Replace the conductor on the Keadby leg of the Creyke Beck to Keadby to Killingholme three-ended circuit. This would raise the circuit's thermal rating.
DERE **Drax to Eggborough 1 circuit – reconductor and replace cable section** Status: Project not started Boundaries affected: B6, B7a	Replace the conductors in the Drax to Eggborough 1 circuit with higher rated conductor, and replace the cable section with larger cable of higher rating, to increase the circuit's thermal rating.
DREU **Generator circuit breaker replacement to allow Thornton to run two-way split** Status: Project not started Boundaries affected: B7, B8, B9	This reinforcement is to replace generator owned circuit breakers with higher rated equivalents. This would allow Thornton substation to be run coupled more often in winter as a higher fault level can be tolerated. This would improve load sharing on circuits post fault.
WHRE **West Burton to High Marnham circuit – complete gantry works to match circuit rating** Status: Project not started Boundary affected: B8	Carry out gantry works at High Marnham substation to complete the uprating of the West Burton to High Marnham circuit and increase its thermal rating.
KCRE **Reconductor the Keadby to Cottam 400kV double circuit** Status: Project not started Boundaries affected: B7a, B8	Replace the conductors in the Keadby to Cottam double circuit with higher rated conductor to increase the circuits' thermal rating.
WEOS **Western HVDC Link fast de-load scheme** Status: Design/development Reduced build option Boundary affected: B8	A scheme to automatically and almost instantaneously de-load the Western HVDC Link following various transmission circuit faults in the area near its landing point in Flintshire. This would prevent thermal overload of circuits in this local area during such conditions.
TCRE **Treuddyn Tee to Connah's Quay reconductoring** Status: Project not started Boundary affected: B8	Replace the conductors in the Connah's Quay leg of the Connah's Quay to Legacy to Trawsfynydd double circuit with higher rated conductor. This would increase the circuits' thermal rating.

TLH1

Treuddyn Tee to Legacy thermal upgrade
Status: Project not started
Reduced build option
Boundary affected: B8

Thermal upgrade of the Treuddyn Tee to Legacy circuits to allow them to operate at higher temperatures, and increase their thermal rating.

Proposed options

4.3
Reinforcement options – East of England

BMMS **225 MVAr MSCs at Burwell Main** Status: Project not started Boundary affected: EC5	Three new 225 MVAr switched capacitors (MSCs) at Burwell Main would provide voltage support to the East Anglia area as system flows increase in future.
BRRE **Reconductor remainder of Bramford to Braintree to Rayleigh route** Status: Project not started Boundariy affected: EC5	Replace the conductors in the parts of the existing Bramford to Braintree to Rayleigh overhead line that have not already been reconductored with higher rated conductor, to increase the circuit's thermal rating.
NBRE **Reconductor Bramford to Norwich double circuit** Status: Project not started Boundary affected: EC5	The double circuits that run from Norwich to Bramford would be reconductored with higher-rated conductor.
BTNO **A new 400kV double circuit between Bramford and Twinstead** Status: Project not started Boundary affected: EC5	Construct a new 400kV double circuit between Bramford substation and Twinstead tee point to create double circuits that run between Bramford–Pelham and Bramford–Braintree–Rayleigh Main. It would increase power export capability from East Anglia into the rest of the transmission system.
SGDC **South east to East Anglia HVDC link** Status: Project not started Boundary affected: EC5	A 2 GW HVDC link to transfer power between the south east and East Anglia regions of the transmission system, and reduce the effects of faults in either area limiting the power transmission capacity.
CTRE **Reconductor remainder of Coryton South to Tilbury circuit** **RTRE** **Reconductor remainder of Rayleigh to Tilbury circuit** Status: Project not started Boundary affected: EC5	Replace the conductors in the Coryton South to Tilbury and Rayleigh to Tilbury circuits that have not recently been reconductored with higher rated conductor. These would increase the circuits' thermal rating.

Chapter four

RBRE **Reconductor newly formed second Bramford to Braintree to Rayleigh Main circuit (following Bramford to Twinstead new double circuit)** Status: Project not started Boundary affected: EC5	Replace the conductors in the newly formed second Bramford to Braintree to Rayleigh Main circuit with higher rated conductor to increase the circuit's thermal rating.
PRRE **Reconductor newly formed second Bramford to Pelham circuit (following Bramford to Twinstead new double circuit)** Status: Project not started Boundary affected: EC5	Replace the conductors in the newly formed second Bramford to Pelham circuit with higher rated conductor to increase the circuit's thermal rating.
BPEU **Uprate non-conductor components of Bramford to Pelham double circuit (following Bramford to Twinstead new double circuit)** Status: Project not started Boundary affected: EC5	Replace some components in Pelham substation that connect to the Bramford to Pelham double circuit. This would allow the full rating of the reconductored circuits to be utilised.
RMEU **Uprate non-conductor components of newly formed Bramford to Braintree to Rayleigh Main double circuit (following Bramford to Twinstead new double circuit) at Rayleigh Main** Status: Project not started Boundary affected: EC5	Replace some components in Rayleigh substation that connect to the Bramford to Braintree to Rayleigh Main double circuit. This would allow the full rating of the reconductored circuits to be utilised.

Proposed options

4.4
Reinforcement options – South of England

BFHW **Bramley to Fleet circuits thermal uprating** Status: Project not started Reduced build option Boundary affected: SC1	Thermal upgrade of the Bramley to Fleet circuits to allow them to operate at higher temperatures, and increase their thermal rating.
SCRC **South East coast reactive compensation** Status: Scoping Boundaries affected: SC1, SC2, B15	Install dynamic voltage support (known as an SVC) on the south east coast. This would provide reactive post-fault power to help maintain voltage stability on the south east coast.
BNRC **Bolney and Ninfield additional reactive compensation** Status: Project not started Boundaries affected: SC1, SC2	Provide additional reactive compensation equipment at Bolney and Ninfield substations, to maintain voltages within acceptable operational limits in future network operating conditions.
SEEU **Reactive compensation protective switching scheme** Status: Project not started Reduced build option Boundary affected: SC2	Provide a new communications system, and other equipment, to allow existing reactive equipment to be switched in or out of service very quickly following transmission system faults. This would allow better control of system voltages following faults.
LNHW **Lovedean to Ninfield thermal uprate** Status: Project not started Reduced build option Boundaries affected: SC1, SC2	Thermal upgrade of the Lovedean to Bolney to Ninfield circuits to allow them to operate at higher temperatures, and increase their thermal rating.
SCN1/SCN2/SCN3 **New 400kV transmission route between South London and the south coast (there are three alternative designs for this option)** Status: Project not started Boundaries affected: SC1, SC2	Construct a new transmission route from the south coast to south London and carry out associated work. These works would provide additional transmission capacity between the south of London and the south coast.

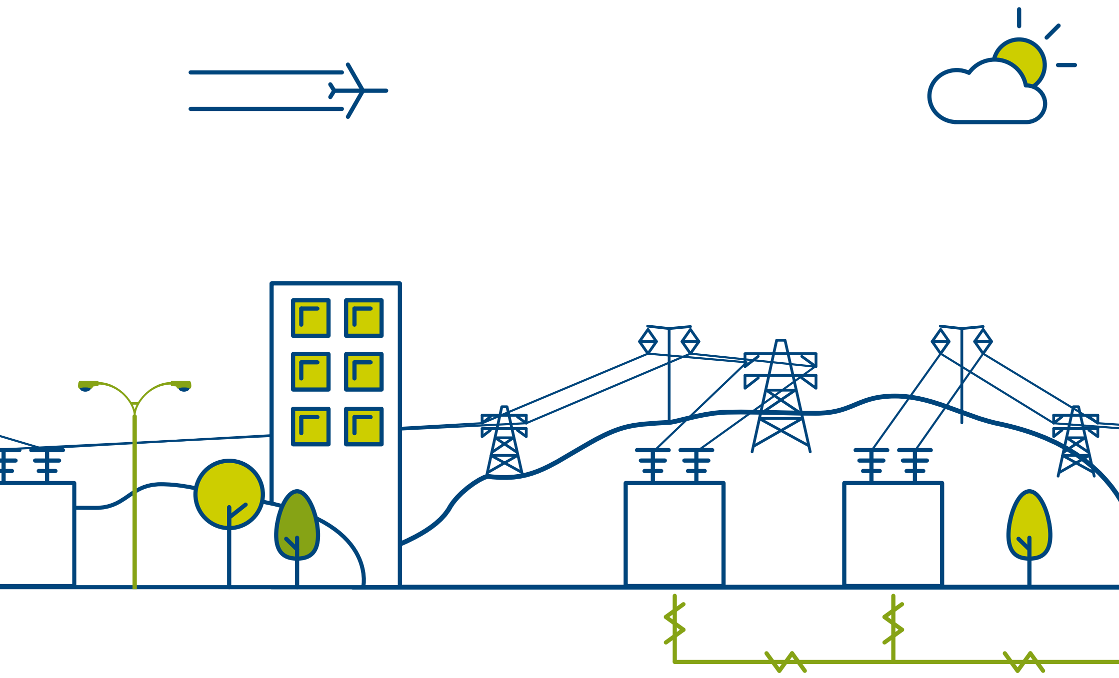
FLRE **Fleet to Lovedean reconductoring** Status: design/development Boundary affected: SC1	Replace the conductors in the Fleet to Lovedean circuits with a higher rated conductor to increase their thermal ratings.
KLRE **Kemsley to Littlebrook circuits uprating** Status: design/development Boundaries affected: SC1, B15	The 400kV circuits running from Kemsley via Longfield Tee to Littlebrook would be reconductored with higher-rated conductor.
HSNO **Hinkley Point to Seabank new double circuit** Status: Scoping Boundaries affected: SC1, B13	Establishing a new 400kV double circuit from Hinkley Point to Seabank. to increase power export capability from the South West into the rest of the transmission system.
THRE **Reconductor Hinkley Point to Taunton double circuit** Status: Project not started Boundary affected: SC1	Replace the conductors in the Hinkley Point to Taunton circuits with higher rated conductor to increase the circuits' thermal rating.
ATHW **Alverdiscott to Taunton double circuit thermal uprating** Status: Project not started Reduced build option Boundary affected: SC1	Thermal upgrade of the Alverdiscott to Taunton circuits to allow them to operate at higher temperatures, and increase their thermal rating.
WYTI **Wymondley turn-in** Status: Project not started Boundary affected: B14e	Modify the existing circuit that runs from Pelham to Sundon. Turn in the circuit at Wymondley to create two separate circuits that run from Pelham to Wymondley and from Wymondley to Sundon to improve the balance of flows.
WYQB **Wymondley quad boosters** Status: Project not started Boundary affected: B14e	Install a pair of quad boosters on the double circuits running from Wymondley to Pelham at the Wymondley 400kV substation. The quad boosters would improve the capability to control the power flows on the North London circuits.
WEC1 **Willesden to Wimbledon 275kV cable Ealing diversion** Status: Project not started Boundary affected: B14e	Constructing a second 275kV cable transmission route from Willesden to Ealing. Associated work would include modifying Ealing 275kV substation by rerouting the Willesden to Wimbledon circuit into a quad booster at Ealing.

Proposed options

4.5
Reinforcement options – Wales and the West of England

WPNO **Wylfa to Pentir second double circuit route** Status: Design/development Boundary affected: NW1	Constructing a second 400kV transmission route from Wylfa to Pentir.
WPDC **North Wales to South Wales HVDC Link** Status: Project not started Boundaries affected: SW1, NW2, NW3	A new offshore 2GW HVDC subsea link between Wylfa and Pembroke to transfer power between the North Wales and South Wales parts of the transmission network. It would reduce the effects of faults in either area limiting the power transmission capacity.
BCRE **Reconductor the Connah's Quay legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits** Status: Project not started Boundaries affected: NW2, NW3	Replace the conductors in the sections between Bodelwyddan and Connah's Quay on the Pentir to Bodelwyddan to Connah's Quay double circuit with higher rated conductor to increase the circuits' thermal rating.
PBRE **Reconductor Pentir legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits** Status: Project not started Boundary affected: NW3	Replace the conductors in the sections between Pentir and Bodelwyddan on the Pentir to Bodelwyddan to Connah's Quay double circuit with higher rated conductor to increase the circuits' thermal rating.
PTNO **Pentir to Trawsfynydd second circuit** Status: Project not started Boundary affected: NW2	Create a second Pentir to Trawsfynydd 400kV circuit by using the existing circuit infrastructure and corridor including constructing new cable sections.
PTC1 **Pentir to Trawsfynydd 1 cable replacement – single core per phase** Status: Project not started Boundary affected: NW2	Replacing cable sections of the Pentir to Trawsfyndd 1 circuit with a large cable sections increasing the circuit's thermal rating.

PTC2 **Pentir to Trawsfynydd 1 and 2 cables – second core per phase and reconductor of an overhead line section on the existing Pentir to Trawsfynydd circuit** Status: Project not started Boundary affected: NW2	Replace the conductors in part of the circuits between Pentir and Trawsfynydd with higher rated conductor. Construct a second single core per phase cable section on these circuits. These two activities would increase the circuits' thermal rating.
PTRE **Pentir to Trawsfynydd circuits – reconductor the remaining overhead line sections** Status: Project not started Boundary affected: NW3	Replace the conductors in remaining parts of the circuits between Pentir and Trawsfynydd with higher rated conductor to further increase the circuits' thermal rating.
HCC1 **Cowley to Minety and Cowley to Walham cables (Hinksey cables) upgrade** Status: Project not started Boundary affected: SW1	Increase thermal rating of double circuit by installing a new single core per double circuit phase cable adjacent to existing cabled section, so each circuit would then have two cores.
SEC1 **Severn Tunnel 400kV cable circuit uprate** Status: Project not started Boundary affected: SW1	Construct a new cable tunnel with a single core per phase so there would be two cores per phase in each circuit. This would remove the restriction on the circuit capacity imposed by the existing cable and increase the circuits' thermal ratings.
PWTI **Pembroke to Walham circuit turn-in to Swansea North** Status: Project not started Boundary affected: SW1	Turn-in the existing Pembroke to Walham circuit into the Swansea North substation to improve load sharing in the local circuits.
CIQB **Quad booster installation at Cilfynydd** Status: Project not started Boundary affected: SW1	Installating a quad booster at Cilfynydd 400kV substation on each of the Cilfynydd to Imperial Park and Cilfynydd to Seabank 400kV circuits. This would resolve the thermal overloading issues by rerouting power to other lightly loaded circuits.



Chapter five

Investment recommendations

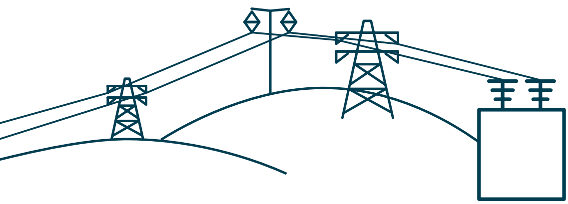
5.1
Introduction

Chapter 5 presents our investment recommendations from our cost–benefit analysis. The results give the best cost–benefit strategy for each scenario, and enable us to identify our preferred options and the recommended next steps for works required in each region.

Key statistics

This year 17 options are considered critical and 14 have a Proceed decision. This means that the TOs are recommended to invest £83 million this year on options that have a total investment of almost £3.8 billion over their lifetime. Our analysis considered what is truly necessary as the energy landscape changes and, as a result, significant savings are possible from delaying options.

We recommend to delay 3 projects which may have committed over £2 million of spend this investment year. Through utilising the scenario-based, single-year least regret analysis our *NOA* 2016/17 recommendations will ensure that the GB transmission network can continue supporting the transition to the future energy landscape in an efficient, economical and coordinated way.

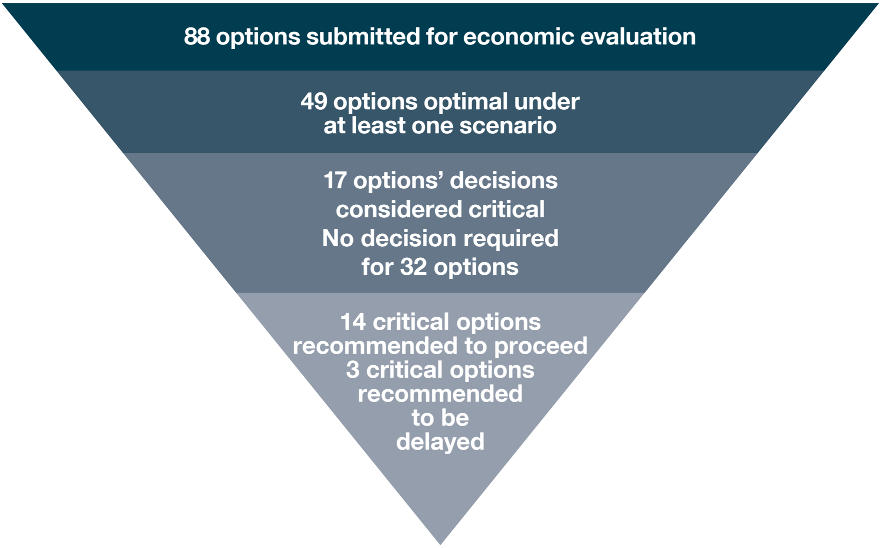


£83m
Investing £83 million this year

14
Through 14 options

£3.8bn
Total worth of £3.8 billion

Figure 5.1
How the options went through the process



Throughout this chapter, we take the options presented in Chapter 4 – Proposed options as the inputs to our cost–benefit analysis and we perform this analysis for each geographical region under each energy scenario. Our economic analysis provides us with three sets of results and this chapter is laid out to cover each set in turn. If you would like to understand the theory behind our cost–benefit analysis then please refer to Chapter 2 – Methodology.

The three sets of results are as follows:

1. Recommended delivery dates
Each option has an optimum year of completion which delivers the most benefit for the GB consumer under each energy scenario. If an option's optimum delivery date is the same as its EISD then it is considered a critical option because a decision must be made this year. If the optimum delivery date is later than the EISD in all scenarios and sensitivities then no decision is required this year and the decision can be delayed to when we will have more information.

This section lists all the options and their recommended delivery dates, as well as highlighting those which are critical.

2. Critical options' least regret analysis
All critical options must have a recommendation made this year and so advance onto our single year least regret analysis. This measures and compares the regret associated with proceeding each critical option by one year against the regret of delaying it. If a region has multiple critical options then we compare the regret associated with delivering different combinations of critical options. For each region, we will always recommend the option, or combination of options, that minimises the levels of regret across all four energy scenarios plus any sensitivities. If an option is being driven by a single scenario then we will investigate the drivers behind that option further to ensure that the right decision really is being made.

Investment recommendations

3. Recommendation for each option
Following the single year least regret analysis, we will be in a position to make a recommendation for each option. All options will be allocated to one of the following outcomes:

Do not proceed: This option is not optimal at this time.

No decision required: The option is not critical this year and so a decision is not yet required. A recommendation can be made in later years when we will have more information.

Delay: It is no longer economic to deliver this option by its EISD. Any work in progress should be suspended to delay the delivery of this option by one year.

Proceed: Work should continue or commence in order to maintain the EISD.

As our energy landscape is changing, our recommendations for an option may adapt accordingly. This means that an option that we recommended to proceed last year may be recommended to be delayed this year and vice versa. The robustness of the single year least regret analysis is that an ongoing project is reevaluated each year to ensure that its planned completion date remains best for the consumer.

Stakeholder engagement

Please give us your views on the single year least regret process and ways to improve it.

Local Contracted and No Local Contracted

As well as our four future energy scenarios, we also analyse an option's performance under two of our additional sensitivities: 'Local Contracted' and 'No Local Contracted'. The 'Local Contracted' scenario considers if every single customer were to have connected by their connection date, and 'No Local Contracted' sensitivity considers if none of our customers were to have connected by their connection dates. Our 'Scotland and the North' region is geographically very large and has a number of customers due to connect which means neither of these sensitivities are credible for the whole region. You will see both sensitivities considered in our other regions which are small enough for them to be credible. Although not credible for the whole region, there are some areas within the 'Scotland and the North' region with sufficiently little generation diversity to justify these sensitivities and they are discussed after Table 5.1.

5.2
Recommended delivery dates

This section lists all the options that are seen to be optimal at this time and their recommended delivery dates as well as highlighting those which are critical.

Tables 5.1 to 5.5 show the optimal delivery date for each option before the next stage of analysis. Options whose optimum delivery date is the same as their EISD are considered critical options as a decision must be made this year. Critical options are in **bold**.

Some options are marked as ‘N/A’ as they are not optimal under that particular scenario or sensitivity. We found 32 options which were not optimal under any of the scenarios at this time and are therefore not included in the table. However, they are available to view in our final tables 5.9 to 5.12 with the recommendation ‘Do Not Proceed’ and their descriptions can be found in Chapter 4 – Proposed options.

Table 5.1
Scotland and the North region

Option name and code	EISD	Optimum Delivery Date			
		Gone Green	Consumer Power	Slow Progression	No Progression
Reactive compensation at Tummel and Melgarve (TMRC)	2021	2028	2029	2034	N/A
East Coast onshore 275kV upgrade (ECU2)	2022	2024	2023	2024	2025
East Coast onshore 400kV incremental reinforcement (ECUP)	2027	N/A	N/A	2034	N/A
Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)	**2024**	**2024**	**2024**	**2024**	2026
Windyhill to Lambhill to Longannet 275kV circuit turn in to Denny North 275kV substation (WLTI)	2020	2024	2023	2024	2025
Denny to Wishaw 400kV reinforcement (DWNO)	2027	N/A	N/A	2029	N/A
Eastern subsea HVDC Link from Torness to Hawthorn Pit (E2DC)	**2024**	**2024**	N/A	N/A	N/A
Torness to North East England AC reinforcement (TLNO)	**2028**	N/A	N/A	**2028**	N/A
Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit (WHTI)	**2020**	**2020**	**2020**	**2020**	**2020**
Reconductor Lackenby to Norton single 400kV circuit (LNRE)	**2022**	**2022**	**2022**	N/A	N/A
Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit (NOR1)	**2022**	2025	2023	**2022**	2026
Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit (NOR2)	2019	2020	2023	2025	2026

Chapter five

Investment recommendations

Table 5.1 continued
Scotland and the North region

Option name and code	EISD	Optimum Delivery Date			
		Gone Green	Consumer Power	Slow Progression	No Progression
Norton to Osbaldwick 400kV double circuit – reconductor full length of circuits (NOR3)	2021	2026	N/A	2028	N/A
New east–west circuit between the north east and Lancashire (HPNO)	2026	2027	N/A	N/A	N/A
New east–west circuit between the north east and Lancashire (NPNO)	2026	N/A	2032	N/A	N/A
Lister Drive quad booster (LDQB)	**2020**	**2020**	**2020**	**2020**	2021
Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV (MRUP)	**2023**	**2023**	**2023**	**2023**	2026
Central Yorkshire reinforcement (OENO)	**2024**	**2024**	2025	**2024**	**2024**
Install series reactors at Thornton (THS1)	2021	2022	2022	2022	N/A
Install series reactors at Thornton (THS2)	2021	N/A	N/A	N/A	2022
Western HVDC Link fast de-load scheme (WEOS)	2019	2023	2025	2025	2024
Treuddyn Tee to Connah's Quay reconductoring (TCRE)	2020	2027	N/A	N/A	N/A
Treuddyn Tee to Legacy thermal upgrade (TLH1)	2020	2027	N/A	N/A	N/A

For 'Scotland and the North' region, there are nine critical options:

- Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC).
- Eastern subsea HVDC Link from Torness to Hawthorn Pit (E2DC).
- Torness to North East England AC reinforcement (TLNO).
- Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit (WHTI).
- Reconductor Lackenby to Norton single 400kV circuit (LNRE).
- Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit (NOR1)
- Lister Drive quad booster (LDQB).
- Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV (MRUP).
- Central Yorkshire reinforcement (OENO).

We considered Local Contracted and No Local Contracted sensitivities for the B0 and B2a boundaries as the generation diversity is small enough for these sensitivities to be credible. Our studies showed that further reinforcement across these boundaries was not optimum at this time.

Table 5.2
The East region

Option name and code	EISD	Optimum Delivery Date					
		Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted
225MVAr MSCs at Burwell Main (BMMS)	**2023**	2024	2028	2026	**2023**	**2023**	N/A
Reconductor Bramford to Norwich double circuit (NBRE)	2020	2025	2029	2027	N/A	2024	N/A
Reconductor remainder of Bramford to Braintree to Rayleigh route (BRRE)	2021	2026	2030	2032	N/A	2026	N/A
A new 400kV double circuit between Bramford and Twinstead (BTNO)	2023	2027	2035	2033	N/A	2027	N/A
Reconductor remainder of Rayleigh to Tilbury circuit (RTRE)	2019	2031	2035	2033	N/A	2031	N/A
Reconductor newly formed second Bramford to Braintree to Rayleigh Main circuit (following Bramford to Twinstead new double circuit) (RBRE)	2020	2031	2036	2034	N/A	2031	N/A
Reconductor newly formed second Bramford to Pelham circuit (following Bramford to Twinstead new double circuit) (PRRE)	2020	2031	2036	2034	N/A	2031	N/A
Uprate non-conductor components of Bramford to Pelham double circuit (following Bramford to Twinstead new double circuit) (BPEU)	2019	2031	2036	2034	N/A	2031	N/A
Reconductor remainder of Coryton South to Tilbury circuit (CTRE)	2019	2031	2036	2034	N/A	2031	N/A
Uprate non-conductor components of newly formed Bramford to Braintree to Rayleigh Main double circuit (following Bramford to Twinstead new double circuit) at Rayleigh Main (RMEU)	2019	2031	2036	2034	N/A	2031	N/A
South east to East Anglia HVDC link (SGDC)	2030	2032	N/A	N/A	N/A	2031	N/A

For the East region, there is one critical option:

- 225 MVAr MSCs at Burwell Main (BMMS).

Investment recommendations

The South region

We have studied the South region for two overall sensitivities that are 'import' and 'export'. When there are exports to continental Europe, the power transfer through and around London, combined with the demand, presents different issues from when there are imports from continental Europe. The *ETYS* carries more information on this topic on page 94. Table 5.4 assumes 100% exports but we have to consider tables 5.3 and 5.4 together to give a more accurate forecast.

Table 5.3
South Import

Option name and code	EISD	Optimum Delivery Date					
		Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted
South East coast reactive compensation (SCRC)	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**
Bolney and Ninfield additional reactive compensation (BNRC)	2021	2023	2023	2023	2023	2023	N/A
Reactive compensation protective switching scheme (SEEU)	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**
Lovedean to Ninfield thermal uprate (LNHW)	2019	2023	2023	2023	2023	2023	N/A
Fleet to Lovedean reconductoring (FLRE)	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**
Kemsley to Littlebrook circuits uprating (KLRE)	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**
Hinkley Point to Seabank new double circuit (HSNO)	2023	2026	2027	2031	2034	2024	N/A

Table 5.4
South Export

Option name and code	EISD	Optimum Delivery Date					
		Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted
South East coast reactive compensation (SCRC)	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**
Bolney and Ninfield additional reactive compensation (BNRC)	2021	2023	2023	2023	2023	2023	2023
Reactive compensation protective switching scheme (SEEU)	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**
Lovedean to Ninfield thermal uprate (LNHW)	2019	2023	2023	2023	2023	2023	2023
Fleet to Lovedean reconductoring (FLRE)	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**	**2020**
Kemsley to Littlebrook circuits uprating (KLRE)	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**	**2021**
Wymondley turn-in (WYTI)	**2020**	2029	2024	2030	**2020**	2029	2029
Wymondley quad boosters (WYQB)	2020	2030	2025	2031	2024	2030	2030
Willesden to Wimbledon 275kV cable Ealing diversion (WEC1)	2022	2030	2025	2031	2024	2030	2030
Hinkley Point to Seabank new double circuit (HSNO)	2023	2026	2027	2031	2034	2024	N/A

For the South region, there are five critical options:

- South East coast reactive compensation (SCRC).
- Reactive compensation protective switching scheme (SEEU).
- Fleet to Lovedean reconductoring (FLRE).
- Kemsley to Littlebrook circuits uprating (KLRE).
- Wymondley turn-in (WYTI).

Investment recommendations

Table 5.5
The West region

Option name and code	EISD	Optimum Delivery Date					
		Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted
Wylfa to Pentir second double circuit route (WPNO)	2024	2030	2030	2029	N/A	2025	N/A
Pentir to Trawsfynydd second circuit (PTNO)	2023	2028	2028	2027	N/A	2024	N/A
Pentir to Trawsfynydd 1 cable replacement – single core per phase (PTC1)	2022	2030	2030	2029	N/A	2025	N/A
Pentir to Trawsfynydd 1 and 2 cables – second core per phase and reconductor of an overhead line section on the existing Pentir to Trawsfynydd circuit (PTC2)	2021	2030	2030	2029	N/A	2025	N/A
Reconductor the Connah's Quay legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits (BCRE)	2020	2031	2031	2030	N/A	2026	N/A

For the West region, there are no critical options. The Local Contracted and No Local Contracted backgrounds were for the North Wales boundaries which are within the West region.

5.3
Critical options' least regret analysis

This section analyses the critical options in each region and compares their regret values across each scenario.

Economic regret

In economic analysis an option's 'regret' is defined as the difference in benefit for that option against the benefit of the best option for that scenario. Therefore in each scenario the best option will have a regret of zero, and the other options will have different levels of regret depending how they compare to the best option. We always choose the option with the least regret across all scenarios. For more information, please see Chapter 2 – Methodology.

For each region, there will be a combination of options which will be the most economic and efficient for the network. As there are a number of critical options that could be progressed this year, there are several combinations, one of which will have the lowest value of regret across the scenarios. The options that make up this combination will be recommended to proceed. The worst regret for each combination will be highlighted in bold and the combination with the smallest worst regret across the energy scenarios will be highlighted in green.

Scotland and the North region
This region has nine critical options that present 512 different possible combinations. The option 'Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit' (WHTI) has an optimum year of delivery that is the same as its EISD for all scenarios.

This means that there is no requirement to perform single year regret analysis for this option, as progressing it to maintain its EISD is the correct course of action under all scenarios. It's worth noting that WHTI is a modification of *NOA1*'s ELEU (Eastern Link onshore works) and has an earlier EISD.

Having taken account of WHTI, this leaves this region with eight critical options and therefore 256 different possible combinations:

- Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC).
- Eastern subsea HVDC Link from Torness to Hawthorn Pit (E2DC).
- Torness to North East England AC reinforcement (TLNO).
- Reconductor Lackenby to Norton single 400kV circuit (LNRE).
- Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit (NOR1).
- Lister Drive quad booster (LDQB).
- Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV (MRUP).
- Central Yorkshire reinforcement (OENO).

The SO performed the least regret analysis on all 256 combinations. Table 5.6 below shows the top performing combinations ranked (1) to (10). We've also shown the levels of regret if no options were to be progressed, ranked at position (241).

Investment recommendations

Table 5.6
Regrets for the Scotland and North region options

Combination	Gone Green	Consumer Power	Slow Progression	No Progression	Worst Regret
(1) Progress all critical options except LNRE	£2.6m	**£4.0m**	£0.6m	£3.5m	**£4.0m**
(2) Progress all critical options except LNRE and MRUP	**£7.4m**	£3.2m	£1.9m	£3.5m	**£7.4m**
(3) Progress all critical options except MRUP	£7.6m	**£8.9m**	£1.9m	£3.5m	**£8.9m**
(4) Progress all critical options	£2.8m	**£9.6m**	£0.6m	£3.5m	**£9.6m**
(5) Progress all critical options except NOR1	£2.8m	£9.6m	**£12.0m**	£3.5m	**£12.0m**
(6) Progress all critical options except NOR1 and MRUP	£7.6m	£8.9m	**£13.3m**	£3.5m	**£13.3m**
(7) Progress all critical options except LNRE and NOR1	£2.6m	**£15.7m**	£12.0m	£3.5m	**£15.7m**
(8) Progress all critical options except LNRE, NOR1 and MRUP	£7.4m	**£19.4m**	£13.3m	£3.5m	**£19.4m**
(9) Progress all critical options except LDQB, LNRE and MRUP	**£35.9m**	£22.3m	£28.1m	£3.5m	**£35.9m**
(10) Progress all critical options except LDQB and MRUP	**£36.2m**	£28.0m	£28.1m	£3.5m	**£36.2m**
(241) Progress no critical options	**£1200m**	£400m	£400m	£100m	**£1200m**

The least regret option is to progress all reinforcements in this region except LNRE but including WHTI. This includes the following options:

- E4DC to meet its EISD of 2024.
- E2DC to meet its EISD of 2024.
- TLNO to meet its EISD of 2028.
- NOR1 to meet its EISD of 2022.
- LDQB to meet its EISD of 2020.
- MRUP to meet its EISD of 2023.
- OENO to meet its EISD of 2024.

As well as enhancing north to south transfer capability across the network, each of the three options (E4DC, E2DC and TLNO) would provide benefits to security of supply in Scotland.

We recommend proceed for E4DC, E2DC and TLNO. E4DC is optimal under all four energy scenarios and so we recommend that it is taken forward to prepare an SWW needs case. Delivery of either E2DC or TLNO is optimal under **Gone Green** and **Slow Progression** respectively. Both have low front end costs and therefore risk is minimised by recommending both proceed this year. This allows either to be delivered in the future and the SWW study will draw a clear conclusion as to which is the best option to proceed with.

We also recommend NOR1, LDQB, MRUP and OENO to proceed. These options do not require an SWW needs case as they do not meet the SWW criteria.

Although NEEU is not recommended to proceed on its own for the local boundary B2a, it is an integral part of the E4DC option and therefore we recommend proceed for delivery in 2024.

In addition to the options above, we've also commented on the option below which was given a 'proceed' recommendation in *NOA* 2015/16.

- Western HVDC Link fast de-load scheme (WEOS).

WEOS was 'proceed' in last year's *NOA* however it is not a critical option in this year's *NOA*, and so we recommend the delivery to be delayed.

This option is no longer critical this year due to a change in generation background. This includes early closure of some generation in all scenarios and marks a significant change to the 2015 *FES* as well as delayed connection of others. WEOS is no longer critical as the main driver has either delayed or disappeared completely.

The East region

This region has only one critical option which presents two different possible courses of action – proceed with the option or do not proceed.

- 225MVAr MSCs at Burwell Main (BMMS).

Table 5.7
Regrets for the East region

	Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted	Worst Regret
Progress BMMS	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**
Do not Progress BMMS	£0.0m	£0.0m	£0.0m	£1.4m	**£190m**	£0.0m	**£190m**

BMMS has zero spend in its first year and therefore there is no regret in progressing this option. Therefore the SO recommends that option BMMS is proceeded to maintain its EISD of 2023.

The South region

The South region has five critical options that present 32 different possible combinations. For the following options, their optimum years of delivery are the same as their EISDs for all scenarios.

- South East coast reactive compensation (SCRC).
- Reactive compensation protective switching scheme (SEEU).
- Fleet to Lovedean reconductoring (FLRE).
- Kemsley to Littlebrook circuits uprating (KLRE).

This means that there is no requirement to perform single year regret analysis upon the above options, as progressing these options to maintain their EISD is the correct course of action under all scenarios. Therefore this region has only one critical option to be analysed which presents two different courses of action – proceed with the option or do not proceed.

- Wymondley turn-in (WYTI).

Investment recommendations

Table 5.8
Regrets for the South region

	Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted	Worst Regret
Progress WYTI	£0.6m	£0.3m	£0.7m	**£1.9m**	£0.6m	£0.6m	**£1.9m**
Do not Progress WYTI	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**	**£0.0m**

The least regret option is to delay Wymondley turn-in. Therefore the SO recommends that option WYTI is not progressed.

In addition to the critical options in the South region, the SO has analysed the Hinkley Point to Seabank new double circuit (HSNO). This reinforcement was considered critical in NOA 2015/16 and we recommended this project to proceed. For 2016/17 we continue to recommend proceeding with the SWW project based on the contracted connection date. This will determine the actual optimum date for the new double circuit.

The West region

This region has no critical options and therefore there are no necessary investment decisions to be made this year.

5.4
Recommendation for each option

This section presents the recommendation for each option based upon how the options have performed in the economic analysis.

In addition, we present the recommendation from last year's *NOA* for comparison and give an indication whether an option could be an SWW.

Table 5.9
Scotland and the North region

Option name	Potential SWW?	*NOA* 2015/16 Recommendation	*NOA* 2016/17 Recommendation
Beauly to Shin to Loch Buidhe 132kV double circuit reconductoring (BLR1)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Beauly to Fyrish 275kV double circuit reconductoring and generation connection reconfiguration (FBRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Beauly to Loch Buidhe 275kV double circuit reconductoring and generation connection reconfiguration (BLR2)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Beauly to Loch Buidhe and Loch Buidhe to Dounreay 275kV double circuit reconductoring (BDRE)	Yes	Not featured in *NOA* 2015/16	**Do not proceed**
New Beauly to Loch Buidhe 275kV double circuit (BLN2)	Yes	Do not proceed	**Do not proceed**
Reactive compensation at Tummel (TURC)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Reactive compensation at Tummel and Melgarve (TMRC)	Yes	Not featured in *NOA* 2015/16	**No decision required**
Reactive compensation at Tummel and Melgarve and inter-bus Transformers at Fort Augustus (B1RC)	Yes	Not featured in *NOA* 2015/16	**Do not proceed**
New Beauly to Kintore 400kV double circuit (BKNO)	Yes	Do not proceed	**Do not proceed**
New Beauly to Blackhillock 400kV double circuit (BBNO)	Yes	Delay	**Do not proceed**
New 275kV phase shifting transformers at Blackhillock on the circuits from Knocknagael (BLQB)	No	Not featured in *NOA* 2015/16	**Do not proceed**
North east 400kV and 275kV network reinforcement (NEEU)	Yes	Not featured in *NOA* 2015/16	**Do not proceed**
Rothienorman substation with reconductoring of the 275kV Rothienorman to Kintore circuit (RKEU)	Yes	Not featured in *NOA* 2015/16	**Do not proceed**
East Coast onshore 275kV upgrade (ECU2)	Yes	No decision required	**No decision required**
East Coast onshore 400kV incremental reinforcement (ECUP)	Yes	Not featured in *NOA* 2015/16	**No decision required**
East Coast onshore 400kV reinforcement (ECU4)	Yes	Do not proceed	**Do not proceed**
Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)	Yes	Proceed	**Proceed**
Windyhill to Lambhill to Longannet 275kV circuit turn in to Denny North 275kV substation (WLTI)	No	Not featured in *NOA* 2015/16	**No decision required**
Denny to Wishaw 400kV reinforcement (DWNO)	No	Do not proceed	**No decision required**

Investment recommendations

Table 5.9 continued
Scotland and the North region

Option name	Potential SWW?	*NOA* 2015/16 Recommendation	*NOA* 2016/17 Recommendation
Eastern subsea HVDC Link from Torness to Hawthorn Pit (E2DC)	Yes	No decision required	**Proceed**
Torness to North East England AC reinforcement (TLNO)	Yes	No decision required	**Proceed**
Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit (WHTI)	No	Proceed (was previously referred to as ELEU)	**Proceed**
Deploy FACTS device on West Boldon to Offerton circuit (WOSR)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Install quad booster in West Boldon to Offerton circuit (WBQB)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Harker SuperGrid Transformer 6 replacement (HAEU)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Reconductor Lackenby to Norton single 400kV circuit (LNRE)	No	No Decision Required	**Delay**
Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit (NOR1)	No	No Decision Required	**Proceed**
Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit (NOR2)	No	Not featured in *NOA* 2015/16	**No decision required**
Norton to Osbaldwick 400kV double circuit – reconductor the rest of the circuits (NOR3)	No	Not featured in *NOA* 2015/16	**No decision required**
Thermal uprate 55km of the Norton to Osbaldwick 400kV double circuit (NOHW)	No	Not featured in *NOA* 2015/16	**Do not proceed**
New east–west circuit between Hawthorn Pit and Padiham (HPNO)	Yes	Not featured in *NOA* 2015/16	**No decision required**
New east–west circuit between Norton and Padiham (NPNO)	Yes	No decision required	**No decision required**
Lackenby to Thornton double circuit – uprate cable and thermal uprate overhead line sections (LTR1)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Lackenby to Thornton double circuit – uprate cable section and reconductor sections (LTR2)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Osbaldwick to Thornton 1 circuit thermal upgrade (OTHW)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Lister Drive quad booster (LDQB)	No	No Decision Required	**Proceed**
Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV (MRUP)	No	Not featured in *NOA* 2015/16	**Proceed**
Central Yorkshire reinforcement (OENO)	No	Not featured in *NOA* 2015/16	**Proceed**
Install series reactors at Thornton (THS1/THS2)	No	Do not proceed (previously a combined option THSR)	**No decision required**
Reconductor Drax to Thornton double circuit (TDRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Reconductor Garforth Tee to Keadby leg of the Creyke Beck to Keadby to Killingholme Circuit (GKRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Drax to Eggborough 1 circuit – reconductor and replace cable section (DERE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Generator circuit breaker replacement to allow Thornton to run two-way split (DREU)	No	Not featured in *NOA* 2015/16	**Do not proceed**
West Burton to High Marnham circuit – complete gantry works to match circuit rating (WHRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Reconductor the Keadby to Cottam 400kV double circuit (KCRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Western HVDC Link fast de-load scheme (WEOS)	No	Proceed	**Delay**
Treuddyn Tee to Connah's Quay reconductoring (TCRE)	No	Not featured in *NOA* 2015/16	**No decision required**
Treuddyn Tee to Legacy thermal upgrade (TLH1)	No	Do not proceed	**No decision required**

Table 5.10
The East region

Option name	Potential SWW?	*NOA* 2015/16 Recommendation	*NOA* 2016/17 Recommendation
225MVAr MSCs at Burwell Main (BMMS)	No	No decision required	**Proceed**
Reconductor remainder of Bramford to Braintree to Rayleigh route (BRRE)	No	Not featured in *NOA* 2015/16	**No decision required**
Reconductor Bramford to Norwich double circuit (NBRE)	No	Delay	**No decision required**
A new 400kV double circuit between Bramford and Twinstead (BTNO)	No	Delay	**No decision required**
Reconductor remainder of Coryton South to Tilbury circuit (CTRE)	No	Delay	**No decision required**
Reconductor remainder of Rayleigh to Tilbury circuit (RTRE)	No	Delay	**No decision required**
Reconductor newly formed second Bramford to Braintree to Rayleigh Main circuit (RBRE)	No	Not featured in *NOA* 2015/16	**No decision required**
Reconductor newly formed second Bramford to Pelham circuit (PRRE)	No	Not featured in *NOA* 2015/16	**No decision required**
Uprate non-conductor components of Bramford to Pelham double circuit (BPEU)	No	Not featured in *NOA* 2015/16	**No decision required**
Uprate non-conductor components of newly formed Bramford to Braintree to Rayleigh Main double circuit (RMEU)	No	Not featured in *NOA* 2015/16	**No decision required**
South east to East Anglia HVDC link (SGDC)	Yes	Not featured in *NOA* 2015/16	**No decision required**

Table 5.11
The South region

Option name	Potential SWW?	*NOA* 2015/16 Recommendation	*NOA* 2016/17 Recommendation
Bramley to Fleet circuits thermal uprating (BFHW)	No	Not featured in *NOA* 2015/16	**Do not proceed**
South East coast reactive compensation (SCRC)	No	Proceed (previously called SCVC)	**Proceed**
Bolney and Ninfield additional reactive compensation (BNRC)	No	Not featured in *NOA* 2015/16	**No decision required**
Reactive compensation protective switching scheme (SEEU)	No	Not featured in *NOA* 2015/16	**Proceed**
Lovedean to Ninfield thermal uprate (LNHW)	No	Not featured in *NOA* 2015/16	**No decision required**
New 400kV transmission route between South London and the south coast (SCN1/SCN2/SCN3)	No	Do not proceed	**Do not proceed**
Fleet to Lovedean reconductoring (FLRE)	No	Proceed	**Proceed**
Kemsley to Littlebrook circuits uprating (KLRE)	No	Proceed	**Proceed**
Hinkley Point to Seabank new double circuit (HSNO)	Yes	Proceed	**Proceed**
Reconductor Hinkley Point to Taunton double circuit (THRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Alverdiscott to Taunton double circuit thermal uprating (ATHW)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Wymondley turn-in (WYTI)	No	Delay	**Delay**
Wymondley quad boosters (WYQB)	No	Delay	**No decision required**
Willesden to Wimbledon 275kV cable Ealing diversion (WEC1)	No	No decision required	**No decision required**

Investment recommendations

Table 5.12
The West region

Option name	Potential SWW?	*NOA* 2015/16 Recommendation	*NOA* 2016/17 Recommendation
Wylfa to Pentir second double circuit route (WPNO)	No	Delay but local conditions mean proceed	**Proceed to meet customer agreement**
North Wales to South Wales HVDC Link (WPDC)	Yes	Do not proceed	**Do not proceed**
Severn Tunnel 400kV cable circuit uprate (SEC1)	No	Do not proceed	**Do not proceed**
Reconductor the Connah's Quay legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits (BCRE)	No	Do not proceed (was part of combined option CPRE)	**No decision required**
Reconductor Pentir legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits (PBRE)	No	Do not proceed (was part of combined option CPRE)	**Do not proceed**
Pentir to Trawsfynydd second circuit (PTNO)	No	Delay	**No decision required**
Pentir to Trawsfynydd 1 cable replacement – single core per phase (PTC1)	No	No decision required	**No decision required**
Pentir to Trawsfynydd 1 and 2 cables – second core per phase and reconductor of an overhead line section on the existing Pentir to Trawsfynydd circuit (PTC2)	No	No decision required	**No decision required**
Pentir to Trawsfynydd circuits – reconductor the remaining overhead line sections (PTRE)	No	Not featured in *NOA* 2015/16	**Do not proceed**
Cowley to Minety and Cowley to Walham cables (Hinksey cables) upgrade (HCC1)	No	Do not proceed	**Do not proceed**
Pembroke to Walham circuit turn-in to Swansea North (PWTI)	No	Do not proceed	**Do not proceed**
Quad booster installation at Cilfynydd (CIQB)	No	Do not proceed	**Do not proceed**

5.5
Onshore competition

This section considers the options' eligibility for onshore competition.

Overview
Through the Extending Competition in Electricity Transmission (ECIT) project, we are working with Ofgem to increase the role of competitive tendering where this can bring value to consumers. We will identify those onshore options which could be competitively tendered to a CATO (Competitively Appointed Transmission Owner) who would be responsible for delivering the option.

Ofgem published a consultation on proposed arrangements for competitive onshore tendering in October 2015. Arrangements for the competitive onshore regime were further developed in the consultation published on 27 May 2016 and then the 'ECIT: Decision on criteria, pre-tender and conflict mitigation arrangements' published in November 2016. You can find this document on the Ofgem website **https://www.ofgem.gov.uk/publications-and-updates/extending-competition-electricity-transmission-decision-criteria-pre-tender-and-conflict-mitigation-arrangements**. This is with a view to being ready to run competitive tenders in 2018.

However, not all options are suitable for competition. Ofgem proposed three criteria as indicators that an option is eligible for onshore competition. The option must fulfil all criteria in order to be considered.

- The option must be **new** which means that it proposes completely new transmission assets or a complete replacement of transmission assets.
- The option must be **separable** which means that ownership between these assets and other (existing) assets can be clearly delineated.
- The option must be **high value** which means that its expected capital of the new assets is £100 million or more.

EISDs have not been adjusted to account for any time that tendering might take.

Investment recommendations

Eligibility analysis

To assess whether the option meets the 'new' criterion, we test the options against whether they involve the implementation of completely new assets or the replacement of existing assets.

To assess whether the option meets the 'separable' criterion, we test the options against whether the new assets can be clearly delineated from existing assets.

To assess whether the option meets the 'high value' criterion we assess whether the capex for the assets which meet the new and separable criteria is £100 million or more. We use the costs that the TO(s) have provided, which were previously scrutinised.

The following projects meet the above criteria – as per Chapter 2, not all of these provide boundary capability, but still meet the requirements of an SWW project:

- Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC).
- Eastern subsea HVDC Link from Torness to Hawthorn Pit (E2DC).
- Torness to North East England AC reinforcement (TLNO).
- Central Yorkshire reinforcement (OENO).
- Orkney link.
- Western Isles link.
- Shetland link.
- Hinkley to Seabank (HSNO).
- NW Coast Connection (Moorside).

An SWW needs case might cover multiple options where there are alternatives or because options work in combination.

Table 5.13 shows the number of projects that have been recommended as 'proceed' in this year's *NOA* in each of several cost bands. The bands are intended to give an idea of the value of projects.

Table 5.13
The number of 'proceed' projects in their cost bands

Cost band	Number of projects
£100m to £1000m	4
£1000m to £2000m	1
More than £2000m	0

Chapter six

Interconnection analysis

6.1
Introduction

Chapter 6 presents our interconnection analysis from our pan-European market modelling. The output from this analysis aims to facilitate the development of interconnector capacity as part of an efficient, coordinated and economical system of electricity transmission.

This is a market-based analysis and does not consider risk or challenges of project delivery nor power system impacts on the onshore networks.

Key statistics

- Under all scenarios, the GB consumer can benefit from more interconnection to European markets beyond the Cap and Floor window 1 projects. However, interconnection is most beneficial under **Gone Green**.
- Interconnection delivered in earlier years provides greater lifetime benefit than if it were to be delivered in later years. Icelandic, Irish and Danish markets provide the greatest opportunity for both GB and European consumers.
- Under all scenarios, Europe and GB would benefit economically and environmentally from increased interconnection.

In order to improve information to the industry, we have developed our methodology for interconnection analysis to be more ambitious and insightful than before.

This year we developed the way we assess European interconnection by providing our view of the European markets, capacity and timing of additional future interconnection. This assessment provides the most benefit to the GB consumer under each energy scenario. This analysis is undertaken to inform the industry of the potential benefits of future interconnection.

This interconnection analysis is a parallel process to onshore investments (presented in Chapter 5 – Investment recommendations). These two sets of analysis remain independent and uninfluenced by the other. The interconnection analysis provides a view from the market perspective and is not designed to provide onshore investment considerations.

This chapter gives a summary of the methodology employed and the results of our analysis. You can find full details of the methodology in the methodology document which is available on the *NOA* website.

www2.nationalgrid.com
> UK Sites > Industry Information (more information) > Future of Energy > Network Options Assessment

6.2
Interconnection theory

Electricity interconnectors are the physical connections between transmission networks allowing the transfer of electricity across nations. Currently GB has ~4 GW of interconnection with European markets however, through our *FES* 2016, we see an increase to between 9.6 GW in **No Progression** and 20.1 GW in **Consumer Power** by 2025. Ofgem's Cap and Floor window 1 would take this total to 11.3 GW by 2022.

This increase in interconnection can deliver benefits to the industry and consumer in several ways:
- Greater security of supply – the physical connection across borders allows both markets greater access to generation to secure their nation's energy needs.
- Greater access to renewable energy – the increased access to generation delivers additional benefit as it allows increased exploitation of intermittent renewable generation. This will consequently displace domestic non-renewable sources.
- Increased competition – the increased access to cheaper generation and more consumers increases competition and allows participants in both markets to enjoy financial benefits. These financial benefits are measured as Socio-Economic Welfare.

'Socio-Economic Welfare' (SEW) is a term which captures the financial benefits and detriments seen by market participants as a result of increased interconnection. Increased SEW is primarily attained through the following:
- The reduced price for consumers in the higher priced market as their suppliers have increased access to cheap renewable generation.
- The increased revenue for generators in the lower priced market who now enjoy access to more customers.
- The created revenue for interconnector businesses who sell capacity across their interconnectors.

In turn, SEW must also capture the detriments that some market participants will face which is usually brought about through the following means:
- The reduced revenue for generators in the higher priced market who are competing against cheaper overseas generation.
- The increased price for consumers in the cheaper market as they share their access to cheaper generation with more consumers.

The increase in SEW must also be balanced against the capital costs of the delivery of the increased interconnection capacity. As capacity is increased between two suitable markets and SEW is consequently gained, the prices between the two markets begin to converge. Upon further interconnection, the market prices continue to converge until further interconnection brings no benefit. We then consider the interconnection capacity as 'optimised' as the benefits derived from interconnection are at a maximum.

Interconnection analysis

6.3
Current and potential interconnection

As identified by *FES* 2016 and *ETYS* 2016, the total interconnector capacity from *FES* 2016 has increased compared with *FES* 2015. This is due to greater regulatory certainty as a result of Ofgem's Cap and Floor regime. The *FES* 2016 also suggests that we may see connection to more countries than before, through a diverse spread of connection points.

If you want to find out more about Ofgem's Cap and Floor regime then visit their website.

www.Ofgem.gov.uk
> Electricity > Transmission Networks> Electricity Interconnectors

https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors

Table 6.1 below shows the current and planned interconnection levels which have formed this study's base interconnection capacity, all assumed to be connected by 2022. The table does not include any planned interconnection going through Ofgem's second Cap and Floor regime, but includes mature projects with varying degrees of regulatory approval including acceptance under Ofgem's first Cap and Floor window. If all these projects do successfully connect on time, this will represent a substantial increase in interconnection over the next six years.

Table 6.1
Current interconnection capacities and 2022 base case

	Belgium	Denmark	France	Germany	Iceland	Ireland	Netherlands	Norway	Spain	Total
2016 Capacity (GW)	0	0	2	0	0	1	1	0	0	**4**
2022 Base Case (GW)	1	1	5.4	0	0	1.5	1	1.4	0	**11.3**

6.4
Methodology

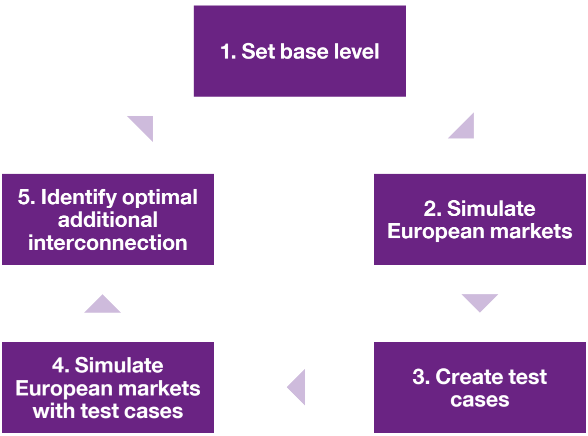
The interconnection analysis aims to identify the optimal interconnection across the nine European markets featured in Table 6.1 for a selection of study years. The choice of markets and study years were defined during the development of the methodology, which remains available on the *NOA* website, where you can find further detail on the methodology and the rationale behind the approach taken.

www2.nationalgrid.com
> UK Sites > Industry Information (more information) > Future of Energy > Network Options Assessment

For each of the energy scenarios, we optimised the GB interconnection levels using market studies within our electricity market modelling software BID3. This produced four pictures of the optimal level of interconnection. The market study involved a step-by-step process where the market was modelled with a base level of interconnection, including the current interconnection levels and mature projects totalling 11.3GW. An iterative process then directed where the additional interconnection should be implemented. This is described in Figure 6.1.

www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=8589936185

Figure 6.1
Iterative process for Interconnection Optimisation



Interconnection analysis

1. Set base level

The base level of interconnection was the total capacity GB has with each of the nine studied markets at the start of the iteration. The year of connection was also taken into account, such that the levels of interconnection per market were described out to 2036. In the first iteration, the base level was defined as specified in section 6.3 from 2022 onwards.

2. Simulate European markets

The base level of interconnection was implemented in a model of the European electricity markets, and then simulated. The SEW associated with this base was measured.

3. Create test cases

To test the impact of additional capacity for each market, 500 MW of interconnection was added in each of the four spot years, creating four test cases per market, and a total of thirty-six test cases for the nine markets.

4. Simulate European markets with test cases

The test cases were each implemented in a model of the European electricity markets, and then simulated. The SEW associated with this test was measured.

5. Identify optimal additional interconnection

For each test case, the SEW increase compared to the base case was calculated, as was the estimated cost of construction for the 500 MW of capacity introduced in the test case. The test case that resulted in the largest SEW increase was deemed optimal. The test case corresponded directly with a 500 MW of additional capacity to a particular market in a particular year. This then formed the base case for the next iteration.

When the base case showed more SEW than any test case, the base was considered optimal and optimisation process completed.

Estimation of construction costs

This study was driven by wholesale price differentials and offshore construction costs only. Possible physical landing points were approximated to allow an estimation of the CAPEX. The capital costs were derived from a publicly available ACER document[1], based on surveys carried out on a range of European projects, and approximations of median possible cable lengths.

[1] http://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/UIC%20Report%20%20-%20Electricity%20 infrastructure.pdf

6.5
Outcome

The market studies undertaken generated SEW for each of the test and base cases analysed. This section presents where future interconnection was a benefit to the GB consumer, and to Europe as a whole.

The output is presented in three parts:
1. Optimal Path for European SEW.
2. GB consumer benefit.
3. Benefits of overall increase in interconnection.

6.5.1
Optimal path for European SEW

This section explores the optimal creation of European SEW through the development of interconnection against each of the scenarios. The final result describes the markets to connect to, and the years to connect in, in order to maximise SEW.

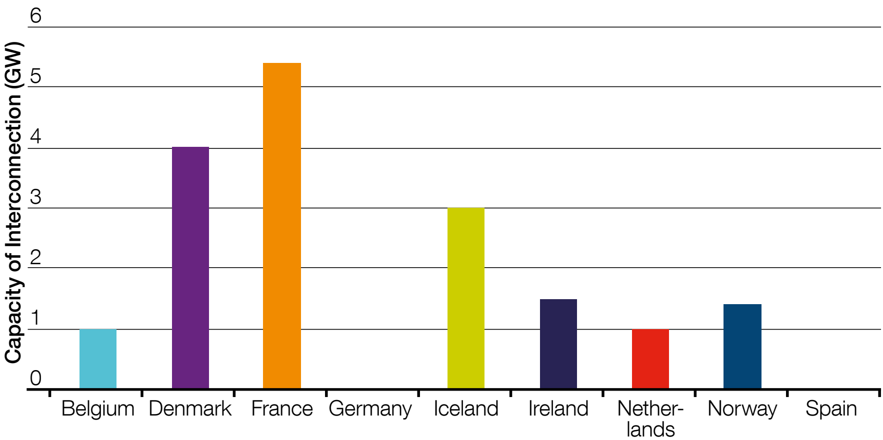
The methodology for defining an optimal interconnection development path chosen defines how the results should be interpreted:

- Projects to markets that are not in the optimal paths may well be beneficial, but simply not the most beneficial under the assumptions made in this study.
- There is more SEW to be captured by an increased level of interconnection above the base levels assumed (presented in Table 6.2), but the SEW reduces as interconnection increases by between 3.5GW and 6GW above the base levels.
- Different scenarios cause different markets to be more or less attractive. This means there is uncertainty as to where the best opportunities lie, driven by uncertainty in the future market conditions.
- The optimal build up from the market perspective is not a forecast; many other factors will also influence the true picture for interconnection that emerges in the coming years.
- Network and construction constraints have an important and substantial impact on the attractiveness of projects, but these are out of scope for this study.
- The optimal path followed is the most efficient way to optimise interconnection. Other pathways could result in a higher total level of interconnection, generating similar levels of SEW.

The starting interconnection capacities presented in Table 6.1 are based on projects aiming to connect by 2022. These have regulatory arrangements in place that represent a high level of maturity. This represents a much higher level than is currently connected, which causes considerable price convergence between GB and mainland Europe as seen in the modelling. As the SEW generated by additional interconnection depends on the price difference between GB and European markets, the interconnectors which form the base case potentially diminish the level of additional SEW further interconnection can bring. Figure 6.2 presents the optimal level of interconnection for Gone Green to each European market.

Interconnection analysis

Figure 6.2
Optimal level of interconnection under ***Gone Green***



The capacity and timing of the additional interconnection in each of the four optimal paths is shown in Table 6.2.

Table 6.2
Most efficient path to optimal interconnection per market

	Market	2022/23	2025/26	2027/28	2030/31	Total
Gone Green	Denmark	0	0	0	+ 3GW	**+ 3GW**
Slow Progression						
No Progression						
Consumer Power						
Gone Green	Iceland	+ 2GW	+ 0.5GW	0	+ 0.5GW	**+ 3GW**
Slow Progression		+ 1.5GW	+ 1GW	0	+ 0.5GW	**+ 3GW**
No Progression		0	0	+ 2GW	+ 0.5GW	**+ 2.5GW**
Consumer Power		+ 1.5GW	+ 1GW	0	+ 0.5GW	**+ 3GW**
Gone Green	Ireland					
Slow Progression		+ 0.5GW	0	0	0	**+ 0.5GW**
No Progression		0	0	0	+ 2GW	**+ 2GW**
Consumer Power		0	0	0	+ 1GW	**+ 1GW**

The four scenarios all showed possible welfare benefits from an increase in capacity above the 11.3GW base level for 2022. **Slow Progression** drove the smallest interconnection optimising at 14.8GW and **Gone Green** optimising at 17.3GW.

The optimisation analysis has resulted in a clear indication that Iceland would be the most beneficial market for increased interconnection. The effective wholesale price of electricity is very low in Iceland, due to plentiful renewable generation. This implies large price arbitrage opportunities will exist and be stable in the future, which could generate substantial welfare. Any such interconnection would result in an increased cost for Icelandic consumers; this study has not made any assumptions on how welfare may be redistributed to avoid excessive burdens on any particular group of market participants.

Under **Gone Green**, the Danish market has the lowest average price after the Icelandic interconnection is optimised. Denmark's future generation balance will include substantial renewables, having large wind and solar contributions. This leads to a fluctuating Danish price that can generate market price differences and flows in either direction between Denmark and GB. This is a possibility for multiple markets in the region; however Denmark–GB coupling proved most effective under this modelling.

The average Irish price is modelled as generally higher than GB. A second mechanism which generates welfare is the alleviation of Ireland's synchronous constraint, wherein there is an imposed limit on how much demand Irish wind can meet. These effects result in Ireland exports to Britain to avoid curtailing wind, and British flows to Ireland to exploit arbitrage; both sets of flows generate welfare.

Markets not selected by this methodology still showed welfare benefits outweighing estimated costs, however they did not form part of the optimal path, and as iterations increased potential benefits were diminished as prices throughout the region moved closer together due to higher levels of interconnection.

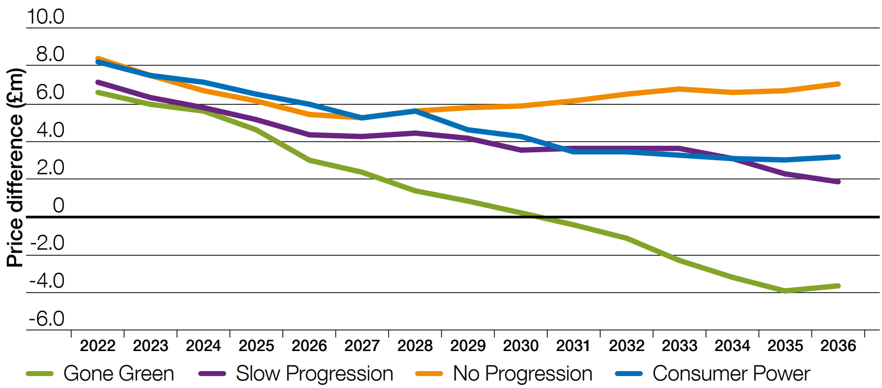
6.5.2 GB consumer benefit

The GB consumer stands to gain further from interconnection to cheaper wholesale markets beyond what is captured in the base case. The base case includes the interconnection currently operational and contracted – mostly under Ofgem's Cap and Floor window 1.

Benefit to the GB consumer is most prevalent under **No Progression** as GB can import cheap renewable energy. **Under No Progression, 500MW of interconnection to any of the nine studied European markets provides savings to the GB consumer**. Conversely under **Gone Green**, significant developments in domestic renewable generation would result in interconnection to other markets being substantially less beneficial to the GB consumer, but would instead benefit the connected market. Under **Gone Green**, only connection to the Icelandic market would bring reduced wholesale costs to the GB consumer.

Interconnection analysis

Figure 6.3
Average price difference between GB and European markets



Through the scenarios, benefits for GB consumers are most prevalent under **No Progression** where GB would benefit by importing large volumes of renewable power from European markets. These benefits sharply decline under **Gone Green** as GB's domestic renewable sources grow rapidly. Opportunities for interconnection in **Gone Green** rise again post-2030 as GB's domestic renewable supplies are sufficient to allow it to become an exporting market.

6.5.3
Benefits of overall increase in interconnection

The optimised paths bring significant benefit to GB and European consumers in terms of both cheaper wholesale energy and exploitation of renewable power under each of the four energy scenarios.

6.5.3.1 Overall impact on wholesale prices

The additional interconnection drives down the average European price. This is because of increased market access for cheap generation. The very cheap Icelandic generation is underused, due to low internal demand in Iceland. Upon connecting to GB, this generation can then displace expensive generation to drive down average prices in GB and the other markets forming the interconnected European network. Note that price difference in the short term has higher value; volatile prices can often drive more interconnector value as they present more opportunities to exploit price differences. Volatile prices are more likely to arise in future states with more intermittent renewable generation.

Table 6.3
Average reduction in wholesale energy prices for the European consumer

Average Price change across Europe per MWh	
Gone Green	-£0.76
Slow Progression	-£0.71
No Progression	-£0.32
Consumer Power	-£0.61

Table 6.4
Combined increases in welfare (including netting off Capex spend) for all years, all Europe

Impact on European Welfare	
Gone Green	£19bn
Slow Progression	£18bn
No Progression	£15bn
Consumer Power	£18bn

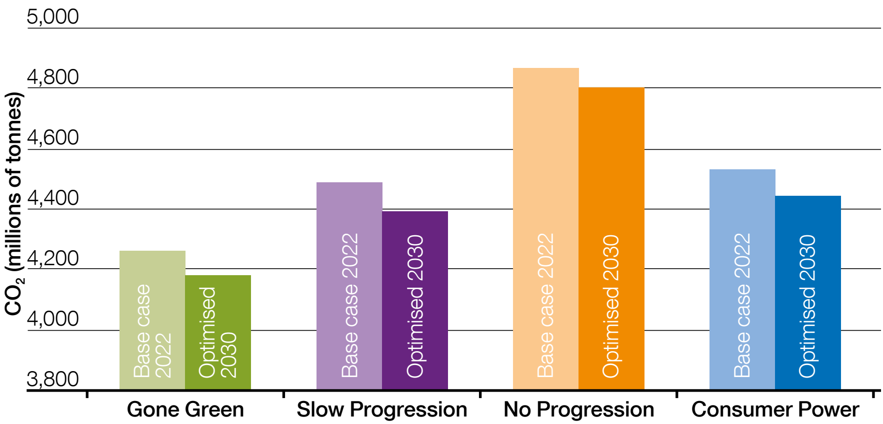
These price changes, combined with the different total demands behind each scenario, drive large overall European welfare as shown in Table 6.4.

6.5.3.2 Environmental implications

Interconnectors can increase access to renewable sources of power. Interconnection allows surplus power to be exported, rather than curtailed. This exported power can reduce or eliminate the need for more expensive-to-run technologies in other regions, which increasingly are those which employ fossil fuels. The model employed for the Interconnection analysis supports this argument; as interconnection levels are increased through the iterative process, there is a reduction in Europe-wide need to curtail clean sources of power, with a resultant drop in CO_2 output over the study window.

Interconnection analysis

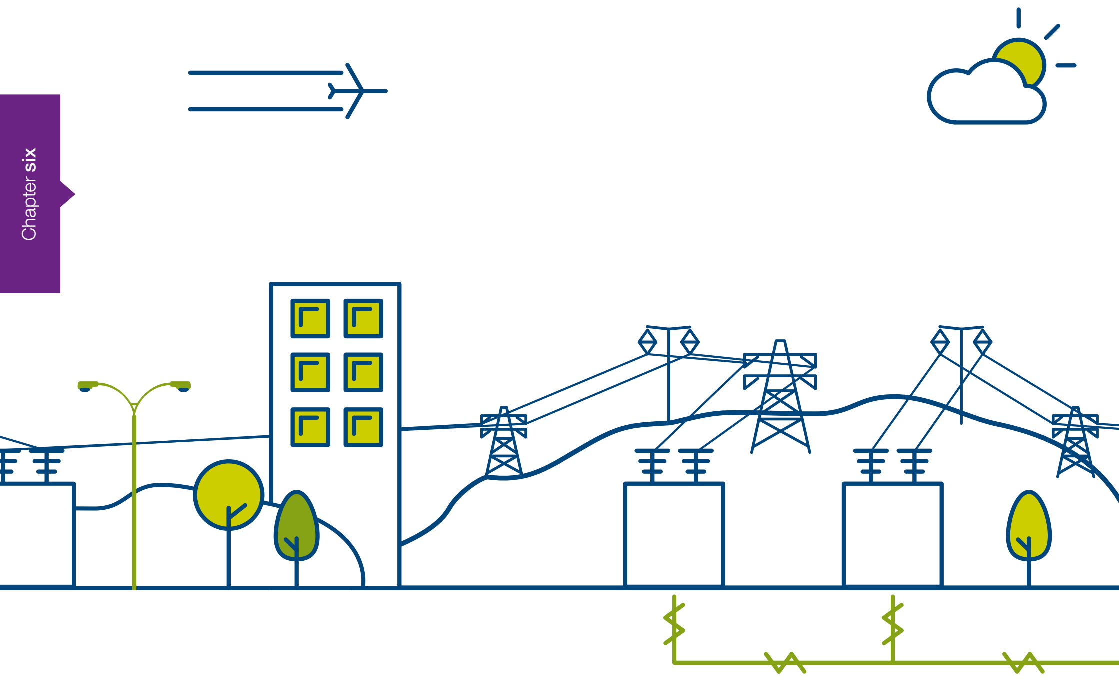
Figure 6.4
Reduction in CO_2 output under optimised path



6.6
Summary

Interconnection continues to present an opportunity for creating value for Europe and GB as a whole, by allowing for the more efficient dispatch of Europe's generation portfolio. This has the potential to lead to savings for consumers, extra profits for generators and a good business case for developers. However, by increasing competition and pulling market prices closer together, there can be a detriment to current market participants. The engineering complexity of subsea cables leads to a substantial cost of construction, which must be recoverable to support any such projects. Additionally the identification, design and construction of onshore reinforcements to facilitate interconnector flows adds another dimension of complexity and cost.

The market study showed that there are economic and environmental benefits yet to be unlocked through interconnection. The challenges that the physical network presents, the uncertainty in the future state of Europe's power markets, and interconnection's other avenues for creating value mean these outcomes do not present the complete picture, but it does suggest that it remains worthwhile to investigate opportunities to increase GB's interconnection portfolio.



Chapter seven

Stakeholder engagement

7.1 Introduction

We'd like your feedback and comments on this *NOA* publication and your help to improve it. Please take part in our 2017 stakeholder engagement programme so we know what you need.

7.2
Continuous development

Your feedback is an important part of the way we continue revising and developing the *NOA* and the *ETYS*. And because the two documents are closely related, we'll make sure that the way we communicate and consult with you reflects this.

We'll make sure the *NOA* publication continues to add value by:
- identifying and understanding our stakeholders' views and opinions
- providing opportunities for constructive debate throughout the process
- creating open and two-way communication with our stakeholders to discuss assumptions, drivers and outputs and
- telling you how your views have been considered and reporting on the engagement process.

The *NOA* annual review process will help us develop the publication. We'll encourage all interested parties to get involved, which will help us improve the publication every year.

After we published the first *NOA* in March 2016, we received some very helpful feedback. For example, you told us you wanted to see how the publication fits into the wider collection of SO publications. So, we developed a simple way to explain this, which you can find on pages 7–8. You also wanted us to explain more about the cost–benefit process in our methodology chapter. We have now made these changes and would like to hear more about how we can improve the *NOA* publication.

Stakeholder engagement

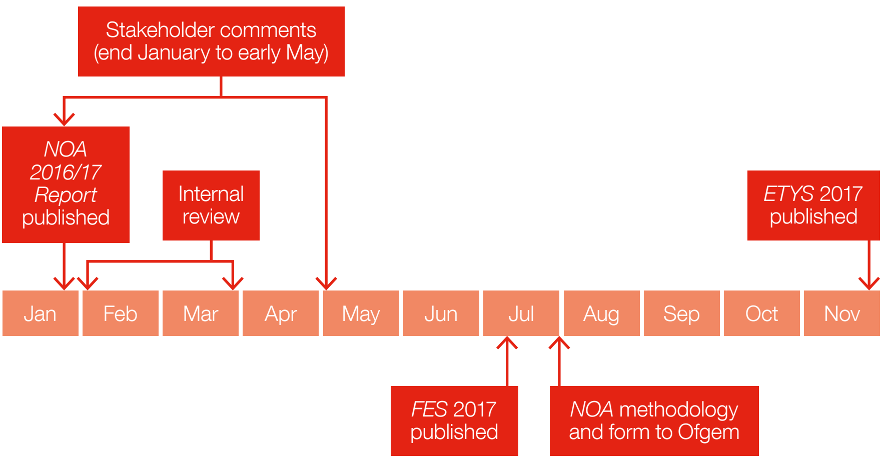
7.3
Stakeholder engagement

We are always happy to listen to your views:
- at consultation events as part of our customer seminars
- at operational forums
- through responses to **transmission.etys@nationalgrid.com**
- at bilateral stakeholder meetings and
- through any means most convenient for you.

Now that the *NOA* is published we'll start the review process and we are looking forward to having conversations with you from now to early May 2017. This consultation will centre around the methodology as well as the publication and its contents.

Where can we improve the *NOA* publication to meet your needs?

Figure 7.1
ETYS/NOA stakeholder activities programme



Chapter eight

Appendix A
SWW projects

8.1
Shetland Link

1. Background
Shetland possesses attractive renewable resources which have been targeted by developers seeking to invest in onshore wind projects. At present there is no connection between Shetland and the GB Main Interconnected Transmission System (MITS). There is a total of 488 MW generation connected and contracted for connection. This excludes 67 MW of diesel generation at Lerwick Power Station and 15 MW of export from the Sullom Voe Terminal. There are further interests from developers of renewable energy connection projects of up to 200 MW. As a consequence of these projects a link to the Scottish mainland will be required to facilitate export into the GB MITS.

2. Option development
A number of reinforcement options have been considered to provide transmission capacity between Shetland and the Scottish mainland in order to facilitate the connection of the island generation. The Shetland Link reinforcement would also help to improve the security of supply on the Shetland Islands. The factors taken into account in developing the options include:

- Corridor (the geographical route between Shetland and the MITS on the UK mainland).
- Technology (High Voltage Direct Current (HVDC) technology versus Alternating Current (AC) technology).
- Capacity (MW rating including the potential for future growth in renewables on the island).

Details of the options considered are given below.

2.1 Options
(a) Caithness–Shetland 600 MW HVDC Link, EISD: 2021

Construct a 278km, 600 MW Voltage Sourced Converter (VSC) HVDC connection between Shetland (at Kergord) and the Caithness–Moray HVDC link due to be completed in 2018 via the HVDC Switching Station at Noss Head (in Caithness) to form a three terminal HVDC scheme. The work includes a 132kV AC Gas Insulated Switchgear (GIS) substation and a 600 MW VSC HVDC converter at Kergord.

(b) Caithness–Shetland 450 MW HVDC Link, EISD: 2021

Construct a 278km, 450 MW VSC HVDC connection between Shetland (at Kergord) and the Caithness – Moray HVDC link due to be completed in 2018 via the HVDC Switching Station at Noss Head (in Caithness) to form a three terminal HVDC scheme. The work includes a 132kV AC GIS substation and a 450 MW VSC HVDC converter at Kergord.

(c) Shetland–Moray 600 MW HVDC Link, EISD: 2021

Construct a 343km, 600 MW VSC HVDC connection between Shetland (at Kergord) and the Blackhillock substation in Moray. The work includes a 132kV AC GIS substation and a 600 MW VSC HVDC converter at Kergord and a 600 MW converter at Blackhillock.

2.2 Lead option
Following an optioneering exercise that was undertaken to identify the most economic, efficient and coordinated option, the Caithness–Shetland 600MW HVDC Link option was identified as the lead option. This is because there are high wind load factors on Shetland and the 450MW HVDC Link option would leave too much generation being constrained when there is a large penetration of wind on the islands. The additional cost of the 600MW HVDC Link reinforcement is more than recovered by reductions in constraint costs under the high wind penetration scenario and therefore the 600MW HVDC Link is identified as the least worst regret option.

The optioneering work will need to be revisited when the conclusion of the UK Government Department for Business, Energy & Industrial Strategy (BEIS) consultation is known. This may result in an alternative least worst regret option.

2.3 Status
On 9 November 2016 BEIS published an industry consultation[1] on the future subsidy regime for onshore wind projects located on the Scottish islands. The consultation closes on 31 January 2017. Depending on the outcome of the consultation, the economic assessment carried out as part of the optioneering exercise may need to be revised accordingly.

The key project milestones will be reviewed and amended accordingly when the outcome of the consultation is known. To meet the current Shetland Link target completion date of 2021, it is expected that the Contracts for Difference (CfD) eligibility and application process would be completed by mid-2017 to allow approval of the Needs Case and Project Assessment during the third quarter of 2017. Construction work would be expected to start at the end of first quarter of 2018. Over the next six months the key activities include:
- Progression of key planning and consenting activities.
- Preparation of Needs Case and Project Assessment submissions.
- Continuation of stakeholder engagement.

[1] https://www.gov.uk/government/consultations/consultation-on-treatment-of-non-mainland-gb-onshore-wind-projects

Appendix A
SWW projects

8.2
Orkney Link

1. Background
Orkney possesses attractive renewable resources which have been targeted by developers seeking to invest, in particular marine and onshore wind projects. At present there are 2 x 33kV subsea cable connections with 23MVA firm capacity between Orkney and the GB Main Interconnected Transmission System (MITS). A total of 460 MW generation capacity is contracted for connection. In addition there are 324 MW of enquiries from embedded generators that Scottish Hydro Electric Power Distribution (SHEPD) is assessing.

As a consequence of these projects a higher capacity link to the Scottish mainland will be required to facilitate export into the GB MITS.

2. Option development
A number of reinforcement options have been considered to provide additional transmission capacity between Orkney and the Scottish mainland in order to facilitate the connection of the islands' generation. The Orkney Link reinforcement would also help to improve the security of power supply on the islands. The factors taken into account in developing the options include:

- Corridor (the geographical route between Orkney and the MITS on the UK mainland).
- Technology (High Voltage Direct Current (HVDC) technology versus Alternating Current (AC) technology).
- Capacity (MW rating including the potential for future growth in renewables on the islands).

Details of the options considered are given below.

2.1 Options
(a) Dounreay to Bay of Skaill Subsea Link, EISD: 2022

Install a 200 MW AC subsea cable approximately 70km between Dounreay and Bay of Skaill on the Orkney Islands. At Bay of Skaill the cable will interface with the local Orkney infrastructure via a new 132kV substation.

(b) Gills Bay to South Ronaldsay Subsea Link, EISD: 2022

Install a 220 MW AC subsea cable approximately 34km between the planned Gills Bay 132kV substation and South Ronaldsay on the Orkney Islands. At South Ronaldsay the cable will interface with the local Orkney infrastructure via a new 132kV substation.

(c) Dounreay to South Hoy Subsea Link, EISD: 2022

Install a 220 MW AC subsea cable approximately 40km between Dounreay and the south of Hoy on the Orkney Islands. At Hoy the cable will interface with the local Orkney infrastructure via a new 132kV substation.

(d) Dounreay to Bay of Skaill and Dounreay to South Hoy subsea links: 2022

Install a 200 MW AC subsea cable approximately 70km between Dounreay and Bay of Skaill and a 220 MW AC subsea cable approximately 40km between Dounreay and the south of Hoy on the Orkney Islands. At Bay of Skaill and Hoy the cables will interface with the local Orkney infrastructure via new 132kV substations.

An optioneering exercise is underway to identify the most economic, efficient and coordinated development option. The optioneering exercise considers the impact of the cable landing points on the island infrastructure. A cost–benefit analysis (CBA) will also be undertaken in line with the Western Isles and Shetland CBAs carried out by the SO to inform the preferred option.

2.2 Status

On the 9 November 2016 the BEIS published an industry consultation on the future subsidy regime for onshore wind projects located on the Scottish islands. The consultation[2] closes on 31 January 2017.

The CBA for the Orkney Link will take into account the outcome of the government consultation and the April 2017 CfD auction. The latter will inform the future volume of wave and tidal generation.

In order to meet the current Orkney Link target completion date of 2022, it is expected that the CfD eligibility and application process would be completed in 2017 to allow approval of the Needs Case and Project Assessment during 2019. Construction work would be expected to start in 2020. Over the next six months the key activities include:

- Conclusion of optioneering exercise.
- Commencement of key planning and consenting activities.
- Continuation of stakeholder engagement.

[2] https://www.gov.uk/government/consultations/consultation-on-treatment-of-non-mainland-gb-onshore-wind-projects

Appendix A
SWW projects

8.3
Western Isles Link

1. Background
The Western Isles possess attractive renewable resources which have been targeted by developers seeking to invest in onshore wind and marine generation projects. At present the existing Western Isles system operates with a restricted 132kV connection to the Scottish mainland[3]. A total generation capacity of 380MW is made up of generation either connected, under construction or contracted for connection.

As a consequence of these projects a higher capacity link to the Scottish mainland will be required to facilitate export into the GB Main Interconnected Transmission System (MITS).

2. Option development
A number of reinforcement options have been developed to provide additional transmission capacity between the Western Isles and the Scottish mainland in order to facilitate the connection of the island generation. The Western Isles Link reinforcement would also help to improve the security of supply on the Western Isles. The factors taken into account in developing the options include:
- Corridor (the geographical route between Western Isles and the MITS on the UK mainland).
- Technology (High Voltage Direct Current (HVDC) technology versus Alternating Current (AC) technology).
- Capacity (MW rating including the potential for future growth in renewables on the island).

Details of the options considered are given below.

2.1 Options
(a) Beauly–Dundonnell–Arnish 300MW HVDC Link, EISD: 2021
Construct a 300MW Voltage Sourced Converter (VSC) HVDC connection between Beauly on the Scottish mainland (located north west of Inverness) and Arnish on the east coast of the Isle of Lewis via Dundonnell on the west coast of Scotland. The circuit will be a mix of onshore (77km between Beauly and Dundonnell) and offshore (79km between Dundonnell and Arnish) cable. The 300MW converter stations will be located at Beauly and Arnish. At Beauly the circuit will interface with the GB MITS via a 400kV GIS substation. At Arnish the circuit will interface with the local Lewis infrastructure via a 132kV GIS substation.

(b) Beauly–Dundonnell–Arnish 450MW HVDC Link, EISD: 2021
Construct a 450MW Voltage Sourced Converter (VSC) HVDC connection between Beauly on the Scottish mainland (located north west of Inverness) and Arnish on the east coast of the Isle of Lewis via Dundonnell on the west coast of Scotland. The circuit will be a mix of onshore (77km between Beauly and Dundonnell) and offshore (79km between Dundonnell and Arnish) cable. The 450MW converter stations will be located at Beauly and Arnish. At Beauly the circuit will interface with the GB MITS via a 400kV GIS substation. At Arnish the circuit will interface with the local Lewis infrastructure via a 132kV GIS substation.

[3] Single circuit connection from Fort Augustus which includes a 33kV section between Ardmore – Harris.

(c) Beauly–Dundonnell–Arnish 600MW HVDC Link, EISD: 2021

Construct a 600MW Voltage Sourced Converter (VSC) HVDC connection between Beauly on the Scottish mainland (located north west of Inverness) and Arnish on the east coast of the Isle of Lewis via Dundonnell on the west coast of Scotland. The circuit will be a mix of onshore (77km between Beauly and Dundonnell) and offshore (79km between Dundonnell and Arnish) cable. The 600MW converter stations will be located at Beauly and Arnish. At Beauly the circuit will interface with the GB MITS via a 400kV GIS substation. At Arnish the circuit will interface with the local Lewis infrastructure via a 132kV GIS substation.

2.2 Lead option

An optioneering exercise was undertaken to identify the most economic, efficient and coordinated development option. Based on the latest analysis that is not yet completed, the current lead option is the 450MW HVDC Link. The TO is currently undertaking a retender exercise for provision of the HVDC Link. The optioneering work will need to be revisited when this is concluded. This may result in an alternative least worst regret option.

2.3 Status

On 9 November 2016 the UK Government Department for Business, Energy & Industrial Strategy published an industry consultation on the future subsidy regime for onshore wind projects located on the Scottish Islands. The consultation[4] closes on 31 January 2017. Depending on the outcome of the consultation, the economic assessment carried out as part of the optioneering exercise may need to be revised accordingly to inform the selection of the preferred option.

The key project milestones will be reviewed and amended accordingly when the outcome of the consultation is known. In order to meet the current Western Isles Link target completion date of 2021, it is expected that the CfD eligibility and application process would be completed by mid-2017 to allow approval of the Needs Case and Project Assessment during the third quarter of 2017. Construction work would be expected to start in the first quarter of 2018. Over the next six months the key activities include:

- Conclusion of tender negotiations.
- Progression of key planning and consenting activities.
- Preparation of Needs Case and Project Assessment submissions.
- Continuation of stakeholder engagement.

[4] https://www.gov.uk/government/consultations/consultation-on-treatment-of-non-mainland-gb-onshore-wind-projects

Appendix A
SWW projects

8.4
Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)

1. Background
The scope of the Eastern subsea HVDC Link from Peterhead to Hawthorn Pit reinforcement option (E4DC) involves the construction of a 2 GW HVDC link between Peterhead in North East Scotland and Hawthorn Pit in North East England, with associated AC onshore works on either end.

The objective of E4DC is to increase the north to south transfer capability of the Scottish and northern England Transmission system between boundaries B1 in the Scottish Hydro Electric Transmission (SHE Transmission) area and B7a in the National Grid Electricity Transmission (NGET) area in the north of England. This includes key boundaries between SHE Transmission and SP Transmission (B4) and between SP Transmission (SPT) and NGET (B6). The recommendation from the 2016 *NOA* process is to progress this reinforcement in this year to maintain an earliest in-service date (EISD) of 2024.

This reinforcement option is proposed in accordance with the NETS SQSS[5] and pursuant to the Transmission Owners' obligations in their transmission licences. The requirement to reinforce the transmission network is driven fundamentally by the growth of predominantly renewable generation in the SHE Transmission and SPT areas, including offshore windfarms situated in the Moray Firth and in the Firth of Forth. Figure 8.1 and Figure 8.2 show the Required Transfers[6] for boundaries B4 and B6 for the four scenarios in the 2016 *Future Energy Scenarios (FES)*. The figures also show the current network capabilities across the two boundaries as well as capability increases for approved reinforcements. The difference between the Required Transfers and the network capability shows a requirement for further network reinforcement.

[5] The NETS SQSS is the National Electricity Transmission System Security and Quality of Supply Standard. GB Transmission Owners have licence obligations to develop their transmission systems in accordance with the NETS SQSS.

[6] The Required Transfer figures shown take into account interconnectors connecting to the GB Transmission system in the 2016 *Future Energy Scenarios*.

Figure 8.1
Boundary B4 (SHE Transmission/ SPT) required transfer and capability

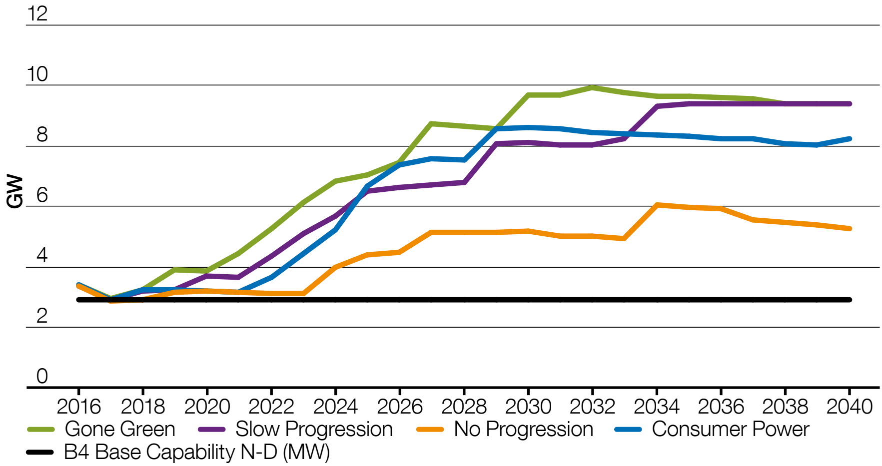
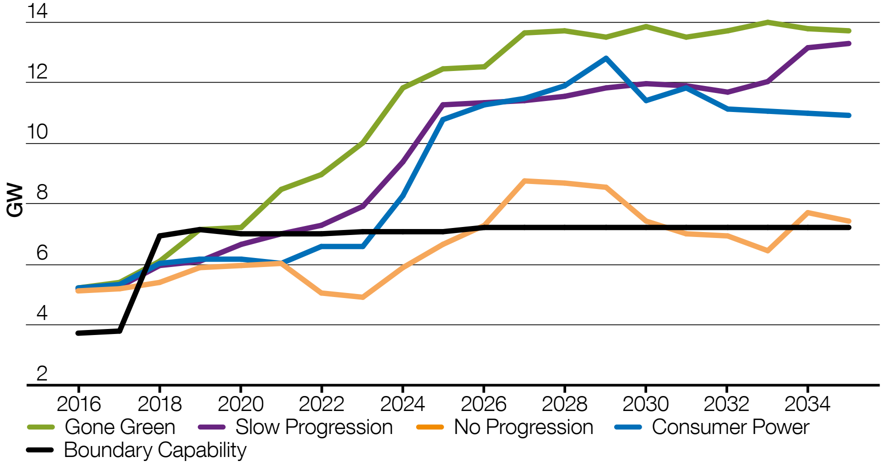


Figure 8.2
Boundary B6 (SPT/NGET) required transfer and capability



Appendix A
SWW projects

2. Option development
A number of reinforcement options have been developed which improve boundary capability across boundaries B1 to B7a. These options consider onshore and offshore solutions.

2.1 Options
(a) East Coast onshore 275kV upgrade (ECU2)
Establish new 275kV substations at Alyth and Fiddes, including phase shifting transformers at Fiddes and shunt reactive compensation at Alyth, re-profile the 275kV circuits between Kintore, Alyth and Kincardine and uprate the 275kV circuits between Alyth, Tealing, Westfield and Longannet. This reinforcement option provides additional transmission capacity across boundaries B1, B1a, B2, B4 and B5.

(b) East Coast onshore 400kV incremental reinforcement (ECUP)
Following ECU2, establish new 400kV substations at Rothienorman and Kintore, uprate Alyth substation for 400kV operation, re-insulate the 275kV circuits between Blackhillock, Rothienorman, Kintore, Fetteresso, Alyth and Kincardine for 400kV operation and install phase shifting transformers at Blackhillock. This reinforcement option provides additional transmission capacity across boundaries B1, B1a, B2, B4.

(c) East Coast onshore 400kV reinforcement (ECU4)
Establish new 400kV substations at Rothienorman, Kintore and Alyth, re-insulate the 275kV circuits between Blackhillock, Rothienorman, Kintore, Fetteresso, Alyth and Kincardine for 400kV operation, install phase shifting transformers at Blackhillock, re-profile the 275kV circuits between Tealing, Westfield and Longannet, and uprate the cable sections at Longannet. This reinforcement option provides additional transmission capacity across boundaries B1, B1a, B2, B4 and B5.

(d) Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)
Construct a new offshore 2 GW HVDC subsea link from Peterhead (north east of Scotland) to Hawthorn Pit (north of England), including AC/DC converter stations and associated AC onshore works at the Peterhead and Hawthorn Pit ends of the link. The AC onshore works at the Peterhead end include the upgrade of the 275kV circuits along the Blackhillock–Rothienorman–Peterhead route to 400kV operation. The AC onshore works at Hawthorn Pit include a new 400kV Hawthorn Pit GIS substation, uprating of the Hawthorn Pit–Norton circuit and associated circuits reconfiguration works in the area. This reinforcement option provides additional transmission capacity across boundaries B1, B1a, B2, B2a, B4, B5, B6, B7, and B7a.

(e) Eastern Scotland to England Link: Torness to Hawthorn Pit Offshore HVDC (E2DC)
Construct a new offshore 2 GW HVDC subsea link from Torness area to Hawthorn Pit, including AC/DC converter stations and associated AC works at Torness and Hawthorn Pit. The AC onshore works in the vicinity of the Torness end include extension of the pre-existing ‘Branxton 400kV substation’ by two 400kV GIS bays to provide connection to the ‘Branxton Converter Station’. The AC onshore works at Hawthorn Pit include a new 400kV Hawthorn Pit GIS substation, uprating of the Hawthorn Pit–Norton circuit and associated circuits reconfiguration works in the area. This reinforcement option provides additional transmission capacity across boundaries B6, B7 and B7a.

(f) Denny–Wishaw 400kV Reinforcement
Construct a new 400kV double circuit overhead line from Bonnybridge to Newarthill and reconfigure associated sites to establish a fourth north to south double circuit Supergrid route through the Scottish central belt.

One side of the new overhead line will be operated at 400kV, the other at 275kV. This reinforcement will establish Denny–Bonnybridge, Bonnybridge–Wishaw, Wishaw–Strathaven No.2 and Wishaw–Torness 400kV circuits, and a Denny–Newarthill–Easterhouse 275kV circuit. This reinforcement option provides additional transmission capacity across boundary B5.

(g) Eastern Scotland to England Link: Torness to North East England double circuit (TLNO)
Install a new double circuit overhead line from a new 400kV substation in the Torness area to a connection point on the transmission system in North East England. Construct a new 400kV overhead line from the Torness area to the SPT/NGET border. Continue construction of the OHL into a suitable connection point in North East England, providing additional substation equipment where required. This reinforcement option provides additional thermal capacity across boundaries B6, B7 and B7a.

2.2 Lead options

(a) Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)
In an optioneering exercise to identify the most economic, efficient and coordinated development option, E4DC is found to be an economic reinforcement in all of the four *FES* scenarios. It is a critical reinforcement in each *FES* scenario except **No Progression** where the optimal timing of the build is two years after its EISD.

E4DC is a justified reinforcement as it provides capability across boundaries B1 to B7a. In order to get the full benefit of E4DC across all boundaries, other reinforcements, including ones for the B8 boundary, must be built. Note that the exact combination of reinforcements varies depending on the *FES* scenario used.

(b) Eastern Scotland to England Link: Torness to North East England double circuit (TLNO)
The analysis showed that TLNO is a critical reinforcement for **Slow Progression** though not the other scenarios. TLNO has a late EISD which prevents it from having a larger impact but front end costs are low. As a result the regrets are low for TLNO and it has a 'proceed' recommendation which keeps the option open.

(c) Eastern Scotland to England Link: Torness to Hawthorn Pit Offshore HVDC (E2DC)
The analysis shows that E2DC is a critical reinforcement for the **Gone Green** scenario. As per the regret analysis, E2DC has a 'proceed' recommendation. It is not included in the other three scenarios as part of their optimal paths. E2DC provides capacity to B6 to B7a and allows for additional capacity to be realised from other reinforcements which as a group facilitates for positive economic benefit.

Status
Preliminary subsea cable routeing and survey have been carried out, however further technical and environmental surveys will be required. Planning permission for the 400kV substation at Peterhead has been granted and a preferred location for the convertor station at Peterhead has been identified. Design checks will be required for increasing the operating voltage of the overhead line between Peterhead and Blackhillock. Further preliminary works at the Hawthorn Pit end of the link will be required to establish the details of requirements in the area. It is expected in this *NOA* that the construction of the HVDC project will take place between 2022 and 2024.

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8.5
Eastern Scotland to England Link: Torness to Hawthorn Pit Offshore HVDC (E2DC)

1. Background
The scope of the Eastern Scotland to England Offshore HVDC Link from Torness to Hawthorn Pit (E2DC) entails the construction of approximately 200km of a 2 GW VSC HVDC circuit between Torness area in South East Scotland and Hawthorn Pit in North East England, with associated AC onshore reinforcement works at both terminals.

The objective of E2DC is to increase the north to south transfer capability of the Scottish and northern England Transmission system between boundaries B6 in the SP Transmission (SPT) area and B7a in the National Grid Electricity Transmission (NGET) area. The recommendation from the 2016 *NOA* process is to progress this reinforcement in the coming year to maintain an earliest in-service date (EISD) of 2024.

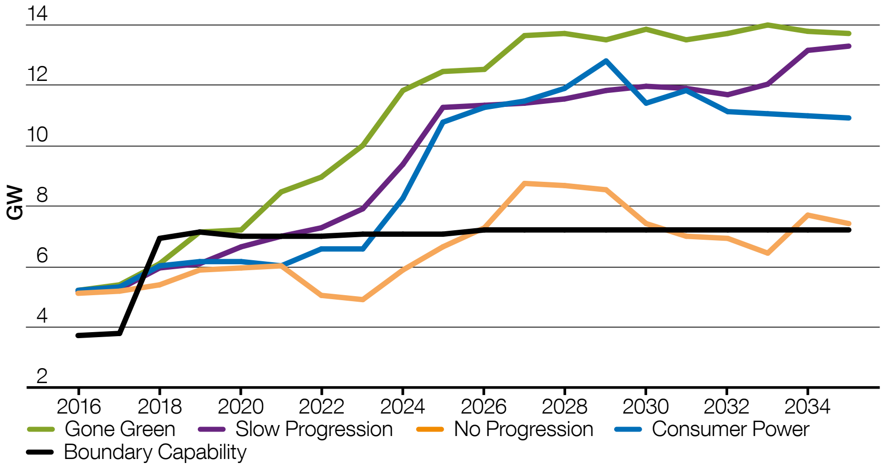
This reinforcement option is proposed in accordance with the NETS SQSS[7] and pursuant to the Transmission Owners' obligations in their transmission licences.

The requirement to reinforce the transmission network is driven fundamentally by the growth of predominantly renewable generation in the SHE Transmission and SPT areas. Figure 8.3 depicts the Required Transfers[8] on boundary B6 for the four scenarios in the 2016 *Future Energy Scenarios (FES)*. The figure also shows the current network capability across the boundary B6 as well as capability increase for approved reinforcements. The difference between the Required Transfers and the network capability shows a requirement for further network reinforcement.

[7] The NETS SQSS is the National Electricity Transmission System Security and Quality of Supply Standard. GB Transmission Owners have licence obligations to develop their transmission systems in accordance with the NETS SQSS.

[8] The Required Transfer figures shown take into account interconnectors connecting to the GB Transmission system in the 2016 *Future Energy Scenarios*.

Figure 8.3
Boundary B6 (SPT/NGET) required transfer and capability



2. Option development
A number of reinforcement options have been developed which improve boundary capability across boundaries B6 to B7a. Due to the broad nature of the reinforcement requirement, a full review and assessment of all potential options for providing capacity to these boundaries will be required for which the following identified onshore and offshore options will be included.

2.1 Options
(a) Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)
Construct a new offshore 2GW HVDC subsea link from Peterhead (north east of Scotland) to Hawthorn Pit (north of England), including AC/DC converter stations and associated AC onshore works at the Peterhead and Hawthorn Pit ends of the link. The AC onshore works at the Peterhead end include the upgrade of the 275kV circuits along the Blackhillock–Rothienorman–Peterhead route to 400kV operation. The AC onshore works at Hawthorn Pit include a new 400kV Hawthorn Pit GIS substation, uprating of one of the Hawthorn Pit–Norton circuits from 275kV to 400kV operation, and associated circuits reconfiguration works in the area. This reinforcement option addresses the thermal and voltage limitations associated with boundaries B1, B1a, B2, B2a, B4, B5, B6, B7, and B7a.

(b) Eastern Scotland to England Link: Torness to Hawthorn Pit Offshore HVDC (E2DC)
Construct a new offshore 2GW HVDC subsea link from Torness area to Hawthorn Pit, including AC/DC converter stations and associated AC works at Torness and Hawthorn Pit. The AC onshore works in the vicinity of the Torness end include establishment of a 400kV Converter Station. The AC onshore works at Hawthorn Pit include a new 400kV Hawthorn Pit GIS substation, uprating of one of the Hawthorn Pit–Norton circuits from 275kV to 400kV operation and associated circuits reconfiguration works in the area. This reinforcement option provides additional transmission capacity across boundaries B6, B7 and B7a.

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(c) Eastern Scotland to England Link: Torness to North East England double circuit (TLNO)

Install a new double circuit overhead line from a new 400kV substation in the Torness area to a connection point on the Transmission system in North East England. Construct a new 400kV overhead line from the Torness area to the SPT/NGET border. Continue construction of the OHL into a suitable connection point in North East England, providing additional substation equipment where required. This reinforcement option provides additional thermal capacity across boundaries B6, B7 and B7a.

2.2 Lead options

(a) Eastern subsea HVDC Link from Peterhead to Hawthorn Pit (E4DC)

In an optioneering exercise to identify the most economic, efficient and coordinated development option, E4DC is found to be an economic reinforcement in all of the four *FES* scenarios. It is a critical reinforcement in each *FES* scenario except **No Progression** where the optimal timing of the build is two years after its EISD.

E4DC is a justified reinforcement as it provides capability across boundaries B1 to B7a. In order to get the full benefit of E4DC across all boundaries, other reinforcements, including ones for the B8 boundary, must be built. Note that the exact combination of reinforcements varies depending on the *FES* scenario used.

(b) Eastern Scotland to England Link: Torness to North East England double circuit (TLNO)

The analysis showed that TLNO is a critical reinforcement for **Slow Progression** though not the other scenarios. TLNO has a late EISD which prevents it from having a larger impact but front end costs are low. As a result the regrets are low for TLNO and it has a 'proceed' recommendation which keeps the option open.

(c) Eastern Scotland to England Link: Torness to Hawthorn Pit Offshore HVDC (E2DC)

The analysis shows that E2DC is a critical reinforcement for the **Gone Green** scenario. As per the regret analysis, E2DC has a 'proceed' recommendation. It is not included in the other three scenarios as part of their optimal paths. E2DC provides capacity to B6 to B7a and allows for additional capacity to be realised from other reinforcements which as a group facilitates for positive economic benefit.

Status

A preliminary Strategic Environmental Assessment has been carried out to consider the potential for the development of onshore sites to accommodate transmission infrastructure within the Torness area. Six potential sites together with five potential cable landing points have been identified for the development of all required infrastructure. These sites will require to be considered in more detail.

Studies relating to the subsea cable have been progressed to the route optioneering stage, with a preferred cable yet to be identified. There are a number of significant environmental constraints in the coastal area surrounding Torness including the area in proximity to the route corridor options. Further environmental studies and mitigation solutions are required to identify a subsea cable route which minimises the potential impacts.

Further preliminary works at the Hawthorn Pit end of the link will be required to establish the details of requirements in the area. It is expected in *NOA2* that the construction of the HVDC project will take place between 2022 and 2024.

A feasibility assessment has taken place for potential onshore routes from South East Scotland to North East England. This assessment concluded that an onshore reinforcement should be considered as a credible design option for providing additional capacity between Scotland and England in the future. A number of broad route corridors were investigated and it was determined that one or more would be practicable.

8.6 North West Coast connections project

1. Background

1.1 The potential need for this project is driven by NuGen's proposed 3,387 MW power station at Moorside near Sellafield in Cumbria. The proposed power station would consist of three 1,129 MW units to be connected sequentially in 2024, 2025, and 2026.

1.2 This project is being developed under the current RIIO-T1 Strategic Wider Works (SWW) framework, which means that information is published as part of the assessment process between Ofgem and National Grid. Further information about this project and other SWW can be found on Ofgem's website here **https://www.ofgem.gov.uk/electricity/transmission-networks/critical-investments/strategic-wider-works**. Ofgem is already consulting on the Initial Needs Case and the consultation is due to close after the publication of this *NOA*.

1.3 The proposed project has been subject to extensive public consultation so information is available through **http://www.northwestcoastconnections.com/**.

2. Options assessment

2.1 There is no existing transmission infrastructure in the vicinity of the proposed Moorside power station location. There are existing distribution network assets in this area but these do not have the capacity to accommodate a connection of Moorside's size. It was therefore concluded that new transmission circuits would be required.

2.2 National Grid carried out power system analysis to identify the minimum level of reinforcement required to provide a National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) compliant connection for Moorside. This analysis determined that a minimum of four new transmission circuits are required to ensure a NETS SQSS compliant connection.

2.3 Project Development

2.3.1 At the early stages of the project National Grid identified several possible strategic options that could deliver a connection to Moorside, and gave consideration to the feasible connection technologies. To assess the strategic options National Grid undertook onshore and offshore studies to identify potential route corridors for the new circuits. These were assessed against a number of factors in accordance with National Grid's licence obligations, and further information on the assessment and conclusions can be found in Statement of Proposed Route Corridor[9].

2.3.2 In June 2015, National Grid concluded that the preferred connection option would be made up of an onshore double circuit north and an onshore double circuit south with a tunnel crossing underneath Morecambe Bay. These options will require the removal of an existing 132kV overhead line operated by Electricity North West Limited. This option is also supported by the cost–benefit analysis studies that have been undertaken, which demonstrate that across the Future Energy Scenarios the preferred connection option (outlined above) is the least worst regret option. This option has remained robust through a range of sensitivity analysis which has involved looking at various uncertainties such as wider generation timing.

[9] Statement of Proposed Route Corridor (June 2015) http://www.northwestcoastconnections.com/docs/SPRC.pdf

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2.3.3 Further development work has now been undertaken to define the proposed alignment of the connection within the corridor of the preferred option.

2.4 Proposed Connection Option

2.4.1 Following the announcement of the preferred route corridor in June 2015 National Grid, supported by external consultants including landscape architects, ecologists, archaeologists and socio-economic specialists, has completed the process to identify the route alignment for the connection and any areas that may require mitigation through the use of undergrounding or landscaping.

2.4.2 National Grid ran its statutory consultation on the project from 28 October 2016 to 24 February 2017. This consultation provided information on the connection proposals, including the identification of the 23.4km of 400kV undergrounding through the Lake District National Park.

3. Strategic Wider Works

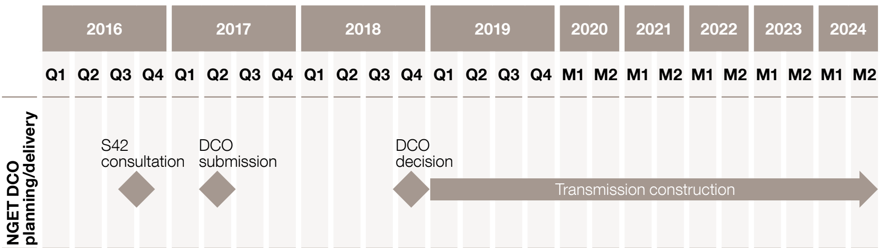
3.1 Ofgem formally confirmed that the NWCC project meets the eligibility criteria for a Strategic Wider Works project in November 2015. In order to meet the Strategic Wider Works process, an Initial Needs Case was submitted in May 2016. The Initial Needs Case includes information on the technical need for the project, cost benefit analysis and presents the strategic options considered with reasons for discounting them. The information demonstrates the process for selecting the preferred connection option and how this option meets National Grid's statutory obligations and is in the best interest of consumers. Ofgem is currently undertaking a consultation on the Initial Needs Case and the suitability for tendering: **https://www.ofgem.gov.uk/system/files/docs/2016/12/nwcc_consultation_2016.pdf**

3.2 Cost–benefit analysis was undertaken and the recommendation was for a double overhead line to Harker and south from Moorside including a tunnel under Morecambe Bay to Middleton to satisfy the connection obligation at this stage. As part of the development of the project further cost–benefit analysis will be undertaken to support the Final Needs Case.

4. Project timeline

4.1 National Grid is working closely with the generator, NuGen, to ensure the timelines are closely aligned. Both National Grid and NuGen are intending to submit their DCO applications in 2017 to allow the 400kV project construction to commence in 2019.

Figure 8.4
North West Coast connections timeline



8.7
Hinkley Point C connection project

1. Background

1.1 The potential need for this project is driven by the increased levels of generation requested by customers, most notably the proposed NNB Generation Company (HPC) Limited (referred to as EDF) new nuclear power station at Hinkley Point, Somerset with a Transmission Entry Capacity (TEC) of 3.34 GW. The proposed power station would consist of two 1.67 GW units, currently contracted, according to the TEC Register[10], to be connected respectively in 2022 and 2023. Contracts for the power station were signed by EDF and its development partners and the UK government in September 2016, at which point EDF confirmed that "the first electricity is due to be produced in 2025"[11].

1.2 National Grid undertook a full option appraisal that concluded that Hinkley Point to Seabank overhead line would best meet National Grid's technical, economic and environmental obligations, and was identified as the preferred strategic option. National Grid then refined this option in consultation with stakeholders, and concluded that the proposals should include underground cables in the Mendip Hills AONB, removal of existing distribution infrastructure and a new pylon design. The proposed project was subject to extensive public consultation between October 2009 and March 2014 and was granted development consent by the Secretary of State (SoS) for Energy and Climate Change in January 2016.

1.3 Information on the project, including the development consent order (DCO) made by the SoS, and project documents including the Consultation Report and environmental information can be found here: **https://infrastructure.planninginspectorate.gov.uk/projects/south-west/hinkley-point-c-connection/**. Extensive information on this consented project can be found on our website at **http://www.hinkleyconnection.co.uk/**

2. Options assessment

2.1 The process of options assessment carried out is summarised below, and is explained further in the Project Need and Alternatives chapter of the Environmental Statement submitted in support of the DCO application for the Hinkley Point C Connection project, which can be found here: **https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN020001/EN020001-000770-5.2.1%20ES%20Project%20Need%20and%20Alternatives.pdf**

2.2 This document also signposts the various documents referred to below.

Consideration of strategic options

2.3 Having identified the need to reinforce the high voltage transmission system, National Grid considered an extensive range of options to resolve the need case, as reported in a Strategic Options Report (SOR) published in 2009. 23 alternative options were originally considered, of which 11 were discounted as they would not meet National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS). Eight options were discounted on the basis of excessive costs, and two were 'parked' (i.e. they would be reconsidered should issues arise with the options taken forward for further investigation) as lower cost solutions and options providing better coordination of transmission works were available – these options were connections between Hinkley Point and Melksham and Nursling

[10] http://www2.nationalgrid.com/UK/Services/Electricity-connections/Industry-products/TEC-Register/

[11] https://www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c/news-views/contracts-signed

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substations respectively. The 2009 SOR concluded that a new 400kV overhead line between Hinkley Point and Seabank was the preferred option.

2.4 In response to representations made concerning its consideration of alternative connection options and the scope of its options appraisal, National Grid undertook a review and updated information on alternative connection options. This information is documented in a further SOR published in 2011. This report assessed five potential connections listed below:

- PC1: Hinkley – Aberthaw (subsea).
- PC2: Bridgwater – Melksham.
- PC3: Bridgwater – Nursling.
- PC4: Bridgwater – Seabank (onshore).
- PC5: Hinkley Point – Seabank (subsea).

2.5 The 2011 SOR concluded that the option of constructing an overhead transmission line between Bridgwater and Seabank would best meet National Grid's technical, economic and environmental obligations and should remain the preferred option to take forward for further investigation, taking National Grid's statutory obligations and its licence standards into account. It was recognised that sections of the proposed connection may be placed underground and that these and other mitigation measures would be investigated in the next stage of the project.

Route corridor study

2.6 Having identified that the preferred connection should be based on a new 400kV overhead line between Bridgwater and Seabank, a Route Corridor Study was undertaken to identify potential route corridors between these locations, taking into account National Grid's Schedule 9 Statement, the Holford Rules and its undergrounding policy to identify areas that route corridors should seek to avoid and those on which corridors should minimise effects. Two broad route corridors, one of which contained two options, were identified. The corridors and options identified are summarised in the table below.

Table 8.1
Corridors and options for Hinkley Point C connection project

Option	Option description
Corridor 1, option A	Route corridor based on an existing 132kV overhead line owned and operated by Western Power Distribution (South West) plc. Option A involved the removal of the existing WPD 132kV overhead line which travels in a broadly north-to-south direction between Bridgwater and Seabank, via Portishead in North Somerset and the construction of a new 400kV overhead line in its place.
Corridor 1, option B	Route corridor based on an existing 132kV overhead line owned and operated by WPD. Option B considered the construction of a new 400kV overhead line parallel to the existing 132kV overhead line, either to the east or west of the existing overhead line. For this option the existing WPD 132kV overhead line would not be removed.
Corridor 2	Corridor 2 sought to avoid the paralleling of existing transmission and distribution overhead lines, although this would not be possible in certain locations due to the presence of environmental constraints and urban areas. The existing WPD 132kV overhead line would not be removed.

2.7 The Route Corridor Study concluded that Corridor 1 Option A was clearly the least environmentally constrained corridor as it would use the route of an existing 132kV overhead line and would not result in any additional overhead lines in the landscape. This corridor would also minimise effects on the Mendip Hills Area of Outstanding National Beauty, and designated Special Protection Areas, Special Areas for Conservation, Ramsar sites, National Nature Reserves, Scheduled Monuments and settlements.

Detailed route selection and consideration of undergrounding

2.8 During 2012 and 2013, the preferred route corridor was separated into a number of sections within which a range of overhead line routes were developed. An underground cable route was also developed within each of the sections, and in accordance with National Policy Statement EN-5 a comparison was made to determine whether the benefits from the non-overhead line alternative would clearly outweigh any additional economic, social and environmental impacts and the technical difficulties were surmountable. This process is documented in the Connection Options Report (2012), and determined the final route alignment of the overhead line. It also concluded that the benefits from the use of underground cables as an alternative to an overhead line in the Mendip Hills AONB (Section C) would clearly outweigh the extra economic, social and environmental impacts and the additional costs of undergrounding could therefore be justified.

Statutory consultation process

2.9 Statutory consultation on National Grid's proposals took place over an eight-week period between 3 September and 29 October, 2013. Statutory and non-statutory consultees and members of the public were included within the consultation. 1,635 representations were received during the consultation, some of which requested changes to the design of the development. A structured change request process was implemented to address all requests for such changes. As a result, some local refinements to the alignment were proposed (e.g. a new alignment in the Mark/Southwick area).

3. Strategic Wider Works

3.1 National Grid's RIIO-T1 settlement, which was reached during the consultation and development stage of the preferred option, identified the majority of the proposed Hinkley Point C Connection works as eligible for the Strategic Wider Works (SWW) framework. Further information about this project and other SWW can be found on Ofgem's website here **https://www.ofgem.gov.uk/electricity/transmission-networks/critical-investments/strategic-wider-works**.

3.2 National Grid proposes to submit a Final Needs Case to Ofgem for this project, currently anticipated to be in Spring 2017.

4. Project timeline

4.1.1 A DCO for the project as described above was made by the SoS in January 2016. National Grid is currently working with EDF to confirm its timescales for developing the Hinkley Point C and will then revise the programme.

Appendix B
Meet the NOA team

Richard Smith
Head of Network Capability (Electricity)
Richard.Smith@nationalgrid.com

The Network Capability (Electricity) team addresses the engineering challenges of electricity network operability by studying from the investment options stage in a changing energy landscape through to network access just a day ahead of real time.

Julian Leslie
Head of Electricity Network Development
Julian.Leslie@nationalgrid.com

The Electricity Network Development team is to ensure the development of an efficient and operable GB and offshore electricity transmission system by understanding present capabilities and working out the best options to meet the possible requirements that future energy scenarios show might happen.

Electricity Network Development

In addition to publishing the *NOA* we are responsible for developing a holistic strategy for the NETS. This includes performing the following key activities:

- Testing the *FES* against models of the GB NETS to identify potential transmission requirements and publish in the *ETYS*.
- Managing the technical activities relating to all connections.
- Facilitating system access for NETS development or maintenance activities while ensuring the system can be operated both securely and economically.
- Providing the customer point of contact for all transmission generation and demand connections.
- Developing strategies to enable a secure and operable GB transmission network in the long term against the network development and industry evolution background.

You can contact us to discuss about:

Cost–benefit analysis and *Network Options Assessment*

Marc Vincent
Economics Team Manager
Marc.Vincent@nationalgrid.com

Network requirements and *Electricity Ten Year Statement*

Nicholas Harvey
GB System Capability Manager
Nicholas.Harvey@nationalgrid.com

Supporting parties

Strategic network planning and producing the *NOA* requires support and information from many people. Parties who provide support and information that makes our work possible include:

- National Grid Electricity Transmission Asset Management
- SHE Transmission
- SP Transmission
- our customers.

Don't forget you can also email us with your views on *NOA* at:
transmission.etys@nationalgrid.com

Appendix C
List of options' four-letter codes

The list below is of the options assessed in this *NOA* publication together with their four-letter codes. The four-letter codes appear through the report in tables and charts. The list below is in the alphabetical order of the code. We've included the scheme number where it is available. Some options do not have scheme numbers, for instance if the option is very new. Other options have more than one scheme number where schemes have been combined for an option.

The TORI number is the Transmission Owner Reinforcement Instruction number and applies in Scotland.

Four-letter code	Description	TORI or scheme number
ATHW	Alverdiscott to Taunton double circuit thermal uprating	
B1RC	Reactive compensation at Tummel and Melgarve and inter-bus Transformers at Fort Augustus	SHET-RI-69, SHET-RI-66
BBNO	New Beauly to Blackhillock 400kV double circuit	SHET-RI-7a
BCRE	Reconductor the Connah's Quay legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits	32018L1
BDRE	Beauly to Loch Buidhe and Loch Buidhe to Dounreay 275kV double circuit reconductoring	
BFHW	Bramley to Fleet circuits thermal uprating	
BKNO	New Beauly to Kintore 400kV double circuit	
BLN2	New Beauly to Loch Buidhe 275kV double circuit	
BLQB	New 275kV phase shifting transformers at Blackhillock on the circuits from Knocknagael	SHET-RI-026
BLR1	Beauly to Shin to Loch Buidhe 132kV double circuit reconductoring	
BLR2	Beauly to Loch Buidhe 275kV double circuit OHL reconductoring and generation connection reconfiguration	
BMMS	225 MVAr MSCs at Burwell Main	33452
BNRC	Bolney and Ninfield additional reactive compensation	33698, 33699
BPEU	Uprate non-conductor components of Bramford to Pelham double circuit (following Bramford to Twinstead new double circuit)	
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route	33458
BTNO	A new 400kV double circuit between Bramford and Twinstead	21847, 20834-1, 20834-4, 20834-3, 20834-5, 20834-6, 20834-2, 20834-2C, 20834_2A, 20834-2Q
CIQB	Quad booster installation at Cilfynydd	33432
CTRE	Reconductor remainder of Coryton South to Tilbury circuit	21850-1
D2NO	Dounreay to Orkney, Bay of Skaill and Dounreay to Orkney, South Hoy subsea link	
DERE	Drax to Eggborough 1 circuit – reconductor and replace cable section	
DHNO	Dounreay to Orkney, South Hoy subsea link	
DREU	Generator circuit breaker replacement to allow Thornton to run two-way split	
DSNO	Dounreay to Orkney, Bay of Skaill subsea link	SHET-RI-019
DWNO	Denny to Wishaw 400kV reinforcement	SPT-RI-003

Appendix C
List of options' four-letter codes

Four-letter code	Description	TORI or scheme number
E2DC	Eastern subsea HVDC Link from Torness to Hawthorn Pit	
E4DC	Eastern subsea HVDC Link from Peterhead to Hawthorn Pit	SHET-RI-025b, SHET-RI-025c, SHET-RI-025d
ECU2	East Coast onshore 275kV upgrade	SPT-RI-004
ECU4	East Coast onshore 400kV reinforcement	SHET-RI-026, SPT-RI-200
ECUP	East Coast onshore 400kV incremental reinforcement	SHET-RI-026, SPT-RI-200
FBRE	Beauly to Fyrish 275kV double circuit reconductoring and generation connection reconfiguration	
FLRE	Fleet to Lovedean reconductoring	31671-2
GKRE	Reconductor Garforth Tee to Keadby leg of the Creyke Beck to Keadby to Killingholme Circuit	
GSNO	Gills Bay to Orkney, South Ronaldsay subsea link	
HAEU	Harker SuperGrid Transformer 6 replacement	
HCC1	Cowley to Minety and Cowley to Walham cables (Hinksey cables) upgrade	20903L, 33700
HPNO	New east–west circuit between the north east and Lancashire	
HSNO	Hinkley Point to Seabank new double circuit	20898, 30010, 20897L1A, 20897L1B, 20897L2, 20897L2A, 20897L2B, 21132L, 21132S, 20899, 20897L4, 20897Q, 20899C
KCRE	Reconductor the Keadby to Cottam 400kV circuits	
KLRE	Kemsley to Littlebrook circuits uprating	20846-4
LDQB	Lister Drive quad booster	21590
LNHW	Lovedean to Ninfield thermal uprate	
LNRE	Reconductor Lackenby to Norton single 400kV circuit	20669
LTR1	Lackenby to Thornton double circuit – uprate cable and thermal uprate overhead line sections	31380
LTR2	Lackenby to Thornton double circuit – uprate cable section and reconductor sections	33454C & 33454L
MRUP	Uprate the Penwortham to Washway Farm to Kirkby 275kV double circuit to 400kV	
NBRE	Reconductor Bramford to Norwich double circuit	11630, 11630I, 11630F
NEEU	North east 400kV and 275kV network reinforcement	SHET-RI-025d
NOHW	Thermal uprate 55km of the Norton to Osbaldwick 400kV double circuit	
NOR1	Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit	20640
NOR2	Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit	33705
NOR3	Norton to Osbaldwick 400kV double circuit – reconductor the rest of the circuits	
NPNO	New east–west circuit between the north east and Lancashire	
NR01	B4/B5 Notional Reinforcement 1	
NR02	B4/B5 Notional Reinforcement 2	
OENO	Central Yorkshire reinforcement	
OTHW	Osbaldwick to Thornton 1 circuit thermal upgrade	

Four-letter code	Description	TORI or scheme number
PBRE	Reconductor Pentir legs of the Pentir to Bodelwyddan to Connah's Quay 1 and 2 circuits	32018L2
PRRE	Reconductor newly formed second Bramford to Pelham circuit (following Bramford to Twinstead new double circuit)	
PTC1	Pentir to Trawsfynydd 1 cable replacement – single core per phase	33711
PTC2	Pentir to Trawsfynydd 1 and 2 cables – second core per phase and reconductor of an overhead line section on the existing Pentir to Trawsfynydd circuit	33708
PTNO	Pentir to Trawsfynydd second circuit	30311, 30311-1L, 30311-1S, 30311-2, 30311-3C, 30311-6
PTRE	Pentir to Trawsfynydd circuits – reconductor the remaining overhead line sections	33712
PWTI	Pembroke to Walham circuit turn-in to Swansea North	33432
RBRE	Reconductor newly formed second Bramford to Braintree to Rayleigh Main circuit (following Bramford to Twinstead new double circuit)	
RKEU	Rothienorman substation with reconductoring of the 275kV Rothienorman to Kintore circuit	SHET-RI-105
RMEU	Uprate non-conductor components of newly formed Bramford to Braintree to Rayleigh Main double circuit (following Bramford to Twinstead new double circuit) at Rayleigh Main	
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit	21850-1
SCN1/SCN2/ SCN3	New 400kV transmission route between South London and the south coast (three alternative options)	31832-2, 31832-3
SCRC	South East coast reactive compensation	31338, 31339, 21497-5
SEC1	Severn Tunnel 400kV cable circuit uprate	32897
SEEU	Reactive compensation protective switching scheme	33702
SGDC	South east to East Anglia HVDC link	
TCRE	Treuddyn Tee to Connah's Quay reconductoring	33457
TDRE	Reconductor Drax to Thornton double circuit	
THRE	Reconductor Hinkley Point to Taunton double circuit	
THS1	Install series reactors at Thornton	33506
THS2	Install series reactors at Thornton	
TLH1	Treuddyn Tee to Legacy thermal upgrade	
TLNO	Torness to North East England AC reinforcement	
TMRC	Reactive compensation at Tummel and Melgarve	SHET-RI-69
TURC	Reactive compensation at Tummel	SHET-RI-69
WBQB	Install quad booster in West Boldon to Offerton circuit	
WEC1	Willesden to Wimbledon 275kV cable Ealing diversion	33417, 20774CA
WEOS	Western HVDC Link fast de-load scheme	33519
WHRE	West Burton to High Marnham circuit – complete gantry works to match circuit rating	20314SI
WHTI	Turn-in of West Boldon to Hartlepool cct at Hawthorn Pit	21898-1
WLTI	Windyhill to Lambhill to Longannet 275kV circuit turn in to Denny North 275kV substation	
WOSR	Deploy FACTS device on West Boldon to Offerton circuit	
WPDC	North Wales to South Wales HVDC Link	30915

Appendix C
List of options' four-letter codes

Four-letter code	Description	TORI or scheme number
WPNO	Wylfa to Pentir second double circuit route	30310, 30310-3, 30346S
WYQB	Wymondley quad boosters	32581S
WYTI	Wymondley turn-in	32586S

Appendix D
Glossary

Acronym	Word	Description
	Ancillary services	Services procured by a system operator to balance demand and supply and to ensure the security and quality of electricity supply across the transmission system. These services include reserve, frequency control and voltage control. In GB these are known as balancing services and each service has different parameters that a provider must meet.
ACS	Average cold spell	Average cold spell is defined as a particular combination of weather elements which gives rise to a level of winter peak demand which has a 50% chance of being exceeded as a result of weather variation alone. There are different definitions of ACS peak demand for different purposes.
BEIS	Department of Business, Energy & Industrial Strategy	A UK government department. The Department of Business, Energy & Industrial Strategy (BEIS) works to make sure the UK has secure, clean, affordable energy supplies and promote international action to mitigate climate change. These activities were formerly the responsibility of the Department of Energy and Climate Change (DECC) which closed in July 2016.
BID3		BID3 is an economic dispatch optimisation model supplied by Pöyry Management Consulting. It can simulate all European power markets simultaneously including the impact of interconnection between markets. BID3 has been specifically developed for National Grid to model the impact of electricity networks in GB allowing the System Operator to calculate constraint costs it would incur to balance the system, post-gate closure.
	Boundary allowance	An allowance in MW to be added in whole or in part to transfers arising out of the NETS SQSS economy planned transfer condition to take some account of year-round variations in levels of generation and demand. This allowance is calculated by an empirical method described in Appendix F of the security and quality of supply standards (SQSS).
	Boundary transfer capacity	The maximum pre-fault power that the transmission system can carry from the region on one side of a boundary to the region on the other side of the boundary while ensuring acceptable transmission system operating conditions will exist following one of a range of different faults.
CBA	Cost–benefit analysis	A method of assessing the benefits of a given project in comparison to the costs. This tool can help to provide a comparative base for all projects to be considered.
CCS	Carbon Capture and Storage	Carbon (CO_2) Capture and Storage (CCS) is a process by which the CO_2 produced in the combustion of fossil fuels is captured, transported to a storage location and isolated from the atmosphere. Capture of CO_2 can be applied to large emission sources like power plants used for electricity generation and industrial processes. The CO_2 is then compressed and transported for long-term storage in geological formations or for use in industrial processes.
	Climate change targets	Targets for share of energy use sourced from renewable sources. The 2020 UK targets are defined in the Directive 2009/28/EC of the European Parliament and of the Council of the European Union, see **http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32009L0028&from=EN#ntc1-L_2009140EN.01004601-E0001**
CCGT	Combined cycle gas turbine	Gas turbine that uses the combustion of natural gas or diesel to drive a gas turbine generator to generate electricity. The residual heat from this process is used to produce steam in a heat recovery boiler which, in turn, drives a steam turbine generator to generate more electricity.
CHP	Combined heat and power	A system whereby both heat and electricity are generated simultaneously as part of one process. Covers a range of technologies that achieve this.
	Contracted generation	A term used to reference any generator who has entered into a contract to connect with the National Electricity Transmission System (NETS) on a given date while having a transmission entry capacity (TEC) figure as a requirement of said contract.
CP	Consumer Power	A Future Energy Scenario. Consumer Power is a world of relative wealth, fast-paced research and development and spending. Innovation is focused on meeting the needs of consumers, who focus on improving their quality of life.

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Acronym	Word	Description
	Double circuit overhead line	In the case of the onshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span in SHE Transmission's system or NGET's transmission system or for at least two miles in SP Transmission system. In the case of an offshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span.
DSR	Demand side response	A deliberate change to an industrial and commercial user's natural pattern of metered electricity or gas consumption, brought about by a signal from another party.
DNO	Distribution Network Operator	Distribution network operators own and operate electricity distribution networks.
EISD	Earliest In Service Date	The earliest date when the project could be delivered and put into service, if investment in the project was started immediately.
	Embedded generation	Power generating stations/units that don't have a contractual agreement with the National Electricity Transmission System Operator (NETSO). They reduce electricity demand on the National Electricity Transmission System.
ENTSO-E	European Network of Transmission System Operators – Electricity	ENTSO-E is an association of European electricity TSOs. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising electricity markets in the EU.
EU	European Union	A political and economic union of 28 member states that are located primarily in Europe.
FES	*Future Energy Scenarios*	The *FES* is a range of credible futures which has been developed in conjunction with the energy industry. They are a set of scenarios covering the period from now to 2050, and are used to frame discussions and perform stress tests. They form the starting point for all transmission network and investment planning, and are used to identify future operability challenges and potential solutions.
GEP	Grid entry point	A point at which a generating unit directly connects to the national electricity transmission system. The default point of connection is taken to be the busbar clamp in the case of an air insulated substation, gas zone separator in the case of a gas insulated substation, or equivalent point as may be determined by the relevant transmission licensees for new types of substation. When offshore, the GEP is defined as the low voltage busbar on the platform substation.
GSP	Grid supply point	A point of supply from the GB transmission system to a distribution network or transmission-connected load. Typically only large industrial loads are directly connected to the transmission system.
GG	Gone Green	A Future Energy Scenario. Gone Green is a world where green ambition is not restrained by financial limitations. New technologies are introduced and embraced by society, enabling all carbon and renewable targets to be met on time.
GTYS	*Gas Ten Year Statement*	The *GTYS* illustrates the potential future development of the (gas) National Transmission System (NTS) over a ten year period and is published on an annual basis.
GW	Gigawatt	1,000,000,000 watts, a measure of power
GWh	Gigawatt hour	1,000,000,000 watt hours, a unit of energy
GB	Great Britain	A geographical, social and economic grouping of countries that contains England, Scotland and Wales.
HVAC	High voltage alternating current	Electric power transmission in which the voltage varies in a sinusoidal fashion, resulting in a current flow that periodically reverses direction. HVAC is presently the most common form of electricity transmission and distribution, since it allows the voltage level to be raised or lowered using a transformer.
HVDC	High voltage direct current	The transmission of power using continuous voltage and current as opposed to alternating current. HVDC is commonly used for point to point long-distance and/or subsea connections. HVDC offers various advantages over HVAC transmission, but requires the use of costly power electronic converters at each end to change the voltage level and convert it to/from AC.

Acronym	Word	Description
IED	Industrial Emissions Directive	The Industrial Emissions Directive is a European Union directive which commits member states to control and reduce the impact of industrial emissions on the environment post-2015 when the Large Combustion Plant Directive (LCPD) expires.
ITPR	Integrated Transmission Planning and Regulation	Ofgem's Integrated Transmission Planning and Regulation (ITPR) project examined the arrangements for planning and delivering the onshore, offshore and cross-border electricity transmission networks. Ofgem published the final conclusions in March 2015.
	Interconnector	Electricity interconnectors are transmission assets that connect the GB market to Europe and allow suppliers to trade electricity between markets.
LCPD	Large Combustion Plant Directive	The Large Combustion Plant Directive is a European Union Directive which introduced measures to control the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant.
	Load factor	The average power output divided by the peak power output over a period of time.
	Marine technologies	Tidal streams, tidal lagoons and energy from wave technologies (see **http://www.emec.org.uk/**)
MW	Megawatt	1,000,000 Watts, a measure of power.
MWh	Megawatt hour	1,000,000 Watt hours, a measure of power usage or consumption in 1 hour.
	Merit order	An ordered list of generators, sorted by the marginal cost of generation.
MITS	Main Interconnected Transmission System	This comprises all the 400kV and 275kV elements of the onshore transmission system and, in Scotland, the132kV elements of the onshore transmission system operated in parallel with the supergrid, and any elements of an offshore transmission system operated in parallel with the supergrid, but excludes generation circuits, transformer connections to lower voltage systems, external interconnections between the onshore transmission system and external systems, and any offshore transmission systems radially connected to the onshore transmission system via single interface points.
NETS	National Electricity Transmission System	The National Electricity Transmission System comprises the onshore and offshore transmission systems of England, Wales and Scotland. It transmits high-voltage electricity from where it is produced to where it is needed throughout the country. The system is made up of high voltage electricity wires that extend across Britain and nearby offshore waters. It is owned and maintained by regional transmission companies, while the system as a whole is operated by a single system operator (SO).
NETSO	National Electricity Transmission System Operator	National Grid acts as the NETSO for the whole of Great Britain while owning the transmission assets in England and Wales. In Scotland, transmission assets are owned by Scottish Hydro Electricty Transmission Ltd (SHE Transmission) in the North of the country and Scottish Power Transmission SP Transmission in the South.
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standards	A set of standards used in the planning and operation of the national electricity transmission system of Great Britain. For the avoidance of doubt the national electricity transmission system is made up of both the onshore transmission system and the offshore transmission systems.
NGET	National Grid Electricity Transmission plc	National Grid Electricity Transmission plc (No. 2366977) whose registered office is 1–3 Strand, London, WC2N 5EH
NTS	National Transmission System	A high-pressure gas transportation system consisting of compressor stations, pipelines, multijunction sites and offtakes. NTS pipelines transport gas from terminals to NTS offtakes and are designed to operate up to pressures of 94 barg.
	Network access	Maintenance and system access is typically undertaken during the spring, summer and autumn seasons when the system is less heavily loaded and access is favourable. With circuits and equipment unavailable the integrity of the system is reduced. The planning of the system access is carefully controlled to ensure system security is maintained.

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Acronym	Word	Description
NOA	*Network Options Assessment*	The *NOA* is the process for assessing options for reinforcing the National Electricity Transmission System (NETS) to meet the requirements that the sytem operator (SO) finds from its analysis of the *Future Energy Scenarios (FES)*.
NP	No Progression	A Future Energy Scenario. No Progression is a world focused on achieving security of supply at the lowest possible cost. With low economic growth, traditional sources of gas and electricity dominate, with little innovation affecting how we use energy.
Ofgem	Office of Gas and Electricity Markets	The UK's independent National Regulatory Authority, a non-ministerial government department. Their principal objective is to protect the interests of existing and future electricity and gas consumers.
	Offshore	This term means wholly or partly in offshore waters.
	Offshore transmission circuit	Part of an offshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables, overhead lines and DC converters but excludes busbars and onshore transmission circuits.
	Onshore	This term refers to assets that are wholly on land.
	Onshore transmission circuit	Part of the onshore transmission system between two or more circuit-breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes busbars, generation circuits and offshore transmission circuits.
OCGT	Open cycle gas turbine	Gas turbines in which air is first compressed in the compressor element before fuel is injected and burned in the combustor.
	Peak demand	The maximum power demand in any one fiscal year: Peak demand typically occurs at around 5:30pm on a week-day between December and February. Different definitions of peak demand are used for different purposes.
pa	Per annum	Per year.
PV	Photovoltaic	A method of converting solar energy into direct current electricity using semi-conducting materials.
	Planned transfer	A term to describe a point at which demand is set to the National Peak when analysing boundary capability.
	Power supply background (aka generation background)	The sources of generation across Great Britain to meet the power demand.
	Ranking order	A list of generators sorted in order of likelihood of operation at time of winter peak and used by the NETS SQSS.
	Reactive power	Reactive power is a concept used by engineers to describe the background energy movement in an alternating current (AC) system arising from the production of electric and magnetic fields. These fields store energy which changes through each AC cycle. Devices which store energy by virtue of a magnetic field produced by a flow of current are said to absorb reactive power; those which store energy by virtue of electric fields are said to generate reactive power.
	Real power	This term (sometimes referred to as 'Active Power') provides the useful energy to a load. In an AC system, real power is accompanied by reactive power for any power factor other than 1.
	Seasonal circuit ratings	The current carrying capability of circuits. Typically, this reduces during the warmer seasons as the circuit's capability to dissipate heat is reduced. The rating of a typical 400kV overhead line may be 20% less in the summer than in winter.
	SHE Transmission	Scottish Hydro-Electric Transmission (No.SC213461) whose registered office is situated at Inveralmond HS, 200 Dunkeld Road, Perth, Perthshire PH1 3AQ.
SP	Slow Progression	A Future Energy Scenario. Slow Progression is a world where slower economic growth restricts market conditions. Money that is available is spent focusing on low cost long-term solutions to achieve decarbonisation, albeit it later than the target dates.

Acronym	Word	Description
	SP Transmission	Scottish Power Transmission plc (No. SC189126) whose registered office is situated at 1 Atlantic Quay, Robertson Street, Glasgow G2 8SP.
	Summer minimum	The minimum power demand off the transmission network in any one fiscal year: Minimum demand typically occurs at around 06:00am on a Sunday between May and September.
	Supergrid	That part of the national electricity transmission system operated at a nominal voltage of 275kV and above.
SGT	Supergrid transformer	A term used to describe transformers on the NETS that operate in the 275–400kV range.
	Switchgear	The term used to describe components of a substation that can be used to carry out switching activities. This can include, but is not limited to, isolators/disconnectors and circuit breakers.
	System inertia	The property of the system that resists changes. This is provided largely by the rotating synchronous generator inertia that is a function of the rotor mass, diameter and speed of rotation. Low system inertia increases the risk of rapid system changes.
	System operability	The ability to maintain system stability and all of the asset ratings and operational parameters within pre-defined limits safely, economically and sustainably.
SOF	*System Operabiltiy Framework*	The *SOF* identifies the challenges and opportunities which exist in the operation of future electricity networks and identifies measures to ensure the future operability.
SO	System Operator	An entity entrusted with transporting energy in the form of natural gas or power on a regional or national level, using fixed infrastructure. Unlike a TSO, the SO may not necessarily own the assets concerned. For example, National Grid operates the electricity transmission system in Scotland, which is owned by Scottish Hydro Electricity Transmission and Scottish Power.
	System stability	With reduced power demand and a tendency for higher system voltages during the summer months fewer generators will operate and those that do run could be at reduced power factor output. This condition has a tendency to reduce the dynamic stability of the NETS. Therefore network stability analysis is usually performed for summer minimum demand conditions as this represents the limiting period.
SWW	Strategic Wider Works	This is a funding mechanism as part of the RIIO-T1 price control that allows TOs to bring forward large investment projects that have not been funded in the price control settlement.
	Transmission circuit	This is either an onshore transmission circuit or an offshore transmission circuit.
TEC	Transmission entry capacity	The maximum amount of active power deliverable by a power station at its grid entry point (which can be either onshore or offshore). This will be the maximum power deliverable by all of the generating units within the power station, minus any auxiliary loads.
	Transmission losses	Power losses that are caused by the electrical resistance of the transmission system.
TO	Transmission Owners	A collective term used to describe the three transmission asset owners within Great Britain, namely National Grid Electricity Transmission, Scottish Hydro-Electric Transmission Limited and SP Transmission Limited.
TSO	Transmission System Operators	An entity entrusted with transporting energy in the form of natural gas or power on a regional or national level, using fixed infrastructure.

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You can write to us at:
NOA Team
Electricity Network Development
National Grid House
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

National Grid UK

@nationalgriduk

National Grid

NationalGridUK

National Grid plc
National Grid House,
Warwick Technology Park,
Gallows Hill, Warwick.
CV34 6DA United Kingdom
Registered in England and Wales
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