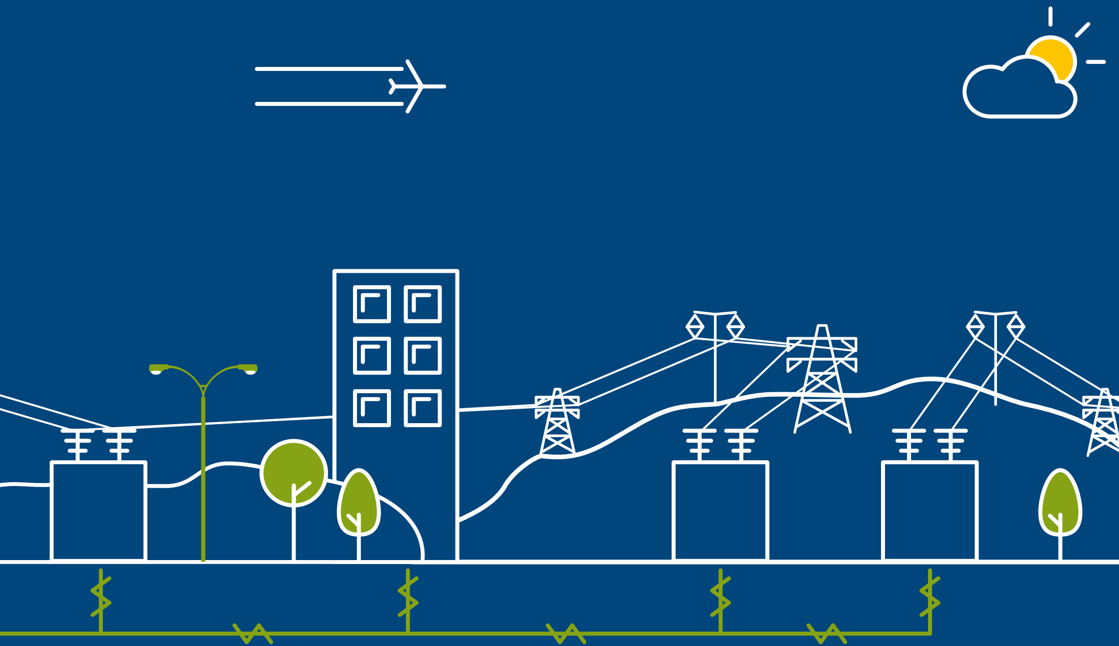
nationalgrid

Network Options Assessment 1

UK electricity transmission



MARCH 2016

Contents

Executive summary

In this the first Network Options Assessment report, we recommend proceeding with the development of eight projects valued at £2.2bn over their life time. These projects will enhance the capability of the Great Britain electricity transmission system and ensure that it is fit for purpose for the future energy landscape.

Identifying the future capability of the Great Britain (GB) electricity transmission system is critical to allow us to meet the needs of consumers. In March 2015, National Grid, as System Operator (SO), was asked by the industry regulator, Ofgem, to take on an enhanced role designed to make sure that the high voltage electricity network in England, Wales, Scotland, offshore and across our national borders is planned in an economic, efficient and coordinated way.

Our increased role as SO

Our new SO responsibilities include identifying system needs and coordinating and developing options to meet those needs to support efficient asset delivery and protect consumers against undue costs and risks. This new Network Options Assessment (NOA) process forms part of our new responsibilities. Under this process we review a range of network investment options through our NOA Methodology[1] and recommend the ones we expect will meet future system needs in the most efficient and economical way.

This NOA report is the last document in our 2015 Future of Energy suite and concludes the annual electricity transmission planning cycle. When read together, the suite's contents – the NOA report, the Future Energy Scenarios (FES), the Electricity Ten Year Statement (ETYS) and the System Operability Framework (SOF) – tell a clear and compelling story of future development of the electricity transmission system.

The new NOA process

To conduct the NOA, we asked each of the Transmission Owners (TOs) 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. These options included commercial, operational and asset solutions (onshore, offshore or a combination of both).

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 stranding risk of 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 use an operational costs assessment tool – the Electricity Scenario Illustrator (ELSI)[2] – to analyse and establish the benefits to the system of different options. We've continuously developed and improved the input to – and the modelling – of ELSI, which we've been using to help us make investment decisions since 2013. An important aspect of our NOA recommendation is the application of single-year least-regret criteria to our cost-benefit analysis results. The future energy landscape is uncertain, so the information we use in the cost-benefit analysis changes over time –

[1] NOA Methodology: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=44227

[2] ELSI: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=39022

we revisit our data, assumptions and analysis results every year to make sure that the preferred strategy is still the optimal solution. So when it comes to responding to market- or policy-driven changes, the criteria allow us to be flexible in our investment decision-making while also keeping the cost associated with this flexibility to the minimum.

Our decisions on preferred options

In this NOA, we've considered more than 70 GB transmission system investment options. Of those proposed options, we identified 13 projects that required a decision this year. A NO DECISION REQUIRED outcome for the remaining projects means that the time needed to deliver the transmission investment is less than the time between now and the time that the option is needed, so there is no need to make a decision this year.

For the 13 projects that required a decision this year in order to meet the future network requirements, we have identified recommendations from three further outcomes from our analysis:

- **PROCEED.** This means TOs should maintain the earliest in service date (EISD) for that investment. For schemes under the Strategic Wider Works process, this would involve further optioneering.
- **DO NOT PROCEED.** This means it is not economic to start work with this option.
- **DELAY.** This means we recommend that there should be a delay to the EISD. For individual projects, TOs should, following discussion with the SO, determine where work needs to continue for an EISD +1 year to be maintained.

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

For 2016, eight of these projects have a PROCEED decision. This means the TOs will spend £28m on projects that have a total value of £2.2bn over their lifetime. Our analysis considered what is really necessary as the energy landscape changes and, as a result, what savings are possible from deferring or cancelling projects. Through utilising the scenario based, single-year least worst regrets analysis our NOA recommendations are to DELAY five projects which would have committed £33m of spend in 2016.

The project options we have recommended in this 2016 NOA 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.

We welcome your views

This is the first edition of the NOA Report. Our customers and stakeholders have contributed to the production of this NOA report 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
- responses to our email transmission.etys@nationalgrid.com
- feedback form at https://www.surveymonkey.com/r/2015NOA
- bilateral stakeholder meetings.

The Stakeholder Engagement chapter sets out further information on our 2016 ETYS/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.

Executive summary

Table of outcomes for projects requiring a decision

Executive summary								Executive summary		
Transmission Solution	Network Area	Optimal Delivery Date						2014 Recommendation	2015 Recommendation	Project status
		Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted			
New Beauly – Blackhillock 400kV double circuit	North Scotland	2024	2028	2024	N/A	2024	N/A	N/A	Delay	Scoping
New Hawthorn Pit 400kV substation, turn-in of West Boldon – Hartlepool circuit at Hawthorn Pit and Hawthorn Pit to Norton single circuit 400kV upgrade	Scotland/ England	2023	2023	2023	2025	2023	N/A	N/A	Proceed	Project not started
Eastern subsea HVDC Link Peterhead – Hawthorn Pit	Scotland/ England	2023	2024	2023	2029	2023	N/A	Continue pre-construction scoping	Proceed[3]	Project not started
New 400kV double circuit between Bramford and Twinstead	East Anglia	2027	2031	N/A	N/A	2025	N/A	Delay	Delay	Project not started
Western HVDC Link fast de-load scheme	North Wales	2019	2019	2019	2019	2019	2019	N/A	Proceed	Project not started
Wylfa to Pentir second double circuit	North Wales	2029	2030	2032	N/A	2025	N/A	Complete pre-construction	Delay[4]	DCO started – indemnified by customer
Kemsley to Littlebrook circuits uprating	South East	2019	2019	2019	2019	2019	2023	No decision required	Proceed	Optioneering/ development phase
South-east coast dynamic reactive compensation	South Coast	2019	2019	N/A	2021	2019	N/A	Delay	Proceed	Moving from development phase to construction
Dungeness to Sellindge reconductoring	South Coast	2016	2016	2016	2021	2016	N/A	No decision required	Proceed	Under construction/ commissioning
Fleet to Lovedean reconductoring	South Coast	2020	2020	2020	2030	2020	N/A	N/A	Proceed	Optioneering/ development phase
Wymondley turn-In	South East	2024	2022	2024	2019	2024	2024	Complete pre-construction	Delay	Project not started
Wymondley QBs	South East	2024	2022	2024	2019	2024	2024	Complete pre-construction	Delay	Project not started
Hinkley Point to Seabank new double circuit	South West	2024	2025	2026	2028	2024	N/A	Commence pre-construction	Proceed	DCO approved

[3] There are a number of uncertainties in the generation background. This causes increasing uncertainty in triggers for Eastern HVDC Link, meaning that while the recommendation is to proceed, it is also for the TOs to minimise any spend this year.

[4] Work to secure a Development Consent Order for the Wylfa to Pentir second double circuit has already started, and should continue due to a local commercial agreement in place.

Further details on the full range of options considered and the drivers for the investments are contained within Chapter 4 of this document.

Chapter one
Aim of the report

- Introduction
- How the NOA Report fits in with the FES, ETYS and SOF
- The NOA Report methodology
- Navigating through the document
- Stakeholder engagement and feedback

1.1 Introduction

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

The 2015 NOA Report is the first to be published. It's produced for you, our stakeholders, and we'll use what you tell us to develop it further.

The NOA will help develop an efficient, coordinated and economical 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 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).

This report is one of the publications underpinned by our Future Energy Scenarios (FES). This means that the NOA Report and the ETYS – as well as the Gas Ten Year Statement and System Operability Framework (SOF) – have a consistent base for assessing the potential development of both the gas and electricity transmission networks. When read together, the ETYS and NOA Report give the full picture of requirements and potential options for the national electricity transmission system.

The 2015 NOA Report is published at the end of the 2015/16 year.

1.2 How the NOA Report fits in with the FES, ETYS and SOF

We use our FES to assess the transfer needs for power flows across boundaries on the GB national electricity transmission system, as defined in ETYS. We published these requirements in the ETYS in November and the TOs responded with options for reinforcing those boundaries. These are in the NOA Report.

The report summarises each reinforcement option and our cost-benefit analysis of those options. The report also identifies a preferred option or options for each boundary, based on cost-benefit analysis. For some options, we have included a summary of the Strategic Wider Works (SWW) analysis in this report.

It's important to note that while the SO identifies its preferred 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 non-build. The NOA Report emphasises reinforcing boundaries and we are very interested in innovative ways to do that. The SOF refers to some of the new technologies that could be used.

1.3 The NOA Report methodology

We started the NOA Report methodology in early 2015, working with the onshore TOs and Ofgem. The initial draft of the methodology was published on our website in June 2015 and, after more discussions and refinement, the methodology was published in September 2015.

The methodology is introduced in Chapter 2.

1.4 Navigating through the document

As explained earlier, the NOA Report follows the ETYS. Chapter 4 describes the options for necessary boundary reinforcements. There's a summary introduction for each boundary, but you can read this report in conjunction with the ETYS for more detail.

Some options are not in our NOA process analysis and are described in Chapter 3.

1.5 Stakeholder engagement and feedback

We want your views to help develop this document. There are stakeholder engagement prompts throughout the document and we've highlighted areas in each section where we'd like your views. The box below shows the format that you'll find in other key areas of the document.

Stakeholder engagement
We'd appreciate the industry's views on the availability assumptions of these generation types to further enhance our constraint modelling analysis.

Throughout the document, you'll see areas where we want to hear from you and share your industry experience. However, feedback isn't limited to those questions 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 Report.

Chapter two
Methodology

2.1 Introduction

This chapter highlights the methodology used for the NOA and how it ties in with the Strategic Wider Works (SWW) process.

2.2 NOA Report methodology

We have published our methodology for the NOA Report on our website. This is a link to the methodology: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=44227

We have summarised the methodology below. The NOA Report methodology is similar to the Network Development Policy methodology. You can find a copy of our NDP methodology on our website: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=34153

Figure 2.1 shows how we produced the NOA Report. We used the four Future Energy Scenarios (FES):

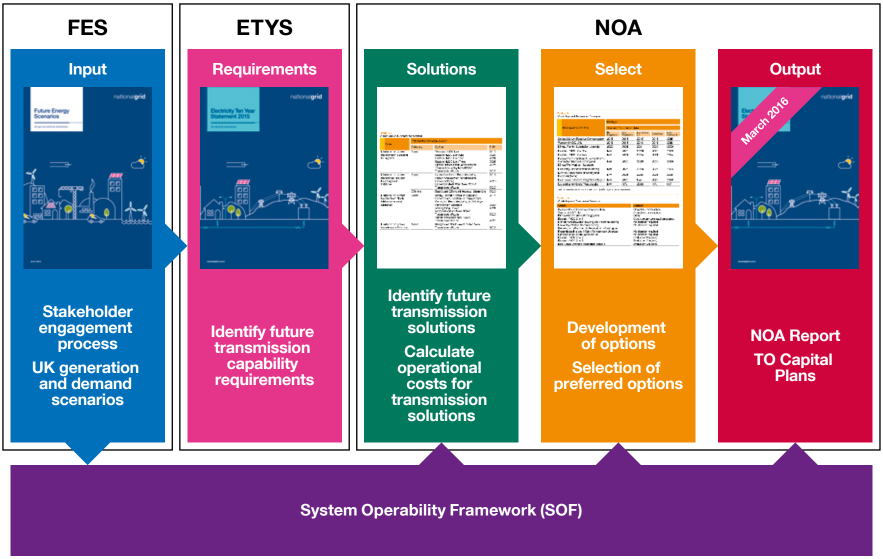
- Gone Green
- Slow Progression
- Consumer Power
- No Progression.

We produced the scenarios working with electricity industry stakeholders. The scenarios give us the generation and demand mix, which we turn into a location-based model that causes power transfers across the NETS. We use this to work out transfer needs across a set of boundaries on the NETS, which we have published in the Electricity Ten Year Statement (ETYS) for 2015. We have used ‘Local contracted’ and ‘No local contracted’ sensitivities where appropriate.

Transmission Owners (TOs) propose options to meet the reinforcement needs. Options include forecast capital costs. We use our understanding of operational costs to perform cost-benefit analysis of the options. This narrows the proposed options down to a preferred option or options, which are in Chapter 4 of the NOA Report.

2.2 NOA Report methodology

Figure 2.1
NOA Report process



In accordance with our licence condition, Major National Electricity Transmission System reinforcements are in the 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 **enabling works**. If the NOA analysis changes the timing of these works, it might affect the users' enabling works but not necessarily the connection date. If this happens, we will work with those stakeholders and keep them informed.

2.3 How the NOA Report connects to the SWW process

For the NOA Report process we, as the SO, identify the reinforcements that the NETS needs, then the TOs show possible solutions. Some viable options may need little or no building. We use the NOA Report process to look at the costs and benefits of potential solutions. If the preferred options involve large infrastructure solutions that satisfy the criteria for SWW the TOs do more detailed analysis to develop the needs case to justify the right solution.

It's important to note that the TO leads on developing needs cases for SWW projects. The SO supports the TO with the cost-benefit 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 key 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 option's funding.

We have published our methodology for the SO Process for Input into TO-led SWW Needs Case Submissions on our website. This is a link to the methodology: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=44227

2.3.1 Summary description of the SWW methodology

Where the project is designated SWW, cost-benefit analysis examines the economic benefit of a range of reinforcement options against the counterfactual network across their lifetimes. The counterfactual is usually 'do nothing' or 'do minimum' and has no associated capital costs. Constraint costs are forecast for the counterfactual and each network solution across all scenarios and sensitivities. We calculate the present value of constraint savings compared to the counterfactual for each network solution. These are then subtracted from the 'Spackman'[1] present value of capital expenditure associated with each network solution, giving a net present value for each network solution. Taking these net present values, we use lifetime least worst regret analysis to determine a preferred network solution and an optimal delivery year. The results are tested through robustness analysis to show how changing project capital costs and constraint savings would affect the conclusions.

The process may be varied where modelling the counterfactual network is not straightforward. Such variations are assessed, case by case, with Ofgem.

[1] 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.

2.4 Operational costs assessment inputs

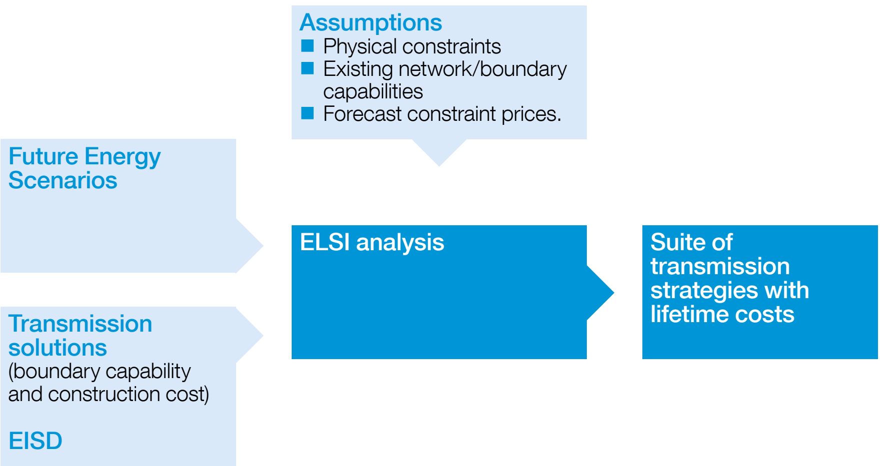
When the power transfer that's needed across a transmission system boundary is above that boundary's maximum operational capability, we incur operational constraint costs. This is because we'll have to pay generators within the affected boundary to limit their output; and we'll also have to replace this energy with generation taken from an unconstrained area of the network.

When we're assessing wider works, such as a new route to reinforce across a major boundary, operational constraint cost assessment is an important factor in our decision-making process. It's all a question of timing: if we make the transmission investment too early, we run the risk of stranded or inefficient use of assets; but if we build the additional network capacity too late, we run the risk of incurring operational constraint costs. It takes time to construct a reinforcement and so this time, which varies from one option to another, is a factor in our analysis. This gives the earliest in service date (EISD).

Every energy scenario is unique, with its own axioms. So we use a detailed cost-benefit analysis to work out the optimum combination of transmission solutions for each of the demand and generation scenarios.

We use the Electricity Scenario Illustrator (ELSI) tool to simulate the operation of generation and pumped storage to meet consumer needs. It forecasts the costs of operational 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 2015.

Figure 2.2
ELSI tool inputs



2.4 Operational costs assessment inputs

Figure 2.2 shows the various inputs to ELSI (you'll find more detail in Appendix A of this report). The inputs fall broadly into three categories:

1. **Existing boundary capabilities and their future development –** these were calculated using a separate power system analysis package. ELSI doesn't model their dependence on generation and demand or the power sharing across circuits. The input to ELSI includes the increase in capability, cost and the EISD
2. **Future Energy Scenarios –** ELSI assesses all option reinforcements against each of the detailed Future Energy Scenarios. The resulting analysis takes us up to 2035 (the values from 2036 are extrapolated so that we can estimate full lifetime costs). ELSI analyses lifetime costs for various transmission strategies, combinations and timings of transmission solutions to identify the optimum cost benefit for each of the scenarios and sensitivities
3. **Assumptions –** ELSI's other input data takes account of fuel cost forecasts, plant availabilities and prices in interconnected European member states.

If you'd like to run your own analysis on the possible development of wider works, you can access a copy of the ELSI tool at **http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=39022**

Chapter three
Methodology variations

3.1 Introduction

This chapter describes how we have varied from the NOA Report methodology and where options have been excluded from the NOA Report.

3.2 Why there are exclusions

This report looks at all the options that could help meet the National Electricity Transmission System's (NETS) reinforcement needs.

The process for this first NOA Report assesses boundary reinforcement needs. So the report 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 Strategic Wider Works category (SWW))
- options that provide benefits, such as voltage control over the summer minimum, but no boundary capability improvement (this is an area where we particularly welcome stakeholder feedback)
- analysis of options where, by inspection, the costs for the expected benefits would be prohibitive.

3.3 Excluded options

The analysis doesn't include SWW projects that Ofgem has already approved, but they do form part of the base line for the NOA Report. The one project is the Caithness – Moray HVDC Link and associated AC works in Caithness and Morayshire.

The single-year regret analysis in the first NOA Report doesn't include schemes with no boundary capability. Options in Scotland that are funded via the volume driver and that are not 'major' are not in the report.

3.4 Included options

The System Operator (SO) will include a summary of results in the NOA Report for projects where the Transmission Owner (TO) has started the 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.

Chapter four
Overview of transmission solution options

4.1 Introduction

The Electricity Ten Year Statement (ETYS) shows the likely future transmission needs of bulk power transfer capability of the National Electricity Transmission System (NETS). This chapter focuses on the potential options for the NETS to fulfil those needs.

4.1.1 General considerations

When the SO and TOs develop and implement a transmission strategy we run an inclusive and robust optioneering process. This helps us evaluate each transmission option and agree the best solution. With this assessment we balance the conflicting priorities of network benefit, cost and the build programme with their associated risks. All the parties involved need to work together to make sure that a timely, economic and efficient network solution is delivered for consumers.

Strategic optioneering
In looking for solutions to develop the NETS we consider both onshore and offshore transmission solutions – and we recognise that offshore options have different considerations.

Future generation connections, especially nuclear and renewables, are likely to need major network reinforcements in some regions. These can be onshore or offshore and may involve extensive planning and construction programmes. Significant strategic pre-construction work may be needed to deliver an efficient transmission strategy. It's also important that delivering the overall strategy isn't compromised while progressing local connections for individual projects.

Under Connect and Manage (C&M), generation projects may connect to the transmission system before wider transmission reinforcement works are complete. Wherever possible, no-build and commercial options will be taken forward to manage the increasing requirements in network capability. This should be consistent with the strategies identified.

As well as the most economic and efficient solution, the following factors are identified for each transmission solution. This provides consistency for the cost-benefit analysis.

Lead-time: as provided by the Transmission Owner (TO), the time required to develop and deliver each transmission solution drives the Earliest In Service Date (EISD). We know that for some major infrastructure projects (such as new overhead lines that require planning consents) there's significant lead-time risk. This report will, where necessary, describe the preferred option or options.

Cost: the forecast total cost for delivering, delaying or cancelling the project as provided by the TOs.

4.1.2 Planning consents

The transmission system options in this document don't refer to development consent or planning permission. Please note that planning permissions are needed when physically developing the NETS.

The TO is responsible for complying with all respective planning requirements.

4.2 Commercial and non-build options

Commercial and non-build solutions can help boost boundary capacity by complementing or offering an alternative to asset solutions. We would like to explore this possibility with our stakeholders.

We're keen to discuss the possibility and benefits of commercial, non-build solutions to meet transmission capacity needs. Please tell us how you'd like to be more involved in meeting future network requirements through initiatives such as:

- providing network support from demand side response and distributed resources (embedded generation, load, and storage)
- Active Network Management on generation and demand (inter-trips, for example)
- third party asset investment at specific locations to support the system (reactive power services, for example).

We considered the commercial and non-build options listed in the NOA Report methodology (see Table A1) but only one has been progressed in this report.

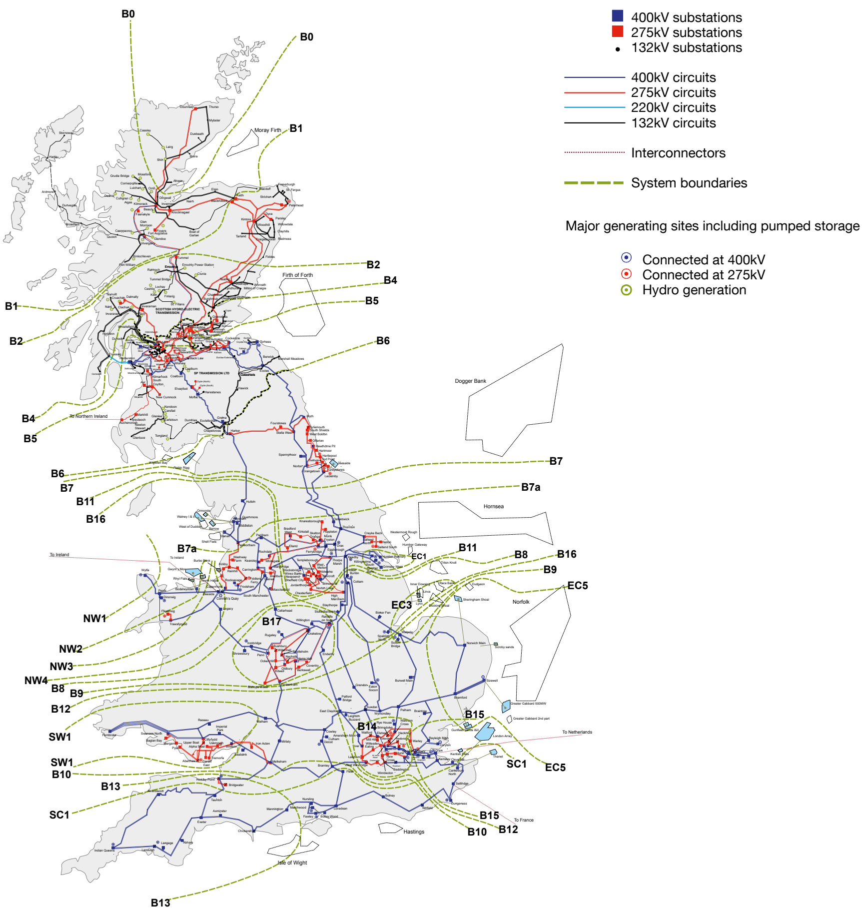
Stakeholder engagement
We'd appreciate hearing your views on commercial and non-build solutions.

4.3 Boundary descriptions

This section provides a short introduction to the boundaries on the NETS with existing infrastructure and including authorised reinforcements. You'll find a fuller description in this year's ETYS.

Figure 4.1 shows all the boundaries we have considered for this year's analysis.

Figure 4.1
ETYS GB boundaries



4.3 Boundary descriptions

North

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 NETSO.

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.

Table 4.1
Effective reinforcement options

Unique reference	Reinforcement title	Boundaries affected
BLUP	Rebuild of Beauly to Shin to Loch Buidhe 132kV double circuit OHL to 275kV double circuit	B0
BLN2	New Beauly to Loch Buidhe 275kV double circuit	B0
BLN4	New Beauly to Loch Buidhe 400kV double circuit	B0
BBNO	New Beauly to Blackhillock 400kV double circuit	B1
BBU1	Rebuild of Beauly – Nairn – Elgin – Blackhillock 132kV double circuit OHL to 400kV double circuit	B1
BKNO	New Beauly to Kintore 400kV double circuit	B1
BBU2	Rebuild of Beauly to Knocknagael to Blackhillock 275kV double circuit OHL to 400kV double circuit	B1
ECU2	East Coast onshore 275kV upgrade	B4, B5
ECU4	East Coast onshore 400kV upgrade	B2, B4
E4DC	Eastern subsea HVDC Link from Peterhead to Hawthorn Pit	B2, B4, B5, B6, B7, B7a
E1DC	Eastern subsea HVDC Link from Peterhead to Torness to Hawthorn Pit	B2, B4, B5, B6, B7, B7a
DWNO	Denny to Wishaw 400kV reinforcement	B4, B5
TLNO	Torness to Lackenby AC reinforcement	B6, B7, B7a
E2DC/E3DC	Eastern subsea HVDC Link from Torness to Hawthorn Pit/Lackenby	B6, B7, B7a
AHNO	Dumfries and Galloway reinforcement	B6
WEDC	Western HVDC Link	B7a, B7, B6, NW4
ELEU	New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade	B6, B7, B7a
NOR1	Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit	B7a, B7
LNRE	Reconductor Lackenby to Norton single 400kV circuit	B7a, B7
NPNO	New east – west circuit between Norton and Padiham	B7, B7a, B11
HSUP	Uprate Harker to Stella West circuits from 275kV to 400kV	B7a, B7, B11
LDQB	Lister Drive quad booster	B7a
PCRE	Penwortham to Padiham and Penwortham to Carrington ('south') reconductoring	B7a

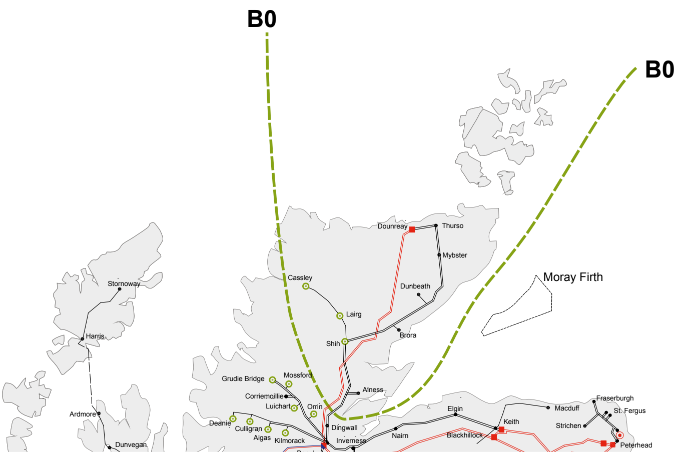
Unique reference	Reinforcement title	Boundaries affected
SSRE	Reconductor the Stella West to Spennymore circuits	B11
WEOS	Western HVDC Link fast de-load scheme	B8
CASR	Carrington series reactor	B8
CDH1	Cellarhead to Drakelow OHL thermal upgrade	B8, B11
KWR1	Reconductor the Keadby to West Burton No1 circuit	B11
KWR2	Reconductor the Keadby to West Burton No2 circuit	B9, B11
BSRE	Bredbury to South Manchester cable replacement, uprating and OHL reinstatement	B8
LIRE	Legacy – Ironbridge conductor replacement	B8, NW4
DMC1	Reconductor the Daines to Macclesfield circuit	B8
KWSR	Install series reactors in both Keadby to West Burton circuits	B9
THSR	Install series reactors at Thornton	B9
WPNO	Wylfa to Pentir second double circuit route	NW1
PTNO	Pentir to Trawsfyndd second circuit	NW2
PTC1	Pentir to Trawsfyndd 1 cable replacement – single core per phase	NW2
PTC2	Pentir to Trawsfyndd 1 and 2 cables – second core per phase	NW2
CPRE	Pentir to Bodelwyddan to Connah's Quay reconductoring	NW2, NW3
IRMS	Install reactive compensation at Ironbridge	NW4
TLH1	Treuddyn Tee to Legacy thermal upgrade	NW4
CAM1	Install reactive compensation for North Wales export	NW4
CAM2	Install additional reactive compensation for North Wales export	NW4
WPDC	North Wales to South Wales HVDC Link	NW1, NW4, B8, SW1
LIQB	Legacy to Ironbridge quad booster uprating	NW4
QDRE	Reconductor the Connah's Quay – Daines circuits	NW4

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

4.3 Boundary descriptions

Boundary B0 – Upper North SHE Transmission

Figure B0.1
Geographic representation of boundary B0

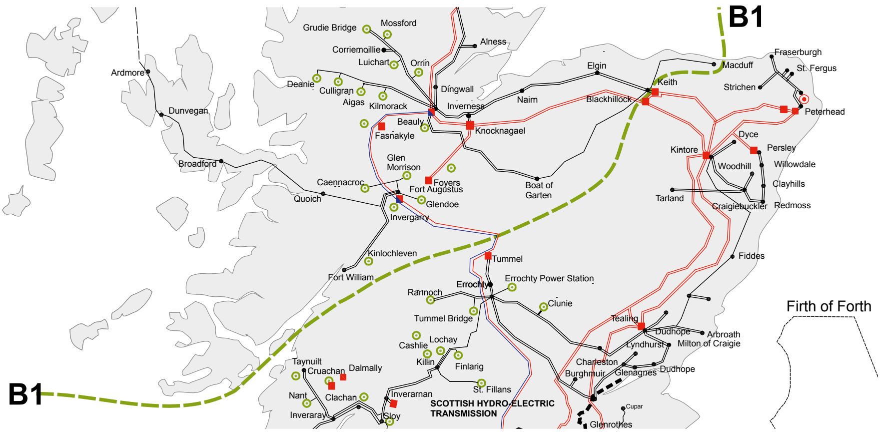


Boundary B0 separates the area north of Beauly, comprising north Highland, Caithness, Sutherland and Orkney. The existing transmission infrastructure north of Beauly is relatively sparse.

The boundary cuts across the existing 275kV double circuit and 132kV double circuits 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, Mybster and Thurso. Orkney is connected via a 33kV subsea link from Thurso. High renewables output causes high transfers across the B0 boundary.

Boundary B1 – North West SHE Transmission

Figure B1.1
Geographic representation of boundary B1

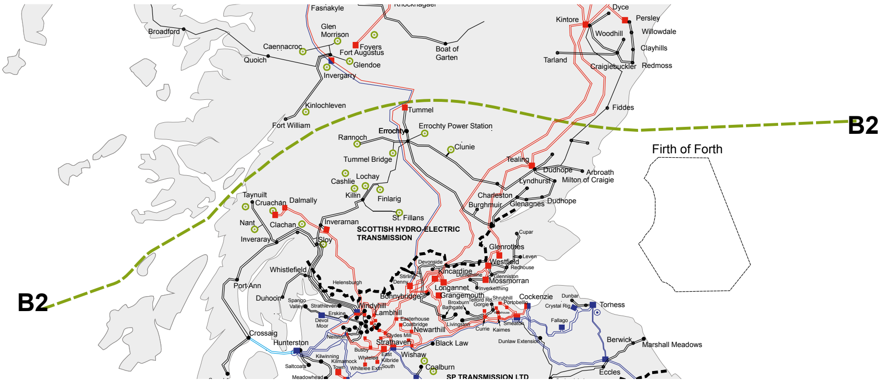


Boundary B1 runs from the Moray coast near Macduff to the west coast near Oban, separating the North West of Scotland from the southern and eastern regions. The boundary crosses the 275kV double circuit running eastwards from Knocknagael to Blackhillock, the 275/132kV interface at Keith and the 275/400kV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

4.3 Boundary descriptions

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 B4 – SHE Transmission to SP Transmission

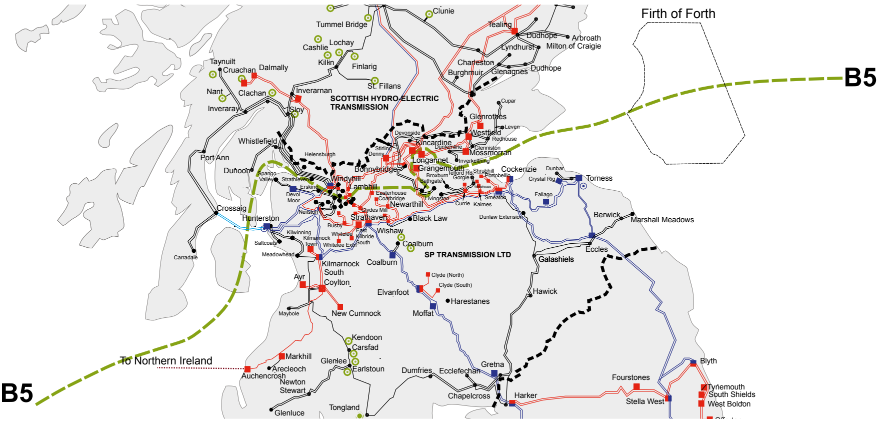
Figure B4.1
Geographic representation of boundary B4

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.

4.3 Boundary descriptions

Boundary B5 – North to South SP Transmission

Figure B5.1
Geographic representation of boundary B5



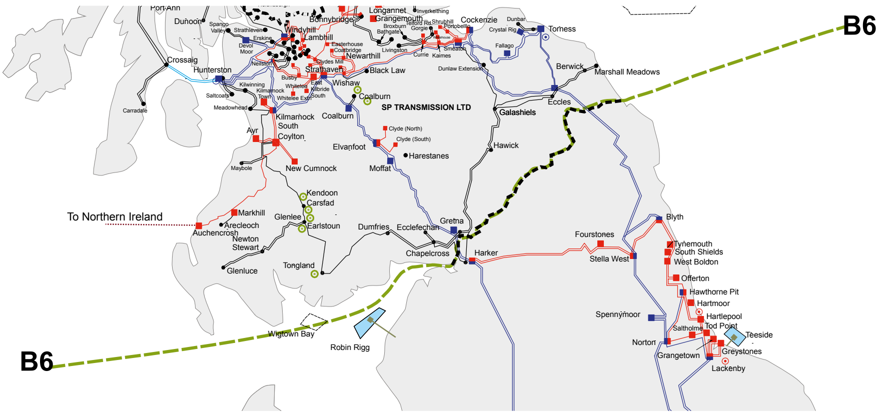
Boundary B5 is internal to the SP Transmission system and runs from the Firth of Clyde in the west to the Firth of Forth in the east. Pumped storage generating stations, together with the demand groups served from Windyhill, Lambhill and Bonnybridge 275kV substations, are located to the north of boundary 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.

Chapter four

Boundary B6 – SP Transmission to NGET

Figure B6.1
Geographic representation of boundary B6

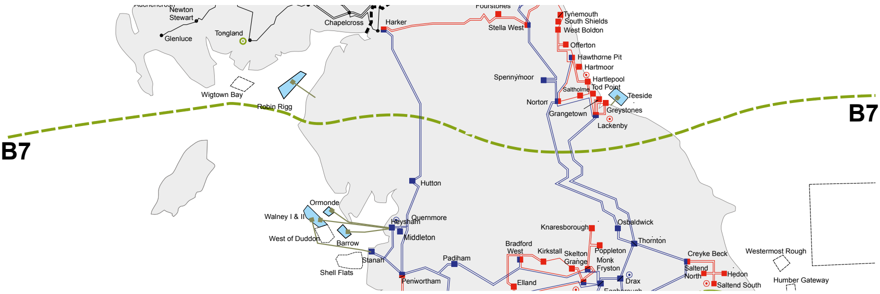


Boundary B6 separates the SP Transmission and the National Grid Electricity Transmission (NGET) systems. The existing transmission network across the boundary primarily consists of two double-circuit 400kV routes. There are also some limited capacity 132kV circuits across the boundary. The key 400kV 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.

4.3 Boundary descriptions

Boundary B7 – Upper North

Figure B7.1
Geographic representation of boundary B7

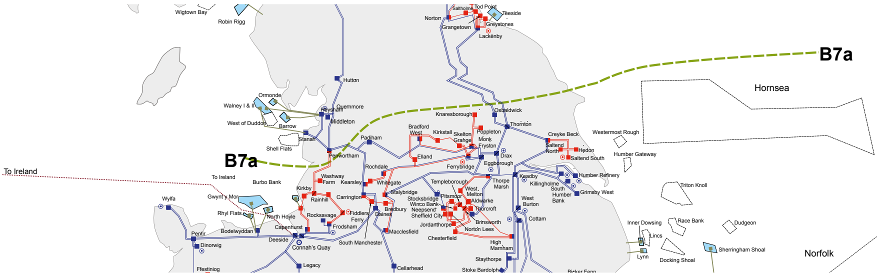


Boundary B7 bisects England south of Teesside, cutting across Cumberland. It is characterised by three 400kV double circuits: two in the east and one in the west.

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.

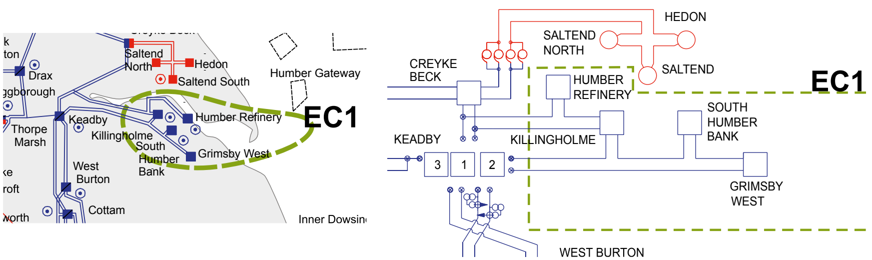
Boundary B7a – Upper North

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.

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.

4.3 Boundary descriptions

East

Introduction

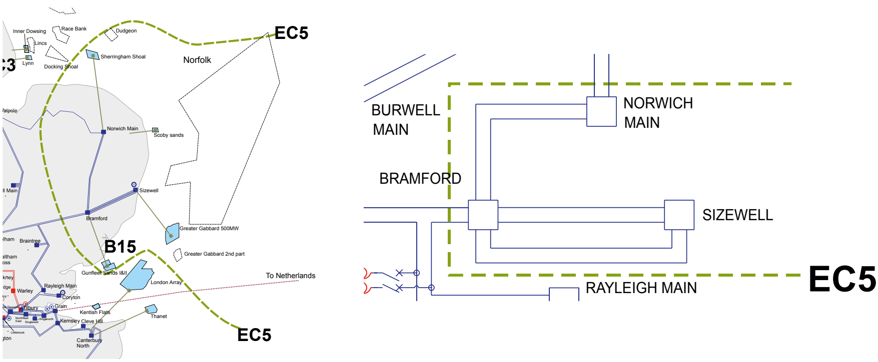
The East region includes the counties of Norfolk and Suffolk. The transmission boundaries EC3 and EC5 cover the transmission network in the area. Both boundaries are considered local, based on the generation and demand currently connected.

Table 4.2
Effective reinforcement options

Unique reference	Reinforcement title	Boundaries affected
BMMS	Burwell Main MSCs	EC5
CTRE	Coryton South – Tilbury reconductoring	EC5
RTRE	Rayleigh – Tilbury reconductoring	EC5
NBRE	Norwich Main – Bramford reconductoring	EC5
BRH1	Thermal upgrade of Bramford to Braintree to Rayleigh route	EC5
BTNO	Bramford – Twinstead new overhead line	EC5
RMSR	Rayleigh Main series reactors	EC5
TPNO	Pelham – Twinstead new overhead line	EC5
SWRE	Sundon – Wymondley reconductoring	EC5

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.

4.3 Boundary descriptions

South

Introduction

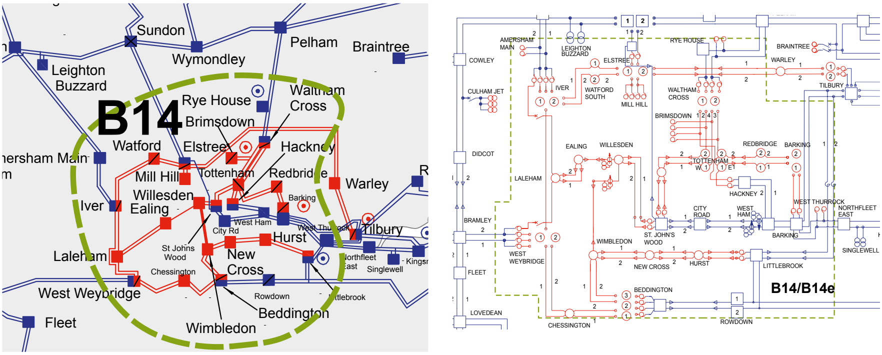
The South region stretches from London across to Devon and Cornwall. It has a high concentration of power demand and generation, with much of the demand found in London and generation in the Thames Estuary. Interconnection to Continental Europe is present along the south coast and influences power flows in the region by being able to import and export power with Europe. The South region includes boundaries B14, B15 and SC1.

Table 4.3
Effective reinforcement options

Unique reference	Reinforcement title	Boundaries affected
DCRE	Dungeness – Sellindge reconductoring and Dungeness circuit swap	SC1
KLRE	Kemsley – Littlebrook circuits uprating (Littlebrook – Longfield Tee reconductoring)	B14, B15, SC1
SCNO	New 400kV transmission route between South London and south-east coast	B14, B15, SC1
SCVC	South-east coast dynamic reactive compensation	B15, SC1
FLRE	Fleet – Lovedean reconductoring	SC1
WYTI	Wymondley turn-in	B14
WYQB	Wymondley quad boosters	B14
HWUP	Hackney – Tottenham – Waltham Cross upgrade	B14
ESRE	Elstree – Sundon 1 circuit reconductoring	B14
WEC1	Willesden – Wimbledon 275kV cable Ealing Diversion	B14

Boundary B14 – London

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

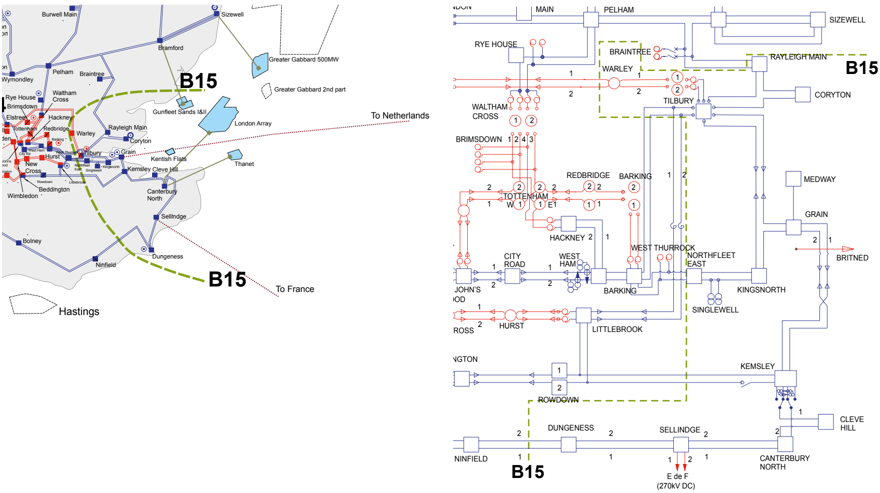


Boundary B14 encloses London and is characterised by high local demand and a small amount of generation. The circuits entering from the north can be heavily loaded during winter peak conditions. The circuits are further stressed when the European interconnectors export to the continent.

4.3 Boundary descriptions

Boundary B15 – Thames Estuary

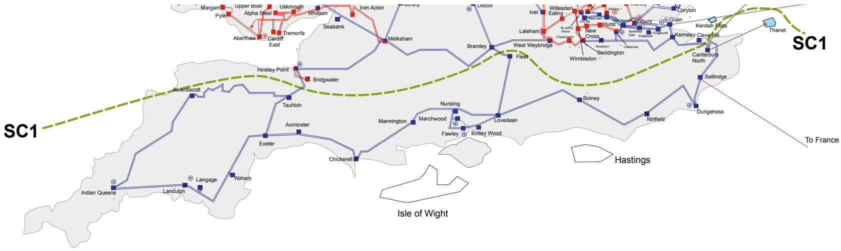
Figure B15.1
Geographic and single-line representation of boundary B15



Boundary B15 is the Thames Estuary boundary, enclosing the south-east corner of England. With its large generation base, the boundary normally exports power to London. Power export is largely influenced by the large interconnectors at Sellindge and Grain connecting to France and the Netherlands. With agreements in place for new interconnectors to France and Belgium within boundary B15, the boundary power flows will become dominated by the interconnector activity.

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.

4.3 Boundary descriptions

West

Introduction

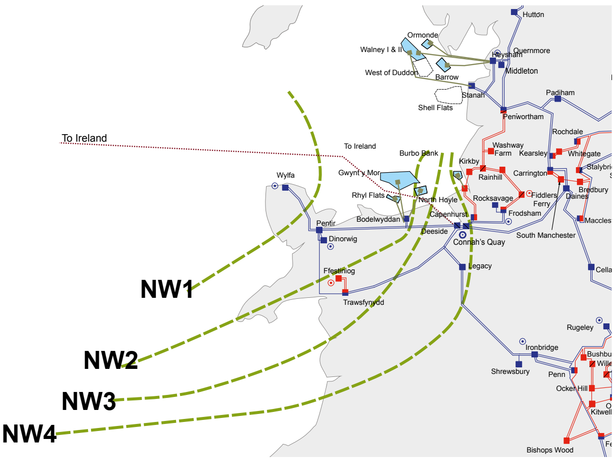
The West region covers the remaining boundaries on the system including Wales, the Midlands and the South West. Some of the boundaries are closely related, such as those for North Wales, but the region also covers large wider boundaries such as B8, B9, B13 and B17.

Table 4.4
Effective reinforcement options

Unique reference	Reinforcement title	Boundaries affected
WEOS	Western HVDC Link fast de-load scheme	B8
BSRE	Bredbury – South Manchester reconductoring	B8
CAM1	Install reactive compensation for North Wales export	NW4
CAM2	Install additional reactive compensation for North Wales export	NW4
CASR	Carrington series reactor	B8
CDH1	Cellarhead – Drakelow OHL thermal upgrade	B8
CIQB	Cilfynydd quad boosters	SW1
CPRE	Pentir – Bodelwyddan – Connah's Quay reconductoring	NW1, NW2, NW3, NW4, B8
DMC1	Cellarhead – Daines – Macclesfield reconductoring	B8, B17
IRMS	Ironbridge MSCs	NW4, B8, B9
KWR1	Keadby – West Burton No1 circuit reconductoring	B9, B11
KWR2	Keadby – West Burton No2 circuit reconductoring	B9, B11
KWSR	West Burton series reactor	B8, B9
LIQB	Replace Legacy quad boosters	NW4, B8, B9
LIRE	Legacy – Ironbridge reconductoring	NW4, B8, B9
PTC1	Pentir – Trawsfynydd cable – single core per phase	NW2
PTC2	Pentir – Trawsfynydd cable – second core per phase	NW2
PTNO	Pentir – Trawsfynydd second overhead line	NW2
PWTI	Rhigos turn-in	SW1
QDRE	Connah's Quay – Daines reconductoring	NW2, NW3, NW4, B8
HSNO	Hinkley Point to Seabank new double circuit	B13
HMRE	Hinkley Point to Melksham circuit reconductoring part 1	B13
FLRE	Fleet to Lovedean reconductoring	SC1
SEC1	Severn Cables upgrade	SW1
CEH1	Upgrade the Cardiff East to Cowbridge leg of the Aberthaw – Cardiff East – Pyle circuit	SW1
HCC1	Hinksey cables upgrade	SW1
SWSC	Walham and Imperial Park reactive compensation	SW1
CIQB	Quad booster installation at Cilfynydd	SW1
THSR	Thornton series reactor	B9
TLH1	Treuddyn – Legacy thermal upgrade	NW4
WEOS	Western HVDC Link operational tripping scheme	B8, B9
WPDC	Wylfa Pembroke HVDC Link	NW1, NW2, NW3, NW4, SW1, B8, B9
WPNO	Wylfa – Pentir new second overhead line	NW1

Boundary NW1, NW2, NW3 and NW4 – North Wales

Figure NW.1
Geographic representation of North Wales boundaries NW1, NW2, NW3 and NW4



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 four 'NW' boundaries are local boundaries.

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.

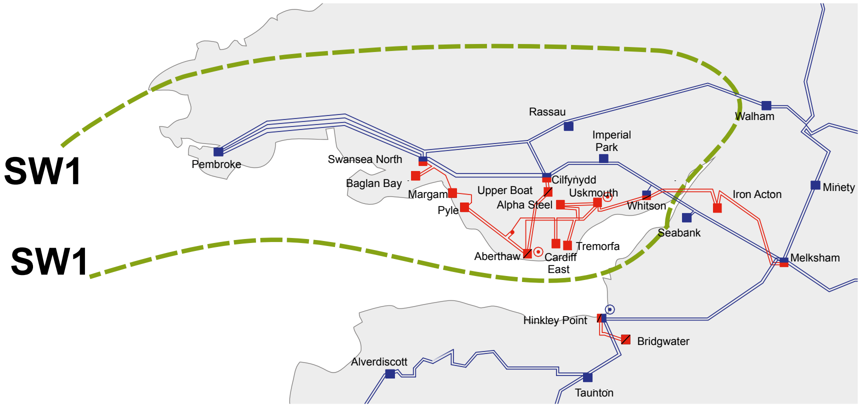
Boundary NW4 – North Wales

Boundary NW4 covers most of North Wales. Given that it contains fairly low generation and demand, it is currently considered a local boundary.

4.3 Boundary descriptions

Boundary SW1 – South Wales

Figure SW1.1
Geographic representation of boundary SW1

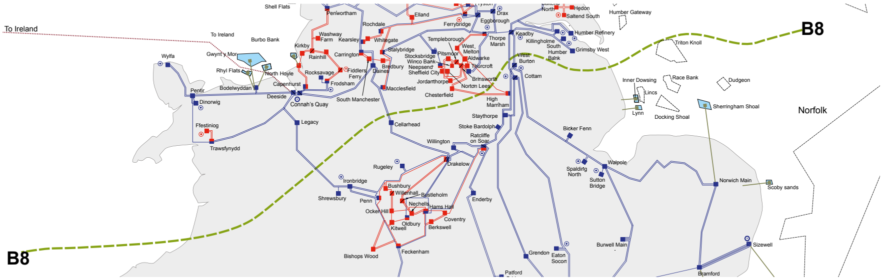


Boundary SW1 encloses South Wales and is considered a local boundary. Within the boundary are a number of thermal generators. Some of the older power stations are expected to close in the future but significant amounts of new generation capacity are expected to connect, including generators powered by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

Chapter four

Boundary B8 – North to Midlands

Figure B8.1
Geographic representation of boundary B8

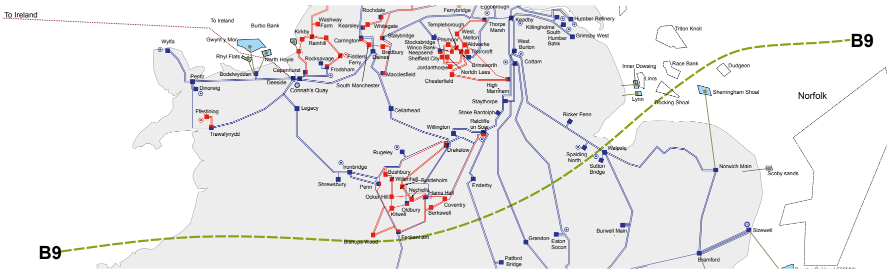


The North to Midlands boundary B8 is one of the wider boundaries that intersects the centre of Great Britain, separating the northern generation zones including Scotland, Northern England and North Wales, from the Midlands and southern demand centres. The boundary crosses four major 400kV double circuits, 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.

4.3 Boundary descriptions

Boundary B9 – Midlands to South

Figure B9.1
Geographic representation of boundary B9

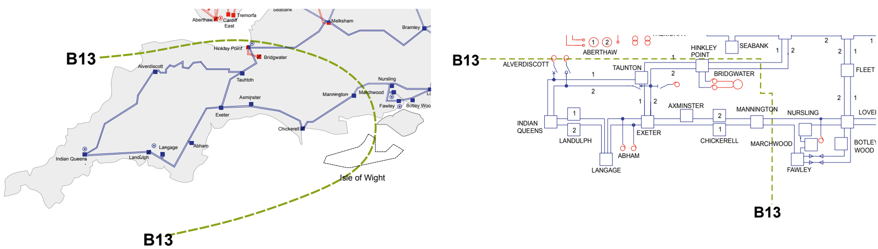


The Midlands to South boundary B9 separates the northern generation zones and the Midlands from the southern demand centres.

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

Boundary B13 – South West

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



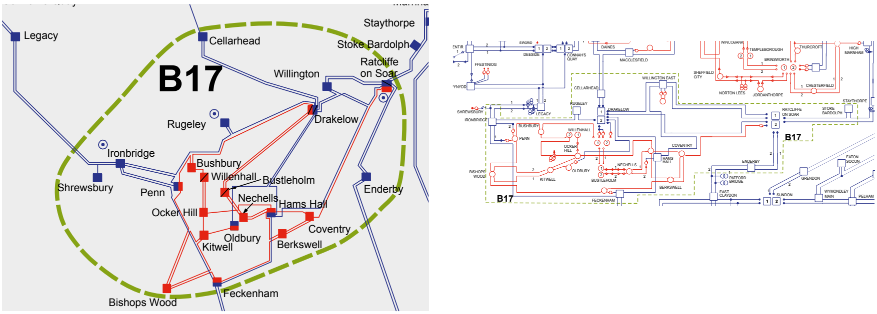
Chapter four

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.

4.3 Boundary descriptions

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.

4.4 Reinforcement options – Scotland and North of England

This section 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 Strategic Wider Works (SWW).

Dounreay to Orkney, Bay of Skaill Boundaries that benefit: radial	Installing a 220kV AC subsea cable rated at around 200MW between Bay of Skaill on the west coast of the Orkney Mainland and the existing 275kV substation at Dounreay, on the north coast of Caithness.
Gills Bay to Orkney, South Ronaldsay Boundaries that benefit: radial	Installing a 220kV subsea cable rated at around 200MW between Newark Bay on the east coast of South Ronaldsay and the proposed new 132kV substation at Gills Bay on the north-east coast of Caithness. A double-circuit 132kV steel tower overhead and cable line is planned to connect Gills Bay substation to the new 275/132kV Thurso South substation.
Spittal to Orkney, South Ronaldsay Boundaries that benefit: radial	Installing a 220kV AC subsea cable rated at around 200MW between Newark Bay on the west coast of South Ronaldsay and the Spittal HVDC substation located in Caithness.
Beauly to Western Isles, Gravir 450MW HVDC Link Boundaries that benefit: radial	This link would connect at the 400kV busbar at Beauly and include a new 400kV GIS switchboard and a 450MW HVDC converter station. The link would comprise 80km of land cable and 76km of subsea cable to a new HVDC converter station at Gravir on the Isle of Lewis.
Beauly to Western Isles, Arnish 450MW HVDC Link Boundaries that benefit: radial	This link would connect at the 400kV busbar at Beauly and include a new 400kV GIS switchboard and a 450MW HVDC converter station. The link would comprise 80km of land cable and 76km of subsea cable to a new HVDC converter station at Arnish on the Isle of Lewis.

4.4 Reinforcement options – Scotland and North of England

Beauly to Western Isles, Arnish 600MW HVDC Link Boundaries that benefit: radial	This link would connect at the 400kV busbar at Beauly and include a new 400kV GIS switchboard and a 600MW HVDC converter station. The link would comprise 80km of land cable and 76km of subsea cable to a new HVDC converter station at Arnish on the Isle of Lewis.
Caithness to Shetland 600W HVDC Link Boundaries that benefit: radial	This is a 600MW HVDC Link between Kergord on Shetland and the HVDC switching station at Noss Head in Caithness. The 320kV HVDC Caithness – Moray circuit would be tied in to the HVDC switching station to form the three-terminal HVDC scheme.
Caithness to Shetland 450W HVDC Link Boundaries that benefit: radial	This is a 450MW HVDC Link between Kergord on Shetland and a HVDC switching station at Noss Head in Caithness. The 320kV HVDC Caithness – Moray circuit would be tied in to the HVDC switching station to form the three-terminal HVDC scheme.
Moray to Shetland 600W HVDC Link Boundaries that benefit: radial	This is a 600MW HVDC Link between Kergord on Shetland and Blackhillock in Moray that involves an HVDC converter at Blackhillock with a 400kV AC connection there.
BLUP **Rebuild of Beauly to Shin to Loch Buidhe 132kV double circuit OHL to 275kV double circuit** Boundaries that benefit: B0	A new 275kV overhead line between the existing substation at Beauly and the substation being built at Loch Buidhe, near Bonar Bridge. The existing substation at Shin and the substation being built at Fyrish would be transferred onto this new overhead line. When the works are finished, the existing 132kV overhead line along the same route would be decommissioned and removed.
BLN2 **New Beauly to Loch Buidhe 275kV double circuit** Boundaries that benefit: B0	A new 275kV overhead line between the existing substation at Beauly and the substation being built at Loch Buidhe, near Bonar Bridge. The Fyrish substation being built would be transferred onto this new overhead line. When the works are finished, the existing 132kV overhead line between Beauly and Shin would be removed.
BLN4 **New Beauly to Loch Buidhe 400kV double circuit** Boundaries that benefit: B0	A new 400kV overhead line between the existing 400kV substation at Beauly and the new substation being built at Loch Buidhe, near Bonar Bridge. The Fyrish substation being built would be transferred onto this new overhead line. When the works are finished, the existing 132kV overhead line between Beauly and Shin 132kV would be removed.

BBNO **New Beauly to Blackhillock 400kV double circuit** Boundaries that benefit: B1	A new 400kV double circuit overhead line between Beauly and Blackhillock. It would follow the route of the existing Beauly – Knocknagael – Blackhillock circuits, running south of Knocknagael.
BBU1 **Rebuild of Beauly – Nairn – Elgin – Blackhillock 132kV double circuit OHL to 400kV double circuit** Boundaries that benefit: B1	Replacing the Beauly – Nairn – Elgin – Keith 132kV double circuit overhead line with a 400kV double circuit overhead line. It would bypass Keith and end at Blackhillock.
BKNO **New Beauly to Kintore 400kV double circuit** Boundaries that benefit: B1	A new 400kV double circuit overhead line between Beauly and Kintore. It would follow the route from Beauly – Knocknagael – Tomatin – Aberlour – Kintore, running south of Knocknagael and avoiding the Cairngorms National Park.
BBU2 **Rebuild of Beauly to Knocknagael to Blackhillock 275kV double circuit OHL to 400kV double circuit** Boundaries that benefit: B1	Replacing the Beauly – Knocknagael – Blackhillock 275kV double circuit overhead line with a 400kV double circuit overhead line along the same route.
ECU2 **East Coast onshore 275kV upgrade** Boundaries that benefit: B4, B5	Establishing a new 275kV substation at Alyth. The Kintore – Alyth – Kincardine 275kV double circuit overhead line would be reprofiled and the Alyth – Tealing – Westfield – Longannet 275kV double circuit overhead line and cables would be uprated. Two 275kV phase shifting transformers would be installed at Kintore on the circuits to Tealing and shunt reactive compensation would be installed at the new Alyth substation.
ECU4 **East Coast onshore 400kV upgrade** Boundaries that benefit: B2, B4	Establishing new 400kV substations at Rothienorman, Alyth and Kintore. Replacing the insulation on the existing 275kV circuits between Blackhillock, Rothienorman, Kintore, Alyth and Kincardine to allow operation at 400kV. The conductors and towers are already constructed to a 400kV specification. The project would also upgrade Fetteresso 275kV substation to operate at 400kV and reconductor the section between Rothienorman and Kintore for high-temperature operation. Two-phase shifting transformers would be added at Blackhillock 275kV substation on the Knocknagael circuits.

4.4 Reinforcement options – Scotland and North of England

E4DC **Eastern subsea HVDC Link from Peterhead to Hawthorn Pit** Boundaries that benefit: B2, B4, B5, B6, B7, B7a	A new offshore 2GW HVDC subsea link from Peterhead to Hawthorn Pit in the North East of England. The onshore works involve building AC/DC converter stations and the associated AC works at Peterhead and Hawthorn Pit.
E1DC **Eastern subsea HVDC Link from Peterhead to Torness to Hawthorn Pit** Boundaries that benefit: B2, B4, B5, B6, B7, B7a	Building a new offshore 2GW HVDC subsea link from Peterhead to Hawthorn Pit via Torness. The onshore works involve constructing AC/DC converter stations and the associated AC works at Peterhead, Torness and Hawthorn Pit.
DWNO **Denny to Wishaw 400kV reinforcement** Boundaries that benefit: B5	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.
TLNO **Torness to Lackenby AC reinforcement** Boundaries that benefit: B6, B7, B7a	This option provides more transmission capacity across the B6, B7, and B7a boundaries. This would be achieved by installing a new double circuit from a new 400kV substation in the Torness area to a new or existing 400kV substation in the North East of England.
E2DC/E3DC **Eastern subsea HVDC Link from Torness to Hawthorn Pit/Lackenby** Boundaries that benefit: B6, B7, B7a	Building a new offshore 2GW HVDC subsea link from the Torness area to Hawthorn Pit or Lackenby. The onshore works would involve new AC/DC converter stations and the associated AC works at Torness and Hawthorn Pit or Lackenby.
AHNO **Dumfries and Galloway reinforcement** Boundaries that benefit: B6	Building an overhead line from Auchencrosh to Dumfries, capable of operation up to 400kV. A new 400kV double circuit from there would connect to Harker and parts of the existing 132kV network would be removed.
WEDC **Western HVDC Link** Boundaries that benefit: B6, B7, B7a	A new 2.4GW (short-term rating) submarine HVDC cable route from Deeside to Hunterston with associated AC network reinforcement works on both ends.

ELEU **New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade** Boundaries that benefit: B6, B7, B7a	Reinforcements at Hawthorn Pit would allow better flow sharing in the north-east ring and carry more power out of the area.
NOR1 **Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit** Boundaries that benefit: B7, B7a	Sections of the Norton – Osbaldwick 400kV double circuit would be reconducted with higher-rated conductor.
LNRE **Reconductor Lackenby to Norton single 400kV circuit** Boundaries that benefit: B7, B7a	Sections of the Lackenby – Norton 400kV circuit would be reconductored with higher-rated conductor and the cross-site cable at Lackenby 400kV substation would be upgraded to a higher rating.
NPNO **New east – west circuit between Norton and Padiham** Boundaries that benefit: B7, B7a, B11	A new 400kV east – west circuit across the North of England between Norton and Padiham to allow better flow sharing between east and west parts of the network.
HSUP **Upgrade the Harker to Stella West circuits from 275kV to 400kV** Boundaries that benefit: B7, B7a, B11	The 275kV circuits between Stella West and Harker would be uprated, including Fourstones to 400kV. This would improve post-fault load sharing between the east and west parts of the network in the North of England.
LDQB **Lister Drive quad booster** Boundaries that benefit: B7a	Replacing the series reactor at Lister Drive with a quad booster to allow better control of power flows in the Mersey Ring area.
PCRE **Penwortham to Padiham and Penwortham to Carrington ('south') reconductoring** Boundaries that benefit: B7a	Penwortham – Padiham and Penwortham – Carrington circuits would be reconductored with higher-rated conductor.
SSRE **Reconductor the Stella West to Spennymoor circuits** Boundaries that benefit: B11	The 400kV circuits between Stella West and Spennymoor would be reconducted with higher-rated conductor to improve capability.

4.4 Reinforcement options – Scotland and North of England

WEOS **Western HVDC Link fast de-load scheme** Boundaries that benefit: B8	Adding fast de-load functionality to the Western HVDC Link. This would be activated automatically for specific network conditions and contingencies.
CASR **Carrington series reactor** Boundaries that benefit: B8	Installing a series reactor connecting the split busbar sections of Carrington 400kV substation.
CDH1 **Cellarhead to Drakelow OHL thermal upgrade** Boundaries that benefit: B8, B11	Thermal upgrading on the double circuit between Cellarhead and Drakelow to increase the north-west to Midlands transfer capacity.
KWR1 **Reconductor the Keadby to West Burton No1 circuit** Boundaries that benefit: B9, B11	The first Keadby – West Burton circuit would be reconductored with higher-rated conductor. This is a separate scheme from the No2 circuit below.
KWR2 **Reconductor the Keadby to West Burton No2 circuit** Boundaries that benefit: B9, B11	The second Keadby – West Burton circuit would be reconductored with higher-rated conductor. This is a separate scheme from the No1 circuit above.
BSRE **Bredbury to South Manchester cable replacement, uprating and OHL reinstatement** Boundaries that benefit: B8	Thermal upgrading and selective replacement of the assets between Bredbury and South Manchester substations to improve the route's capacity.
DMC1 **Reconductor the Daines to Macclesfield circuit** Boundaries that benefit: B8	The Daines – Macclesfield circuit would be reconductored with higher-rated conductor.
KWSR **Install series reactors in both Keadby to West Burton circuits** Boundaries that benefit: B9	Installing series reactors in both Keadby – West Burton circuits with the same thermal rating as the circuits.
THSR **Install series reactors at Thornton** Boundaries that benefit: B9	Installing two 400kV series reactors at Thornton, with one each between the split busbar sections.

WPNO **Wylfa to Pentir second double circuit route** Boundaries that benefit: NW1	Constructing a second 400kV transmission route from Wylfa to Pentir.
PTNO **Pentir to Trawsfyndd second circuit** Boundaries that benefit: NW2	Creating a second Pentir – Trawsfyndd 400kV circuit using the existing towers and corridor.
PTC1 **Pentir to Trawsfyndd 1 cable replacement – single core per phase** Boundaries that benefit: NW2	Replacing cable sections of the Pentir – Trawsfyndd 1 circuit with larger cable sections.
PTC2 **Pentir to Trawsfyndd 1 and 2 cables – second core per phase** Boundaries that benefit: NW2	Installing additional large cables on the cable sections of the Pentir – Trawsfyndd 1 and 2 circuits. This will go ahead only if the second circuit has been built and would include the long sections across the Glaslyn Estuary.
CPRE **Pentir to Bodelwyddan to Connah's Quay reconductoring** Boundaries that benefit: NW2, NW3	Reinforcing the Bodelwyddan tee point to Connah's Quay and from Pentir to Bodelwyddan tee point routes by reconductoring with higher-rated conductor.
IRMS **Install reactive compensation at Ironbridge** Boundaries that benefit: NW4	Installing capacitive shunt reactive compensation at Ironbridge. This would improve voltage performance post-fault with high transfers.
TLH1 **Treuddyn Tee to Legacy thermal upgrade** Boundaries that benefit: NW4	Thermal upgrading the Treuddyn Tee – Legacy leg of the Deeside – Legacy circuit to increase the rating of the circuit.
CAM1 **Install reactive compensation for North Wales export** Boundaries that benefit: NW4	Installing a 400kV switched capacitor (MSC) between Connah's Quay and Ironbridge.
CAM2 **Install additional reactive compensation for North Wales export** Boundaries that benefit: NW4	Installing a second 400kV switched capacitor (MSC) between Connah's Quay and Ironbridge.

4.4 Reinforcement options – Scotland and North of England

WPDC **North Wales to South Wales HVDC Link** Boundaries that benefit: NW1, NW4, B8, SW1	A new offshore 2GW HVDC subsea link between Wylfa and Pembroke. This would join the North Wales and South Wales parts of the transmission network.
LIQB **Legacy to Ironbridge quad booster uprating** Boundaries that benefit: NW4	Replacing and uprating the quad boosters to the maximum possible rating to release the circuit capacity of the overhead line.
LIRE **Legacy – Ironbridge conductor replacement** Boundaries that benefit: B8, B9, NW4	Reconductoring the Legacy – Ironbridge circuit and bypassing the quad boosters that have a low capacity. This will increase both the capacity of the circuit and capacity across the boundary.
QDRE **Reconductor the Connah's Quay – Daines circuits** Boundaries that benefit: NW4	The Connah's Quay to Daines circuit would be reconductored with higher-rated conductor.

4.4 Reinforcement options – East

BMMS **225MVAr MSCs at Burwell Main** Boundaries that benefit: EC5	Three new 225MVAr switched capacitors (MSCs) at Burwell Main would provide voltage support to the East Anglia area. The compensation would help maintain voltage compliance if there was a fault around the area, diverting power flowing through a longer transmission route.
CTRE **RTRE** **Reconductor Coryton South to Tilbury and Rayleigh to Tilbury** Boundaries that benefit: EC5	The circuits that run between Rayleigh Main, Coryton South and Tilbury would have higher-rated conductor installed to replace the existing conductors.
NBRE **Reconductor Bramford to Norwich double circuit** Boundaries that benefit: EC5	The double circuits that run from Norwich to Bramford would be reconductored with higher-rated conductor.
BRH1 **Thermal upgrade of Bramford to Braintree to Rayleigh route** Boundaries that benefit: EC5	Increasing the operating temperature between Bramford, Braintree and Rayleigh Main. This would increase the circuit's thermal capability.
BTNO **A new 400kV double circuit between Bramford and Twinstead** Boundaries that benefit: EC5	A transmission route from Bramford to the Twinstead tee point would create double circuits that run between Bramford – Pelham and Bramford – Braintree – Rayleigh Main.
RMSR **Rayleigh Main series reactors** Boundaries that benefit: EC5	A pair of 3000MVA series reactors would be installed at the Rayleigh Main substation on the Braintree – Rayleigh Main circuits.
TPNO **Pelham to Twinstead new 400kV double circuit** Boundaries that benefit: EC5	This option is to install a 400kV substation at Twinstead tee point on the Bramford – Pelham route and then turn the Bramford – Pelham and Braintree – Bramford – Pelham circuits into the newly established 400kV substation. The project also involves installing a new double circuit between Pelham and the newly established 400kV Twinstead substation.
SWRE **Reconductoring the Sundon to Wymondley circuit** Boundaries that benefit: EC5	Replace the existing conductor on the Sundon to Wymondley single circuit with new conductor to give a higher rating.

4.4 Reinforcement options – South

DCRE **Dungeness to Sellindge to Canterbury North reconductoring** Boundaries that benefit: SC1	The Dungeness to Sellindge overhead line double circuit would be reconductored with higher-rated conductor, increasing the route's thermal capacity.
FLRE **Fleet to Lovedean reconductoring** Boundaries that benefit: SC1	Reconductoring the Fleet – Lovedean double circuit to increase the winter post-fault rating.
KLRE **Kemsley to Littlebrook circuits uprating** Boundaries that benefit: B15	The 400kV circuits running from Kemsley via Longfield Tee to Littlebrook would be reconductored with higher-rated conductor.
SCNO **New 400kV transmission route between South London and the south coast** Boundaries that benefit: SC1	Constructing a 400kV double circuit between South London and the south-east coast.
SCVC **South-east coast dynamic reactive compensation** Boundaries that benefit: SC1, B15	Install a dynamic reactive compensation (known as an SVC) at Bolney, Ninfield and Richborough. This would provide reactive post-fault power to help maintain voltage stability on the south-east coast.
WYTI **Wymondley turn-in** Boundaries that benefit: B14, B14(e)	This option would turn in the Pelham to Sundon circuit at Wymondley to create two separate circuits from Pelham to Wymondley and from Wymondley to Sundon. This work would improve the balance of the power flows on the North London circuit. It would also allow the network to import more power into London from the north transmission routes.
WYQB **Wymondley quad boosters** Boundaries that benefit: B14, B14e	Installing a pair of 2750MVA quad boosters on the double circuits running from Wymondley to Pelham at the Wymondley 400kV substation.
HWUP **Hackney to Tottenham to Waltham Cross uprate** Boundaries that benefit: B14e	Uprating and reconductoring the existing 275kV transmission route between Hackney – Tottenham – Brimsdown – Waltham Cross with higher-rated conductor so that it can operate at 400kV. The double circuit from Pelham to Rye House would be reconductored with higher-rated conductor. There would also be a new Waltham Cross 400kV substation and two new transformers at Brimsdown substation.

ESRE **Elstree to Sundon circuit 1 reconductoring** Boundaries that benefit: B14e	The Elstree – Sundon circuit 1 between Sundon 400kV – Elstree 400kV would be reconductored with higher-rated conductor.
WEC1 **Willesden to Wimbledon 275kV cable Ealing Diversion** Boundaries that benefit: B14e	Constructing a second 275kV cable transmission route from Willesden to Ealing. Associated work would include modifying Ealing 275kV substation by rerouting the Willesden – Wimbledon circuit with quad boosters into Ealing.

4.4 Reinforcement options – West

HSNO **Hinkley Point to Seabank new double circuit** Boundaries that benefit: B13	Establishing a new 400kV transmission route between Hinkley Point and Seabank.
HMRE **Hinkley Point to Melksham circuit reconductoring part 1** Boundaries that benefit: B13	Reconductoring the Hinkley Point – Melksham circuits to increase the thermal rating.
SEC1 **Severn tunnel 400kV cable circuit uprate** Boundaries that benefit: SW1	Increasing the rating of the 400kV cable section crossing the Severn. This may need another set of cables and crossing.
CEH1 **Upgrade the Cardiff East to Cowbridge leg of the Aberthaw to Cardiff East to Pyle circuit** Boundaries that benefit: SW1	Upgrade the Cardiff East – Cowbridge leg of the Aberthaw – Cardiff East – Pyle 275kV circuit to give a higher thermal rating.
HCC1 **Cowley to Minety and Cowley to Walham Cables (Hinksey cables) upgrade** Boundaries that benefit: SW1	Uprating the cable section from Cowley to Walham and Cowley to Minety with additional larger cable sections.
PWTI **SWSC** **Pembroke to Walham circuit turn-in to Rhigos and reactive compensation** Boundaries that benefit: SW1	This option would turn the Pembroke – Walham 400kV circuit in to Rhigos and add reactive compensation at Walham (comprising two dynamic reactive compensation units (SVCs) and two switched capacitors (MSCs)) and Imperial Park (one MSC).
CIQB **Quad booster installation at Cilfynydd – CIQB** Boundaries that benefit: SW1	Installing a pair of quad boosters at Cilfynydd in series with the Cilfynydd – Melksham 400kV circuits.

4.5 Investment recommendations

This section of the chapter uses potential transmission solutions, including offshore and non-build solutions, to perform a regional cost-benefit analysis. The results of this analysis give the best cost-benefit strategy for each scenario, so we can identify the preferred options and the works needed in a region.

We have broken the GB network into regions and published the results region by region. For each region there are at least four tables:

- Investment drivers and options – this table describes the driver behind the reinforcement need and lists the options. The table also puts the options into asset or reduced build categories
- Optimum delivery dates by scenario – this lists the options that show a benefit during the 10 year period of the studies. For each of this year's (2015) FES scenarios, we state the optimum delivery date. The table also shows where a reinforcement depends on another reinforcement, which is described with a four letter code. Options that need a decision this year are called critical options and feed into the investment options and regrets table. Where the transmission solution is not justified for a scenario, we have written N/A in the table. The table includes the EISD and the boundary capability increase for each option. Both values are as accurate as possible at the time of study, though, as projects evolve and become better understood, these values could change. This is especially true for projects that haven't had much development. The boundary capability improvement value is the winter value used in the cost-benefit analysis. For boundaries B0 to B2, the boundary values are for the loss of a single circuit (N-1), whereas other boundaries are for the loss of a double circuit (N-D). This is in accordance with the operational chapters of the SQSS
- Investment options and regrets – this shows the single-year least regret values for the critical options. The regret associated with any potential reinforcement being progressed is calculated against each of the scenarios. The regret is defined as the difference in cost (including both investment and operational costs) between the option being considered and the best possible transmission option for that scenario. We analyse combinations where there is more than one critical reinforcement.

  The total regret is calculated by subtracting the total cost of the optimal solution for each scenario from each of the total costs of the other options, leaving at least one reinforcement with zero regret. The worst regret is the maximum regret possible across all scenarios for each option; the least worst regret is the lowest of them. The option with the least worst regret becomes the NOA recommendation for this year. For a full description of the calculation, see the NOA Report methodology paragraphs A80 to A86 on our website http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=44227
- Investment recommendations – this shows the SO's view on the next steps for each critical reinforcement option. We define these as follows.
  - Proceed: This means TOs should maintain the earliest in service date (EISD) for that investment. For schemes under the Strategic Wider Works process, this would involve further optioneering

4.5 Investment recommendations

- Do not proceed: This means it is not economic to start work with this option
- Delay: This means we recommend that there should be a delay to the EISD. For individual projects, TOs should, following discussion with the SO, determine where work needs to continue for an EISD +1 year to be maintained
- No decision required: The time needed to deliver the scheme is less than the time between now and the time that the option is needed. So there is no need to make a decision this year.

The table includes an indication as to whether the option is likely to be in the SWW category.

The 'change in investment recommendations' table shows where there are differences between the new results and last year's results. In some instances, there isn't a decision from last year, for example if the option is new this year.

4.5 Scotland and the North of England

Table 4.5 summarises the regional drivers for Scotland and the North of England and the corresponding potential transmission solutions suggested for the region. Each of the options listed below was studied for the NOA this year with their incremental capability calculated and fed into the cost-benefit analysis process.

Table 4.5
Scotland and the North of England investment options

Driver	Potential transmission solution		EISD
	Category	Option	
High exports from Orkney, Caithness, Western Isles, Lochaber, Fort Augustus, Beauly and Morayshire areas	Asset	■ Rebuild of Beauly to Shin to Loch Buidhe 132kV double circuit OHL to 275kV double circuit	2022
		■ New Beauly – Loch Buidhe 275kV double circuit	2022
		■ New Beauly – Loch Buidhe 400kV double circuit	2022
		■ New Beauly – Blackhillock 400kV double circuit	2024
		■ Rebuild of Beauly-Nairn-Elgin-Blackhillock 132kV double circuit OHL to 400kV double circuit	2024
		■ New Beauly – Kintore 400kV double circuit	2024
		■ Rebuild of Beauly to Knocknagael to Blackhillock 275kV double circuit OHL to 400kV double circuit	2024
High transfers to the Central Belt	Asset	■ East Coast onshore 400kV upgrade	2022
		■ East Coast onshore 275kV upgrade	2020
High transfers across the Central Belt	Asset	■ Denny – Wishaw 400kV reinforcement	2023
Radial connection and high exports from Scotland to England	Asset	■ Dumfries and Galloway reinforcement (Auchencrosh – Harker 400kV double circuit)	2023
High exports from North Scotland to England	Asset	■ Western HVDC Link	2017
		■ Eastern Link Peterhead – Hawthorn Pit	2023
		■ Eastern Link Peterhead – Torness – Hawthorn Pit	2023
		■ Eastern Link Torness – Hawthorn Pit/Lackenby	2023
		■ Torness to Lackenby AC reinforcement	2027
		■ New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade	2023
High transfers from north to south across Northern England	Asset	■ Norton – Osbaldwick reconductoring	2018
		■ Lackenby – Norton reconductoring	2021
		■ New east – west circuit between Norton and Padiham	2024
		■ Upgrade the Harker to Stella West circuits from 275kV to 400kV	2027
		■ Lister Drive quad booster	
		■ Penwortham to Padiham and Penwortham to Carrington ('south') reconductoring	2018 2024
		■ Keadby – West Burton No1 circuit reconductoring	
		■ Stella West – Spennymoor reconductoring	2019 2024

4.5 Scotland and the North of England

The main limitations are the north-to-south power flows affecting almost every boundary from B0 to B7a. We have many potential solutions, several of which reinforce multiple boundaries.

Going forward, we anticipate significant south to north transfers when there is low output from renewable generation. A number of the options set out in Table 4.5 will support higher south to north transfers.

None of the potential options for the B0 boundary were economically viable for any of the scenarios.

The four potential options for the B1 boundary had similar costs and benefits. The new Beauly to Blackhillock 400kV double circuit has the best value and went to the next stage of analysis.

A combination of schemes would be needed to provide a viable onshore capability for several boundaries. This combination comprised:

- East Coast onshore 275kV or 400kV upgrade
- Denny – Wishaw 400kV reinforcement
- Torness – Lackenby AC reinforcement.

The options would only work together as improving one boundary capability would be nullified by the constraint on the next boundary. As a result, the Eastern HVDC links options showed a better overall benefit based on delivery cost and constraint saving which is a function of by when the option can be delivered against any given scenario. The best value option is the one that would be evaluated further.

The Dumfries and Galloway reinforcement option (Auchencrosh to Harker) was not taken to the next stage of evaluation as other reinforcement options were found to be more economic in reducing constraints across B6.

The following options are not economically viable under this year's analysis:

- New east-west circuit between Norton and Padiham
- Upgrade the Harker to Stella West circuits from 275kV to 400kV
- Keadby – West Burton No1 circuit reconductoring
- Stella West – Spennymoor reconductoring.

Table 4.6 shows the optimal delivery date for each reinforcement option before the next stage of analysis.

Table 4.6
Scotland and the North of England optimum delivery dates by scenario

Transmission Solution	Prerequisites	Optimal delivery date: Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No Local Contracted	Reinforces boundary (with improvement in MW)
New Beauly – Blackhillock 400kV double circuit (BBNO)		2024	2028	2024	N/A	2024	N/A	B1 (580)
East Coast onshore 275kV upgrade (ECU2)		2023	2022	2022	2024	2023	N/A	B4 (500), B5 (200)
New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade (ELEU)		2023	2023	2023	2025	2023	N/A	B6 (600), B7 (1090), B7a (650)
Eastern Link Peterhead – Hawthorn Pit (E4DC)	ELEU	2023	2024	2023	2029	2023	N/A	B2 (300), B4 (1360), B5 (2000), B6 (2010), B7 (620), B7a (360)
Western HVDC Link (WEDC)		2017	2017	2019	2017	2017	2017	B6 (2200), B7 (2500), B7a (2830)
Norton – Osbaldwick reconductoring (NOR1)	E4DC or TLNO	2022	2023	2023	N/A	2023	N/A	B7, B7a
Lackenby – Norton reconductoring (LNRE)	E4DC or TLNO	2023	2024	2024	N/A	N/A	N/A	B7
New east – west circuit between Norton and Padiham (NPNO)		N/A	N/A	2027	N/A	N/A	N/A	B7, B7a, B11 (1330)
Lister Drive quad booster (LDQB)		2020	2021	2021	2024	2021	N/A	B7a
Penwortham to south reconductoring (PCRE)	LDQB	2021	2022	2022	2025	2022	N/A	B7a (530)

*N/A indicates that the transmission solution is not justified against the respective scenario.

4.5 Scotland and the North of England

'Penwortham to south reconductoring' means the Penwortham to Padiham and Penwortham to Carrington ('south') reconductoring. The Lister Drive quad booster (LDQB) is not a critical reinforcement this year and has not been triggered.

Four options are critical reinforcements which need an investment decision this year. These are:

- New Beauly – Blackhillock 400kV double circuit (BBNO)
- New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade (ELEU)
- Eastern Link HVDC Link between Peterhead and Hawthorn Pit (E4DC)
- Penwortham to Padiham and Penwortham to Carrington ('south') reconductoring (PCRE).

The worst regret for each of these options considered against each of the scenarios is shown in Table 4.7.

Table 4.7
Scotland and the North of England investment options and regret (values in £m)

Proceed	All	ELEU, PCRE, E4DC	ELEU, PCRE, BBNO	ELEU, PCRE	ELEU, E4DC, BBNO	ELEU, E4DC	ELEU, BBNO	ELEU	PCRE, E4DC, BBNO	PCRE, E4DC	PCRE, BBNO	PCRE	E4DC, BBNO	E4DC	BBNO	None
GG	0	17	105	122	9	26	114	131	211	228	127	144	220	237	136	153
CP	28	28	27	27	28	28	27	27	1	1	0	0	1	1	0	0
SP	0	9	55	65	0	9	55	65	93	102	12	22	93	102	12	22
NP	6	4	2	0	6	4	2	0	6	4	2	0	6	4	2	0
Worst regret	28	28	105	122	28	28	114	131	211	228	127	144	220	237	136	153

Chapter four

Our analysis shows that the following combinations of options have a very similar worst regret:

a. All of options E4DC, ELEU, PCRE and BBNO
b. Three options ELEU, PCRE and E4DC
c. Three options E4DC, ELEU and BBNO
d. Just two options E4DC and ELEU.

Where the codes are:
- BBNO: New Beauly – Blackhillock 400kV double circuit
- ELEU: New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade
- E4DC: Eastern Link HVDC Link between Peterhead and Hawthorn Pit (E4DC)
- PCRE: Penwortham to Padiham and Penwortham to Carrington ('south') reconductoring (PCRE).

The regret difference between choice d (E4DC and ELEU) and choice a (all four options) is only £300k.

NOA recommendation

Based on the regret costs, the recommendation for this year's NOA for Scotland and the North of England is to proceed with the following options which are in all four combinations:
- New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade (ELEU)
- Eastern Link HVDC Link between Peterhead and Hawthorn Pit (E4DC).

The NOA decision is to proceed with the development of the Eastern subsea HVDC Link Peterhead – Hawthorn Pit. The link is driven predominantly by the connection of onshore and offshore wind in Scotland. However, given the recent development in energy policy and the market uncertainty, change to the volume of wind energy connecting to the system is very likely. This points to increasingly uncertain triggers for the Eastern HVDC Link; therefore as SO we recommend that the TOs should minimise any spend in respect to the NOA decision this year. Further work is ongoing with the TOs to confirm the optimum solution for this year based on more recent projections.

The Penwortham-Carrington-Padiham circuits reconductoring would be triggered due to a series of other conflicting reinforcements in the area in the outage windows. This meant that this reinforcement was pushed forward and would need a decision on whether to proceed now. However, through least worst regrets analysis this option was not optimal.

We recommend that all other solutions do not proceed; they can be deferred until they are reconsidered for next year's NOA. Table 4.8 shows the Scotland and North of England investment recommendations.

4.5 Scotland and the North of England

Table 4.8
Scotland and North of England investment recommendations

Option	Recommendations	Potential SWW?
New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade – ELEU	Proceed	No
Eastern Link Peterhead – Hawthorn Pit – E4DC	Proceed	Yes
New Beauly – Blackhillock 400kV double circuit – BBNO	Delay	Yes
Penwortham to south reconductoring – PCRE	Do not proceed	No
East Coast onshore 275kV upgrade – ECU2	No decision required	Yes
Lister Drive quad booster – LDQB	No decision required	No
Norton – Osbaldwick reconductoring – NOR1	No decision required	No
Lackenby – Norton reconductoring – LNRE	No decision required	No
New east – west circuit between Norton and Padiham – NPNO	No decision required	No

ETYS 2014 said to proceed with pre-construction works for Eastern HVDC Link. The option has now been split apart for 2015. The onshore works New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade are to proceed. The offshore work is to proceed on the two-ended link between Peterhead and Hawthorn Pit.

Table 4.9
Change in Scotland and North of England investment recommendations

Option	2014 NDP recommendation	NOA 1 recommendation	Comments
New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade – ELEU	N/A	Proceed	Solution is new for 2015.
Eastern HVDC Link Peterhead – Hawthorn Pit – E4DC	Continue pre-construction scoping[1]	Proceed	The 2014 decision was to proceed with pre-construction scoping; this year's recommendation is to proceed.
New Beauly – Blackhillock 400kV double circuit – BBNO	N/A	Delay	Scottish solutions were not subject to the 2014 NDP process.
Penwortham to south reconductoring – PCRE	No decision required	Do not proceed	See main text.

[1] ETYS 2014 recorded 'Continue pre-construction scoping' for National Grid TO. ETYS 2014 defined this stage as 'the identification of a broad needs case and consideration of a number of design and reinforcement options to solve boundary constraint issues'.

4.5 East England

Table 4.10, below, summarises the regional drivers for East England and the corresponding potential transmission solutions suggested for the region. Each of the options listed was studied for the NOA and the incremental capability was calculated and fed into the cost-benefit analysis process.

Table 4.10
East England investment options

Driver	Potential transmission solution		EISD
	Category	**Option**	
Ability to export power from East Anglia to Greater London and South East England	Asset	■ Norwich – Bramford reconductoring ■ East Anglia MSCs at Burwell Main ■ Bramford – Braintree – Rayleigh Main reconductoring ■ Bramford – Braintree – Rayleigh Main thermal upgrade ■ Complete Rayleigh – Coryton South – Tilbury reconductoring ■ Bramford – Twinstead new overhead lines ■ Rayleigh Main series reactor ■ Pelham to Twinstead new 400kV double circuit	2019 2022 2018 2018 2018 2025 2019 2027

Of the East England potential options, the Bramford – Braintree – Rayleigh Main reconductoring option was too expensive to justify further analysis. The other options had further analysis.

Table 4.11 shows the optimal delivery date for each reinforcement option before the next stage of analysis. In some cases, a reinforcement depends on another reinforcement coming in first. For these cases, we have put a code in the pre-requisites column of the table.

4.5 East England

Table 4.11
East England optimum delivery dates by scenario

Transmission solution	Prerequisites	Optimal delivery date						
		Gone Green	**Consumer Power**	**Slow Progression**	**No Progression**	**Local Contracted**	**No Local Contracted**	**Reinforces boundary** (with improvement in MW)
Burwell Main MSCs – BMMS		2024	2031	2031	N/A	2022	N/A	EC5 (200)
Rayleigh – Tilbury reconductoring – RTRE	BMMS	2022	2031	2031	N/A	2022	N/A	EC5 (300)
Coryton South – Tilbury reconductoring – CTRE		2022	2031	2031	N/A	2022	N/A	
Norwich Main – Bramford reconductoring – NBRE		2022	2031	2031	N/A	2022	N/A	
Thermal upgrade of Bramford to Braintree to Rayleigh route – BRH1		2022	2031	2031	N/A	2022	N/A	
Rayleigh Main series reactors – RMSR	RTRE, CTRE, NBRE, BRH1	2027	2031	N/A	N/A	2025	N/A	EC5 (1750)
New 400kV double circuit between Bramford and Twinstead – BTNO		2027	2031	N/A	N/A	2025	N/A	
Pelham to Twinstead new 400kV double circuit – TPNO	RMSR, BTNO	2027	2033	N/A	N/A	2027	N/A	EC5 (1270)

*N/A indicates that the transmission solution is not justified against the respective scenario.

We considered the most economic strategy for each scenario and took into account the lead times and boundary benefit of each of the above reinforcements. The only critical reinforcement for the East England region least regret analysis is the potential development of the new 400kV double circuit between Bramford and Twinstead.

Some of the projects considered for the east region are interlinked with neighbouring projects. For example, the full network capacity uplift benefit from the Bramford to Twinstead new overhead lines would not be realised until other schemes that improve thermal capability were completed. These are reconductoring the Rayleigh – Coryton South – Tilbury circuit, Bramford to Norwich circuit and thermal uprating of the Bramford – Braintree – Rayleigh Main circuit.

This year the NOA considered additional options such as the Pelham to Twinstead new 400kV double circuit to provide additional capacity for generation exports from East Anglia towards London under some scenarios.

The worst regret for the only critical reinforcement (Bramford to Twinstead BTNO) against each of the scenarios, is shown in Table 4.12, below.

Table 4.12
East England investment options and regret

Scenario	2015 options	
	BTNO	Do nothing
Gone Green	£1m	£0m
Consumer Power	£2m	£0m
Slow Progression	£7m	£0m
No Progression	£7m	£0m
Local Contracted	£0.7m	£0m
No Local Contracted	£7m	£0m
Worst regret	**£7m**	**£0m**

NOA recommendation
Our recommendation for NOA 1 is to do no work on the options in the East of England this year.

In last year's NDP output, the recommendation was to delay the new 400kV double circuit between Bramford and Twinstead and reconductoring of the Raleigh – Tilbury and Coryton – Tilbury circuits. We retain the 'delay' in this year's NOA results.

4.5 East England

Table 4.13
East England investment recommendations

Option	Recommendation	Potential SWW?
New 400kV double circuit between Bramford and Twinstead – BTNO	Delay	No
Rayleigh – Tilbury reconductoring – RTRE	Delay	No
Coryton South – Tilbury reconductoring – CTRE	Delay	No
Norwich Main – Bramford reconductoring – NBRE	Delay	No
Burwell Main MSCs – BMMS	No decision required	No
Pelham to Twinstead new 400kV double circuit – TPNO	No decision required	No
Thermal upgrade of Bramford to Braintree to Rayleigh route – BRH1	No decision required	No
Rayleigh Main series reactors – RMSR	No decision required	No

There are no changes between this year's NOA 1 recommendation and last year's NDP recommendations.

4.5 South England

Table 4.14 summarises the regional drivers for South England and the corresponding potential transmission solutions suggested for the region. We studied each of the options listed for the NOA this year and calculated their incremental capability, which we then fed into the cost-benefit analysis process.

Table 4.14
South England investment options

Driver	Potential transmission solution		EISD
	Category	Option	
Limitation from the Midlands and through London	Asset	■ Wymondley turn-in ■ Wymondley quad boosters ■ Hackney – Tottenham – Waltham Cross upgrade ■ Elstree – Sundon 1 CCT reconductoring ■ Willesden – Wimbledon 275kV cable Ealing Diversion	2019 2019 2021 2019 2018
Limitation in the south coast	Asset	■ Kemsley – Littlebrook circuits uprating ■ South-east coast dynamic reactive compensation ■ Dungeness – Sellindge reconductoring ■ Fleet – Lovedean reconductoring ■ New 400kV transmission route between South London and the south-east coast	2019 2019 2016 2020 2025

Of the South England potential options, only the new 400kV transmission route between South London and the south-east coast was not optimal at this point in time and the other reinforcements are more cost effective.

Table 4.15 shows the optimal delivery date for each reinforcement option before the next stage of analysis.

4.5 South England

Table 4.15
South England optimum delivery dates by scenario

Transmission solution	Prerequisites	Optimal Delivery Date						Reinforces Boundary (with improvement in MW)
		Gone Green	**Consumer Power**	**Slow Progression**	**No Progression**	**Local Contracted**	**No Local Contracted**	
Kemsley – Littlebrook circuits uprating – KLRE		2019	2019	2019	2019	2019	2023	B15 (2270)
South-east coast dynamic reactive compensation – SCVC	DCRE	2019	2019	N/A	2021	2019	N/A	SC1 (840)
Dungeness – Sellindge reconductoring – DCRE	SCVC	2016	2016	2016	2021	2016	N/A	
Fleet – Lovedean reconductoring – FLRE		2020	2020	2020	2030	2020	N/A	SC1 (3040)
Wymondley turn-in – WYTI		2024	2022	2024	2019	2024	2024	B14 (120), B14e (460)
Wymondley quad boosters – WYQB	WYTI	2024	2022	2024	2019	2024	2024	
Hackney – Tottenham – Waltham Cross upgrade – HWUP		2029	2031	2030	2033	2029	2029	B14e (1300)
Elstree – Sundon 1 CCT reconductoring – ESRE		2029	2031	2030	2033	2029	2029	B14e (570)
Willesden – Wimbledon 275kV cable Ealing Diversion – WEC1		2029	2031	2030	2033	2029	2029	B14e (200)
Hinkley Point – Seabank new double circuit – HNSO		2024	2025	2026	2028	2024	N/A	B13 (3760)
New 400kV transmission route between South London and south-east coast – SCNO	KLRE	N/A	N/A	N/A	N/A	N/A	N/A	SC1 (3880)

*N/A indicates that the transmission solution is not justified against the respective scenario.

Options split into two groups

The south options were split into North London options and the south coast options. The grouped options are independent of each other and so this meant they could be considered separately and reduced the complexity of the least worst regret analysis.

We considered the most economic strategy for each scenario and took into account the lead times and boundary benefit of each of the above reinforcements. The key consideration for the North London least regret analysis is the potential development of the two Wymondley schemes (grouped as WYTI+WYQB) and the Hackney – Tottenham – Waltham Cross upgrade (HWUP). The key consideration for the south coast least regret analysis is the potential development of reconductoring the Kemsley to Littlebrook circuits, reconductoring the Fleet to Lovedean circuits and the south coast dynamic reactive compensation project.

The regrets for the critical options considered against each of the scenarios is shown in Table 4.16 for North London and Table 4.17 for south coast, below. The critical options for South Midlands and London are:

- Wymondley turn-in and quad boosters (WYTI, WYQB)
- Hackney – Tottenham – Waltham Cross upgrade (HWUP).

For south coast, they are:

- Kemsley – Littlebrook circuits uprating (KLRE)
- South-east coast dynamic reactive compensation (SCVC)
- Fleet – Lovedean reconductoring (FLRE).

Table 4.16
South Midlands and London investment options and regret

Scenario	2015 options			
	WYTI+WYQB	**HWUP**	**Proceed both**	**Do nothing**
Gone Green	£252m	£5m	£257m	£0m
Consumer Power	£11m	£6m	£17m	£0m
Slow Progression	£34m	£6m	£40m	£0m
No Progression	£1m	£7m	£8m	£0m
Local Contracted	£252m	£5m	£257m	£0m
No Local Contracted	£188m	£5m	£194m	£0m
Worst regret	**£252m**	**£7m**	**£257m**	**£0m**

4.5 South England

Table 4.17
South coast investment options and regret

Scenario	2015 options							
	KLRE	SCVC	FLRE	Proceed all	KLRE & SCVC	KLRE & FLRE	SCVC & FLRE	Do nothing
Gone Green	£53m	£136m	£180m	£3m	£0m	£55m	£139m	£178m
Consumer Power	£11m	£259m	£264m	£3m	£0m	£14m	£262.2m	£261m
Slow Progression	£51m	£204m	£148m	£6m	£56m	£0m	£153.3m	£199m
No Progression	£0m	£87m	£87m	£0.6m	£0.4m	£0.2m	£88m	£87m
Local Contracted	£64m	£130m	£187m	£5m	£0m	£68m	£135m	£183m
No Local Contracted	£0.02m	£6m	£0.6m	£6m	£6m	£0.6m	£6.3m	£0m
Worst regret	**£64m**	**£259m**	**£264m**	**£6m**	**£56m**	**£68m**	**£262m**	**£261m**

Table 4.18
South West investment options and regret (£m)

	GG	CP	SP	NP	Worst regret
Proceed	0	17	18	18	18
Delay	19	0	0	0	19

NOA recommendation

For the South Midlands and London investment options continuing to deliver the Wymondley turn-in and quad boosters schemes has high potential regret as the scenarios suggest the schemes are not needed yet. Not developing them now offers the lowest potential regret values. Proceeding with the Hackney – Tottenham – Waltham Cross upgrade scheme shows relatively less potential regret, but still more than doing nothing.

For the south coast investment options the least worst regret preference is to proceed with both the Kemsley to Littlebrook and Fleet to Lovedean reconductor schemes and the south coast shunt compensation project. This is because of the relatively low cost and potential for reducing high constraints.

With only one year delivery left for the Dungeness to Sellindge reconductor scheme, and potential delay costs approaching £1m, a straight cost-benefit anaylsis also suggests proceeding with the scheme.

For the Hinkley Point – Seabank reinforcement analysis, we assumed that the optimum timing for the reinforcement would coincide with the commissioning of the first Hinkley Point C unit. The Local Contracted and No Local Contracted sensitivities are omitted for this analysis. The assumed Local Contracted date is the same as that for the Gone Green scenario and so this makes no difference. By removing the No Local Contracted sensitivity the assumption is made that Hinkley Point C will connect in all scenarios and therefore Hinkley Point – Seabank will be required. The difference in regrets between the proceed and delay options is very small and hence the case is marginal. The recommendation is therefore to proceed with the option but to minimise any spend this year.

Table 4.19
South England investment recommendations (combined table)

Option	Recommendation	Potential SWW?
Dungeness – Sellindge reconductoring – DCRE	Proceed	No
Kemsley – Littlebrook reconductoring – KLRE	Proceed	No
South-east coast dynamic reactive compensation – SCVC	Proceed	No
Fleet – Lovedean reconductoring – FLRE	Proceed	No
Wymondley turn-in – WYTI	Delay	No
Wymondley quad boosters – WYQB	Delay	No
Hinkley Point – Seabank new double circuit – HSNO	Proceed	Yes
Hackney – Tottenham – Waltham Cross uprate to 400kV – HWUP	No decision required	No
Elstree – Sundon CCT 1 reconductoring – ESRE	No decision required	No
Willesden – Wimbledon 275kV cable Ealing Diversion – WEC1	No decision required	No
New 400kV transmission route between South London and south-east coast – SCNO	Do not proceed	No

Last year's NDP recommendation was to continue work delivering the Wymondley turn-in and quad booster projects and not to proceed with the south coast shunt compensation and reconductor projects. The Wymondley schemes are needed mainly to avoid any limitations when the southern interconnectors are exporting to Europe.

Last year's expectations, based on analysis using the FES and European market pricing, were that there would be enough interconnector export throughout the next few years to need the schemes now. But this year the FES shows that GB plant margins will be significantly reduced.

This, along with refinements in the European market modelling, suggests that the Southern European interconnectors are not exporting enough in the near future to warrant proceeding with the Wymondley schemes now. Current analysis suggests that the interconnector export may pick up again in five to 10 years, when the Wymondley schemes might be needed. European market prices have affected our decision this year.

The interconnector import conditions support the recommendation to proceed with the south coast investment options for reconductoring and shunt compensation.

The Dungeness to Sellindge reconductor need case is not until 2019 but, with limited outage availability and delay cost, we recommend continuing for 2016 delivery.

The NOA 1 analytical outcome for Hinkley to Seabank is to proceed, taking into account generation connection dates.

We have considered public statements from EDF about project delays and have also considered necessary revisions to project delivery lead times in our assessment.

Table 4.20 shows the changes between the 2014 NDP and NOA 1 recommendations on each of the wider works schemes assessed.

4.5 South England

Table 4.20
Change in South England investment recommendations

Option	2014 NDP recommendation	NOA 1 recommendation	Comments
Wymondley turn-in – WYTI	Complete pre-construction	Delay	Changes in background, particularly lower plant margins, have reduced interconnector export expectations and have taken away the driver for the North London reinforcement.
Wymondley quad booster – WYQB	Complete pre-construction	Delay	
South-east coast dynamic reactive compensation – SCVC	Delay	Proceed	SCVC has become a critical reinforcement and is now recommended for progression. DCRE is also needed in combination by 2019 to realise any boundary capability increase.
Dungeness – Sellindge reconductoring – DCRE	Commence pre-construction	Proceed	A need for 2019, limited system access and significant delay costs drive the recommendation to proceed.
Kemsley – Littlebrook reconductoring – KLRE	Do not proceed	Proceed	Change of background and critical contingency have given this scheme a much larger capability increase than previously, so now the recommendation is to proceed.
Hinkley Point – Seabank new double circuit – HSNO	Commence pre-construction	Proceed	See main text.

4.5 West England and North Wales

Table 4.21 summarises the regional drivers for West England and Wales, and the proposed transmission solution options for the region. We studied each of the options listed for the NOA this year and calculated their incremental capability, which we then fed into the cost-benefit analysis process.

Table 4.21
West England and North Wales investment options

Driver	Potential transmission solution		EISD
	Category	**Option**	
Limitation on power transfer through Midlands	Reduced build	■ Western HVDC Link fast de-load scheme	2019
	Asset	■ Carrington series reactor ■ Cellarhead – Drakelow OHL thermal upgrade ■ Bredbury – South Manchester cable replacement and uprating and OHL reinstatement ■ Daines – Macclesfield reconductoring (single circuit) ■ Reconductor Keadby – West Burton No1 circuit ■ Installation of series reactors on both Keadby – West Burton 400kV circuits ■ Install series reactors at Thornton ■ North Wales to South Wales HVDC Link (Wylfa – Pembroke HVDC Link)	2020 2018 2019 2019 2019 2019 2020 2023
Limitation on power export from North Wales	Asset	■ Wylfa – Pentir second double circuit ■ Pentir – Trawsfyndd second circuit ■ Pentir – Trawsfyndd 1 cable replacement – single core per phase ■ Pentir Trawsfyndd 1 and 2 cables – second core per phase ■ Pentir – Bodelwyddan-Connah's Quay reconductoring ■ Install reactive compensation at Ironbridge ■ Treuddyn Tee to Legacy thermal upgrade ■ MSC in North Wales ■ Legacy – Ironbridge quad booster uprating ■ Connah's Quay – Daines reconductoring ■ Legacy – Ironbridge reconductor ■ Second MSC in North Wales	2023 2019 2019 2020 2019 2019 2019 2019 2019 2023 2018 2019
Limitation on power transfer from South West England to South East England	Asset	■ Severn tunnel 400kV cable circuit uprate ■ Upgrade the Cardiff East to Cowbridge leg of the Aberthaw to Cardiff East to Pyle circuit ■ Cowley – Minety & Cowley – Walham cables (Hinksey cables) upgrade ■ Pembroke – Walham circuit turn-in ■ Pembroke – Walham circuit turn-in into Rhigos with reactive compensation at Walham ■ Quad booster installation at Cilfynydd	2025 2018 2022 2022 2022 2021

Power flows identified across the B9 boundary for the 2015 scenarios aren't high enough to need reinforcement.

Exports from North Wales tend to have a thermal limitation so reinforcements concentrate on this issue. Our analysis has shown voltage constraints behind the thermal constraint but we don't see them biting until after the thermal reinforcements are in service.

For exports from South Wales, flows aren't high enough to justify any reinforcement so we didn't take forward any options.

The key limitations are the north to Midlands transfer, North Wales exports and new connections in the south west. Given the number of drivers, there are many potential solutions, some of which are complementary, solving several of these limitations.

4.5 West England and North Wales

We carried out cost-benefit analysis, considering different combinations and timings of transmission solutions, until the lowest cost strategies were found for each of the scenarios. These optimum strategies are shown in Table 4.22.

Table 4.22
West England and North Wales optimum delivery dates by scenario

Transmission solution	Prerequisites	Optimal Delivery Date Gone Green	Consumer Power	Slow Progression	No Progression	Local Contracted	No local Contracted	Reinforces Boundary (with improvement in MW)
Western HVDC Link fast de-load scheme – WEOS	WEDC before WEOS	2019	2019	2019	2019	2019	2019	B8
Carrington series reactor – CASR		2023	2020	2022	2020	2025	N/A	B8
Pentir-Trawsfynydd second circuit – PTNO		2027	2030	2030	N/A	2024	N/A	NW2
Wylfa to Pentir second double circuit route – WPNO		2029	2030	2032	N/A	2025	N/A	NW1
Pentir-Trawsfynydd cable – single core per phase – PTC1	PTNO before PTC1	2029	2030	2032	N/A	2025	N/A	NW2
Pentir-Trawsfynydd cable – second core per phase – PTC2	PTC1 before PTC2	2029	2030	2032	N/A	2025	N/A	NW2
Cellarhead to Drakelow OHL thermal upgrade – CDH1		2029	2031	2024	N/A	2025	N/A	B8
Bredbury-South Manchester reconductoring – BSRE		2029	2034	2033	N/A	2034	N/A	B8
Legacy-Ironbridge reconductoring – LIRE		2030	N/A	2034	N/A	N/A	N/A	B8
Cellarhead-Daines-Macclesfield reconductoring – DMC1		2034	N/A	N/A	N/A	N/A	N/A	B8

*N/A indicates that the transmission solution is not justified against the respective scenario.

There's a lot of divergence across the range of scenarios for the West England and Wales region. This is why some of the projects being considered in the region have different delivery years across the scenarios.

After Trafford Power (1882MW) is connected at Carrington 400kV substation we will need split busbar running arrangements at four substations to maintain the expected fault levels within equipment ratings. The four substations are both Carrington 400 and 275kV substations, Daines and Connah's Quay.

This new network configuration causes an unbalanced loading on the circuits connecting to these substations. This means early overloading for trips that create a high flow of power on low rating circuits, such as local 275kV circuits.

To improve the boundary capability, as well as the solutions already proposed, we considered two new feasible options: automatic deloading of Western HVDC Link and installing a series reactor between split bus sections of Carrington 400kV substation. The study shows that these two solutions can significantly improve the B8 boundary capability.

We considered the most economic strategy for each scenario and took into account the lead times and boundary benefit of each of the above reinforcements. The key consideration for the West and North Wales region least regret analysis is the potential development of the Western HVDC Link operational tripping scheme (WEOS) and/or the Carrington series reactor (CASR).

Table 4.23 shows the worst regret for each of the critical reinforcement options, considered against each of the scenarios. The critical reinforcement options are:
- Western HVDC Link fast de-load scheme (WEOS)
- Carrington series reactor (CASR).

Table 4.23
West England and North Wales investment options and regret

Scenario	2015 options			
	WEOS	**CASR**	**Proceed both**	**Do nothing**
Gone Green	£0m	£369m	£0.02m	£369m
Consumer Power	£0m	£462m	£7m	£456m
Slow Progression	£0m	£471m	£0.01m	£471m
No Progression	£0m	£401m	£6m	£395m
Local Contracted	£0m	£350m	£0.03m	£350m
No Local Contracted	£0m	£507m	£0.2m	£507m
Worst regret	**£0m**	**£507m**	**£7m**	**£507m**

4.5 West England and North Wales

The Western HVDC Link fast de-load scheme is the optimum current year solution, balancing investment cost against constraint cost. It has been assigned a regret of zero.

There is significant potential regret shown against investing in the CASR project alone. This is produced by a combination of investment cost for a scheme that's not immediately needed and constraint cost by investing in a scheme that doesn't alleviate the contraint cost as much as the Western HVDC Link fast de-load scheme. There is little potential regret in investing in both schemes, which suggests that investing in the CASR may soon be efficient, but isn't now.

NOA recommendation

The present least worst regret NOA recommendation is to develop only the Western HVDC Link fast de-load scheme. The CASR option has a significant regret cost if developed now, so the recommendation is not to proceed now. We'll review it again as part of next year's NOA.

Table 4.24
West England and North Wales investment recommendations

Option	Recommendation	Potential SWW?
Western HVDC Link fast de-load scheme – WEOS	Proceed	No
Wylfa to Pentir second double circuit route – WPNO	Delay but local conditions mean proceed	No
Pentir to Trawsfynydd second circuit – PTNO	Delay	No
Carrington series reactor – CASR	Delay	No
Pentir – Trawsfynydd cable – single core per phase – PTC1	No decision required	No
Pentir – Trawsfynydd cable – second core per phase – PTC2	No decision required	No
Cellarhead to Drakelow OHL thermal upgrade – CDH1	No decision required	No
Bredbury – South Manchester reconductoring – BSRE	No decision required	No

The Wylfa to Pentir second double circuit needs case isn't until 2029 and the initial NOA recommendation was to delay it, however a local commercial agreement with the customer means that this project needs to proceed. Table 4.24 summarises the changes between the 2014 NDP and NOA 1 recommendations on each of the wider works schemes assessed.

Table 4.25
Change in West England and North Wales investment recommendations

Option	2014 NDP recommendation	NOA 1 recommendation	Comments
Western HVDC Link fast de-load scheme	N/A	Proceed	Changes in the substation running arrangements to accommodate new generation connections will cause unbalanced loading.
Wylfa to Pentir second double circuit	Complete pre-construction scoping	Delay	See main notes about proceeding.

Strategic Wider Works (SWW)

The SO has assisted the TOs with the following three SWW projects.

- **Hinkley – Seabank new overhead line**
  Network reinforcements are needed to accommodate the increased levels of generation in South West England and relieve constraints across the B13 boundary. This is because demand at this importing boundary is higher than the generation at peak conditions.

  The potential connection of new generation and interconnectors to the south west – including new nuclear and renewable generation – means that the boundary is expected to change to export power more often than it imports. In relation to the Development Consent Order (DCO) application which the Secretary of State granted on 19 January 2016, the economic and efficient option identified following a full options appraisal to relieve the B13 boundary constraints is a new double circuit between Hinkley Point and Seabank.

- **Dumfries and Galloway reinforcement**
  The driver for reinforcement in the Dumfries and Galloway area is the need to upgrade assets which are approaching the end of their asset life, the facilitation of new embedded wind connections in the local area and provision of continued system access for the Moyle interconnector.

  Four options out of nearly thirty considered were taken forward into the cost-benefit analysis process. One of these options, "option 4" involving a new 400/275kV circuit from Auchencrosh to Harker could provide broader benefits to the GB system by increasing capacity across the major electrical Boundary B6. This option was assessed as part of the NOA Report process and did not demonstrate sufficient benefit to Boundary B6 to be progressed at this stage.

  The cost-benefit analysis to assess these design options is being progressed under the SWW process and an Initial Needs Case, fully taking into account the conclusions of this NOA report, will be submitted to Ofgem in due course.

- **Scottish islands subsea links**
  There are proposals for subsea links to the Western Isles, Orkney and Shetland.

  In each of the Scottish islands cases, the main driver for the project is the connection of renewable generation. At the time of writing the NOA Report, the TO has undertaken initial cost-benefit analysis and the links are awaiting further policy development.

Stakeholder engagement

We'd appreciate your views on how we presented the options to reinforce the national electricity transmission system. Our recommendations are all about making sure there's an optimal, economic and efficient transmission strategy in place – have we explained that clearly to you?

Chapter five
Stakeholder engagement

5.1 Introduction

We'd like your feedback and comments on this first NOA Report and your help to improve it. Please take part in our 2016 stakeholder engagement programme so we know what you need.

5.2 Continuous development

As there have been no previous NOA Reports, your feedback on this first one is especially valuable.

We want your input as the NOA Report and the ETYS are revised and we'll have a joined-up approach to our stakeholder engagement for the two documents.

We'll make sure the NOA Report 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
- telling you how your views have been considered and reporting on the engagement process.

The NOA Report annual review process will help us develop the report. We'll encourage all interested parties to take part, which will help us improve the document each year.

5.3 Stakeholder engagement

We are always happy to listen to our stakeholders' views, including:

- at consultation events as part of our customer seminars
- at operational forums
- through responses to **transmission.etys@nationalgrid.com**
- at bilateral stakeholder meetings.

When the NOA Report is published, we'll start the review and stakeholder engagement. You'll have until July to tell us what you think. This consultation will include the methodology as well as the report and its contents.

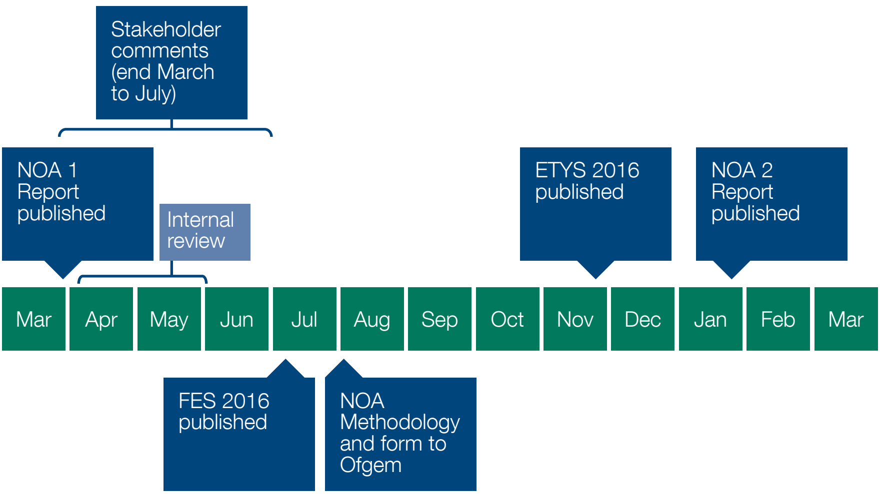
- Where can we improve the NOA Report to meet your needs?

We'd also like your views on our Network Development Policy (NDP) approach to identifying future network reinforcements. The NDP was developed for England and Wales and is used for economic analysis for the network in Scotland.

- Have you any views on the NDP and how to improve it?

Figure 5.1 shows the stakeholder engagement timeline. For more information on the dates, please see the NOA Report methodology paragraphs A96 to A100.

Figure 5.1
ETYS/NOA stakeholder activities programme



Chapter six
Appendices

Appendices overview

Appendix A – Operational cost assessment inputs
Appendix A supports section 2.4 by going into more detail on operational cost assessment inputs.

Appendix B – List of options in order of four letter code
In chapter 4 of the NOA Report, we have used four letter codes to identify reinforcement options. Appendix B lists those options in alphabetical order of the four letter code.

Meet the NOA Report team

Leadership team

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Electricity Network Development

In addition to preparing the NOA Report and ETYS for publication we are responsible for developing a holistic strategy for the electricity transmission system. We use the FES and sensitivities around them for our analysis.
We also:

- manage and implement the Network Development Policy which assesses the need to progress wider transmission system reinforcements
- recommend preferred options for GB transmission network investment under the new ITPR arrangements
- manage the technical activities relating to offshore electricity network design
- facilitate system access for development or maintenance activities while ensuring the system can be operated both securely and economically.

You can contact us to discuss:

Network requirements,
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Don't forget you can also email us with your views on the NOA Report at:
transmission.etys@nationalgrid.com

Meet the NOA Report team

Electricity Policy and Performance

We are responsible for a variety of power system issues including generator and HVDC compliance. We also provide power system models and datasets for network analysis. Our work also includes managing the technical aspects of the GB and European electricity frameworks, codes and standards that are applicable to network development.

You can contact us to discuss:

Network data

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Supporting parties

Strategic network planning and producing the NOA Report requires support and information from many people. Parties who provide support and information that makes our work possible include:
- National Grid ETO
- SHE Transmission
- SP Transmission

Appendix A
Operational cost assessment inputs

We developed ELSI to model future constraints on the GB system. The electricity transmission system in ELSI is represented by a series of zones, separated by boundaries. The total level of generation and demand is modelled so that each zone contains a total installed generation capacity by fuel types (like CCGT, coal and nuclear) and a percentage of overall demand.

For a system to balance, generation must equal demand. The level of zonal connectivity is defined in ELSI to allow the system to balance as a whole. The boundaries represent the actual transmission circuits that make this connectivity happen. Each boundary has a maximum capability that restricts the amount of power that can be securely transferred across it. This may be an N-1, N-D or N-2 capability – it depends on the operational standards that have been applied to the boundary in accordance with the Security and Quality of Supply Standard.

Generation modelling assumptions in ELSI

The availability factors of all generation types are an important assumption within ELSI. Table A1 shows the availability factors of the generation types within ELSI. These align with the assumptions we used to develop our Future Energy Scenarios 2015 and for transmission planning.

Appendix A
Operational cost assessment inputs

Table A1
Generation availability assumptions

Fuel type	Fuel grouping	Winter availability	Spring availability	Summer availability	Autumn availability
Hydro	Renewables	100%	100%	100%	100%
Offshore wind[1]	Renewables	100%	100%	100%	100%
Onshore wind	Renewables	100%	100%	100%	100%
Wave	Renewables	100%	100%	100%	100%
Nuclear	Nuclear	81%	76%	70%	76%
Nuclear new	Nuclear	90%	80%	70%	80%
Biomass – conversion	Renewables	80%	75%	70%	75%
CHP	Gas	80%	75%	70%	75%
CHP new	Gas	80%	75%	70%	75%
CCGT CCS (Carbon capture and storage)	Gas	85%	78%	69%	78%
Wave – enhanced	Renewables	100%	100%	100%	100%
Tidal	Renewables	31%	31%	31%	31%
Tidal – enhanced	Renewables	31%	31%	31%	31%
Base gas	Gas	85%	78%	69%	78%
Mid gas	Gas	85%	78%	69%	78%
Marginal gas	Gas	85%	78%	69%	78%
Interconnector	Interconnector	95%	95%	95%	95%
Biomass – new	Renewables	80%	75%	70%	75%
Supplemental balancing reserve[2]	SBR	97%	97%	0%	97%
Base coal	Coal	88%	79%	70%	79%
Mid coal	Coal	80%	69%	56%	69%
Marginal coal	Coal	80%	69%	56%	69%
Pumped storage	Pumped storage	99%	89%	88%	89%
Oil	Peaking	74%	51%	41%	51%
OCGT	Peaking	91%	84%	84%	84%
Solar	Renewables	100%	100%	100%	100%

[1] Although the availability of certain intermittent renewables (including hydro, offshore wind, onshore wind, wave, wave – enhanced and solar) have been presented as full capacity in Table A, their output is determined using load factors, which are presented later in this section.

[2] Any plant that has been awarded a contract for winter 2015/16 has been combined into one fuel type with a short-run marginal cost equal to the capacity weighted average of its contracted price. The availability has been set to the capacity weighted average for the months that SBR plant is contracted to be available.

ELSI applies a layered model approach to develop a merit order of generation – a model where classifications of generators have marginal costs based on observed industry behaviours. In other words, although the fuel types listed in Table A1 may have the same availability factors, they will have different marginal costs (or different subsidy levels in the case of renewables) that affect the merit order of the plant[3]. You'll find more information about marginal costs later in this appendix.

However, it's worth noting that there are some more modifications to these base availability assumptions. In particular, onshore wind, offshore wind, wave, wave – enhanced and solar all have 100% availability. This is because they have an additional model that uses historic data[4] to calculate the potential output for each time period. The model randomly selects historic data from the appropriate season and assigns this value to each of the five fuel types.

You'll find more information on wind modelling below.

Hydro output assumptions are shown in Table A2 below. The availability of this fuel type varies by season and by period within the day. The daily periods are as follows:

- P1 – peak
- P2 – plateau
- P3 – pick-up / drop-off
- P4 – night trough.

Table A2
Hydro potential output assumptions

Season/period	P1	P2	P3	P4
Winter	62%	47%	33%	26%
Spring/Autumn	38%	32%	21%	18%
Summer	27%	18%	12%	9%

[3] We've categorised coal and gas generators as 'base', mid' or 'marg' plant, based on the age, efficiency and level of the carbon emissions that impact the SRMCs of these fuel types. Wave and tidal fuel types have an 'enhanced' category. The generators classified as enhanced will receive a higher renewable subsidy because of their location.

[4] When it comes to newly developed technology, there's limited availability of output data for wave generation. So we calculate the availability of these generators based on sampling of wind availability.

Appendix A
Operational cost assessment inputs

The solar output assumptions are shown in Table A3. The output varies by month and by period within the day.

Table A3
Solar potential output assumptions

Month/period	P1	P2	P3	P4
January	0.0%	10.9%	4.5%	0.3%
February	0.0%	15.2%	3.9%	0.6%
March	0.0%	21.5%	12.5%	2.2%
April	34.6%	21.4%	11.7%	4.1%
May	30.8%	15.9%	12.8%	4.6%
June	29.7%	18.8%	8.4%	7.8%
July	29.3%	21.9%	8.1%	7.4%
August	25.9%	5.3%	13.4%	5.7%
September	8.5%	23.2%	9.5%	1.8%
October	0.0%	17.2%	1.8%	0.5%
November	0.0%	12.7%	2.1%	0.0%
December	0.0%	8.8%	2.7%	0.4%

The night trough is determined by demand and can be late enough for some light in winter.

Stakeholder engagement
We welcome your views on the availability assumptions of these generation types. We'll use your input to help with our constraint modelling analysis.

Treatment of interconnectors

In ELSI's constraint forecast, interconnectors are treated via an entry in the merit order, each with two prices quoted, which are driven by the forecast system marginal prices in the interconnected member states.

ELSI calculates GB system marginal prices for every day by periods:

- if the GB system price for a particular period in the day is below the lower interconnector price, ELSI assumes that the links will export power (in other words, the receiving country takes advantage of the low power prices available in GB)
- ELSI assumes that there's no power flow between the lower and upper interconnector price (in other words, the interconnectors have no flow on them)
- if the GB system marginal price is above the upper interconnector price, the interconnectors import power (and the GB system benefits from lower power prices abroad).

ELSI's interconnector modelling has improved. We've developed a new and improved model for the power markets of North West Europe. We use it to generate forecast prices for each overseas market for each scenario, year and time period simulated in ELSI. And we use these prices to determine the interconnector flows.

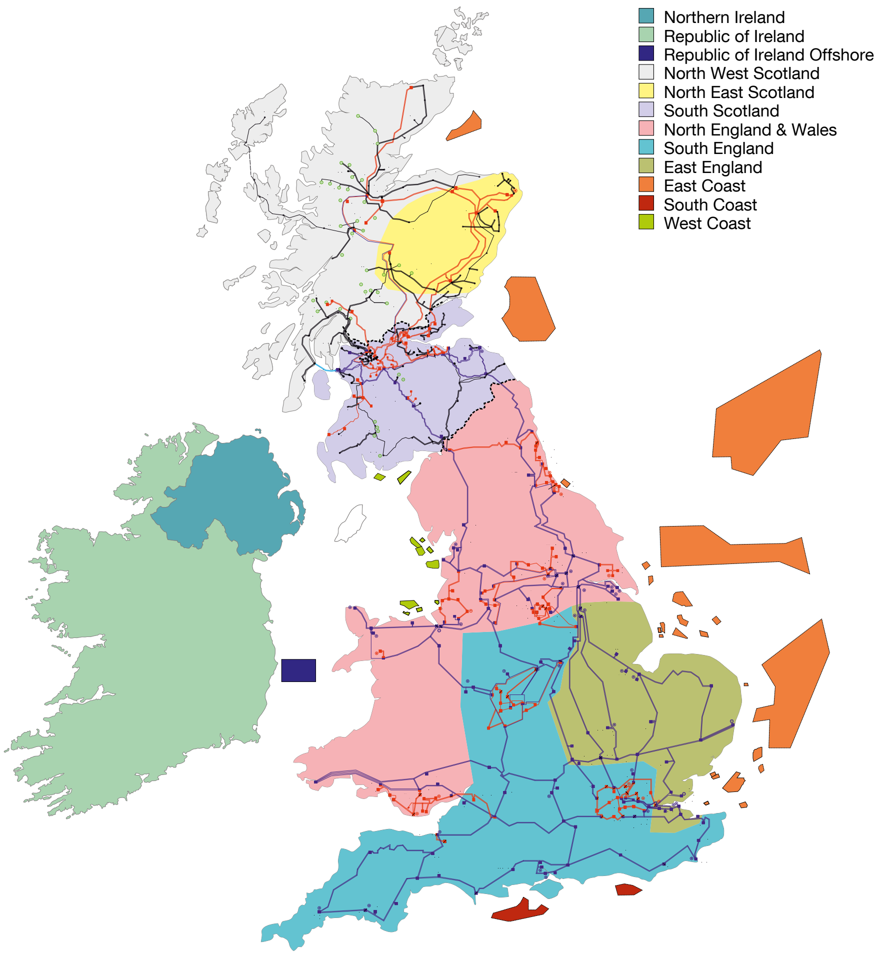
Wind modelling in ELSI

Wind output is represented by sampling historic daily wind speed data for the 12 discrete zones listed in Figure A1, including three Irish zones (two onshore and one offshore) as well as GB onshore and offshore zones. Each of the zones has a 10-year historical representation of wind generation load factor, based on Meteorological Office wind speed source data by different locations. We applied this data, which includes a seasonal variation, to a benchmark wind turbine power curve in order to establish the corresponding wind generation load factors.

The base wind speed data available means that we can break down the zones even further if we need more localised information – we've already done that on a number of projects. In 2014 we increased the number of zones from four to 12, which we believe offers enough diversity of weather and location for a broad analysis.

Appendix A
Operational cost assessment inputs

Figure A1
ELSI wind zones

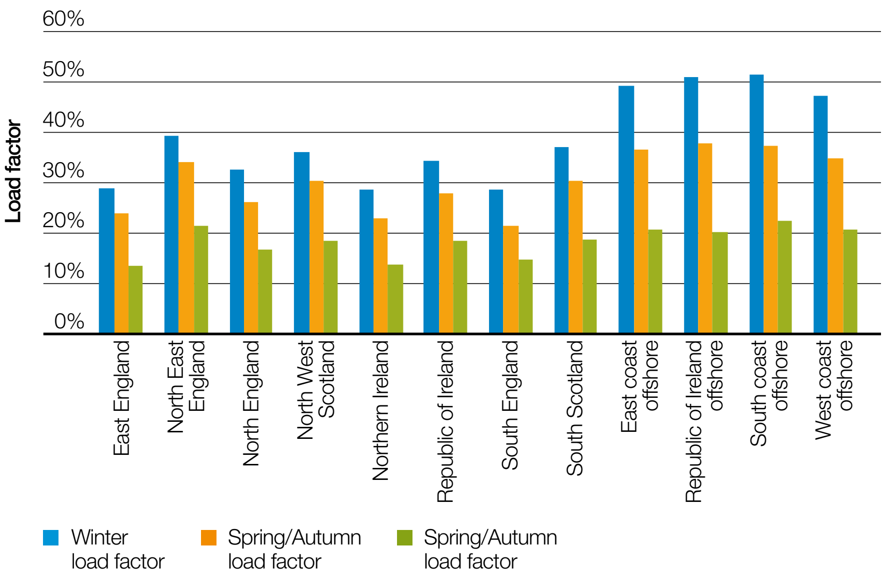


The statistical characteristics of the 12-zone data set are broadly as expected, including the following:

- there's a higher load factor in winter than in spring or autumn, and summer has the lowest load factor
- offshore wind has a higher annual load factor than onshore
- northerly locations (Scotland) tend to have a higher annual load factor.

The seasonal and locational variations in load factor can be seen in Figure A2 below.

Figure A2
Seasonal average wind load factors by zones



Our correlation analysis confirms that the wind generation data within ELSI is appropriate for simulating future onshore and offshore wind generation patterns.

Certain embedded fuel types are modelled in ELSI due to the variability in their output. These fuel types are currently onshore wind and solar. The demand figures used are adjusted to remove the effect of the embedded generation that is explicitly modelled.

Stakeholder engagement
We welcome input from our stakeholders about how we model wind and future interconnector flow assumptions.

Appendix A
Operational cost assessment inputs

Constraint management option costs
Our goal is to deliver the optimum investment at the correct time. To achieve this, we have to balance investment cost with operational cost, taking into account any costs that we'd incur if the investment didn't take place. So we start by calculating the volume of constraints without the investment.

Our long-term constraint forecast tool (ELSI) models the electricity market using a two-step process:

1. unconstrained dispatch: the first step looks at the short-run marginal cost (SRMC[5]) of each zonal fuel type and dispatches available generation (from the cheapest through to the most expensive) until the total level of GB demand is met. At this point, the network (boundaries) is assumed to have infinite capacity
2. constrained dispatch: the second step takes the unconstrained dispatch of generation and looks at the resulting power transfers across the boundaries. ELSI compares the power transfers with the actual boundary capabilities and re-dispatches generation to overcome any constraints that have occurred (in other words, where the power transfer is greater than the capability).

The algorithm in ELSI will relieve the constraints in the most economic and cost-effective way by using the SRMC of each fuel type. The cost associated with moving away from the most economic dispatch of generation (unconstrained dispatch) to a solution that makes sure the transmission network remains within its limits (constrained dispatch), is known as the constraint cost. It's calculated using the bid and offer price of each fuel type.

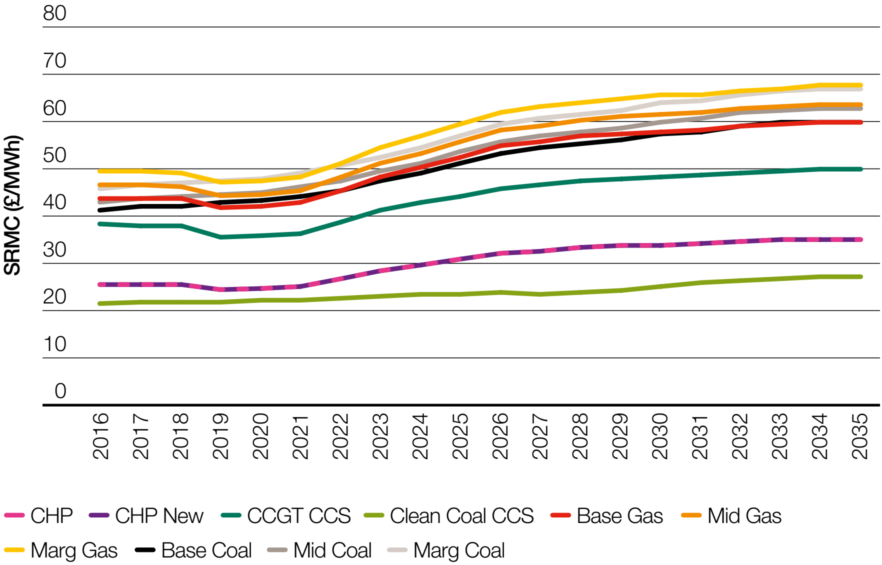
The SRMC forecast assumptions for all types of synchronous generation (apart from nuclear) are based on the fuel and carbon price forecasts in our Future Energy Scenarios 2015 document.

[5] Note that ELSI models SRMC (£/MWh) = Production (£/MWh) + Carbon emissions (£/MWh) + zonal adjuster (£/MWh)

Figure A3 below shows the SRMC forecasts for thermal generators (excluding nuclear) under the Gone Green and No Progression scenarios.

As you can see, coal and gas plant remain very competitive with each other. The carbon capture and storage (CCS) plant is cheaper because there's no carbon cost involved.

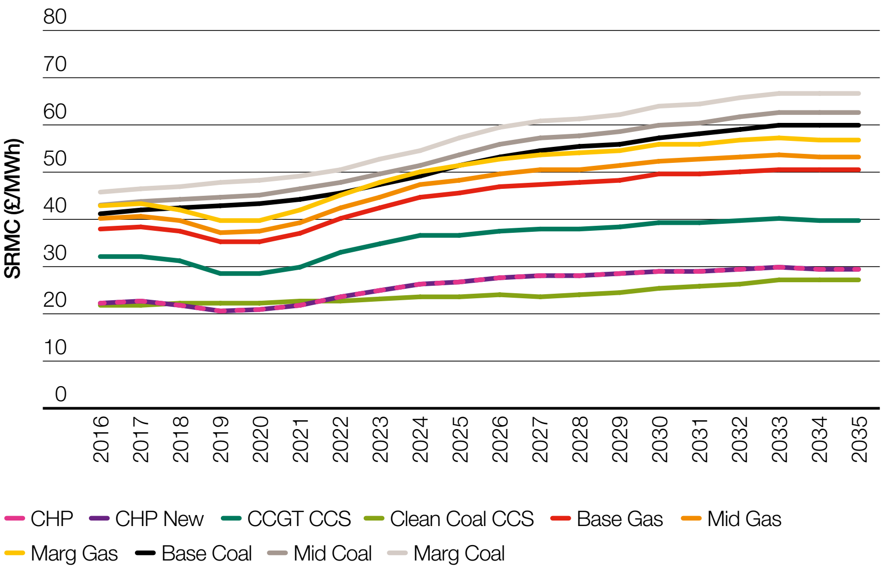
Figure A3
SRMC forecasts for thermal generators under the Gone Green and No Progression scenarios



Appendix A
Operational cost assessment inputs

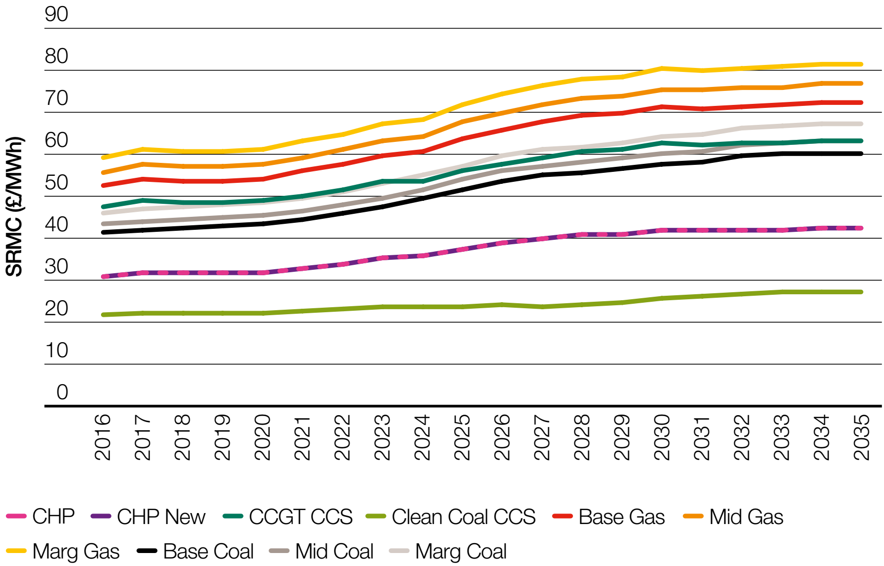
The SRMC forecasts for thermal generators under the Consumer Power scenario are presented in Figure A4 below. In this scenario the gas price is lower, so CCGT plant will be scheduled ahead of coal plant.

Figure A4
SRMC forecasts for synchronous generation under the Consumer Power scenario



The SRMC forecasts for thermal generators under the Slow Progression scenario are presented in Figure A5 below. In this scenario the gas price is higher, so coal plant will be scheduled ahead of CCGT plant.

Figure A5
SRMC forecasts for synchronous generation under the Slow Progression scenario



The SRMCs for all renewable generators are assumed to be nil. Their relative position in the merit order is based on the assumptions about the renewable subsidy available for each unit of energy generated.

When producing our forecasts, we measure the level of support available for different types of renewable generators using Renewable Obligation Certificates (ROCs). We source this data from the ROC to Contracts for Difference (CfD) Bandings Review, which was carried out by DECC and Ofgem and confirms that support for each fuel type will be reviewed every five years. Our current assumptions about future support are consistent with the 2019 estimates.

Appendix A
Operational cost assessment inputs

Table A4
Renewable support forecast in terms of ROCs: all scenarios

ROC to CfD banding	2016/17	2017/18	2018/19	2019/20
Hydro	0.70	0.70	0.70	0.70
Offshore wind	1.80	1.80	1.80	1.80
Onshore wind	0.90	0.90	0.90	0.90
Wave	2.00	2.00	2.00	2.00
Wave – enhanced	5.00	5.00	5.00	5.00
Tidal	2.00	2.00	2.00	2.00
Tidal – enhanced	3.00	3.00	3.00	3.00
Solar	1.20	1.20	1.20	1.20

The monetary forecasts for ROCs from Wood Mackenzie are projected to grow in a linear way from around £47 per ROC in 2014/15 to £52 in 2029/30.

The total constraint cost used to solve a transmission congestion issue is associated with the bid and offer components within the balancing mechanism. The 'bid' is a volume of energy at a £/MWh to reduce generation in an area; and the 'offer' is the associated £/MWh to replace the energy in another area of the system.

The bid prices depend on the type of renewable technology. For synchronous generation, evidence from the National Grid Economic Database (NED) confirms that the bid prices represent a proportional saving achieved by generators. For renewable generators and any other generators receiving subsidies through the CfD framework (such as new nuclear), the bid prices represent the opportunity cost associated with constrained generation so are valued at the level of subsidy available by technology type, as outlined earlier in this section.

In areas where there is no available generation to constrain on or off, the only option is to turn down demand; we have assumed £6,000 per MWh for the system 'value of lost load'. This figure is recommended by Ofgem and DECC in its Reliability Standard Methodology, DECC 2014[6].

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/267613/Annex_C_-_reliability_standard_methodology.pdf

Appendix B
List of options four letter codes

The list below is of the options assessed in the NOA Report 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.

Four letter code	Description
AHNO	Dumfries and Galloway reinforcement – AHNO
BBNO	New Beauly to Blackhillock 400kV double circuit – BBNO
BBU1	Rebuild of Beauly-Nairn-Elgin-Blackhillock 132kV double circuit OHL to 400kV double circuit – BBU1
BBU2	Rebuild of Beauly to Knocknagael to Blackhillock 275kV double circuit OHL to 400kV double circuit – BBU2
BKNO	New Beauly to Kintore 400kV double circuit – BKNO
BLN2	New Beauly to Loch Buidhe 275kV double circuit – BLN2
BLN4	New Beauly to Loch Buidhe 400kV double circuit – BLN4
BLUP	Rebuild of Beauly to Shin to Loch Buidhe 132kV double circuit OHL to 275kV double circuit – BLUP
BMMS	225MVAr MSCs at Burwell Main – BMMS
BRH1	Thermal upgrade of Bramford to Braintree to Rayleigh route – BRH1
BSRE	Bredbury to South Manchester cable replacement, uprating and OHL reinstatement – BSRE
BTNO	A new 400kV double circuit between Bramford and Twinstead – BTNO
CAM1	Install reactive compensation for North Wales export – CAM1
CAM2	Install additional reactive compensation for North Wales export – CAM2
CASR	Carrington series reactor – CASR
CDH1	Cellarhead to Drakelow OHL thermal upgrade – CDH1
CEH1	Upgrade the Cardiff East to Cowbridge leg of the Aberthaw to Cardiff East to Pyle circuit – CEH1
CIQB	Quad booster installation at Cilfynydd – CIQB
CPRE	Pentir to Bodelwyddan to Connah's Quay reconductoring – CPRE
CTRE	Reconductor Coryton South to Tilbury CTRE
DCRE	Dungeness – Sellindge to Canterbury North reconductoring – DCRE
DMC1	Reconductor the Daines to Macclesfield circuit – DMC1
DWNO	Denny to Wishaw 400kV reinforcement – DWNO
E1DC	Eastern subsea HVDC Link from Peterhead to Torness to Hawthorn Pit – E1DC
E2DC/E3DC	Eastern subsea HVDC Link from Torness to Lackenby/Hawthorn Pit – E2DC/E3DC
E4DC	Eastern subsea HVDC Link from Peterhead to Hawthorn Pit – E4DC
ECU2	East Coast onshore 275kV upgrade – ECU2
ECU4	East Coast onshore 400kV upgrade – ECU4
ELEU	New Hawthorn Pit 400kV substation, Turn-in of West Boldon – Hartlepool cct at Hawthorn Pit and Hawthorn Pit to Norton single cct 400kV upgrade – ELEU
ESRE	Elstree to Sundon circuit 1 reconductoring – ESRE
FLRE	Fleet to Lovedean reconductoring – FLRE
HCC1	Cowley to Minety and Cowley to Walham Cables (Hinksey cables) upgrade – HCC1
HMRE	Hinkley Point to Melksham circuit reconductoring part 1 – HMRE
HSNO	Hinkley Point to Seabank new double circuit – HSNO

Appendix B
List of options four letter codes

Four letter code	Description
HSUP	Upgrade the Harker to Stella West circuits from 275kV to 400kV – HSUP
HWUP	Hackney – Tottenham to Waltham Cross uprate – HWUP
IRMS	Install reactive compensation at Ironbridge – IRMS
KLRE	Kemsley – Littlebrook circuits uprating – KLRE
KWR1	Reconductor the Keadby to West Burton No1 circuit – KWR1
KWR2	Reconductor the Keadby to West Burton No2 circuit – KWR2
KWSR	Install series reactors in both Keadby to West Burton circuits – KWSR
LDQB	Lister Drive quad booster – LDQB
LIQB	Legacy to Ironbridge quad booster uprating – LIQB
LIRE	Legacy – Ironbridge conductor replacement – LIRE
LNRE	Reconductor Lackenby to Norton single 400kV circuit – LNRE
NBRE	Reconductor Bramford to Norwich double circuit – NBRE
NOR1	Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit – NOR1
NPNO	New east – west circuit between Norton and Padiham – NPNO
PCRE	Penwortham to Padiham and Penwortham to Carrington (‘south’) reconductoring – PCRE
PTC1	Pentir to Trawsfyndd 1 cable replacement – single core per phase – PTC1
PTC2	Pentir to Trawsfyndd 1 and 2 cables – second core per phase – PTC2
PTNO	Pentir to Trawsfyndd second circuit – PTNO
PWTI	Pembroke to Walham circuit turn-in to Rhigos – PWTI – and reactive compensation – SWSC
QDRE	Reconductor the Connah's Quay-Daines circuits – QDRE
RMSR	Rayleigh Main series reactors – RMSR
RTRE	Reconductor Rayleigh to Tilbury RTRE
SCNO	New 400kV transmission route between South London and the south coast – SCNO
SCVC	South-east coast dynamic reactive compensation – SCVC
SEC1	Severn tunnel 400kV cable circuit uprate – SEC1
SSRE	Reconductor the Stella West to Spennymoor circuits – SSRE
SWRE	Reconductoring the Sundon to Wymondley circuit – SWRE
SWSC	Pembroke to Walham circuit turn-in to Rhigos – PWTI – and reactive compensation – SWSC
THSR	Install series reactors at Thornton – THSR
TLH1	Treuddyn Tee to Legacy thermal upgrade – TLH1
TLNO	Torness to Lackenby AC reinforcement – TLNO
TPNO	Pelham to Twinstead new 400kV double circuit – TPNO
WEC1	Willesden to Wimbledon 275kV cable Ealing Diversion – WEC1
WEC1	Willesden to Wimbledon 275kV cable Ealing Diversion – WEC1
WEDC	Western HVDC Link – WEDC
WEOS	Western HVDC Link fast de-load scheme – WEOS
WPDC	North Wales to South Wales HVDC Link – WPDC
WPNO	Wylfa to Pentir second double circuit route – WPNO
WYQB	Wymondley quad boosters – WYQB
WYTI	Wymondley turn-in – WYTI

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.
	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.
	Counterfactual	This is the network state against which the investment network states are compared in the cost-benefit analysis. The counterfactual network state will usually be the ‘no change’ or ‘do nothing’ network state, but might be different on occasions.
	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’s 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.

Glossary

Acronym	Word	Description
DECC	Department of Energy & Climate Change	A UK government department. The Department of Energy & Climate Change (DECC) works to make sure the UK has secure, clean, affordable energy supplies and promote international action to mitigate climate change.
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	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.
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) expired.

Acronym	Word	Description
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.
	Local boundary	Boundaries drawn around small areas of network where a lack of generation diversity produces a high probability of stressing the local transmission network due to the generation running at the same time.
MSC	Mechanically Switched Capacitor	Shunt capacitor that is switched in or out by a circuit breaker.
	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, the 132kV 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 Electric 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, multi-junction 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.

Glossary

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 system 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 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 weekday 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.
SRMC	Short Run Marginal Cost	The cost of producing 1MWh of electricity for a particular fuel type, including the cost of fuel and carbon emission.
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
	Spackman	The UK Joint Regulators Group recommends a Present Value discounting approach for projects which are privately financed and provide public benefit. The "Spackman" approach is used to discount future financing costs to Present Value by using a Weighted Average Cost of Capital (WACC) to create annuities and then discounting these at the Social Time Preference Rate (STPR). The STPR is determined using guidance provided in the HM Treasury Green Book and the WACC can be obtained from transmission owner specific literature.
	SP Transmission	Scottish Power Transmission Limited (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 Operability 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 Electric Transmission and Scottish Power Transmission.
	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.
	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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