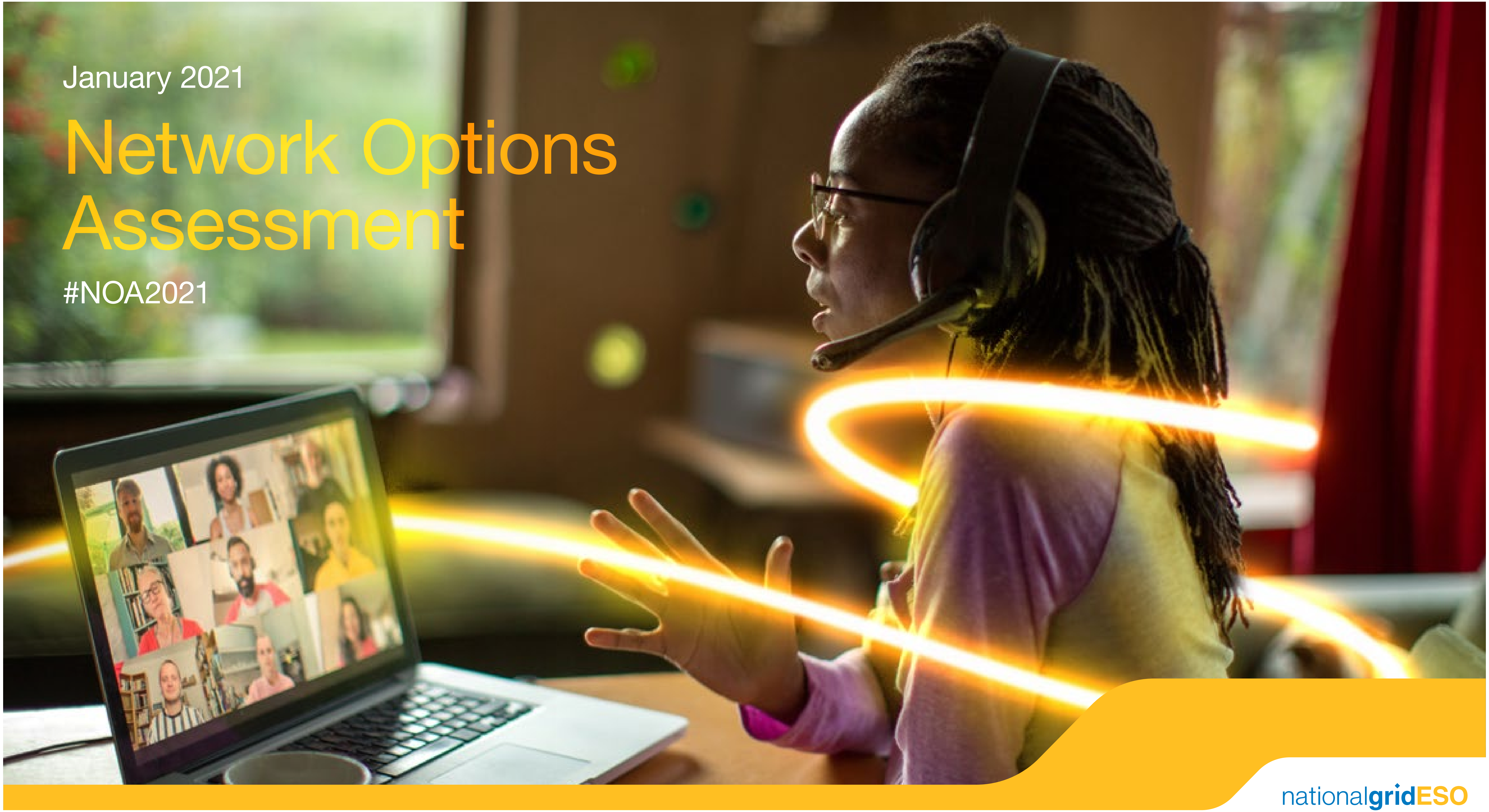
January 2021

Network Options Assessment

#NOA2021



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Click or Roll over highlighted text or the symbol to reveal extra content or take you to a different section

Page navigation explained

Back a page

Forward a page

Return to contents

From here you can navigate to any part of this publication - for example, this will allow you to find your place quickly and easily after you have followed an internal link

www

Click on orange text to go to the appropriate webpage.

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Contents

Welcome

Foreword

Last year saw further development of the Government’s energy ambitions to reach net-zero with the Prime Minister’s Ten Point Plan for a Green Revolution and the publication of the Energy White Paper. Both of these documents set out significant targets for the connection of new generation over the next decade as well as up to 2050 and will require careful consideration of network plans to support these targets.

This year’s *Network Options Assessment (NOA)* is a key publication in recommending the major projects that are needed to deliver a transmission system that is fit for purpose to meet GB’s net zero and green ambitions, whilst balancing the costs to the end consumers. Building on the work of the *Future Energy Scenarios 2020 (FES)* and the *Electricity Ten Year Statement 2020 (ETYS),* the *NOA* is a key part of the Electricity System Operator’s (ESO) role.

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The ESO fully supports the Government’s net-zero targets and will continue to work with stakeholders across industry and government to develop the future network to support these ambitions, to ensure that collectively we can achieve a secure, sustainable and affordable energy future.

We are pleased to present the 6th *NOA* report, with the aim of generating consumer value by avoiding over or under investment in the transmission network. To make sure our processes are transparent, we follow the *NOA methodology*, in full consultation with our stakeholders and which is approved by Ofgem on an annual basis. This methodology sets out how we base recommendations on the data and analysis of the latest *FES* and *ETYS*.

The *NOA* represents a balance between asset investment and network management to achieve the best use of consumers’ money. The future energy landscape is uncertain, and the ESO’s recommendations make sure the GB transmission network is fit for the future. These recommendations are imperative for us all to address the ‘energy trilemma’ of secure, sustainable and affordable energy. They are the key stepping stones for us to meet our 2025 target to operate a carbon-free network and accomplish the wider 2050 ambition of a net zero carbon emission society.

As the ESO we published a report in December concluding the first phase of our *Offshore Coordination Project (OCP)*, setting out the benefits of a more integrated approach to offshore connections. This report has been submitted to the Government as part of their wider network review, whose ultimate conclusions will dictate the future direction of the *NOA.*

This year’s *NOA* has, for the first time, explored offshore wider works in detail. We have learnt from the outputs of the ESO’s *OCP* which identified significant consumer and environmental benefit from the coordination of offshore infrastructure. The *NOA* analysis is restricted solely to constraint savings, and as such does not evaluate the same range of factors as the *OCP.*

In producing this year’s *NOA* we have listened to and acted on your feedback. We are making more changes and enhancements to the process. I would welcome your thoughts as to how we can push the *NOA* even further to drive value for consumers whilst continuing to operate a safe and secure GB transmission system.

NOA / Foreword 04

Executive summary

Executive summary

The *NOA* recommends which reinforcement projects should receive investment during the year. We reach our conclusions using the *FES 2020* scenarios, *ETYS 2020* options, and the latest *NOA methodology report*. The diagram below summarises the key messages in this publication.

171 assessed options

Proceed	45
Delay	2
Hold	66
Do not start or Stop	58
NOA I/C	16.9 to 27.7 GW

£13.9bn
Total Cost

£183m
Investing in 2020/21

4
Number of ESO-led commercial solutions Saving consumers up to £2.1bn

NOA / Executive summary 06

Executive summary

This year's *NOA* analysis signals the need to invest more than £16 billion[1] to manage heavily constrained system boundaries through asset build options into the mid-2030s. This investment will pave the way and help enable the ambitions of a net zero future. The key driver is the large increase in renewable generation, particularly in the North and East of Great Britain, described in the *Future Energy Scenarios* 2020, as we strive to meet net zero climate targets by 2050.

We have identified a need for four Anglo-Scottish subsea reinforcements along the east coast as well as several large onshore reinforcements which combine to facilitate north-to-south power transfer. These options will be refined through the TOs regulatory investment processes.

In the south and east of England, we continue to forecast a growing volume of interconnection capacity over the next decade. Last year we recommended a new offshore transmission route between Suffolk and Kent and a new circuit from Bramford to Twinstead. This year, our analysis shows the need for these links and three further new onshore transmission route circuits across the south east coast from Norfolk to Kent to alleviate increased network constraints.

We also see significant value in pursuing 4 ESO-led commercial solutions across the north of England and Scottish border region and the south east coast region, providing up to £2.1 billion in consumer savings.

Even with the *NOA's* substantial investment recommendations, constraint costs are still forecast to rise significantly over the next decade. We are engaging with BEIS, Ofgem and the industry for alternative ways to manage these constraint costs in the short to medium term.

Our recommendations can be found in Chapter 4 - 'Investment recommendations'; detailed data and a comparison to last year can be found in Appendix A – 'Economic analysis results'.

1 This figure is the total cost of all reinforcements required in the System Transformation scenario up to the mid-2030s. This scenario represents the lowest total spend of the three net zero scenarios.

NOA / Executive summary 07

Executive summary

This year's interconnector analysis suggests a total interconnection capacity range of between 16.9 to 27.7 GW between GB and European markets would provide optimal consumer benefit. These recommendations represent the best view at a snapshot in time. Investment decisions taken by any business should always consider these recommendations in the light of subsequent events and developments in the energy sector. You can find these results in Chapter 6 - 'Interconnector analysis'.

This year, some of the options we've recommended to proceed with are likely to meet Ofgem's criteria for onshore competition. We've expanded this assessment to include any new or modified contracted connection projects for generator and demand connections. The competition assessment is in accordance with Ofgem's agreed methodology. The outcomes are described in Chapter 4 - 'Investment recommendations'.

For the first time, we have demonstrated the economic benefits of offshore integration within our *NOA* analysis. We have proposed a number of conceptual offshore options and tested their benefit solely against constraint reductions, the analysis undertaken by the separate *Offshore Coordination Project (OCP)* has considered other factors beyond the remit of *NOA*. In the future, it is possible that the *NOA* will evolve to account for these factors as well. Our analysis has found that three conceptual options are economically viable in at least one scenario and warrant further investigation. We will continue in conjunction with the *OCP* to engage with the industry in 2021 to seek your views on the *NOA's* offshore wider works results. We've published these results in a new dedicated Chapter 5 - 'Offshore Wider Works'.

This year's *NOA* provides a clear set of recommendations for investment in the transmission network, that are necessary if the UK is to achieve net-zero by 2050. The shift to a decarbonised electricity system requires unprecedented investment over the coming years. We are working together across the industry to deliver the decarbonised, sustainable electricity system of the future.

NOA / Executive summary 08

Have your say

Your views are important in helping us continue to develop and improve the *NOA*. Chapter 7 - ‘Stakeholder engagement’ describes how you can contact us.

Future energy publications

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

The starting point for our flagship publications is the *FES*. This is published every year and involves input from stakeholders from across the energy industry.

These scenarios create a range of credible futures which allow us to provide credible supply and demand projections out to 2050. They inform the energy industry about network analysis and planned investment to benefit our customers.

We set out our long-term view of the electricity transmission capability in our *FES*, *ETYS*, and *NOA* publications. Your input can help shape these publications and inform the energy debate.

NOA / Executive summary 09

Chapter 1

Introduction

Navigating this document

We've structured the *NOA* document to help you understand how we've reached our recommendations and conclusions.

Chapter 2

Methodology

Describes the *NOA* process and the economic theory behind it. This is useful if you are unfamiliar with the *NOA*, or if you would like to understand more about how we carry out the economic analysis of options.

Chapter 3

Proposed options

Describes the reinforcement options that can increase the NETS' capability. It provides an overview of the options being proposed by TOs and ESO.

Chapter 4

Investment recommendations

Shows our investment recommendations for 2020/21. It also summarises the eligibility assessment for competition in onshore electricity transmission.

Chapter 5

Offshore Wider Works

Presents our methodology, options and results for the assessment of conceptual Offshore Wider Works options within the *NOA*.

Chapter 6

Interconnector analysis

Presents our interconnection analysis results. We describe the optimum levels of interconnection between GB and European markets and explain the economic theory behind the benefit of interconnectors to the consumer.

Chapter 7

Stakeholder engagement

Let's you know how to get involved with the *NOA* process and how to use data in the document.

NOA / Introduction / Navigating this document 11

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

The ESO produces a suite of publications on the future of energy for Great Britain, which inform the whole energy debate by addressing specific network planning issues. The *FES*, *ETYS* and *NOA* provide an evolving and consistent voice in the development of GB's electricity network.

We use the *FES* to assess network requirements for power transfers across the GB NETS. The TO responds with options for reinforcing the network and the requirements are published in the *ETYS*. The *NOA* is based on our economic analysis of these options. More information about this can be can be found in Chapter 2 - 'Methodology'.

We summarise our economic analysis of reinforcement options by region. Based on the economic analysis, we give our recommended options for each of the regions. Where appropriate, we've included a summary of those options which meet Ofgem's criteria for further assessment, including Large Onshore Transmission Investments (LOTI).

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

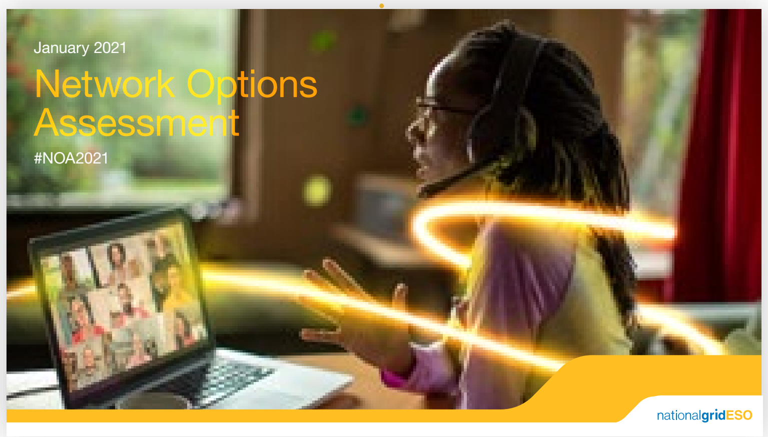
Some alternative options we've evaluated are reduced-build or operational options as explained in Chapter 3 - 'Proposed options'. The *NOA* emphasises the need to reinforce the network, and we are keen to embrace innovative ways to do so.

FES July 2020

A range of plausible and credible pathways for the future of energy from today out to 2050

ETYS November 2020

The future transmission requirements on the electricity system



NOA January 2021

The recommended options to meet reinforcement requirements on the electricity system

Figure 1.1 *NOA* and *ESO* publications

NOA / Introduction / How the NOA fits in with the FES and the ETYS 12

What the *NOA* can and cannot do

The *NOA* can…

- **recommend** the most economic reinforcements, whether build or alternative options, for investment over the coming years, to meet bulk power transfer requirements as outlined by the *ETYS*.
- **recommend** when investments should be made under the different scenarios set out in the *FES* to deliver an efficient, coordinated and economic future transmission system.
- **recommend** whether the TOs should start, continue, delay, hold or stop reinforcement projects to make sure they are completed at a time that will deliver the most benefit to consumers.
- **indicate** the optimum level of interconnection to other European electricity networks and necessary reinforcements.

The *NOA* cannot…

- **provide** recommendations for customer connections. The *NOA* only recommends the most economic reinforcement to resolve wider network issues.
- **insist** that reinforcement options are pursued. We can only recommend options based on our analysis. The TOs or other relevant parties are ultimately responsible for what, where and when they invest.
- **comment** on the details of any specific option, such as how it could be planned or delivered. The TOs or other relevant parties decide how they implement their options.
- **evaluate** the specific designs of any option, such as the choice of equipment, route or environmental impacts. These types of decisions can only be made by the TOs or other relevant parties when the options are at a more advanced stage.
- **assess** network asset replacement projects which don't increase network capability or individual customer connections.
- **procure** products or services. The *NOA* may highlight a need to explore options further, either through the *NOA* Pathfinder projects or further engagement.
- **provide** a recommendation on options that provide no boundary benefit or where the costs for the expected benefit would be prohibitive.
- **forecast** or recommend future interconnection levels. It indicates the optimum level of interconnection.

NOA / Introduction / What the NOA can and cannot do 13

What's new this year?

- ***NOA* Interested Persons' process** - this year we introduced a new submission process, available on our website, allowing options from non-TO parties to be submitted and potentially assess in the annual process. We are gathering lessons learnt from this process and will continue to engage with our stakeholders on how this process will be progressed in future.

- **Offshore Wider Works chapter (OWW)** - We have continued developing conceptual OWW reinforcements for the NOA and this year we have increased the number of reinforcements and the detail of the studies. This year we have included a dedicated chapter to further explain our progress.

- **Handover process** - We continue to improve our processes based on stakeholder feedback. After publishing the *NOA* 2019/20 report, we continued to refine our system requirements form (SRF) and developed a platform for submission to provide a smoother experience in the handover process. Every year we look to improve these tools, to improve the TO's experience of submitting their options as well as adding extra levels of quality assurance to the *NOA* process.

- **The *NOA* Pathfinder projects** - Since we published our Network Development Roadmap, committing to conducting pathfinding projects to explore ways of including other system needs, we have made significant progress. Currently there are three *NOA* Pathfinders: voltage, stability and constraint management. Voltage aims to find a solution to resolve regional high voltage issues. Stability aims to address our immediate needs of national inertia and deliver local short circuit level needs in Scotland. Constraint Management aims to resolve network constraint issues and lower balancing costs. For the most up-to-date information on their progress and to get involved please visit our website.

- **Least Worst Weighted Regret (LWWR)** - this year, academics at the University of Melbourne independently validated the robustness of our *NOA* process and described it as "state of the art planning under uncertainty". In collaboration, we developed a new tool called Least Worst Weighted Regret (LWWR). It provides a sensitivity study of varying the probability of each future energy scenario occurring. We used this tool for the first time this year at the *NOA* Committee, to help improve the robustness of the marginal options presented. You can find out more about LWWR by downloading the report on our website.

- **Contract for Difference (CfDs)** - In this year's *NOA* analysis, we have improved our modelling of forecast constraint costs, to account for wind generators having a Contract for Difference (CfDs). CfDs are the mechanism for subsidising wind, replacing Renewable Obligation Certificates (ROC). This change in subsidy affects the prices wind will bid into the balancing mechanism, and hence affects constraint costs. We have improved our understanding of the effects that large scale adoption of CfDs may have through: stakeholder engagement with industry and academia; and detailed analysis of historical bid price data. We have modelled all future wind generators in our economic tool to respond as we'd expect from a generator with a CfD. This improves how reflective our modelled cost of constraints are in the medium and longer term, which increases our confidence in the *NOA* 2020/21 results. We are committed to continuously improving our modelling of the constraint cost impacts from subsidy changes in future *NOA* iterations. Therefore, we will review our assumptions as more data becomes available.

NOA / Introduction / What's new this year? 14

Chapter 2

Methodology

Introduction and the *NOA* process

This chapter highlights the methodology we use for the *NOA*, and explains the process and economic theory behind our analysis.

The *NOA* methodology describes how we assess major NETS reinforcements to meet the requirements identified from our analysis of the FES. The latest methodology is published on our website, it also includes the methodologies for interconnection analysis included in Chapter 6 – 'Interconnector analysis'. In accordance with our licence condition, major NETS reinforcements are defined in paragraph 1.31 of the *NOA methodology report* 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 customer connection agreements have major reinforcements as their required enabling works for connection.

If the *NOA* recommends a change to the delivery of these works, we will work with these customers to identify if any updates are required to their agreement. Their connections will not be delayed.

In December 2020 Ofgem published their final determinations for the new RIIO-2 framework which starts in April 2021. The new framework changes how TOs are funded for future projects. For RIIO-2, projects will be funded by two uncertainty mechanisms:

- The Medium Sized Investment Projects (MSIP) re-opener, provides TOs with an annual opportunity to request funding for projects valued at less than £100 million.
- The Large Onshore Transmission Investments (LOTI) reopener, assesses larger projects with a value of greater than £100 million.

The LOTI process supersedes the SWW process and the threshold of greater than £100 million is consistent across all TOs.

To find out more about the *NOA* process and what the future holds, check out our explanatory videos on YouTube:

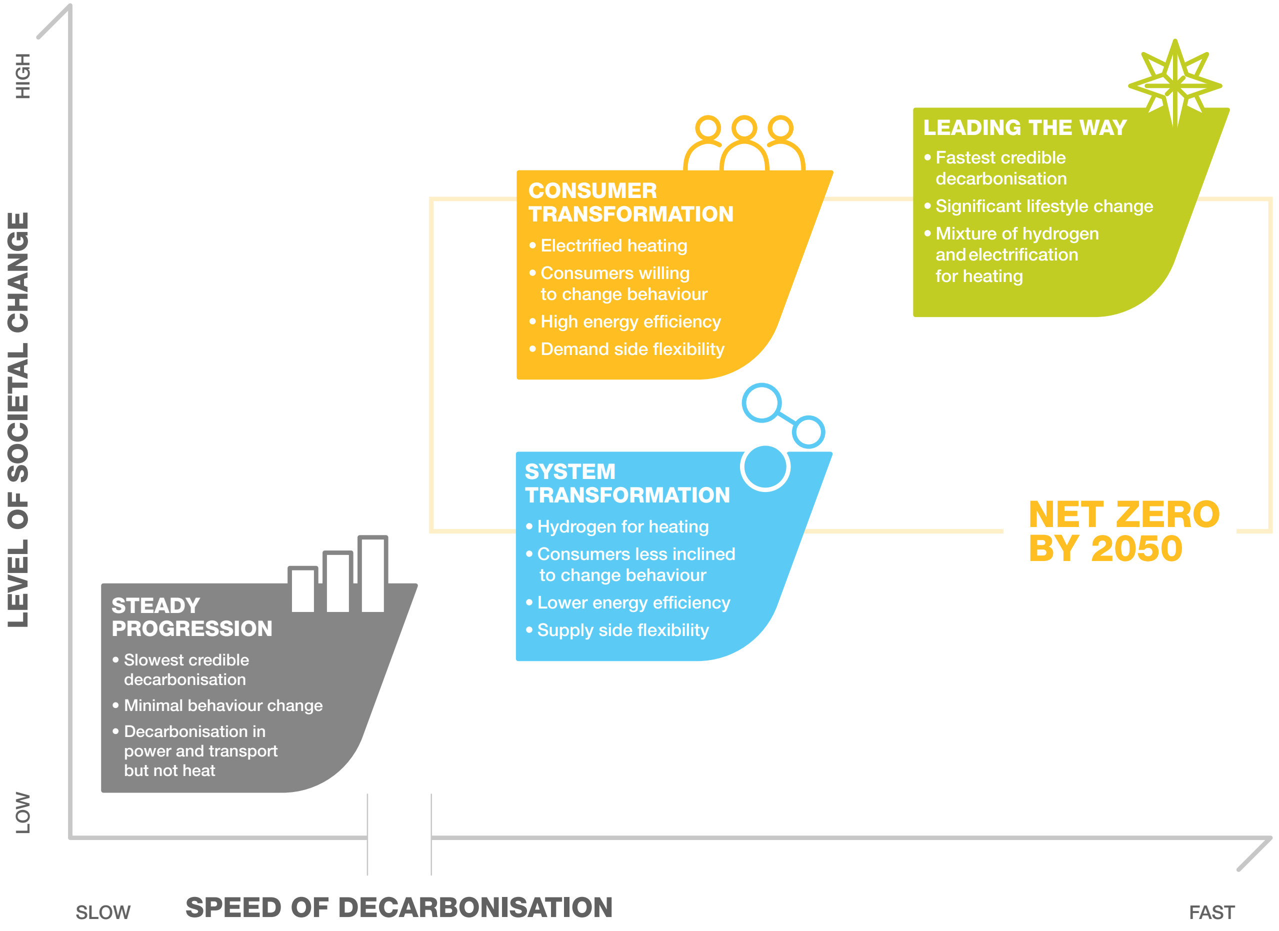
▷ **NOA process**

▷ **Future of the NOA process**

NOA / Methodology / Introduction and the NOA process 16

Future Energy Scenarios

The first stage of the *NOA* process starts with the *FES*. These are a credible range of future scenarios across the whole energy system and the electricity components form the foundation for our studies and economic analysis. The four scenarios published in 2020 are:



This year, a new set of scenarios were developed through extensive industry collaboration. These have net zero at their core and explore how the level of societal change and speed of decarbonisation could lead to a range of possible future pathways.

COVID-19 impact

COVID-19 will impact many aspects of the future of energy. This year's *NOA* uses the latest *FES* 2020 scenarios which, due to the uncertainty and lack of evidence of the pandemic's impact at the time has not been included in the latest *FES*. With further impacts to be discussed with stakeholders this will form part of the *FES* 2021 which will affect *NOA* 2021/22.

NOA / Methodology / Introduction and the NOA process 17

Economic analysis theory

It is important to understand why we recommend investment in the transmission network.

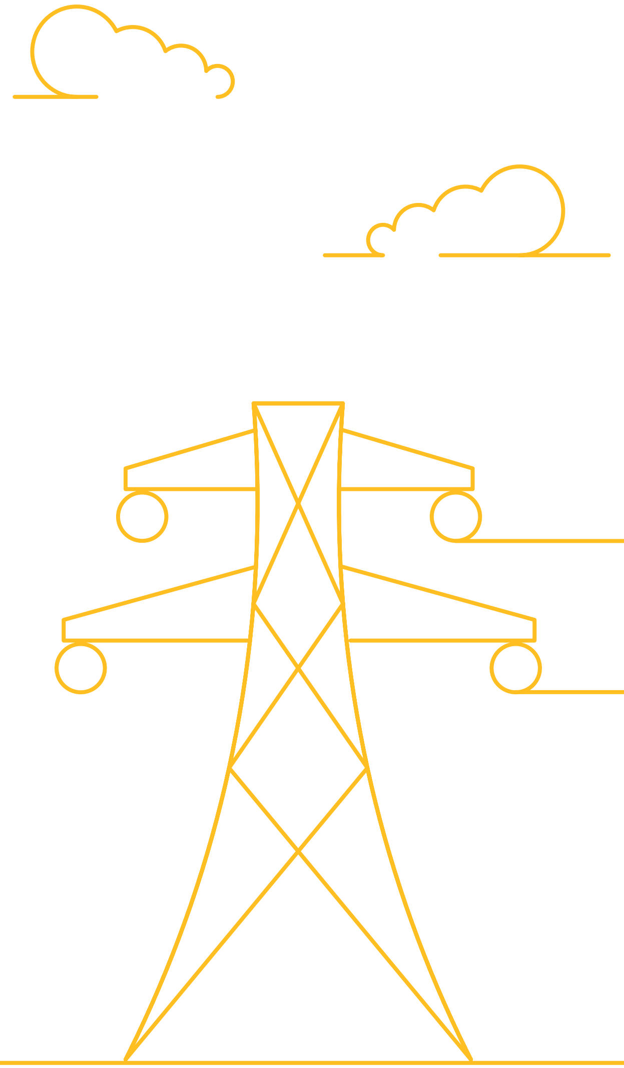
The transfer of energy across our network boundaries occurs because generation and demand are usually in different locations. When the power transfer across a transmission system boundary is above that boundary's capability, our control room must reduce the transfer to avoid overloading the transmission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

When this happens, we ask generators on the exporting side of the stressed boundaries to limit their output. To maintain an energy balance, we replace this energy with generation on the importing side. Balancing the network by switching generation on and off costs money, and if we are regularly constraining the network by large amounts, costs begin to accumulate.

Assessment of future constraint costs is an important factor in our decision-making process. It enables us to evaluate and recommend investments such as adding new overhead lines and underground cables to the network. We call these potential investments 'options' and, although they cost money, they also increase the capability of the network, meaning that more power can be transferred across boundaries without the need to constrain.

We work with the TOs to upgrade the transmission networks at the right time in the right places to give the best balance between investing in the network and constraining it.

You can find out more information about the economic analysis in our full *NOA methodology report* (paragraphs 2.79 to 2.88). This includes a detailed explanation of the cost-benefit analysis, the single year least worst regret selection process and our economic modelling tool.



NOA / Methodology / Economic analysis theory 18

Chapter 3

Proposed options

Introduction

This chapter summarises the reinforcement options that could increase the NETS boundary capability. It also provides an overview of the transmission system boundaries we've studied.

For a more detailed boundary description, please read our *ETYS* report. A summary of options that have started the SWW process are included in Appendix B – 'LOTI projects'. A more detailed description of the options, as well as the boundaries can be found in Appendix C – 'List of options'.

Most of the options we've analysed are large asset-based solutions but we've also explored small scale, low-cost solutions. These can include overhead line conductor re-profiling to increase operating temperature limits, or additional cooling. Operational options usually provide additional transfer capabilities without physically uprating the network. This is normally by operational measures (such as special running arrangements), sometimes with commercial arrangements. We give more details of alternative options in Table 2.2 in the *NOA methodology report*. Our role also includes early development of offshore options in accordance with Part D of licence condition C27. This is so that we can carry out *NOA* analysis of these options. You can find out more about this in 'The options' section of this chapter.

NOA / Proposed options / Introduction 20

The system boundaries

We use boundaries to represent pinch points on the electricity transmission network. How constrained the boundaries are varies from hour to hour throughout the year. Power flows across the system can be significantly impacted by changing demand and generation patterns.

Over the next 10 years, wind generation is forecast to increase to 40GW across Great Britain with a high concentrationed in Scotland and East Anglia. Demand is predominantly located in the south of the country leading to high north-south power flows with high variability. Interconnectors to other European electricity markets help to manage the electricity network, and increasing volumes of intermittent renewable generation, as well as better security and competition, but may also drive boundary reinforcement.

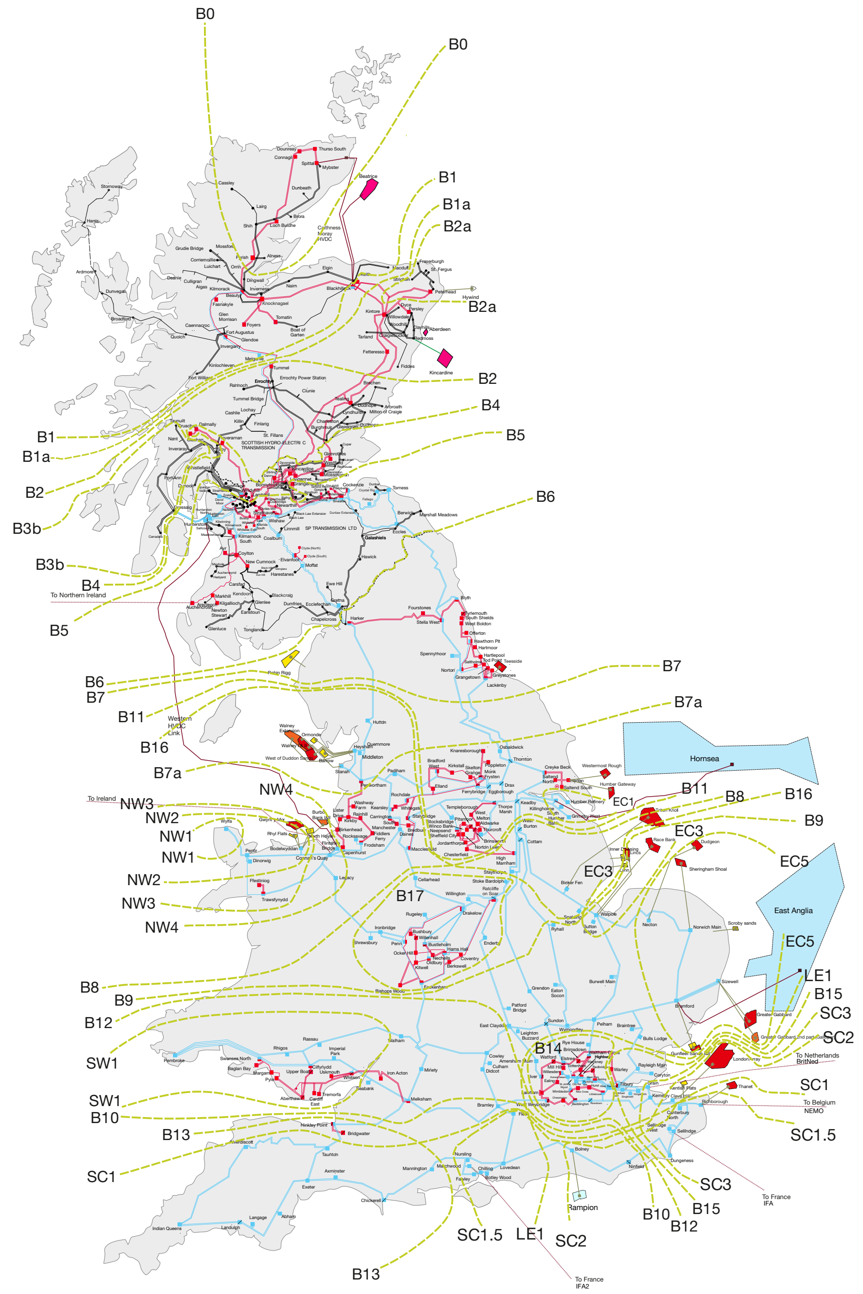
In the move to net zero over the next decade, the GB Transmission System will face growing needs in several regions by 2030:

- Increasing quantities of wind generation connected across the Scottish networks will more than double the north-to-south transfer.

- A potential growth of over 6GW in low-carbon generation and interconnectors in the North of England combined with high Scottish generation, will increase transfer requirements in the Midlands.

- A 10GW increase expected in generation coming from offshore wind on the east coast connecting to East Anglia, will increase the need for reinforcement.

- New Interconnectors connecting in the south of the country will also increase the transfer requirements on the network.



NOA / Proposed options / The system boundaries 21

We provide an overview of the options in this chapter, with more detail in Appendix C – 'List of options' which is listed according to the option codes we use.

Options fall into two groups: asset-based options; and ESO proposed options. Some seek to use existing assets more intensively, though the costs of doing this can vary widely.

Thermal constraints

Thermal constraints are the most common constraints. The constraint 'bites' when a fault overloads the weakest component on the boundary. As the generation mix changes, even in the course of a single day, the overload can move from one area to another. The size of the overload and how much it moves influences the choice of investment. The cost of the proposed reinforcements, how much benefit they'll provide, and their delivery date also influence the choice. Options that could reduce thermal constraints include, but aren't limited to:

Upgrade existing circuits

Examples include replacing overhead line conductors, replacing sections of cable, or increasing the operating voltage, often from 275kV to 400kV. A cheaper approach where possible is to make the most of the clearance distance between overhead lines and nearby structures, trees and other objects. Adjusting the conductor profile, for instance, by re-tensioning the conductors can maintain the clearance distance while carrying higher flows.

Develop new circuits

This might be offshore High Voltage Direct Current (HVDC) links or new onshore circuits, which often re-use existing assets.

Build a new substation or reconfigure an existing substation

The aim is usually to optimise the flows on a pair of overhead line circuits. When the loading isn't balanced, one side will tend to overload before the other. This is often a result of how the network has been configured to meet previous needs; for instance, the location of generation. Options improve the balance of flows by making the ends of two circuits as connected as possible. New substations and redirecting circuits into existing substations can achieve this. Sometimes fault (or short circuit) levels or other characteristics of the network prevent us from electrically connecting substations at the end of heavily-loaded circuits. Some options replace switchgear and other substation infrastructure to change how we operate the substation and ease the constraint.

NOA / Proposed options / The options 22

The options

Control power flow

If we want to alter the flow on a circuit, in some cases, it's worth investing in suitable equipment. We can use quad boosters (QBs) and series compensation, usually reactors, and we expect new technology to become an option that uses solid-state electronics to control the flows.

Alternative options

These include two categories: operational options and reduced-build options. Where possible, we use low-cost means to control thermal loadings while meeting NETS SQSS requirements. One approach is to reduce the loading on an overloaded circuit after a fault, for example, by quickly reducing generation.

This can be by special arrangement with one or more generators for fast de-load services or an intertrip. Payment for the service is subject to the scale and competitiveness of the market. Another approach is to use dynamic ratings where we monitor a circuit's temperature or its immediate environment. This might allow us to increase the rating slightly and relieve the constraint.

Voltage and stability constraints

Some of the approaches detailed above affect the transmission system's voltage performance and we need to take this into account when designing the system. We do have means to manage the system voltages using asset- based solutions such as shunt reactors, shunt capacitors, synchronous compensators and static reactive compensators ('STATCOMs', 'SVCs'). We also use commercial solutions by contracting with customers to produce or consume reactive power but this involves an ongoing cost. We can experience stability constraints on weaker parts of the network, particularly when flows are high. Strengthening the network is often necessary but we are exploring other approaches, such as fast intertrips and series capacitors, to improve the boundary capability.

ESO-led commercial solutions

Commercial solutions formed an integral part of our *NOA* analysis. In this assessment, they are included in the same way as asset-based reinforcements and form part of the final 'optimal' paths, depending on where the analysis indicates they are needed.

Commercial solutions can be contracted flexibly and don't have a fixed 'asset life' or duration so we've assessed when to discontinue them. We factor the availability and arming fee into the operational costs based on our historical data.

Commercial solutions aren't free of capital costs, but only need a relatively small initial investment (mostly on communication and control systems). This, together with the flexibility of their contracts, makes commercial solutions a reasonable alternative option.

Figure 3.1 groups the options for this year's *NOA* and gives the total number for each category. Each option has an associated icon which will be used throughout the report.

NOA / Proposed options / The options 23

The options

Figure 3.1 The reinforcement options in their categories.

Develop new circuits	Control power flow	Build a new substation or reconfigure an existing substation	Upgrade existing circuits	Voltage and stability constraints	Alternative options	ESO-led commercial solutions
Total 48	**Total 27**	**Total 7**	**Total 50**	**Total 27**	**Total 4**	**Total 8**

171 options submitted for economic analysis.

NOA / Proposed options / The options 24

Excluded options

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

- projects which do not increase the transfer of power across critical system boundaries.
- options that provide benefits, such as voltage control during low demand periods in the summer, but no boundary capability improvement. These will be published separately as part of our *NOA* Pathfinder projects.
- analysis of options where the costs would be prohibitive for the expected benefits.
- long-term conceptual options submitted by the TOs to support the analysis; this is explained in more detail next.

Long-term conceptual options

We recommend options for the upcoming investment year, and optimum delivery dates over the next few decades. This long-term strategy allows the TOs to evolve and develop their electricity transmission networks to deliver the best value for consumers.

We receive a wide range of options from the TOs for analysis and comparison, which we then assess for cost and benefit. However, development of reinforcement in the network will be a continuous process where the costs for some options in the distant future are unknown. To represent these long-term eventual reinforcements in our economic analysis, the TOs may also provide more conceptualised reinforcements to support the long-term future network.

These options are in the very early stages of development and are included in the *NOA* process as an indicator for additional long-term reinforcement. Due to the conceptual nature of these reinforcements, it is highly likely that their costs are not reflective of the final design. Whilst the *NOA* will make recommendations on asset-based options, it does not include long-term conceptual options and so their costs are not counted in the overall total CAPEX of the *NOA* report has recommended reinforcement profile.

Offshore Wider Works

For *NOA* 2020/21, our approach has been to create conceptual OWW reinforcements that we can test to connect major offshore wind developments while taking account of the commissioning dates of those developments. We have developed a dedicated chapter to discuss our progress and more information can be found in Chapter 5 - 'Offshore Wider Works'.

There is now a greater drive towards integration due to the expansion of offshore wind, such as round 4. There is also a need to avoid several parties trying to gain consents in the same land corridors to bring their connections to the onshore transmission system. We recently published our final Phase 1 report on the costs and benefits of a more coordinated approach to connecting offshore electricity infrastructure. It includes a report on holistic planning of the offshore transmission network and proposals for changes to the offshore connections regime.

NOA / Proposed options / The options 25

Chapter 4

Investment recommendations

Introduction

Here we present our investment recommendations from our analysis, which gives the most economic investment strategy for each scenario and enables us to identify our preferred options and the recommended next steps for works in each region.

£183m

Investing £183m this year

41

Through 41 asset-based options

£13.9bn

Total cost of £13.9bn

4

Develop 4 ESO-led commercial solutions

£2.1bn

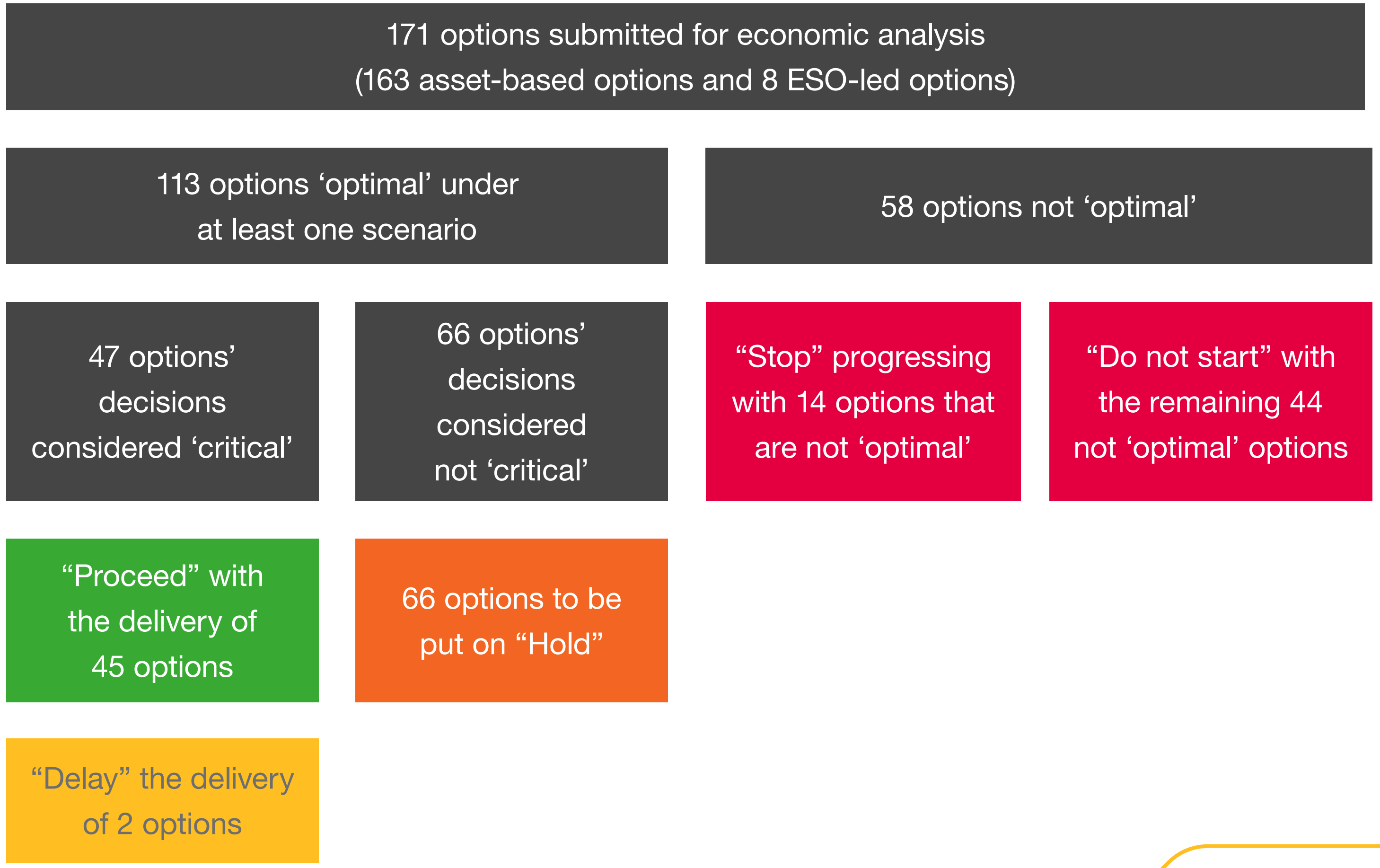
Additional consumer benefit of up to £2.1bn

NOA / Investment recommendations / Introduction 27

Introduction

Figure 4.1 Shows an overview of how the options went through the *NOA* process and obtained their recommendations

Figure 4.1 How the options went through the process



NOA / Investment recommendations / Introduction 28

Interpretation of the *NOA*

This section explains how to interpret the *NOA* outcomes, including the economic analysis results and our investment recommendations.

'Optimal' path and optimum delivery date

Our cost-benefit analysis investigates the economic benefits of different combinations of reinforcement options across four *Future Energy Scenarios*. We identify the single combination that provides the most value for the consumer, which we call the 'optimal' path. A reinforcement on this path is considered 'optimal' if it is in the 'optimal' path on any year in at least one scenario. An option is considered not 'optimal' if it does not appear in any of the 'optimal' paths. The 'optimal' path not only shows the most economic options but also their optimum completion years. If an option's optimum delivery date is its current earliest in service date (EISD) in at least one scenario, it is considered a 'critical' option, as an investment decision must be made by the TOs and/or relevant parties this year to meet the optimum delivery date. If under all scenarios, the optimum delivery date(s) of an option are later than its EISD, the option is not 'critical' and a decision can be put on hold until there is greater certainty.

'Critical' options' single year least regret analysis

A decision on each 'critical' option must be made this year by the TOs and/or relevant parties, so it is further assessed in our single year least regret analysis. This measures and compares the regret of delivering each 'critical' option against the regret of not delivering it. If a region has multiple 'critical' options, we compare the regret of delivering different combinations.

We always recommend the option, or combination of options, that minimises the levels of regret across all scenarios. If an option is driven by a single scenario, we will further investigate the drivers to ensure we make the right recommendation.

Economic regret

In economic analysis, the regret of an investment strategy is the net benefit difference between that strategy and the best strategy for that scenario. So, under each scenario, the best strategy will have a regret of zero, and the other strategies will have different levels of regret depending on how they compare to the best strategy. We always choose the strategy with the least regret across all scenarios. For more information, see Chapter 2 - 'Methodology'.

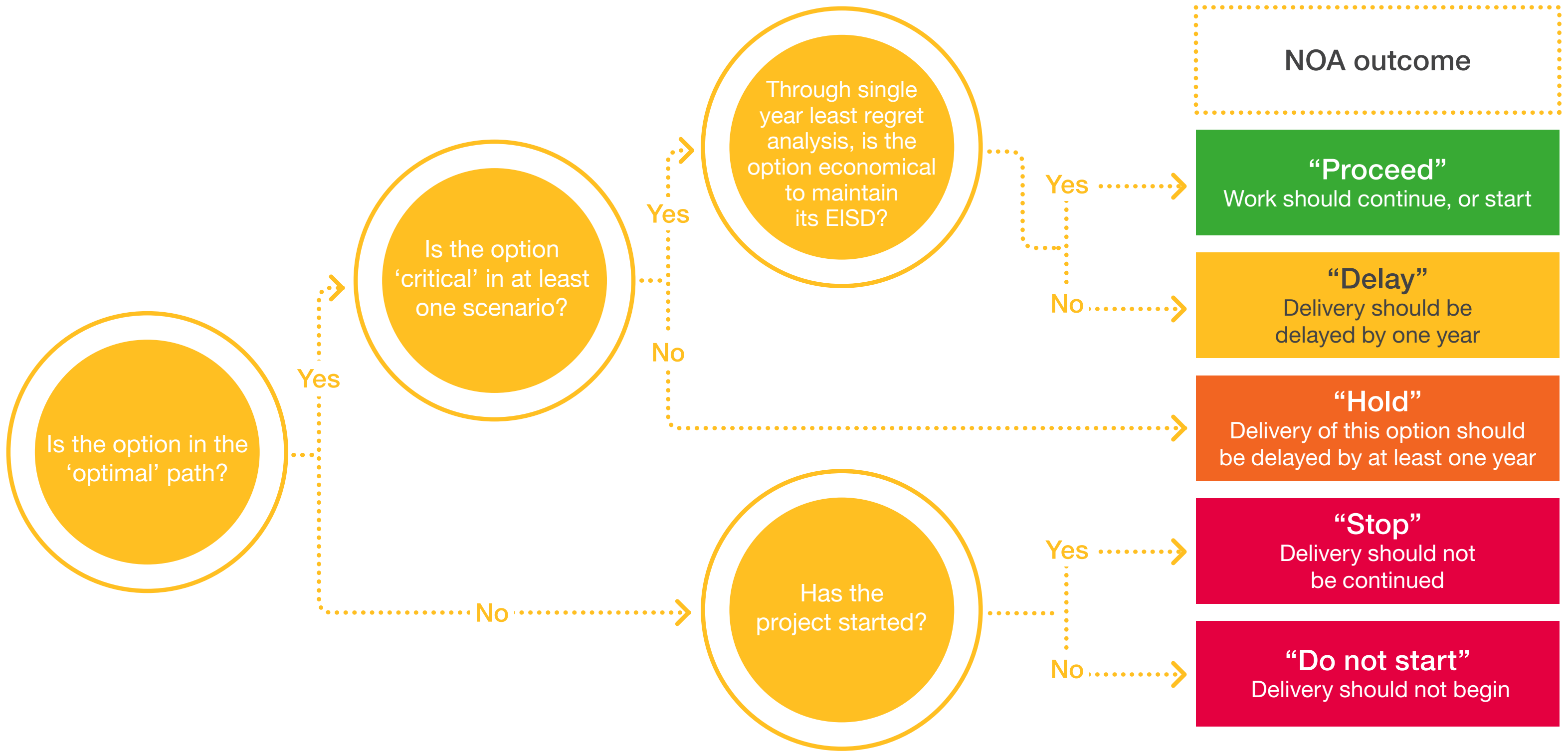
NOA / Investment recommendations / Interpretation of the NOA 29

Interpretation of the *NOA*

Investment recommendations

Following the cost-benefit analysis and single year least regret analysis, we present the results to the *NOA* Committee for additional scrutiny. It focuses on marginal options where recommendations are driven by a single scenario or factor, or are considered sensitive in terms of stakeholder engagement.

The *NOA* Committee brings expertise from across the ESO, including knowledge on operability challenges, network capability development, commercial operations and insight into future energy landscapes. All options will be allocated to one of the outcomes outlined in the diagram below:



An option we don't recommend to "Proceed" can still be considered in any relevant LOTI assessment.

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

NOA / Investment recommendations / Interpretation of the NOA 30

Interpretation of the *NOA*

Eligibility for onshore competition

We assess projects recommended for further development in the *NOA* for their eligibility for competition, and undertake the same assessments on future generator and demand connections to the transmission system.

This includes options we recommend to "Proceed" this year, SWW or LOTI projects with a Needs Case, and contracted connections.

In the competition assessment, we use three criteria: 'new', 'separable' and 'high value', proposed by Ofgem in their latest guidance, as indicators that an option is eligible for onshore competition. The option must fulfil all criteria to be considered.

- To assess if the option meets the 'new' criterion, we test whether it involves completely new assets or the complete replacement of an existing transmission asset.
- To assess if the option meets the 'separable' criterion, we test whether new assets can be clearly delineated from other (existing) assets.
- To assess if the option meets the 'high value' criterion, we assess whether the capital expenditure for the assets which meet the new and separable criteria is £100 million or more. We check costs provided by the TOs as part of our *NOA* process.

The ESO is currently developing the Early Competition Plan, which will set out how competitions could be run to design, build and own transmission assets. If Ofgem decides to introduce the early competition regime, it is proposed that *NOA* will identify projects that meet the early competition criteria alongside those that meet the late competition criteria. Projects that meet the early competition criteria would begin the competitive process prior to the preliminary works stage of project development. Further information on the early competition plan can be found on our website.

NOA / Investment recommendations / Interpretation of the NOA 31

The *NOA* outcomes

This section presents the results of our economic analysis, investment recommendations, and eligibility for onshore competition.

For each region, we focus on the following aspects to identify our final investment recommendations:

- The 'optimal' paths by scenario, which highlight 'optimal' options and their delivery dates.
- 'Critical' options from the 'optimal' paths and single year least regret analysis, which produce the "Proceed" and "Delay" recommendations.
- Drivers such as system needs or changes to the energy landscape and network.

The main outputs of the economic analysis, including 'optimal' paths and initial investment recommendations, are shown in Table 4.1, Table 4.5 and Table 4.9 for the three regions. The 'optimal' options are listed in four-letter codes (as detailed in Appendix C – 'List of options') with the optimum delivery dates highlighted in different colours for different scenarios. If an option is not in the optimal path of a scenario, no optimum delivery year will be highlighted.

The initial recommendations are indicated by different shadings in Table 4.1, Table 4.5 and Table 4.9. 58 options were not currently 'optimal' under any of the scenarios and are not included. The initial recommendation for those is either "Do not start" or "Stop" if work is already in progress.

The economic analysis and initial recommendations were then further scrutinised by the *NOA* Committee and the final recommendation for each option is shown on the interactive map in the Recommendations for each option. There may be differences between initial and final recommendations for some options. In the interests of transparency, we publish the minutes from the *NOA* Committee meetings on our website. A full list of 'optimal' options for each region with descriptions and optimum delivery dates can be found in Recommendations for each option of the report. Some options are marked as 'N/A' as they are not optimal under that particular scenario.

NOA / Investment recommendations / The NOA outcomes 32

Scotland and north of England region

Background setting and context

- Scotland and the north of England is typically an ‘exporting’ region where installed generation capacity is more than enough to supply the local demand. Larger demand areas lie in central and south of England and so the energy flows across the Scottish and northern English boundaries are predominantly north-to-south, which is the main driver for reinforcements.
- All four scenarios suggest different levels of growth in low-carbon and renewable generation, in addition to new storage and interconnector developments. The similarity is that wind energy is the main contributor. With Leading the Way, System Transformation and Consumer Transformation hitting the net-zero CO_2 target by 2050, these three scenarios will see a much faster build-up of wind and a much higher total installed capacity in Scotland and the north of England. As a result, we need more reinforcements delivered on their EISDs to meet the transfer requirement in those three scenarios. On the other hand, the Steady Progression scenario which fails to meet the 2050 target is less demanding on transfer capability and therefore fewer reinforcements are required. We include our recommendation and detailed narratives for each of the reinforcements in the ‘optimal’ path tables. Here are some highlights of our recommendations:

This year several new options were submitted for analysis. These include an additional 2GW eastern HVDC Subsea link from south east Scotland to south Humber region, and several new onshore reinforcements from the south east of Scotland to the north of England and into the midlands facilitating high north to south power flows. For more information about these new options, see TGDC, CMNC, and EDNC on the ‘optimal’ path tables.

This *NOA* included 10 eastern subsea HVDC link options between England and Scotland. These fall into four different categories based on their connection locations. From the analysis, we confirmed the need for four subsea links to accommodate the increasing north-to-south flows. These are from:

- South east Scotland to northern England (E2DC)
- North east Scotland to northern England (E4D3)
- North east Scotland to south Humber (E4L5)
- South east Scotland to south Humber (TGDC)

The analysis recommends proceeding with the Torness to Hawthorn Pit option as the first eastern link (E2DC), the Peterhead to Drax option as the second Eastern HVDC link (E4D3) and the north east Scotland to south Humber (E4L5) option as the third link. In addition, due to the high transfer requirement in the north region this year, we see a strong need for a fourth link from south east of Scotland to the South Humber area (TGDC) as well. These options are needed across all scenarios consistently.

We continued to explore how commercial solutions may help further reduce constraint costs. In this *NOA*, our improved methodology means commercial solutions can be decommissioned to reflect a flexible service life. For this year’s analysis, the commercial solutions are also split into two stages to allow for a more granular investigation of the benefit required. We found two-stage commercial solutions are beneficial in this region and recommend developing them further. For more information, see the hover over text for CS05 & CS06 on Table 4.1

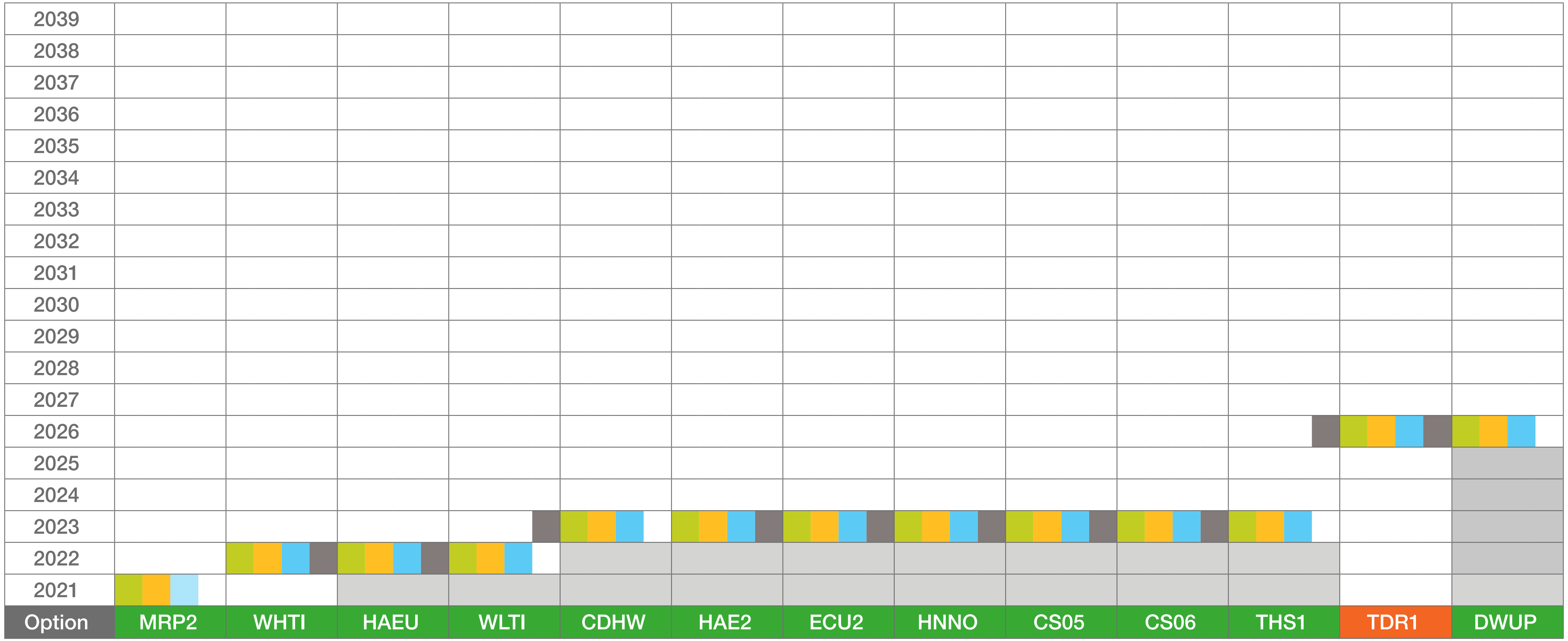
NOA / Investment recommendations / Scotland and north of England region 33

Scotland and north of England region (continued)

Table 4.1 Scotland and the north of England region

Key

- Leading the Way
- Consumer Transformation
- System Transformation
- Steady Progression
- EISD not yet reached
- 'Critical' option to "Proceed"
- 'Critical' option to "Delay"
- Not 'critical' option to "Hold"

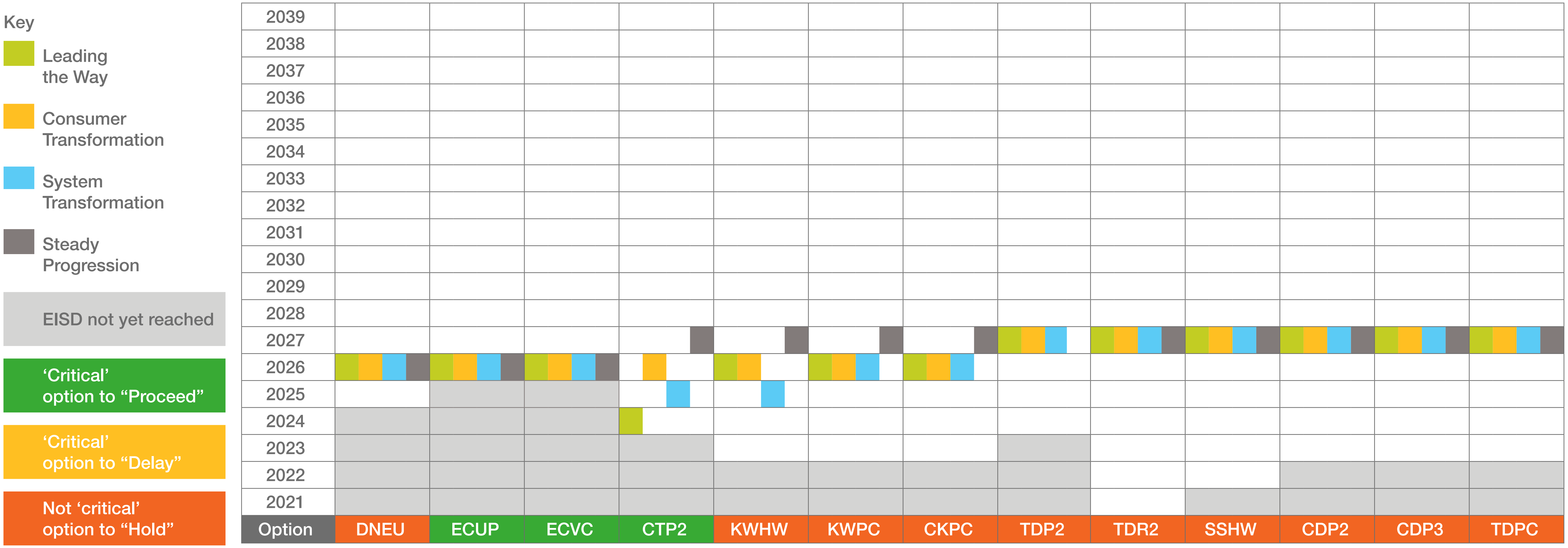


Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / Scotland and north of England region 34

NOA / Investment recommendations / Scotland and north of England region 35

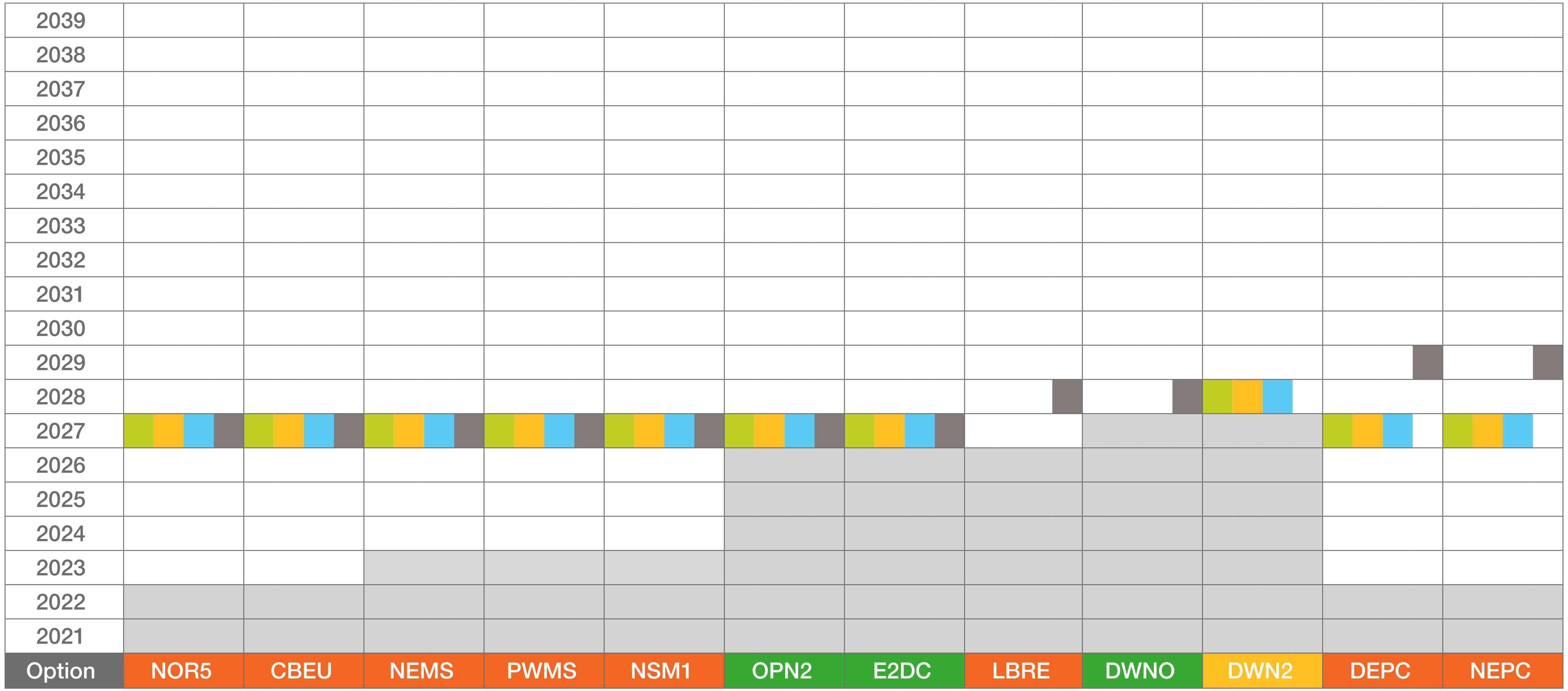
Scotland and north of England region (continued)



Hover over the option codes, at the bottom of the table for further information

Scotland and north of England region (continued)

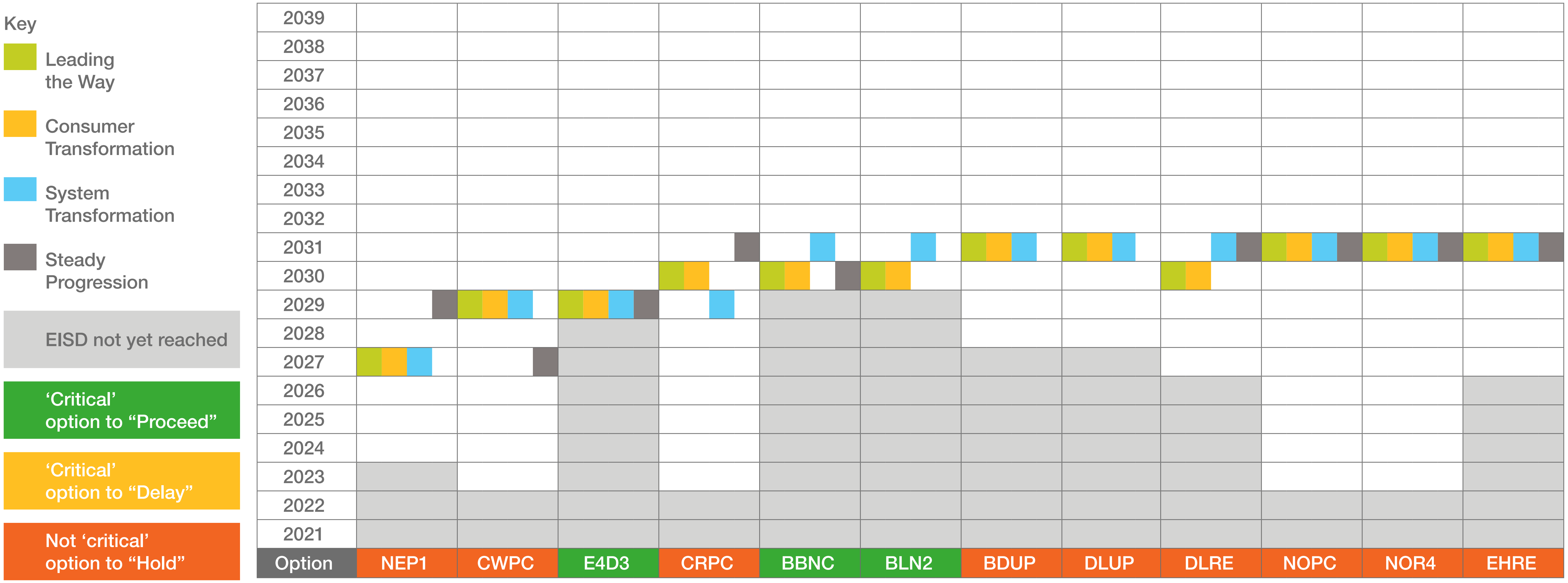
Key
- Leading the Way
- Consumer Transformation
- System Transformation
- Steady Progression
- EISD not yet reached
- 'Critical' option to "Proceed"
- 'Critical' option to "Delay"
- Not 'critical' option to "Hold"



Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / Scotland and north of England region 36

Scotland and north of England region (continued)



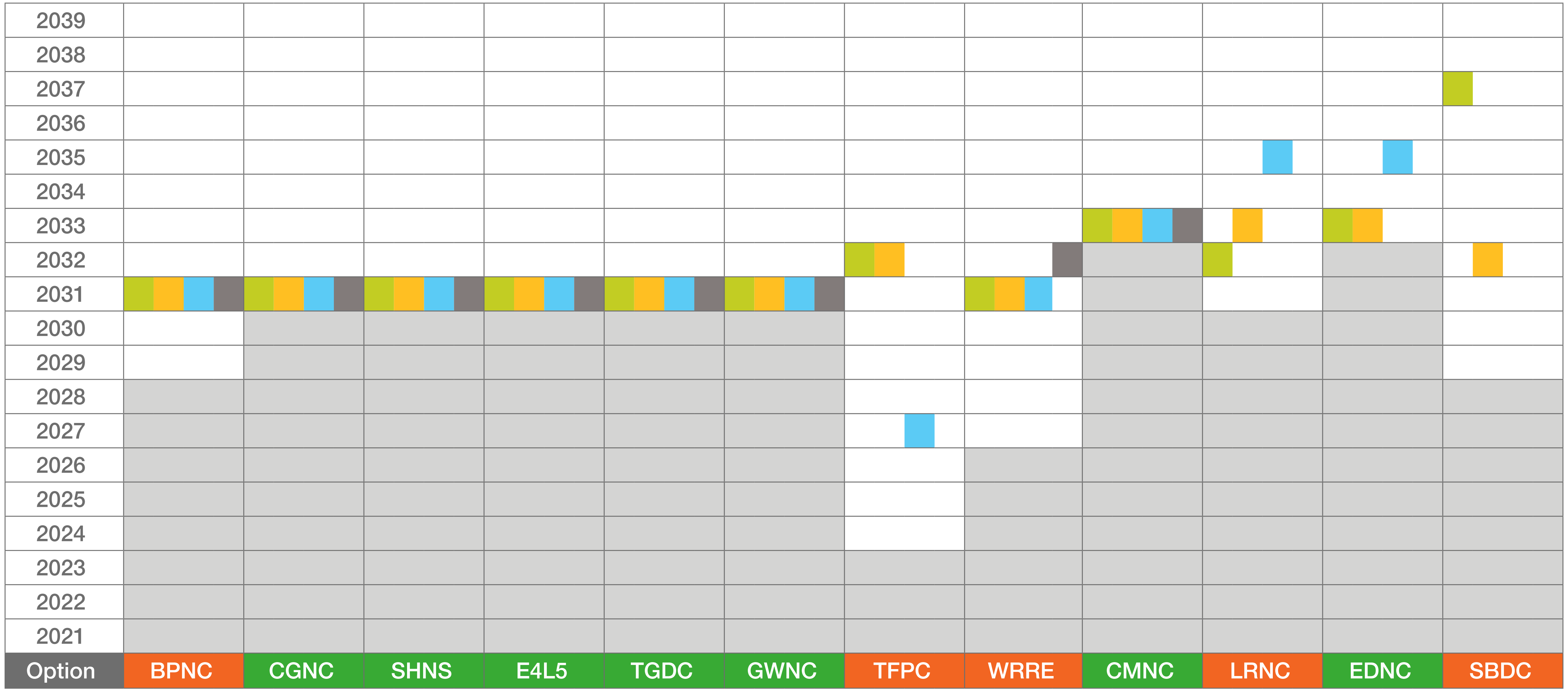
Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / Scotland and north of England region 37

Scotland and north of England region (continued)

Key

- Leading the Way
- Consumer Transformation
- System Transformation
- Steady Progression
- EISD not yet reached
- ‘Critical’ option to “Proceed”
- ‘Critical’ option to “Delay”
- Not ‘critical’ option to “Hold”



Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / Scotland and north of England region 38

Scotland and north of England region (continued)

For Scotland and the north of England region, we identified 62 ‘optimal’ options as shown in Table 4.1. Their optimum delivery dates are highlighted in different colours for different scenarios.

Of the 62 ‘optimal’ options, 28 are ‘critical’ in at least one scenario, and can receive “Proceed” or “Delay” recommendations.

The optimum delivery years of the following options are the same as their EISDs across all four scenarios. These 17 options, as seen in Table 4.2, don’t need to be assessed in the single year least regret analysis, as progressing them to maintain their EISDs is the optimum course of action under all scenarios.

Table 4.2 ‘Critical’ options in all scenarios in Scotland and north England region

Code	Option description
CGNC	A new 400kV double circuit between Creyke Beck and south Humber
CMNC	South east Scotland to north west England AC onshore reinforcement
CS05	Commercial solution for Scotland and the north of England - stage 1
CS06	Commercial solution for Scotland and the north of England - stage 2
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC
E4L5	Eastern Scotland to England 3rd link: Peterhead to south Humber offshore HVDC
ECU2	East Coast onshore 275kV upgrade
ECUP	East Coast onshore 400kV incremental reinforcement
ECVC	Eccles hybrid synchronous compensators and real-time rating system
GWNC	A new 400kV double circuit between south Humber and south Lincolnshire
HAE2	Harker supergrid transformer 6 replacement
HAEU	Harker supergrid transformer 5 and supergrid transformer 9A banking arrangement
HNNO	Hunterston East–Neilston 400kV reinforcement
OPN2	A new 400kV double circuit between the existing Norton to Osbaldwick circuit Poppleton and relevant 275kV upgrades
SHNS	Upgrade substation in south Humber area
TGDC	Eastern subsea HVDC link from south east Scotland to south Humber

NOA / Investment recommendations / Scotland and north of England region 39

Scotland and north of England region (continued)

This leaves 11 options which are 'critical' in some, but not all, scenarios, as seen in Table 4.3, and just over 2048 different possible combinations of the following reinforcements on which we performed the single year least regret analysis. The least regret strategy is to "Proceed" with all critical options except DWN2 - Denny to Wishaw 400kV reinforcement.

Table 4.3 'Critical' options in at least one scenario in Scotland and north England region

Code	Option description
BBNC	Beauly to Blackhillock 400kV double circuit addition
BLN2	Beauly to Loch Buidhe 275kV reinforcement
CDHW	Cellarhead to Drakelow circuits thermal uprating
CTP2	Alternative power control device along Creyke Beck to Thornton
DWN2	Denny to Wishaw 400kV reinforcement
DWNO	Denny to Wishaw 400kV reinforcement
DWUP	Establish Denny North-Clydesmill-Wishaw single 400kV circuit from existing 275kV circuits
EDNC	Uprate Brinsworth and Chesterfield to double circuit to 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield
MRP2	Additional power control devices at both Harker and Penwortham
THS1	Installation of a single series reactor at Thornton substation
WLTI	Windyhill–Lambhill–Longannet 275kV circuit turn-in to Denny North 275kV substation

NOA / Investment recommendations / Scotland and north of England region 40

Scotland and north of England region (continued)

In summary, we recommend progressing with the following reinforcements in Scotland and the north of England region:

Table 4.4 Options to progress in Scotland and north of England region

Code	Option description	To meet its EISD of:
MRP2	Additional power control devices at both Harker and Penwortham	2021
WHTI	Tee-in of the West Boldon to Hartlepool circuit at Hawthorn Pit	2021
CDHW	Cellarhead to Drakelow circuits thermal uprating	2023
HAEU	Harker supergrid transformer 5 and supergrid transformer 9A banking arrangement	2022
WLTI	Windyhill–Lambhill–Longannet 275kV circuit turn-in to Denny North 275kV substation	2022
CS05	Commercial solution for Scotland and the north of England - stage 1	2023
CS06	Commercial solution for Scotland and the north of England - stage 2	2023
ECU2	East Coast onshore 275kV upgrade	2023
HAE2	Harker supergrid transformer 6 replacement	2023
HNNO	Hunterston East–Neilston 400kV reinforcement	2023
THS1	Installation of a single series reactor at Thornton substation	2023
CTP2	Alternative power control device along Creyke Beck to Thornton	2024
DWUP	Establish Denny North-Clydesmill-Wishaw single 400kV circuit from existing 275kV circuits	2026
ECUP	East Coast onshore 400kV incremental reinforcement	2026
ECVC	Eccles hybrid synchronous compensators and real-time rating system	2026
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit	2027
OPN2	A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades	2027
DWNO	Denny to Wishaw 400kV reinforcement	2028
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC	2029
BBNC	Beauly to Blackhillock 400kV double circuit addition	2030
BLN2	Beauly to Loch Buidhe 275kV reinforcement	2030
CGNC	A new 400kV double circuit between Creyke Beck and south Humber	2031
E4L5	Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC	2031
GWNC	A new 400kV double circuit between south Humber and south Lincolnshire	2031
SHNS	Upgrade substation in the south Humber area	2031
TGDC	Eastern subsea HVDC link from south East Scotland to south Humber	2031
CMNC	South east Scotland to north west England AC onshore reinforcement	2033
EDNC	Uprate Brinsworth and Chesterfield to double circuit to 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield	2033

NOA / Investment recommendations / Scotland and north of England region 41

Scotland and north of England region (continued)

Eligibility assessment for onshore competition

Following this, we conducted eligibility assessments for onshore competition for all reinforcements recommended to proceed this year in Scotland and the north of England. The following options meet the competition criteria proposed by Ofgem:

- Beauly to Loch Buidhe 275kV reinforcement (BLN2)
- Beauly to Blackhillock 400kV double circuit addition (BBNC)
- Eastern Scotland to England link: Peterhead to Drax offshore HVDC (E4D3)
- Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC (E4L5)
- Eastern subsea HVDC link from Torness to Hawthorn Pit (E2DC)
- Eastern subsea HVDC link from south east Scotland to south Humber area (TGDC)
- South east Scotland to north west England AC onshore reinforcement (CMNC)
- A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades (OPN2)
- A new 400kV double circuit between Creyke Beck and the south Humber region (CGNC)
- A new 400kV double circuit between the south Humber area and South Lincolnshire (GWNC)
- Uprate Brinsworth and Chesterfield to double circuit to 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield (EDNC)

The options OPN2 and EDNC would have to be split to meet the competition criterion for separability. We also assessed all new or modified contracted connection projects in this region. We identified the following projects which meet the competition criteria proposed by Ofgem:

- 2nd Shetland HVDC link Kergord - Rothienorman
- Dounreay - Orkney 220kV Subsea HVAC Cable link 1
- Dounreay - Orkney 220kV Subsea HVAC Cable link 2
- Western Isles - Beauly HVDC link
- Skye 2nd Circuit reinforcement
- North Argyll substation
- North Argyll - Craig Murrail 275kV Operation
- Glenmuckloch to ZV Route reinforcements

The Orkney and Western Isles links are current SWW projects led by SHE Transmission. Please see Ofgem's website for more information and updates on these projects. The second Shetland link and second Orkney link are not at present live projects and have yet to progress to their LOTI stage. The Argyll and Skye projects are proposed for connections with the latter having non-load asset replacement aspects and each at varying stages of development.

NOA / Investment recommendations / Scotland and north of England region 42

The south and east England region

Background setting and context

The south and east region includes East Anglia and London, touches the Midlands and stretches along the south coast to Devon and Cornwall. The region has a high concentration of power demand and generation, with high demands in London and increased generation capacity in East Anglia and the Thames Estuary. The south coast has several interconnectors that influence power flows in the region through the import and export of power with Europe.

Offshore renewable generation is expected to grow in East Anglia and more interconnectors will be commissioned in the south coast and East Anglia. Combined with the increase in renewable generation in other parts of the country, we expect that the main driver of constraints in the long term will be the north-to-south flows through the region, as well as the flows through and across the East Anglia area.

We have included our recommendation and detailed narratives for each of the reinforcements in Table 4.5. Highlights of our recommendations include:

- BTNO, a new double circuit in East Anglia, supports the export of power out of the area and reinforces the south east area. BTNO continues to be 'critical' in all scenarios due to high exports from East Anglia.
- SCD1 that builds an offshore HVDC link between Suffolk and Kent and bypasses the most constrained areas. As the HVDC link can be configured to transfer power in both directions, it can benefit multiple areas in the south and east region. SCD1 continues to be 'critical' in two scenarios and 'optimal' in all.
- HWUP that upgrades one of the transmission routes that feeds power into London and onwards to the south coast interconnectors.
- A set of three new transmission routes (options AENC, ATNC and TENC) that facilitate power flows from East Anglia to the south coast.

Furthermore, we found that CS07 and CS08, two ESO-led commercial solutions for the East Anglia area, provide economic benefit in our assessment. Commercial solutions use operational measures from commercial providers to increase the volume of power that can be securely transferred through an area. CS07 was required in the 'optimal' paths in three of the scenarios while the CS08 was required in only two of them. These options are at an early stage of development.

Due to the proximity of many options and the large number of new generation connection works in the region, the necessary access to the network in order to deliver our recommendations is expected to be challenging. Recognising this, we have identified several options whose delivery plans should be co-optimised to facilitate the recommendations and the 'optimal' years outlined by *NOA* 2020/21. A detailed delivery plan for these options should be developed and submitted for the *NOA* 2021/22 assessment for the recommendations to be upheld. This is a necessary step to ensure the efficient, economic and coordinated planning of the future electricity transmission system.

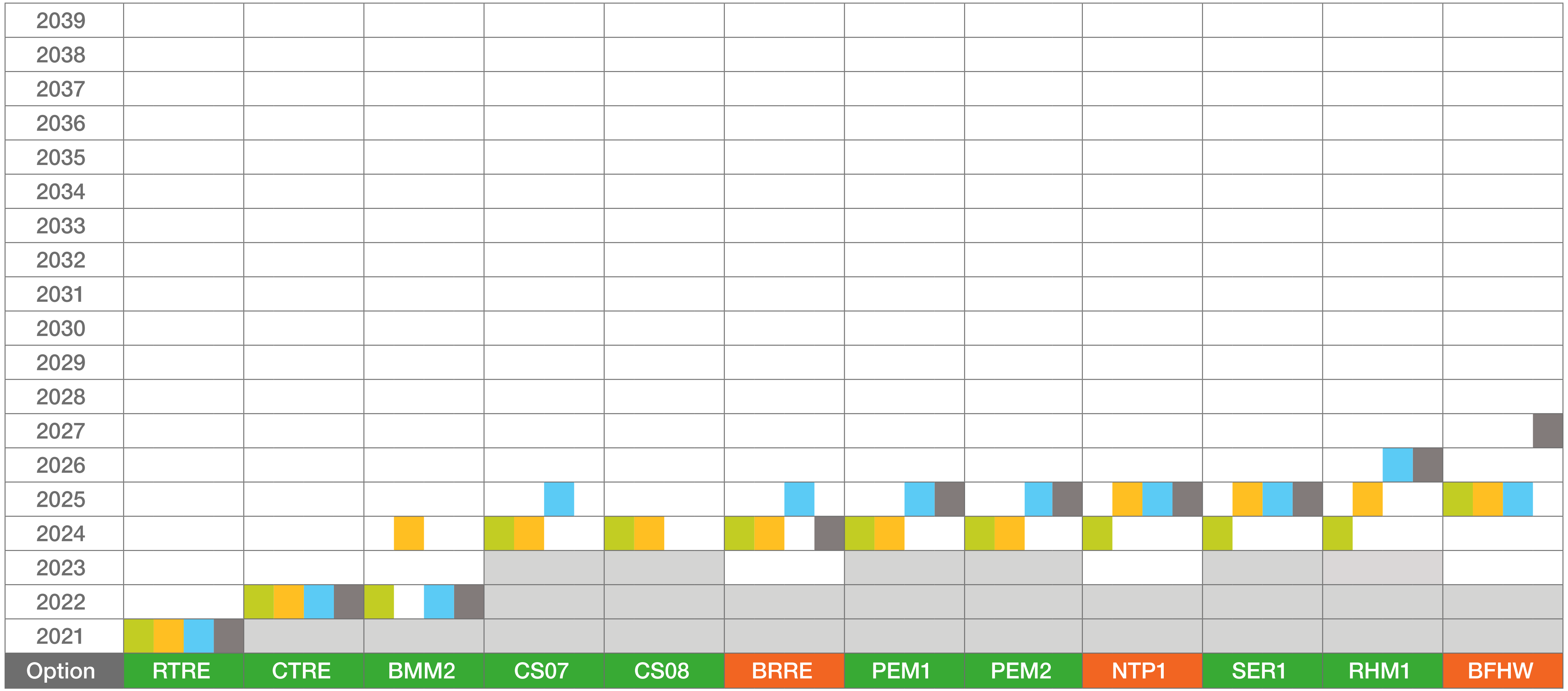
NOA / Investment recommendations / The south and east England region 43

The south and east England region (continued)

Table 4.5 The south and east England region

Key

- Leading the Way
- Consumer Transformation
- System Transformation
- Steady Progression
- EISD not yet reached
- ‘Critical’ option to “Proceed”
- ‘Critical’ option to “Delay”
- Not ‘critical’ option to “Hold”



Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / The south and east England region 44

The south and east England region (continued)

Key

Leading the Way

Consumer Transformation

System Transformation

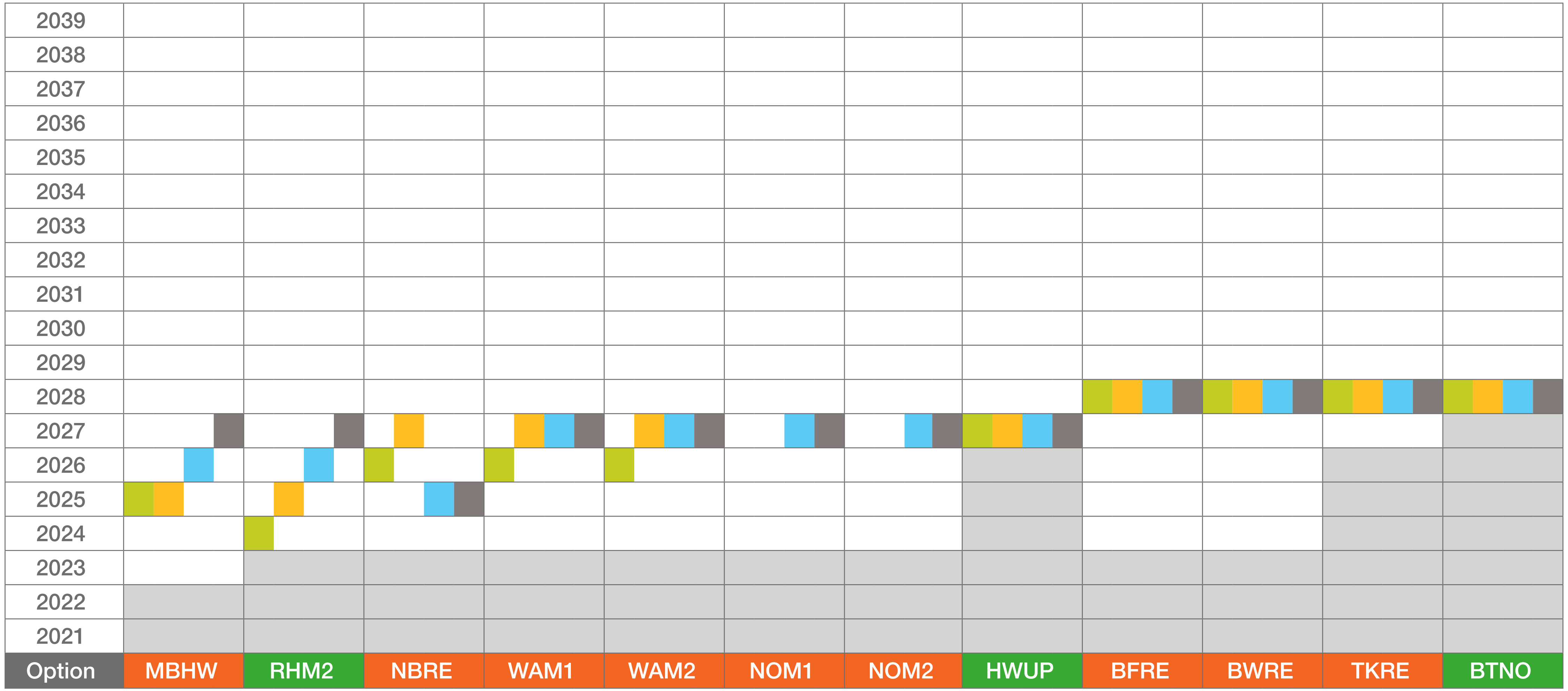
Steady Progression

EISD not yet reached

‘Critical’ option to “Proceed”

‘Critical’ option to “Delay”

Not ‘critical’ option to “Hold”



Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / The south and east England region 45

The south and east England region (continued)

Key

Leading the Way

Consumer Transformation

System Transformation

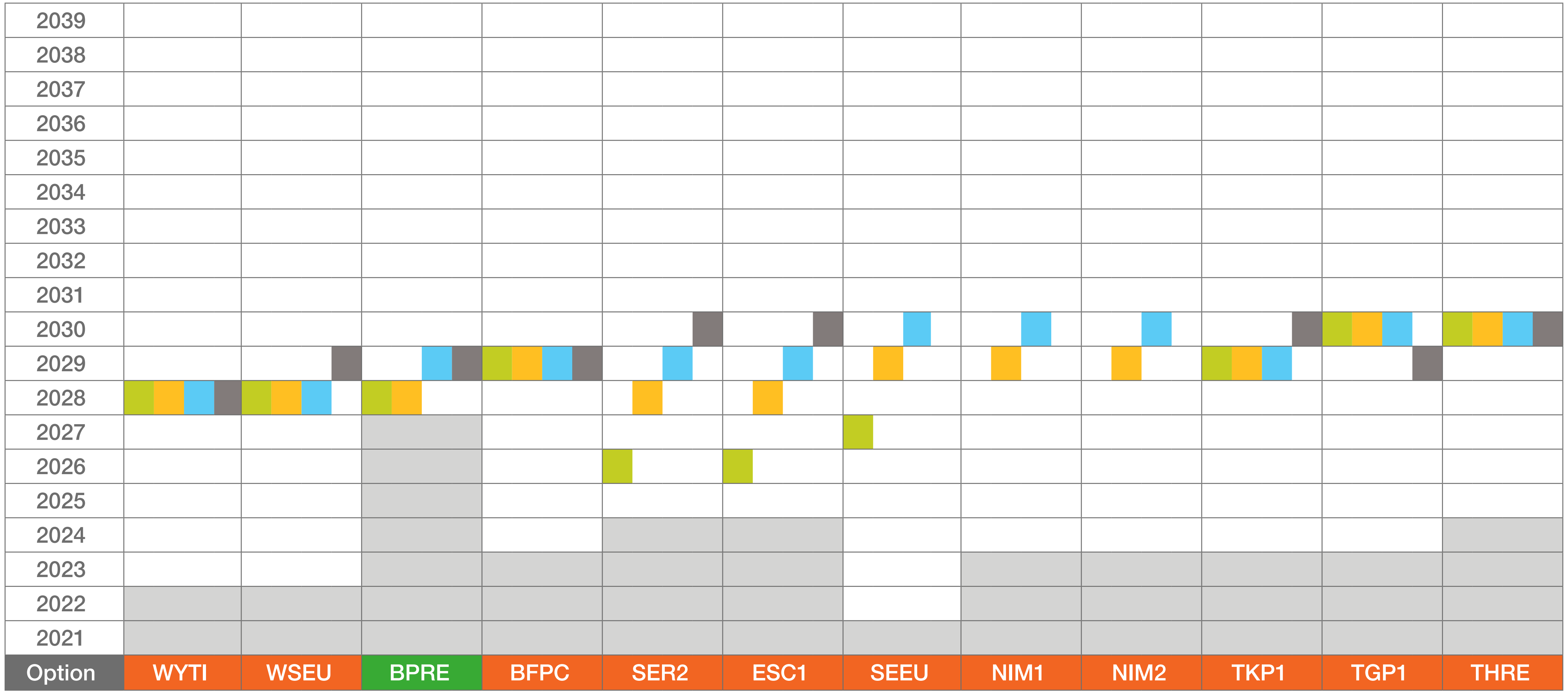
Steady Progression

EISD not yet reached

'Critical' option to "Proceed"

'Critical' option to "Delay"

Not 'critical' option to "Hold"



Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / The south and east England region 46

The south and east England region (continued)

Key

Leading the Way

Consumer Transformation

System Transformation

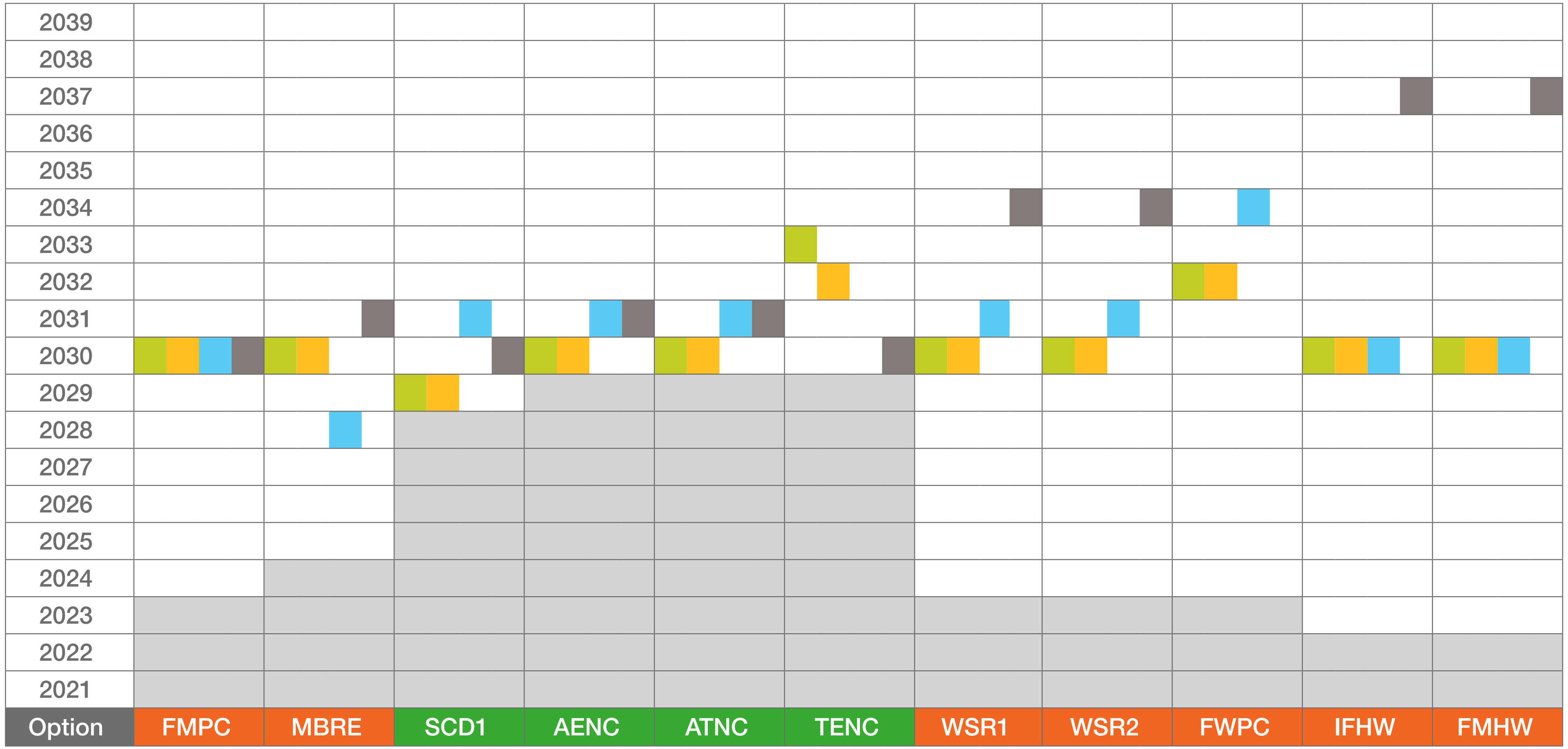
Steady Progression

EISD not yet reached

'Critical' option to "Proceed"

'Critical' option to "Delay"

Not 'critical' option to "Hold"



Hover over the option codes, at the bottom of the table for further information

NOA / Investment recommendations / The south and east England region 47

The south and east England region (continued)

For the south and east England region, we identified 47 'optimal' options as shown in Table 4.5. Their optimum delivery dates are highlighted in different colours for different scenarios.

Of the 47 'optimal' options, 13 are 'critical' in at least one scenario but they have optimum delivery years later than their EISD in some of the scenarios. The 11 asset based options from these could offer 2048 different combinations of "Proceed" or "Delay". The optimum delivery years for 4 options are the same as their EISDs across all four scenarios.

These 4 options, as seen in Table 4.6, don't need to be assessed in the single year least regret analysis, as progressing them to maintain their EISDs is the optimum course of action under all scenarios.

Table 4.6 'Critical' options in all scenarios in the south and east England region

Code	Option description
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit
CTRE	Reconductor remainder of Coryton South to Tilbury circuit
HWUP	Uprate Hackney, Tottenham and Waltham Cross 275kV to 400kV
BTNO	A new 400kV double circuit between Bramford and Twinstead

This leaves 13 'critical' options, as seen in Table 4.7, where the least regret strategy is "Proceed" with all options.

Table 4.7 'Critical' options in at least one scenario in the south and east England region

Code	Option description
BMM2	225MVAr MSCs at Burwell Main
PEM1	225MVAr MSCs at Pelham
PEM2	225MVAr MSCs at Pelham
RHM1	225MVAr MSCs at Rye House
RHM2	225MVAr MSCs at Rye House
SER1	Elstree to Sundon reconductoring
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit
SCD1	New offshore HVDC link between Suffolk and Kent option 1
AENC	A new 400kV double circuit in north East Anglia
ATNC	A new 400kV double circuit in south East Anglia
TENC	Thames Estuary reinforcement
CS07	Commercial solution for East Anglia - stage 1
CS08	Commercial solution for East Anglia - stage 2

NOA / Investment recommendations / The south and east England region 48

The south and east England region (continued)

In summary, we recommend progressing with the following reinforcements in the south and east England region:

Table 4.8 Options to progress in south and east England region

Code	Option description	To meet its EISD of:
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit	2021
BMM2	225MVAr MSCs at Burwell Main	2022
CTRE	Reconductor remainder of Coryton South to Tilbury circuit	2022
CS07	Commercial solution for East Anglia - stage 1	2024
CS08	Commercial solution for East Anglia - stage 2	2024
PEM1	225MVAr MSCs at Pelham	2024
PEM2	225MVAr MSCs at Pelham	2024
RHM1	225MVAr MSCs at Rye House	2024
RHM2	225MVAr MSCs at Rye House	2024
SER1	Elstree to Sundon reconductoring	2024
HWUP	Uprate Hackney, Tottenham and Waltham Cross 275kV to 400kV	2027
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit	2028
BTNO	A new 400kV double circuit between Bramford and Twinstead	2028
SCD1	New offshore HVDC link between Suffolk and Kent option 1	2029
AENC	A new 400kV double circuit in north East Anglia	2030
ATNC	A new 400kV double circuit in south East Anglia	2030
TENC	Thames Estuary reinforcement	2030

NOA / Investment recommendations / The south and east England region 49

The south and east England region (continued)

Eligibility assessment for onshore competition

Following this, we conducted an eligibility assessment for onshore competition for all reinforcements recommended to "Proceed" this year in the south and east of England region. We identified the following options that meet the competition criteria proposed by Ofgem:

- A new 400kV double circuit between Bramford and Twinstead (BTNO)

- A new 400kV double circuit in north East Anglia (AENC)

- A new 400kV double circuit in south East Anglia (ATNC)

- Thames Estuary reinforcement (TENC)

- New offshore HVDC link between Suffolk and Kent option 1 (SCD1)

NOA / Investment recommendations / The south and east England region 50

Wales

Background setting and context

The west region includes north Wales and south Wales. Both the volume and timing of the constraints in this region are heavily dependent on the local generation profile that is forecast across the four scenarios.

In early years, north Wales experiences similar levels of flow both into and out of the region. A large volume of offshore wind capacity is forecasted to connect in the region in all four scenarios throughout the late 2020s and early 2030s. A mixture of biomass, solar and nuclear capacity is also expected to connect into the region which results in predominantly high flows out of the north Wales region, towards demand centres in the Midlands. This rise in export flows results in the requirement for reinforcements on the North Wales boundary in all four scenarios.

South Wales is typically an exporting region although there are some larger demand centres, such as Cardiff, Swansea and surrounding industry. Generation types in south Wales include wind, solar and gas plant. Some plants are due to close in the region, but new generation capacity is expected to connect in the future. The Consumer Transformation scenario experiences the highest growth in capacity in the region, which mainly consists of tidal generation capacity.

Here are some highlights of our recommendations:

- There was a total of 4 options studied in Wales in *NOA* 2020/21, all of which are ‘optimal’ in at least one scenario.
- There is a requirement to reinforce the North Wales boundary in all four scenarios. This requirement is driven by the build-up in generation capacity behind the boundary.
- The South Wales boundary requires reinforcing in one scenario, Consumer Transformation, which has the highest generation - including the earlier connection of tidal generation.

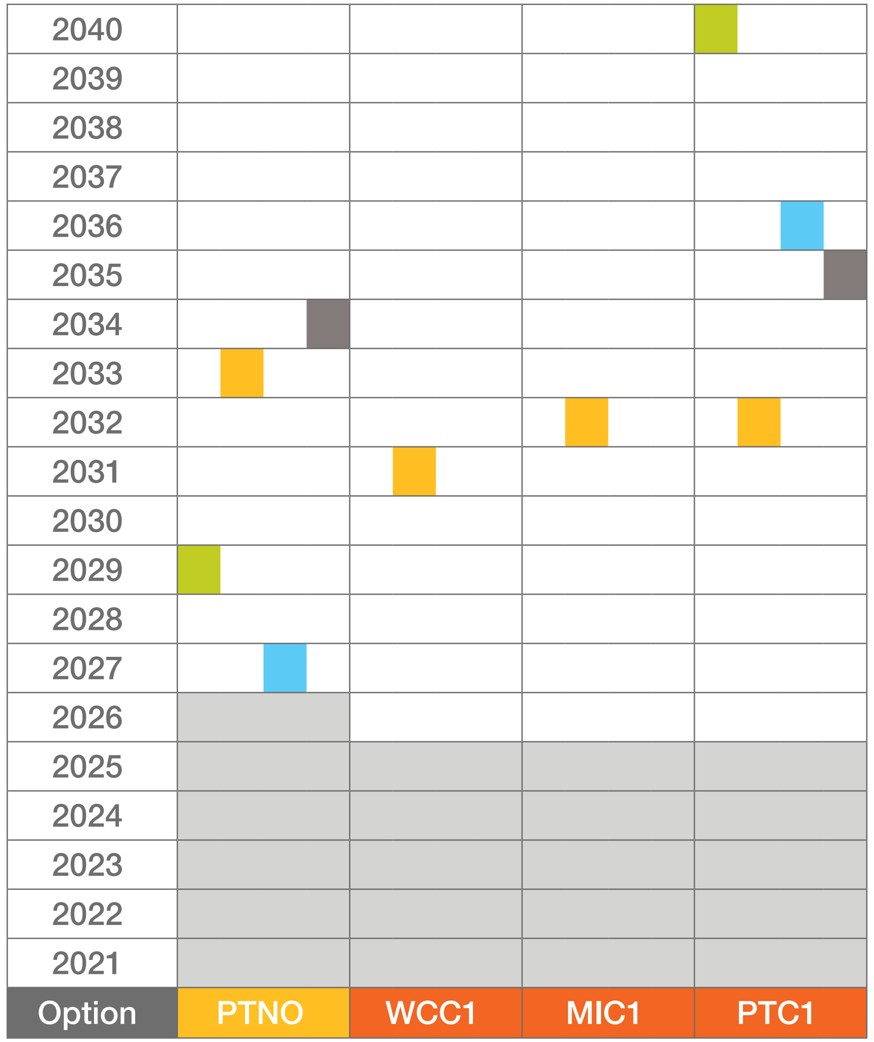
NOA / Investment recommendations / Wales 51

Wales (continued)

Key

- Leading the Way
- Consumer Transformation
- System Transformation
- Steady Progression
- EISD not yet reached
- ‘Critical’ option to “Proceed”
- ‘Critical’ option to “Delay”
- Not ‘critical’ option to “Hold”

Table 4.9 Wales



Hover over the option codes, at the bottom of the table for further information

In Wales, we identified 4 optimal options as shown in Table 4.9. Their optimum delivery dates are highlighted in different colours for different scenarios.

Of the 4 ‘optimal’ options, one option, PTNO, was identified as ‘critical’. No options in Wales had optimum delivery years the same as their EISDs across all four scenarios.

NOA / Investment recommendations / Wales 52

Clean Energy Package

Regulation (EU) 2019/943 on the internal market for electricity (recast) as retained in UK law, also known as the Clean Energy Package, places requirements in Article 13 on planners and operators of networks.

The requirement, as part of the network planning process, is to limit the redispatch of generation from renewable sources to 5%, unless there is more than 50% of total energy being produced from renewable and high-efficiency cogeneration.

From the analysis as part of *NOA* 2020/21, in all scenarios we reach the 50% threshold in renewables and high-efficiency cogeneration this decade (Leading the Way 2024, Consumer Transformation and System Transformation 2025, and Steady Progression 2028). In terms of the quantity of redispatch, the figure is below or just above the threshold, but within the tolerance of the future energy scenarios and our modelling approach. The *NOA* itself provides recommendations for transmission investment to reduce redispatch but is limited by the options brought forward by the TOs and when these options can be delivered on to the network. In addition, in this year's analysis only two options received a "Delay" recommendation and neither of these options have EISDs which would have affected the results of the Clean Energy Package analysis. The two options are:

- Denny to Wishaw 400kV reinforcement (DWN2)
- North Wales reinforcement (PTNO)

The "Proceed" options help to reduce the energy to be redispatched from renewable sources.

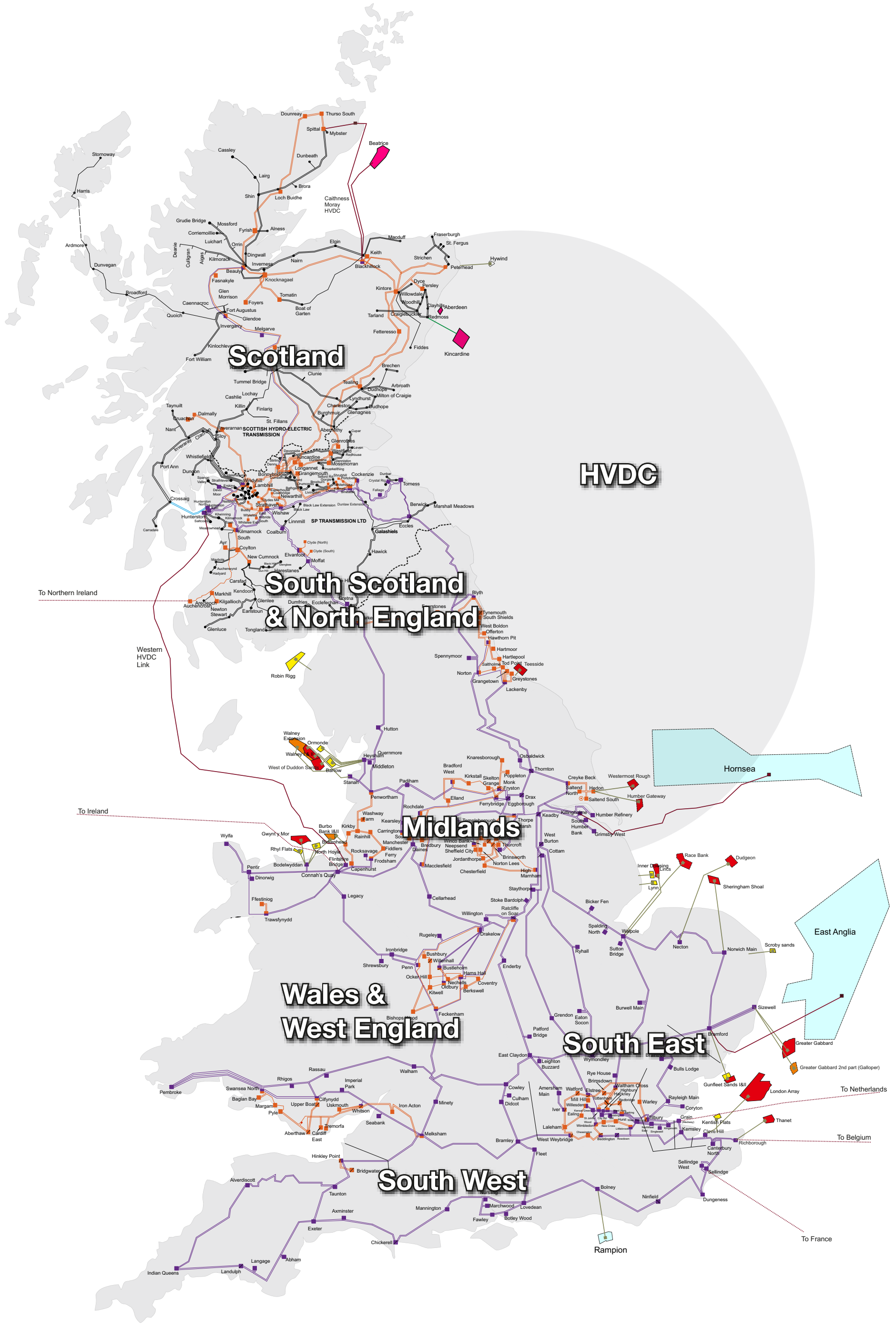
NOA / Investment recommendations / Clean Energy Package 53

Recommendations for each option

This section presents the recommendation for each option assessed in *NOA* 2020/21.

Here we highlight the options and their optimum delivery dates across the different scenarios. For a better understanding of how we make our *NOA* recommendations please refer to the flow diagram on page 30.

The following section provides a visual representation of the options and their recommendations. Options that have received a recommendation of "Do not start" are not shown in the visualisation as we currently do not see a future need for these reinforcements. To view these, and the full list of all the options and their recommendations, navigate to Table A.1, Table A.2 and Table A.3 in Appendix A – 'Economic analysis results'.



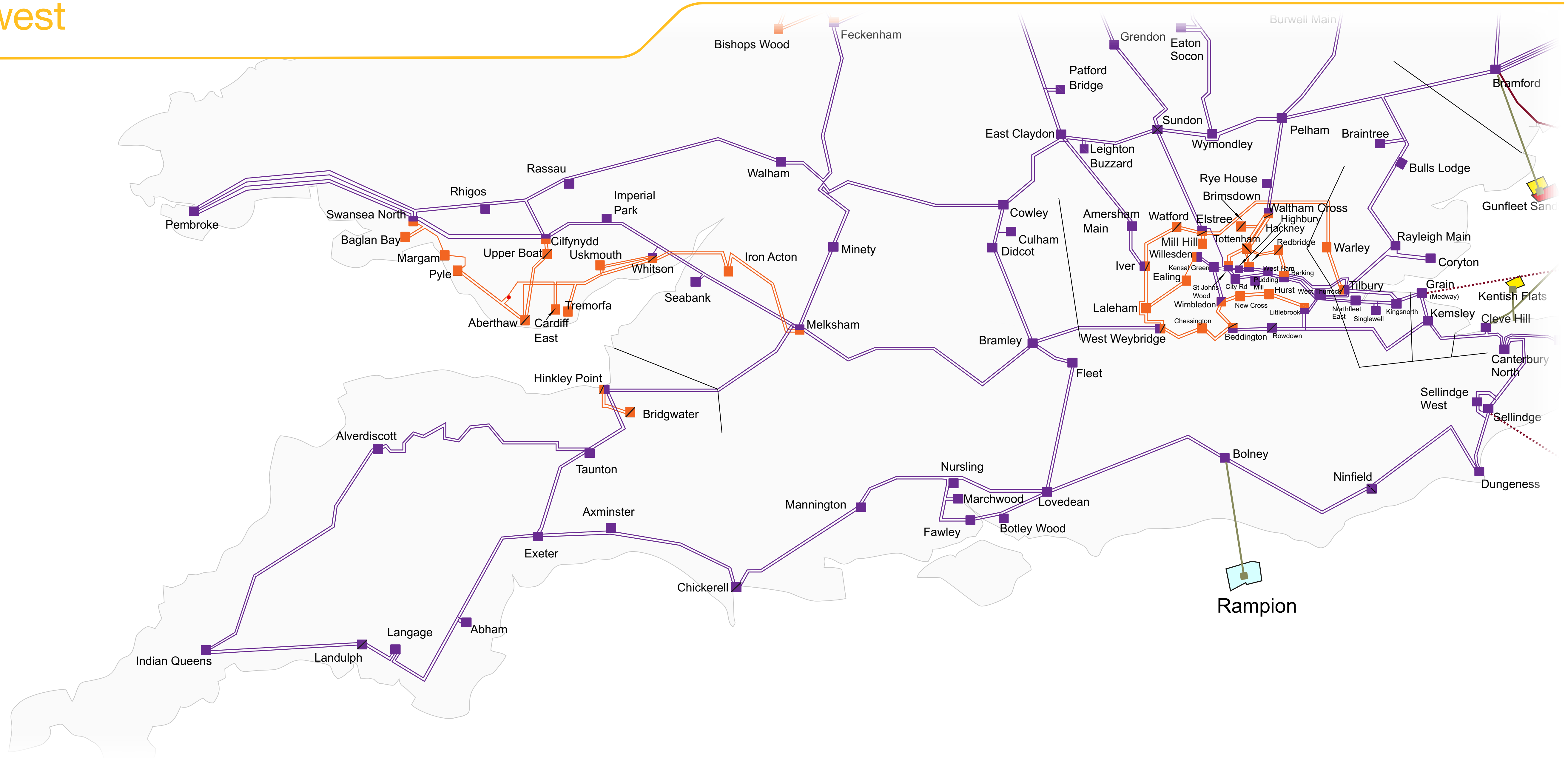
⊕ Boundaries

Disclaimer

All option routes and locations are for illustrative purposes only and are not intended to be an accurate representation of the planned route, locations and/or development of the National Electricity Transmission System, which are yet to be finalised. More details are included in the Disclaimer at the end of the publication.

NOA / Investment recommendations / Recommendations for each option 54

South west



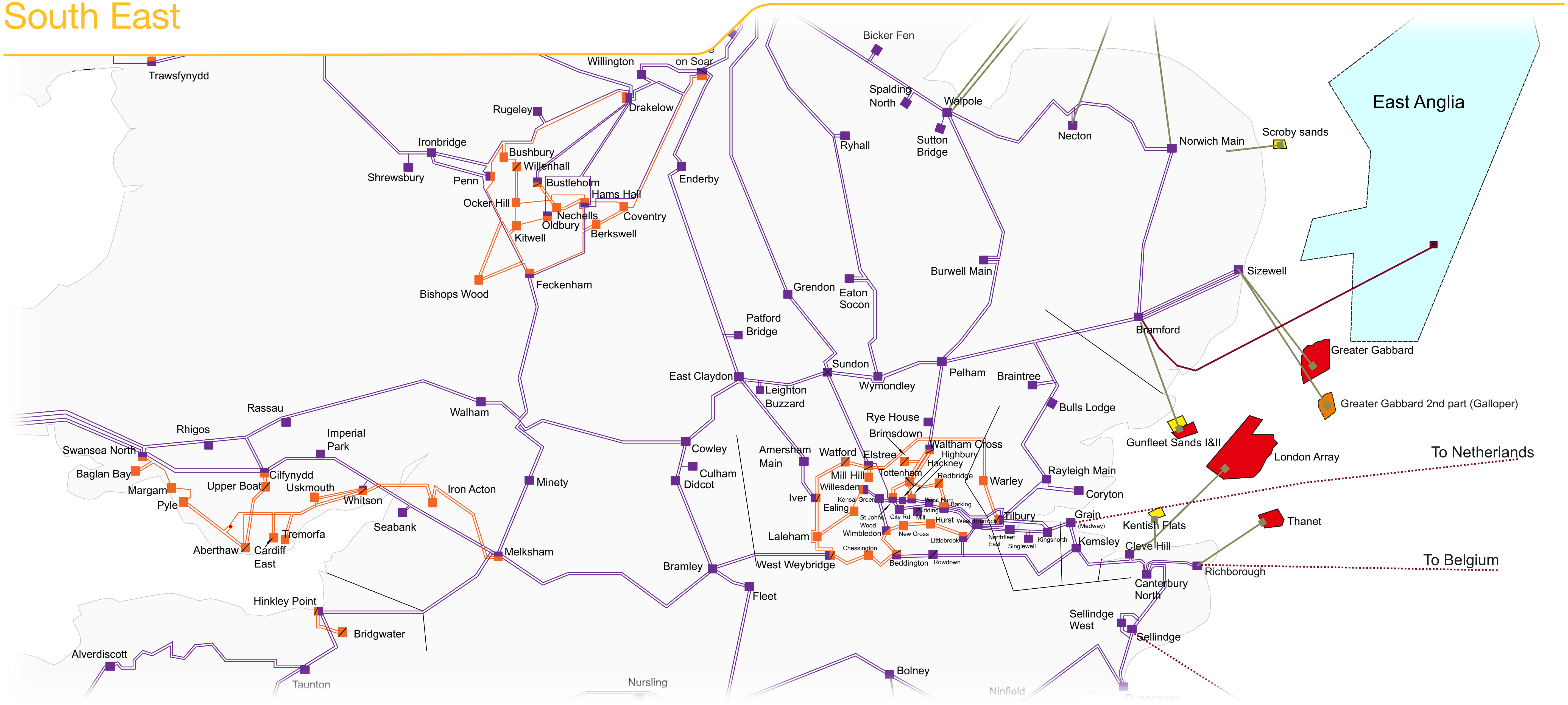
Click here to view details on the options

NOA 2020/21 recommendations

Stop Hold

NOA / Investment recommendations / Recommendations for each option 55

South East



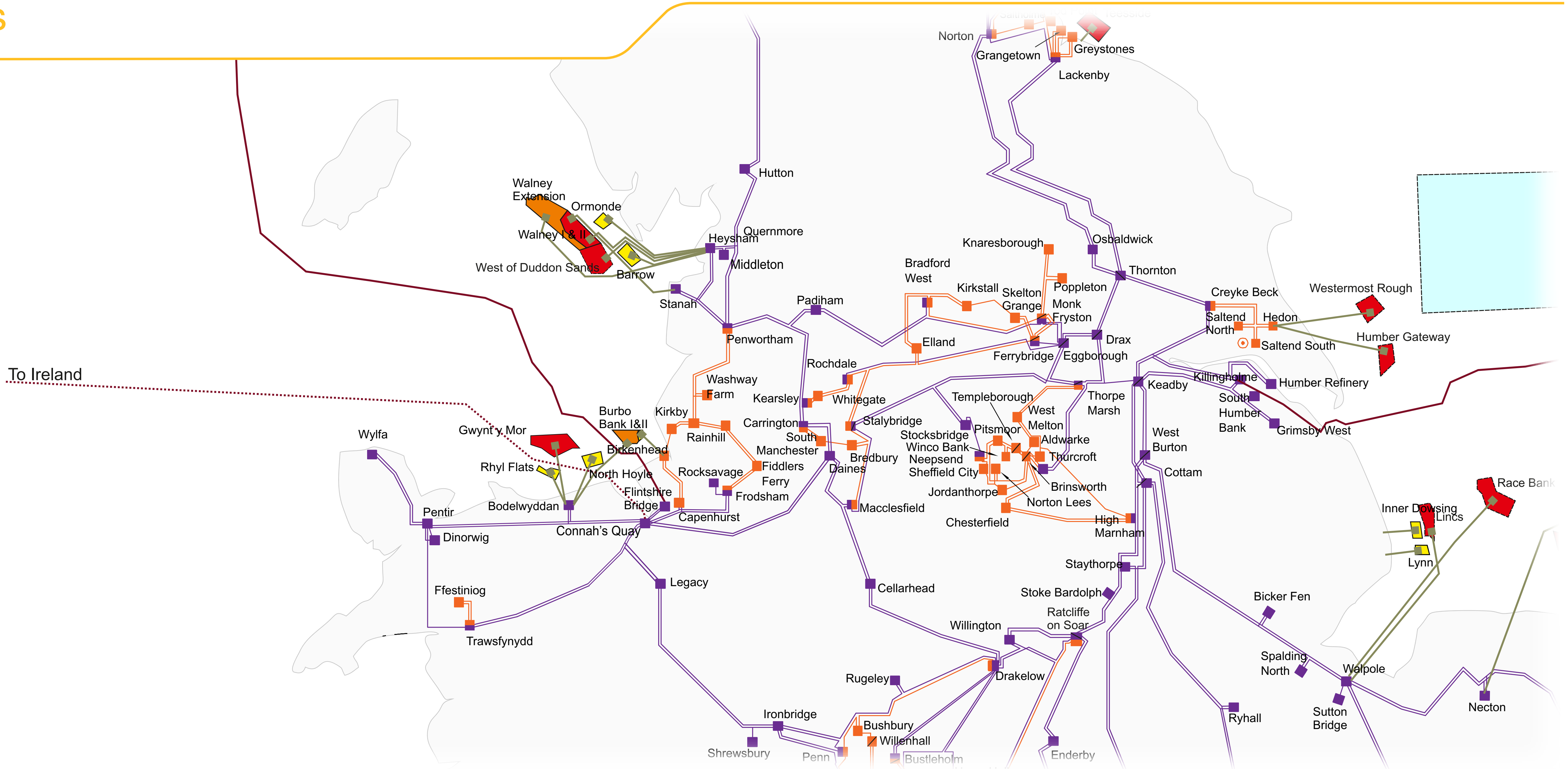
Click here to view details on the options

***NOA* 2020/21 recommendations**

Stop Hold Proceed

NOA / Investment recommendations / Recommendations for each option 56

Midlands



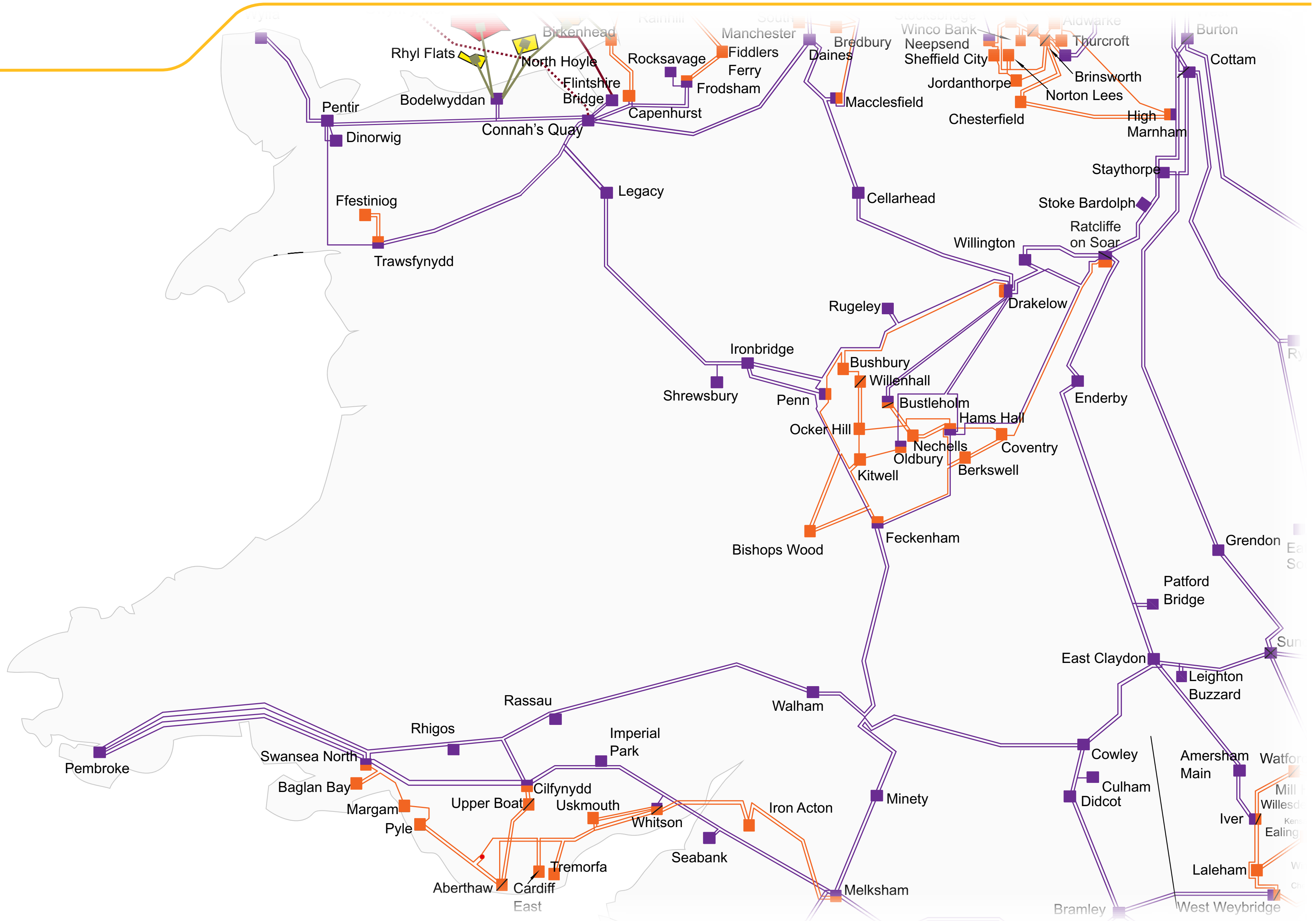
Click here to view details on the options

***NOA* 2020/21 recommendations**

Stop Hold Proceed

NOA / Investment recommendations / Recommendations for each option 57

Wales & West England



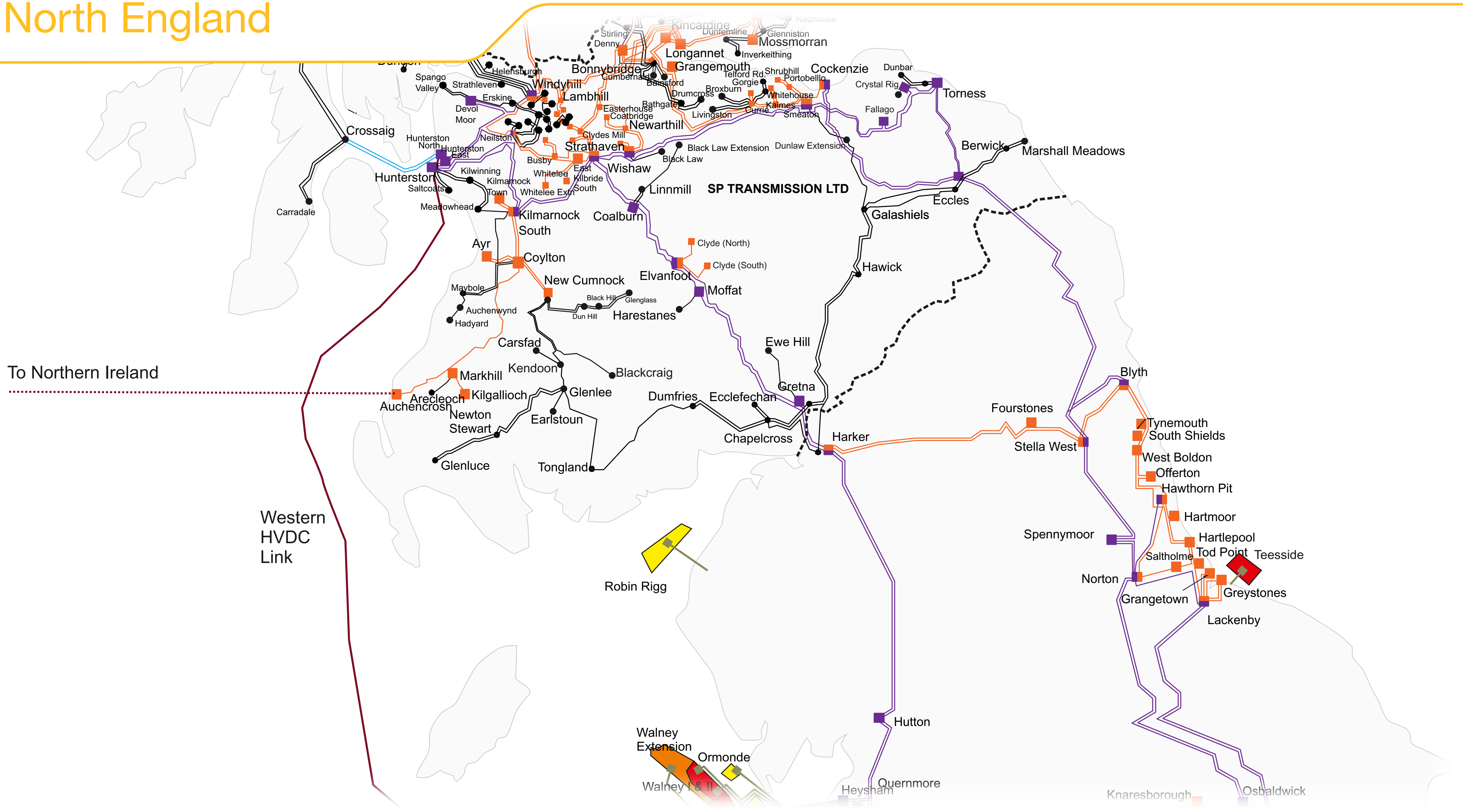
Click here to view details on the options

***NOA* 2020/21 recommendations**

Hold Delay

NOA / Investment recommendations / Recommendations for each option 58

South Scotland & North England



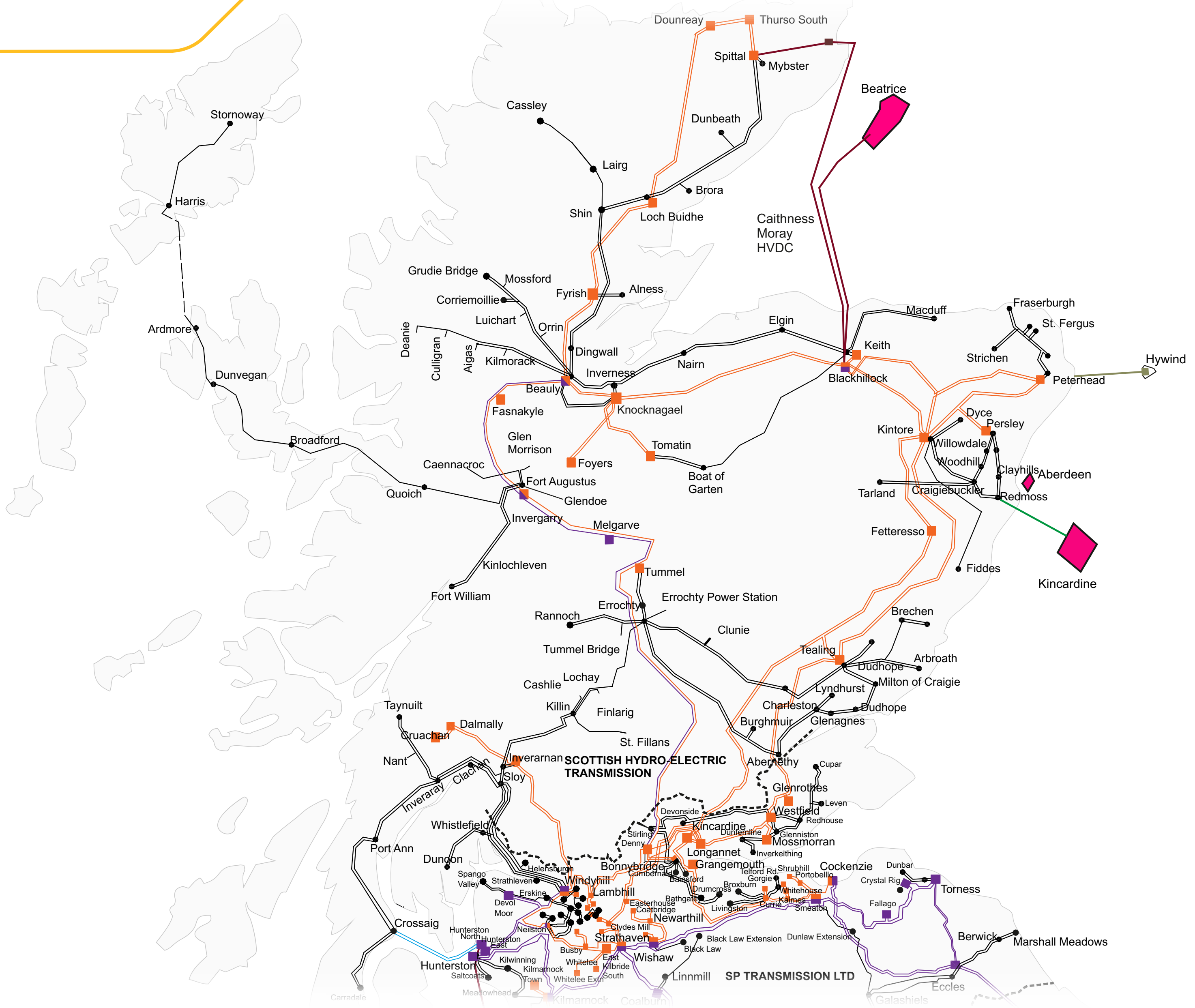
⊕ Click here to view details on the options

***NOA* 2020/21 recommendations**

⊕ Stop ⊕ Hold ⊕ Proceed

NOA / Investment recommendations / Recommendations for each option 59

Scotland



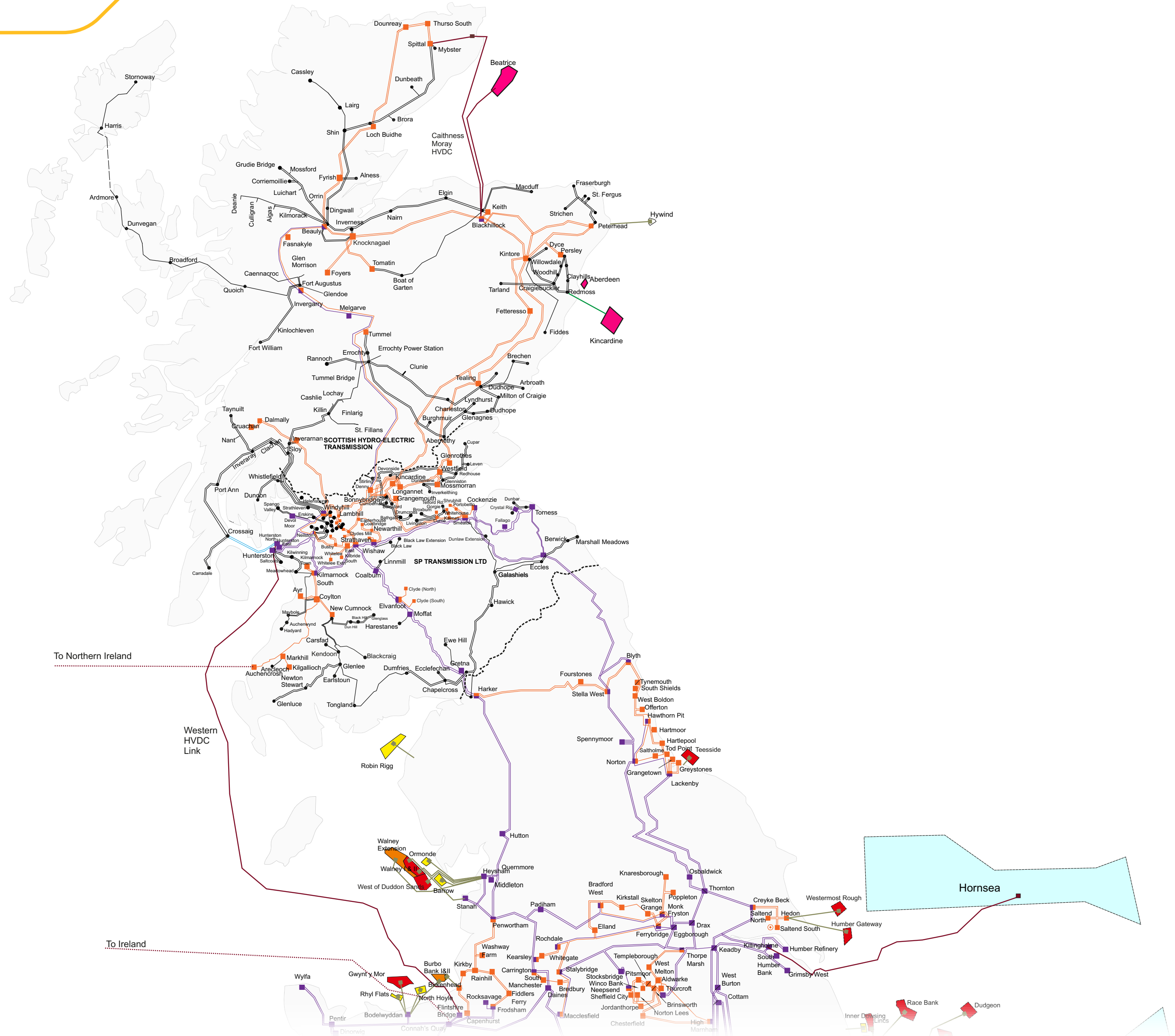
Click here to view details on the options

***NOA* 2020/21 recommendations**

Stop Hold Delay Proceed

NOA / Investment recommendations / Recommendations for each option 60

HVDC



Click here to view details on the options

***NOA* 2020/21 recommendations**

Stop Proceed

NOA / Investment recommendations / Recommendations for each option 61

Chapter 5

Offshore Wider Works

Introduction

For the first time, the ESO has demonstrated the economic benefits of offshore integration within our *NOA* analysis. We have proposed a number of conceptual offshore options and tested their benefit solely against constraint reductions, the analysis undertaken by the separate *Offshore Coordination Project* (*OCP*) has considered other factors beyond the remit of *NOA*.

Like the long-term conceptual options that we describe in Chapter 3 - 'Proposed options', the conceptual OWW reinforcements are used as an indicator of potential reinforcement needs. This meets our licence condition C27 as well as supporting competition for providing transmission assets and services to the national electricity transmission system (NETS). It should also facilitate economy of scale for integration with the rapidly growing offshore wind industry.

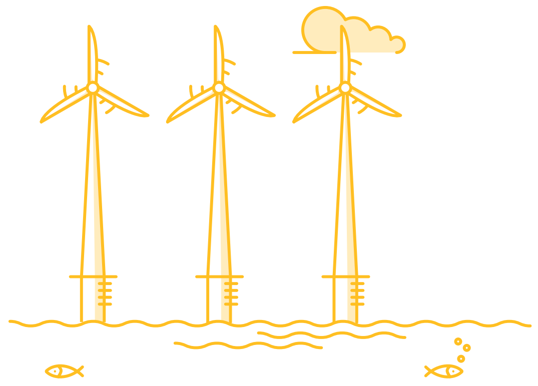
The reinforcements have been developed together with the *Offshore Coordination Project* (*OCP*). This project was set up by the ESO with support from Ofgem and the Department for Business, Energy & Industrial Strategy (BEIS) and forms part of the *Offshore Transmission Network Review*. The *OCP* Phase 1 report concluded that an integrated network in which assets are shared between connected parties offers consumer, environmental, and community benefits, including significant cost reductions.

The *OCP's* work moves to its next phase in January 2021. This will consider how we can facilitate a coordinated network through changes to industry codes, standards and processes as well as further technical analysis and planning. The output of this is likely to shape our future *NOA* analysis.

Our approach for *NOA* 2020/21 has been to create conceptual OWW reinforcements that we can test to connect major offshore wind developments while taking account of their commissioning dates. We then used these reinforcements in the *NOA* economic assessment process by analysing their costs against benefits. We calculated some estimated costs, capability benefits and timings for the reinforcements. This chapter gives a summary of those OWW reinforcements and how they performed in our analysis, allowing us to understand the impact they may have on our onshore planning process and the *NOA*.

The analysis also showed what changes may be needed to work with *OCP* outcomes and engage with stakeholders about the next steps. We hope this will also give an idea of the opportunities for OWW development.

Our analysis has found that three conceptual options are economically viable in reducing constraints in at least one scenario and warrant further investigation.



NOA / Offshore Wider Works / Introduction 63

Methodology

In our *NOA* economic process, we analyse the change to constraint costs that an OWW *NOA* reinforcement causes and then assess that benefit against the cost.

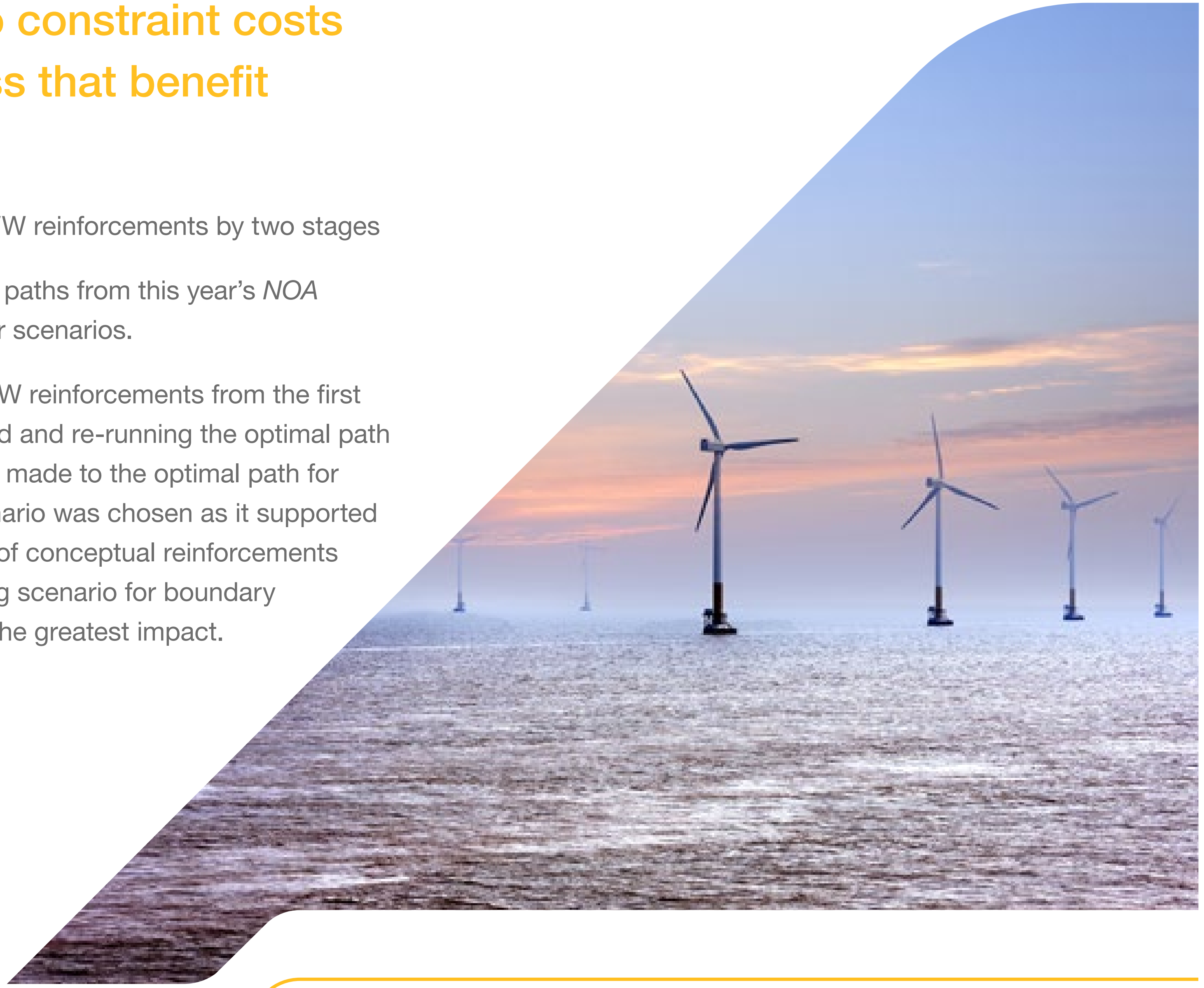
We considered the OWW *NOA* reinforcements in the same way and our *NOA methodology* goes into greater detail about the core *NOA* process. To consider the OWW reinforcements in *NOA* we adapted our modelling tool to accommodate offshore nodes that would have no demand.

The system boundaries of interest for the conceptual OWW study were onshore boundaries B7a in northern England, B8 and B9 in the Midlands, and EC5 in East Anglia.

We analysed the OWW reinforcements after we found the optimal paths based on the standard TO-led and commercial solution options. This means we have a separate set of recommendations for the OWW reinforcements and can compare them against the optimal path. A positive outcome for an OWW reinforcement this year is viable which contrasts with “Proceed” for the standard *NOA* options.

We tested the conceptual OWW reinforcements by two stages

- adding them to the optimal paths from this year’s *NOA* analysis for each of the four scenarios.
- putting the conceptual OWW reinforcements from the first approach in the background and re-running the optimal path to see what difference they made to the optimal path for Leading the Way. This scenario was chosen as it supported the highest number (three) of conceptual reinforcements and as the most demanding scenario for boundary requirements would show the greatest impact.



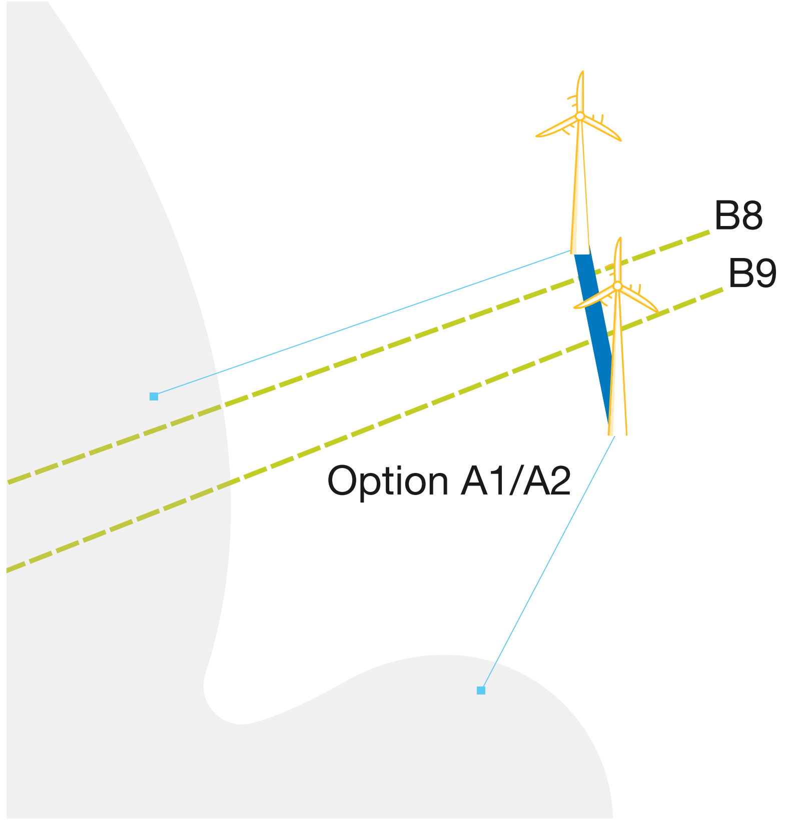
NOA / Offshore Wider Works / Methodology 64

The conceptual options

We devised and developed six conceptual OWW reinforcements for the *NOA* to test their performance in relieving onshore boundaries. This complements the *OCP* work that was focused on zones around GB with drivers of reducing landing points and reducing network constraints. The main factors selecting the reinforcements for the *NOA* analysis were the size and commissioning dates of the proposed windfarms. This determined the order of the reinforcements, limiting the number of combinations to be analysed. Other factors include the technology availability, its rate of development, development timing, minimisation of routing distance and cost. In this assessment the counterfactual is deemed to be the onshore reinforcements as described in the *NOA* 2020/21 optimal paths. Our conceptual OWW *NOA* reinforcements are as follows.

Option A1 1000 MW connection from Dogger Bank area to Hornsea area provides additional transmission capacity across onshore boundaries B8 and B9. As the link would be around 150km, we expect HVDC technology would have to be used and need a converter station at each end and AC connection to the offshore wind farm. The proposed rating of this link would be 1000 MW.

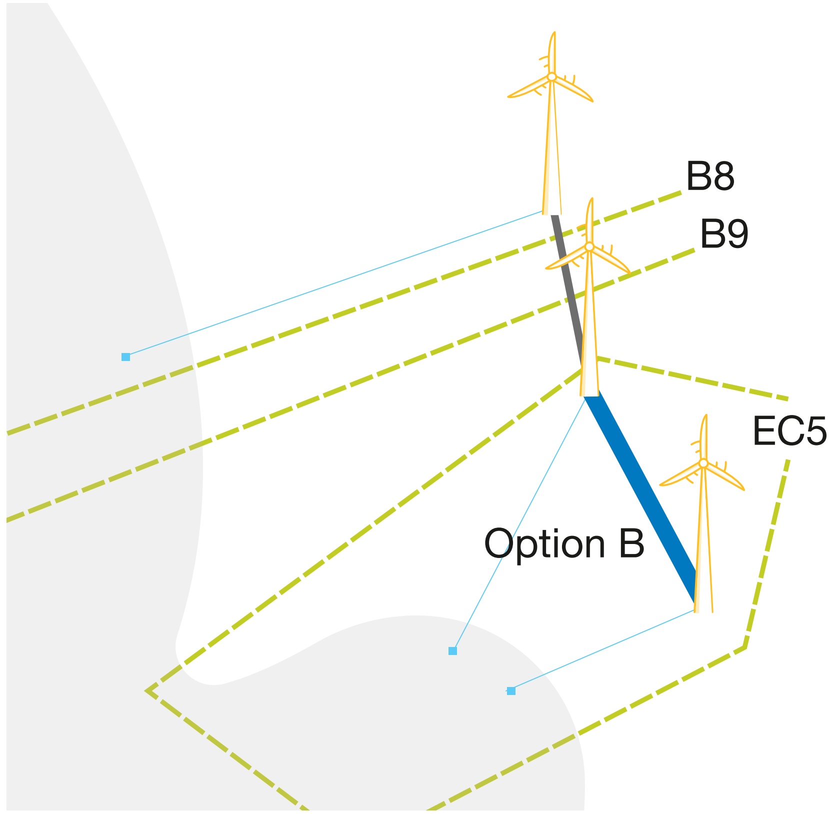
Option A2 1500 MW connection from Dogger Bank area to Hornsea area is the same as A1 but rated at 1500 MW. A2 would be an alternative to A1 so 'mutually exclusive'. The different ratings of options A1 and A2 allow us to test the performance of their reinforcement capacities and whether the benefit from higher capacity cables would justify the additional build costs.



NOA / Offshore Wider Works / The conceptual options 65

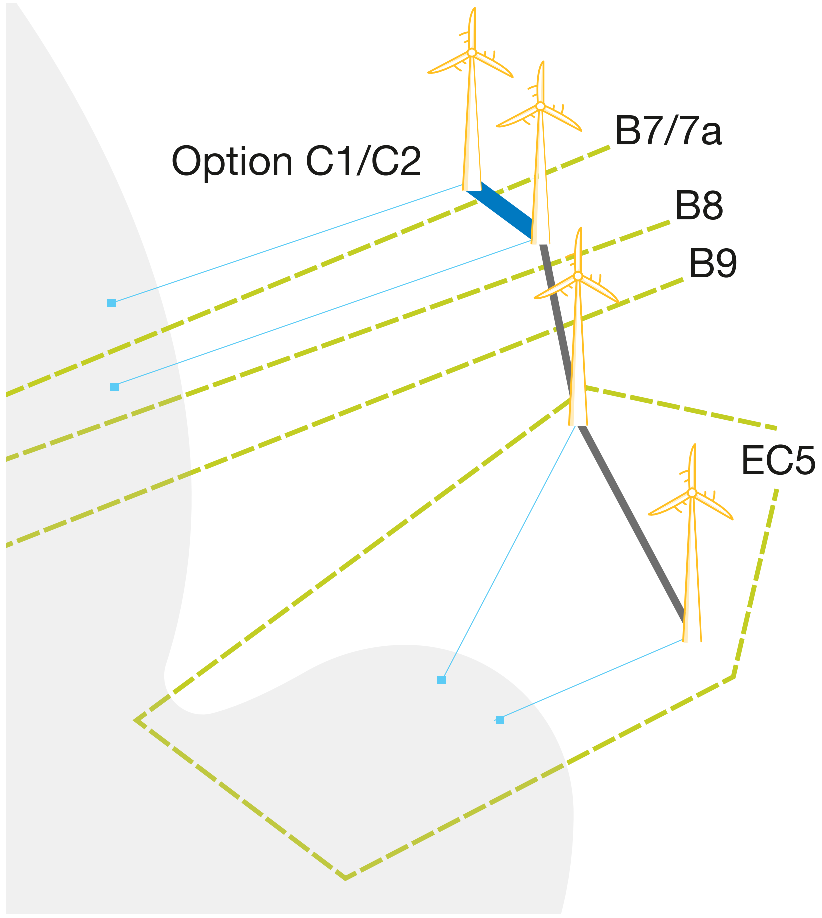
The conceptual options

Option B 1000 MW connection from Hornsea area to East Anglia area would add to A1 or A2 with an HVDC converter platform at East Anglia to create a three ended HVDC link (Dogger Bank – Hornsea – East Anglia). This could provide additional transmission capacity out of East Anglia and to the B8 and B9 boundaries. The East Anglia leg would be about 90km rated at 1000 MW and join to the East Anglia wind farms. This also makes A1 or A2 a pre-requisite to B.



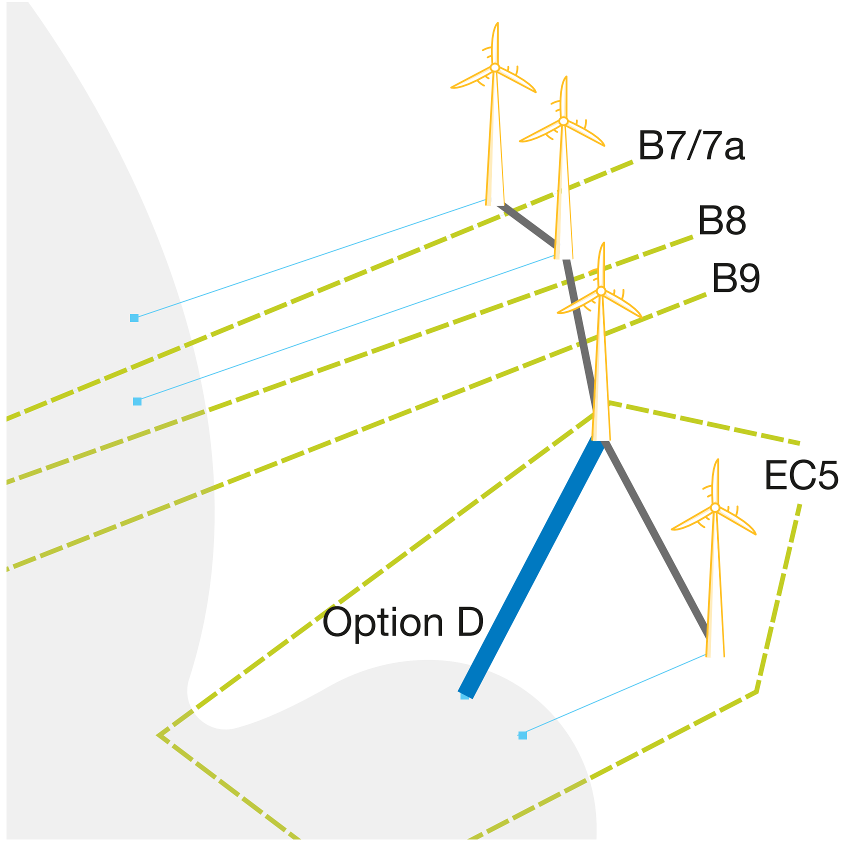
Option C1 400 MW internal connection within Dogger Bank area would connect between wind farms within the Dogger Bank seabed area. Its key assumption is that wind farms within Dogger Bank will connect to the onshore network at Lackenby and Creyke Beck so interconnecting offshore will provide a power flow path, bridging the onshore network across boundaries B7 and B7a. The offshore interconnection distance is assumed to be around 40km by good positioning of the wind farm collector platforms; this would allow AC cables to be used and at a voltage that matches the turbine cable connections, avoiding further transformers. The number of cables could be determined by the optimal capacity needed. For C1 the rating would be 400 MVA taking into account the capacity of the HVDC links to shore already mentioned and the generation load factor. So, C1 would cross and ease boundaries B7 and B7a which are relatively highly constrained.

Option C2 700 MW internal connection within Dogger Bank area is the same as C1 but increases the number of connecting cables to provide a 700 MVA capability. This allows us to test its economic benefit compared to C1.



The conceptual options

Option D Increased rating to 2500 MW of proposed connection from Hornsea area to shore (Norfolk) would increase the capability of a proposed Hornsea wind farm connection to the onshore network from 1500 MW to 2500 MW. This would reduce potential conflict between local wind farm output and interconnection power flow. It would be an HVDC link of about 180km. It would work with reinforcement A1 or A2 and to some extent with B to bring ashore generation output and also cross boundaries B8 and B9. It would however sit behind congested boundary EC5 that we use for westward exports from East Anglia.



We have assumed all the reinforcements, apart from options C1 and C2, would use HVDC technology as they cover distances for which this tends to be more economic. Following conclusions in our *OCP* work, HVDC circuit breakers were not used in our conceptual OWW reinforcements as they did not extend to Scotland, which is where they were used in the *OCP* designs.

When devising the conceptual OWW reinforcements for the *NOA* analysis, the aim is to be able to test them giving boundary capability to the onshore network where it is needed. The designs must take account of the location and timing of offshore generation. The transmission distances between areas affect the choice of AC or HVDC technology. The anticipated offshore wind farm connections and their ratings are a factor in calculating the opportunities for joining up or 'integrating'. Those ratings and any headroom are determined by the wind farms' size. A fundamental point is where wind farms connect to the onshore network and their positions with respect to constraint boundaries. When we perform the economic modelling, we consider the capacity and within-year generation profiles for each targeted wind farm. This has an impact on the offshore reinforcements' loadings so we can compare how different reinforcement ratings perform.

NOA / Offshore Wider Works / The conceptual options 67

NOA / Offshore Wider Works / Results 68

Results

The six conceptual OWW reinforcement options were analysed using the methodology outlined above.

Table 5.1 shows how each option performed against each *future energy scenario.* A viable result indicated that the option provided greater economic benefit in terms of constraints savings compared to the indicative cost of the option. A viable result is not a signal to proceed and build infrastructure but an indication to the industry that from our analysis, the proposed options will help relieve onshore constraints.

Table 5.1 Conceptual OWW reinforcement performance for each scenario. We describe a reinforcement as viable where it has a positive net present value

<table>
<tr><th>Option code</th><th>Description</th><th>Assumed Delivery Year</th><th>Leading the Way</th><th>Consumer Transformation</th><th>System Transformation</th><th>Steady Progression</th></tr>
<tr><td>A1</td><td>1000 MW connection from Dogger Bank area to Hornsea area</td><td>2027</td><td>Viable but larger link (A2) performed better</td><td colspan="3">Not viable</td></tr>
<tr><td>A2</td><td>1500 MW connection from Dogger Bank area to Hornsea area</td><td>2027</td><td>Viable</td><td colspan="3">Not viable</td></tr>
<tr><td>B</td><td>1000 MW connection from Hornsea area to East Anglia area</td><td>2028</td><td colspan="4">Not viable</td></tr>
<tr><td>C1</td><td>400 MW internal connection within Dogger Bank area</td><td>2033</td><td colspan="3">Viable but larger link (C2) performed better</td><td>Not viable</td></tr>
<tr><td>C2</td><td>700 MW internal connection within Dogger Bank area</td><td>2033</td><td colspan="3">Viable</td><td>Not viable</td></tr>
<tr><td>D</td><td>Increased rating to 2500 MW of proposed connection from Hornsea area to shore (Norfolk)</td><td>2029</td><td>Viable</td><td colspan="3">Not viable</td></tr>
</table>

Results

Our analysis concludes that three conceptual options form a viable set of options that may provide economic benefit under the Leading the Way scenario. The options deemed viable are A2, C2 and D.

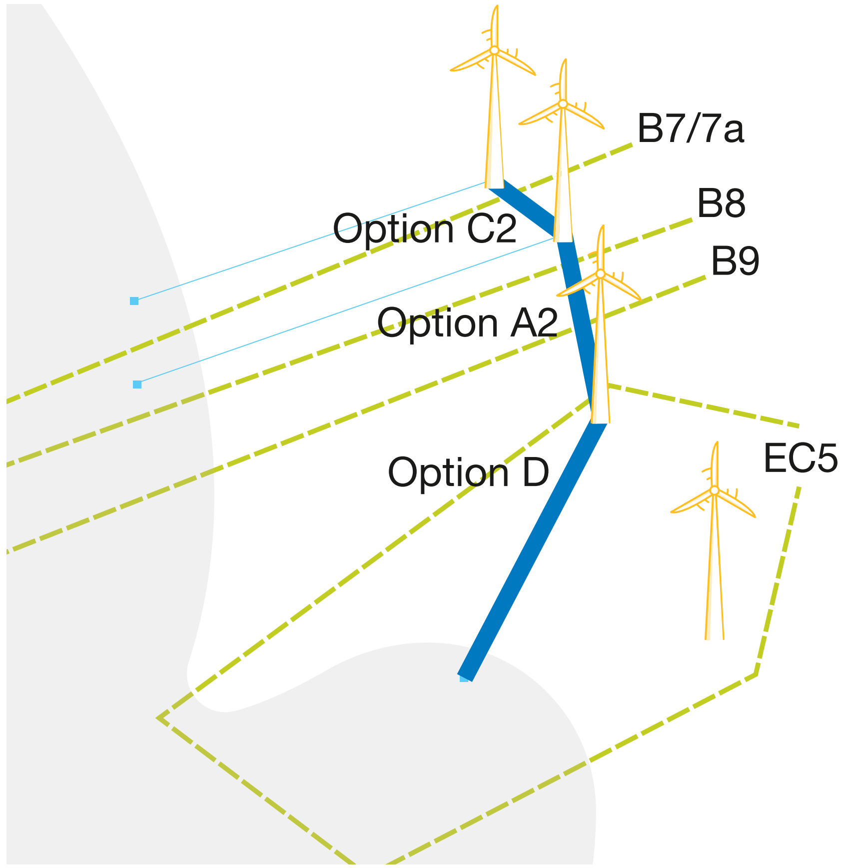
This would create a 700 MW AC link between the Dogger Bank platforms, then a 1500 MW HVDC link to Hornsea, and an increased capacity connection of 2500 MW to shore from Hornsea.

The offshore link between the Dogger Bank platforms (C2) is shown to be viable in all three net zero scenarios as it provides additional boundary capability on B7 and B7a. The other viable options (A2 and D) also provide benefit in the other net zero scenarios (Consumer Transformation and System Transformation), but not enough on their own to make the investment worthwhile.

The link from Hornsea to East Anglia was found to be not viable in our analysis, as it does not provide additional boundary capacity on its own and does not provide enough boundary capacity in conjunction with other options to justify the investment.

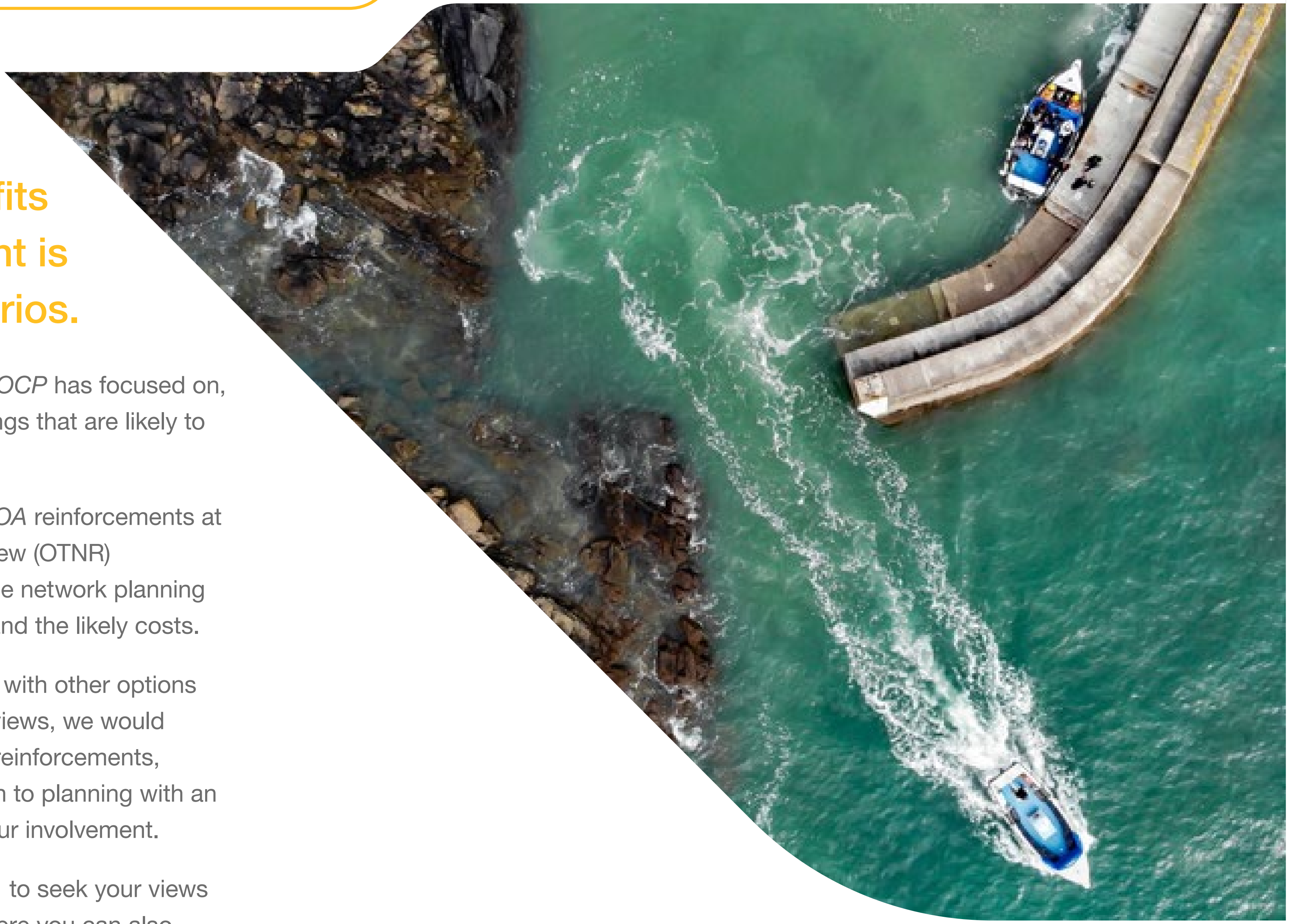
In all cases where both a smaller and larger capacity link were tested, when a small link (A1 and C1) was found to be viable, the large link provided additional economic benefit and is preferred.

Our analysis has also found that the viable offshore options under the Leading the Way scenario do not displace any existing onshore *NOA* recommendations. There were slight changes to optimal delivery dates for some reinforcements, but these did not impact any recommendations.



NOA / Offshore Wider Works / Results 69

Next steps



We have found that three conceptual OWW reinforcements give economic boundary benefits in at least one scenario while one reinforcement is also considered viable all three net zero scenarios.

However, these studies do not consider all of the benefits of integration that the *OCP* has focused on, namely fewer cable landings, less environmental impact, asset expenditure savings that are likely to strengthen the case for reinforcements in an integrated network.

We recognise that the high-level design assumptions of the conceptual OWW *NOA* reinforcements at this stage could affect cost outcomes. The Offshore Transmission Network Review (OTNR) is currently considering the approach to offshore connections, which may change network planning beyond this development but we'd still like your input on what may be possible and the likely costs.

In the future, using the *NOA* to assess OWW reinforcements on an equal footing with other options could be one approach but there may be better ways to do it. If you have other views, we would like to hear about them. We want to improve how we devise and develop OWW reinforcements, particularly the technical design and costing, and also inform the approach taken to planning with an integrated offshore network. These are areas where we are also keen to have your involvement.

We will continue in conjunction with the *OCP* to engage with the industry in 2021 to seek your views on the *NOA's* OWW results. Please keep up to date using our *NOA* webpage where you can also subscribe to updates.

NOA / Offshore Wider Works / Next steps 70

Chapter 6

Interconnector analysis

Introduction

NOA for Interconnectors (*NOA* IC) assesses how much interconnection would provide the most benefit to consumers and other interested parties. It also highlights the potential benefits of efficient levels of interconnection capacity between GB and other markets. For this analysis we have assumed that following the signing of the EU-UK Trade and Cooperation Agreement on 30 December 2020, longer term energy trading arrangements will be agreed so that markets are not affected.

The purpose of this analysis

This analysis outlines the socio-economic benefits of interconnection for consumers, generators and interconnector developers under a range of scenarios.

What *NOA* IC can do:

Provide a market and network assessment of the optimal level of interconnection capacity to GB.

Evaluate the social economic welfare, that is the overall benefit to society of a particular option, as well as constraint costs and capital expenditure costs of both the interconnection capacity and network reinforcements.

What *NOA* IC can't do:

Assess the viability of current or future projects: the final insights are largely independent of specific projects.

Provide any project-specific information.

NOA / Interconnector analysis / Introduction 72

Introduction

NOA and *NOA* IC

The *NOA*'s purpose is to recommend to Britain's Transmission Owners which projects to proceed with to meet the future network requirements as defined within the *Electricity Ten Year Statement*. *NOA* IC uses the output from *NOA* as the baseline network reinforcement assumptions: this maximises consistency between the *NOA* and *NOA* IC.

Value

There are many opportunities for additional GB interconnection to provide economic and environmental benefit for GB and Europe. They are essential to achieving net zero by 2050.

Benefits

Increased levels of interconnection bring benefits to GB and European consumers, both in terms of lower wholesale prices and increased use of renewable power. They are a key source of additional electricity system flexibility, reducing renewable energy supply curtailment, exporting excess intermittent renewable electricity and reducing the need for electricity storage by importing electricity when intermittent renewable electricity levels are too low to meet demand.

16.9 to 27.7 GW

Our analysis shows that interconnection capacity in the range of 16.9 GW to 27.7 GW between GB and European markets by 2040 would provide the maximum benefit to GB and European consumers.

Renewable energy

All four *FES* 2020 scenarios see an increase in renewable generation. Consumer Transformation and Leading the Way see higher levels of renewable generation than previous years, driven by increased government support for some renewable technologies which will be necessary to meet net zero greenhouse gas emissions by 2050. The more established technologies of solar and wind which dominate the mix are intermittent sources, meaning there could be times where there is not enough supply and times where there is an excess.

GB consumer

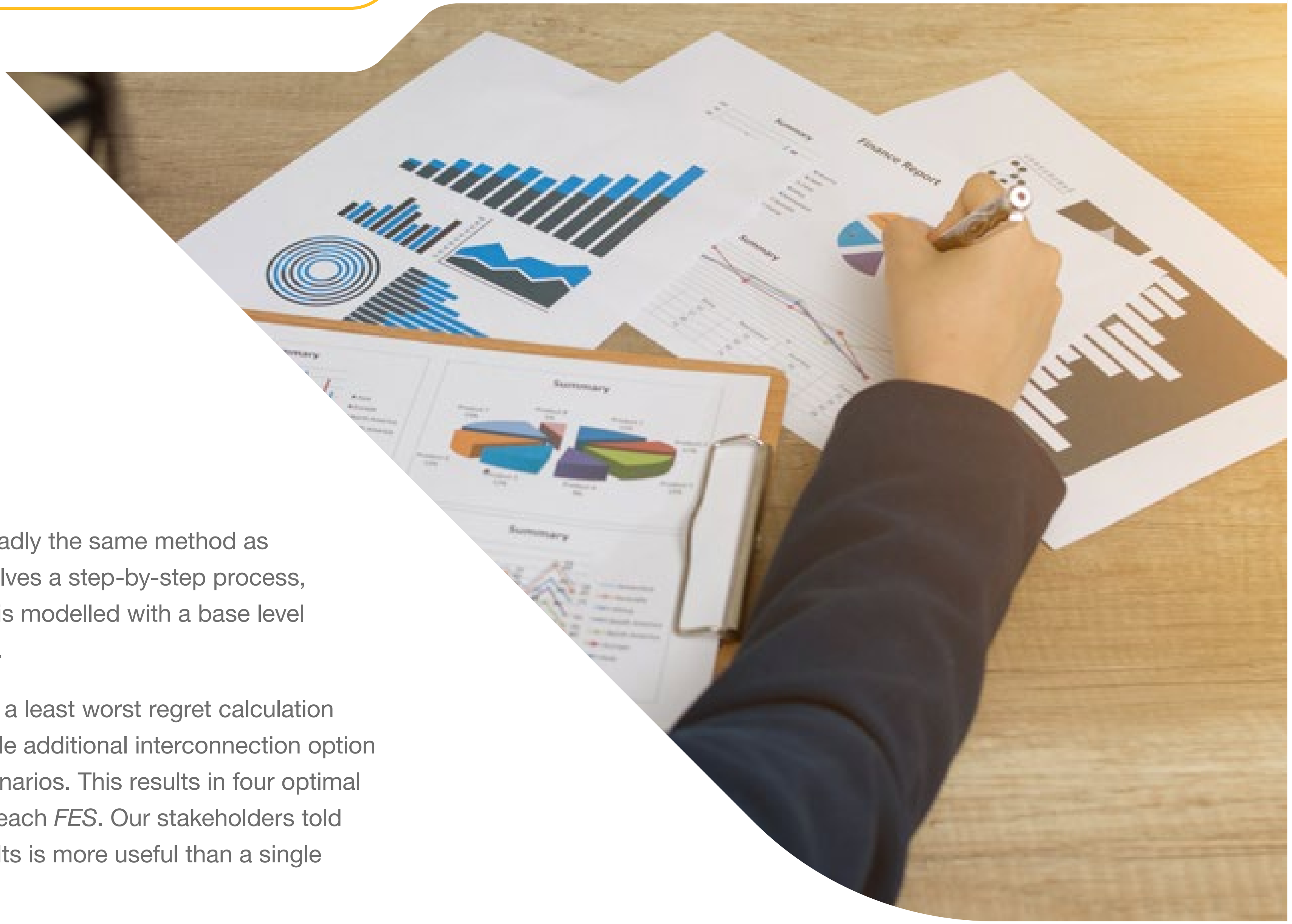
Analysis shows that the GB consumer can benefit from more interconnection projects than those included within Cap and Floor Window 2. For three of the scenarios, the levels of interconnection are significantly above these levels.

Interconnector options

While the analysis results in four optimal interconnector paths based on *FES* 2020, there may be other combinations of interconnectors that will also add value.

NOA / Interconnector analysis / Introduction 73

Introduction



Improvement to this year's analysis

This year, we have continued to develop the methodology approved by Ofgem.

- We have continued to use the output from this year's *NOA* as the baseline network reinforcement assumptions for the *NOA* IC analysis: this provides greater consistency between the *NOA* and *NOA* IC analysis.
- We have focused on identifying the optimum level of interconnection by examining social economic welfare, capital costs and reinforcement costs.
- Based on stakeholder feedback, we have not analysed the impact interconnectors may have on other operational costs, specifically ancillary services.
- We have used broadly the same method as last year. This involves a step-by-step process, where the market is modelled with a base level of interconnection.
- We do not include a least worst regret calculation to assign one single additional interconnection option across all four scenarios. This results in four optimal solutions, one for each *FES*. Our stakeholders told us a range of results is more useful than a single optimal solution.

NOA / Interconnector analysis / Introduction 74

Interconnection theory

Electricity interconnectors allow the transfer of energy between countries.

With the commissioning of the IFA2 interconnector to France at the end of 2020, GB has roughly 6GW of interconnection with other European markets. However, our 2020 *future energy scenarios* (*FES*) see an increase to between 16 GW in Steady Progression and 22 GW in Leading the Way by 2030.

Increases in interconnection can deliver benefits to both industry and consumers.

Social Economic Welfare (SEW) is a common cost-benefit indicator when analysing projects of public interest. It captures the overall benefit, in monetary terms, to society from a given course of action. It is an aggregate of multiple parties' benefits – so some groups in society may lose money because of the option taken. In this analysis, SEW captures the financial benefits and detriments to market participants due to increased interconnection. Figure 6.2 shows how SEW is reached.

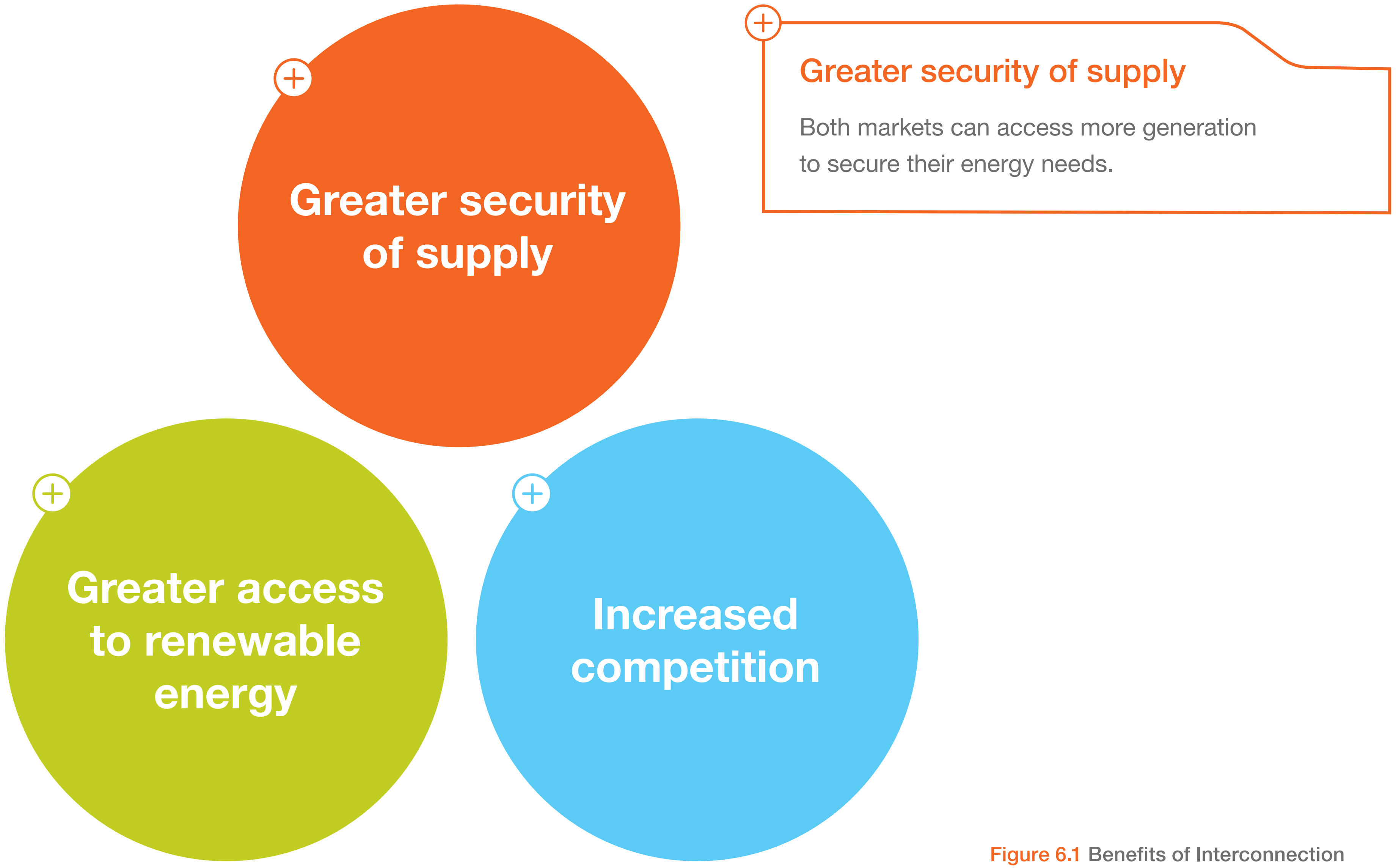


Figure 6.1 Benefits of Interconnection

NOA / Interconnector analysis / Interconnection theory 75

Interconnection theory

The increase in SEW must also be balanced against the capital costs of delivering the increased interconnection capacity and any associated reinforcement costs. As capacity is increased between two markets and SEW delivered, prices begin to converge until further interconnection brings no benefit. The interconnection capacity is optimised, having delivered maximum benefits.

Consumer welfare

Increased consumer welfare due to reduced prices in the higher priced market, as suppliers have increased access to cheap renewable generation.

Reduced consumer welfare due to increased prices in the cheaper market, as access to cheaper generation is shared with more consumers.

Figure 6.2 Social economic welfare

NOA / Interconnector analysis / Interconnection theory 76

Methodology

This section provides an overview of the methodology used for the *NOA* IC analysis, updated using feedback from stakeholders.

Developments to methodology

This year we have continued to focus our analysis on the optimal level of interconnection capacity for GB. The key highlights are:

- The process continues to quantify SEW, capital costs and reinforcement costs of additional interconnection.
- The optimal paths are based on SEW for Europe, not just GB and connecting country. This was necessary to achieve credible results.
- For consistency, we use recommendations from this year's *NOA* as the baseline network reinforcement assumptions for the analysis.
- We have identified four optimal interconnection development paths: one for each future energy scenario. Stakeholders continue to tell us that a range of results was more beneficial, due to the high levels of uncertainty in the European energy market.

NOA / Interconnector analysis / Methodology 77

Current and potential interconnection

As stated within the *FES* 2020, interconnection capacity increases beyond current levels in all four scenarios. Table 6.1 shows the current and planned interconnection levels which form the basis for this study's base interconnection capacity.

The first step is setting an initial baseline level of interconnection. In previous versions of *NOA* IC this has been set lower than within the *FES* to allow us to investigate different combinations of interconnection to those within *FES*. This year we cannot do this because the levels of *FES* interconnection are required to achieve a supply demand balance within the *NOA* IC modelling.

This year's scenarios explore three pathways that meet the UK's legally binding net zero target. Two meet the net zero target at a similar speed of decarbonising, but with varying levels of societal change, and one exceeds these. The levels of interconnection with *FES* 2020 are significantly higher than in previous *FES*, and two of the scenarios have interconnection capacity higher than the levels seen in last year's *NOA* IC. Capacities are higher in the scenarios with greater levels of societal change, as high levels of intermittent generation favour more flexible sources such as interconnectors, which play an increasingly important role in providing flexibility.

In the net zero scenarios flows become more variable due to the high levels of renewable generation capacity, with increased interconnector capacities transporting large volumes of electricity in both directions. As renewable generation capacities increase across GB and Europe, interconnectors help balance supply and demand with flows responding to price differences between countries increasingly driven by variable renewable generation output.

The levels of interconnection in the *FES* are essential to achieving an hourly supply demand balance; it is not possible to run the *FES* 2020 scenarios with a lower level of interconnection than that originally set within the scenarios. So this year's baseline has been set at the *FES* 2020 level.

Using the original *FES* levels of interconnection does have the benefit of keeping the scenarios 'whole', as the *NOA* IC process does not alter a key element of the underlying scenario framework.

For this year's analysis, we have continued to treat any Icelandic interconnection in the *FES* as a generator. The unique properties of the Icelandic market, specifically the levels of renewable generation, result in a very low wholesale electricity price. Further Icelandic interconnection was excluded from the process.

Table 6.1 shows the current and planned interconnection levels of base interconnection capacity. 2028 represents the first year modelled. The baseline levels of interconnection continue to rise in the *FES* as additional interconnectors are added; for example Leading the Way has 27.2 GW of interconnection by 2040.

	Interconnection capacity (GW)
2020 capacity	6
2028 Consumer Transformation	17.9
2028 Leading the Way	18.7
2028 Steady Progression	14.5
2028 System Transformation	15.9

Table 6.1 Interconnection capacity and 2028 base case

Recommendation for capacity development is an optimisation for each future energy scenario to maximise the present value, equal to SEW less CAPEX less constraint costs. Figure 6.3 provides a high-level overview of the process. Further details are available in the *NOA methodology report*.

Methodology

1 Set base level interconnection

2 Create study cases

3 Simulate European markets for all four *FES*

4 Calculate net benefit of each option

5 Identify optimal interconnector solution for each *FES*

6 Update base level of interconnection in each *FES*

1. Set base level interconnection

The base level of interconnection is the total capacity GB has with each of the seven studied markets at the start of the iteration. This year, the original level of *FES* interconnection within each scenario formed the baseline.

Figure 6.3 Iterative process for interconnection optimisation

NOA / Interconnector analysis / Methodology 79

Methodology

Connecting country	Connection Zone	Reinforcement on boundary
Base	Base	None
Belgium	5	EC5
Belgium	5	None
Belgium	7	None
Denmark	2	B7a
Denmark	2	None
Denmark	5	EC5
Denmark	5	None
Denmark	8	None
France	6	None
France	6	SC1
France	7	None
France	7	SC1
Germany	5	EC5
Germany	5	None
Germany	7	LE1
Germany	7	None
Germany	8	None
Ireland	1	None
Ireland	2	None
Ireland	3	None
Ireland	4	None
Netherlands	5	EC5
Netherlands	5	None
Netherlands	7	LE1
Netherlands	7	None
Norway	1	B6
Norway	1	None
Norway	2	B7a
Norway	2	None

Table 6.2 Study cases, showing interconnector connecting country, GB zone and reinforcement options. The connection zones and reinforcements are shown on the map in Figure 6.4

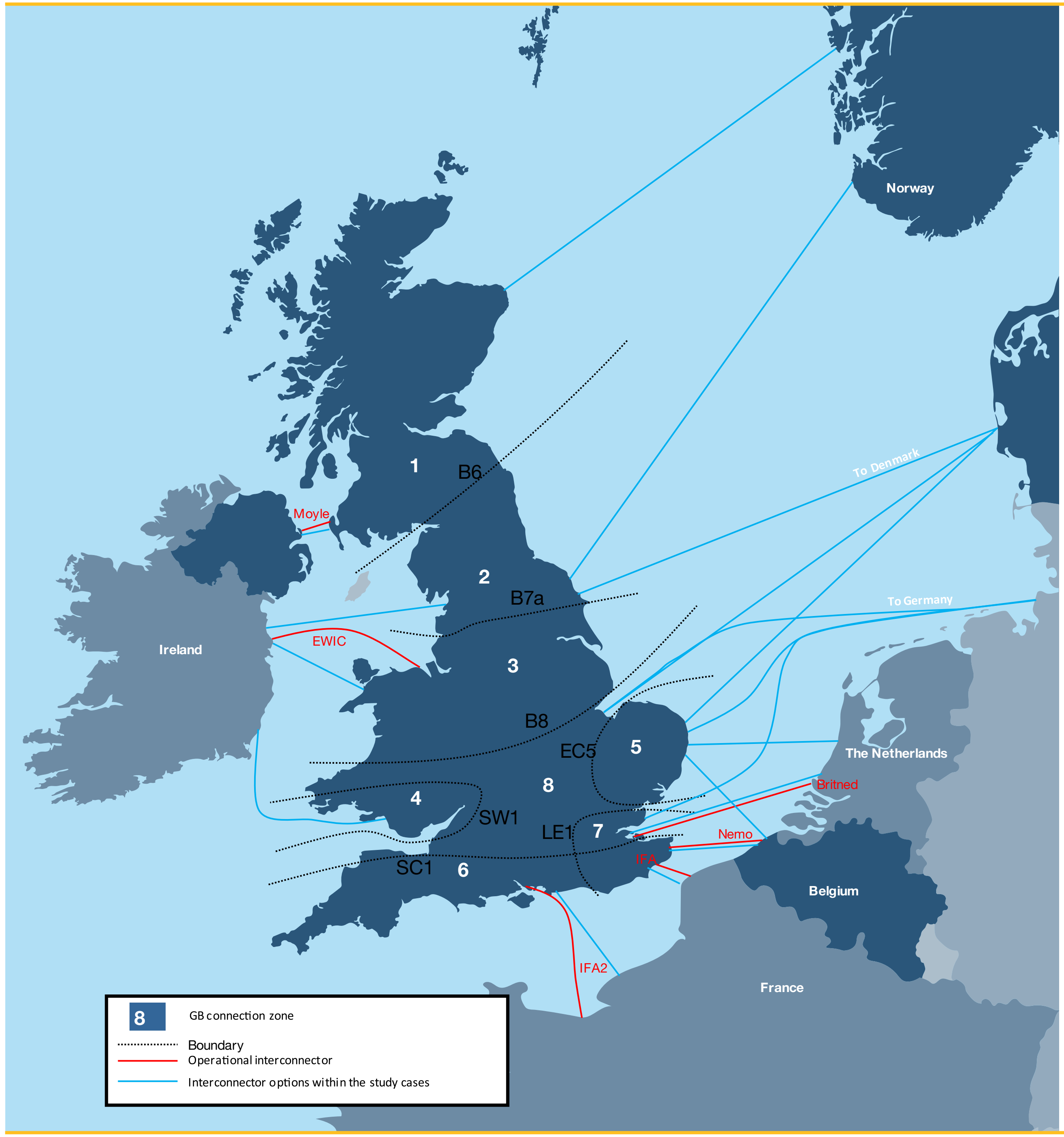
Estimation of interconnection construction costs

The cost of building interconnection capacity varies significantly between different projects, with key drivers including converter technology, cable length and capacity. The capital costs were derived from a publicly-available ACER (Agency for the Cooperation of Energy Regulators) document, based on surveys carried out on European projects, and approximations of median possible cable lengths. Costs were converted to 2020 prices and benchmarked against a range of interconnector cost data in the public domain.

Whilst there was considerable variation across projects, the ACER costs provide a reasonable average.

We also considered including interconnector operational costs (OPEX) but initial investigations showed this is a complex area and operating costs are project-specific. As *NOA* IC is not project specific, we have not attempted to model OPEX but will continue to review this topic with stakeholders.

NOA / Interconnector analysis / Methodology 80



Estimation of network reinforcement costs

Based on the output from this year's *NOA*, we have updated the boundaries to divide the network into high-level zones. The eight zones represent areas of significant constraints on the network or areas of high interconnection.

Figure 6.4 highlights the GB connection zones, boundaries and interconnectors currently operational and the study cases.

Figure 6.4 GB network high level zones, boundaries and interconnector options

NOA / Interconnector analysis / Methodology 81

Outcome

The market studies identified the interconnector options that resulted in the highest Net Present Value. These options provide the most benefit to GB and Europe.

The output is presented in four parts:

1. **Optimal interconnection range.**
2. **GB consumer benefit.**
3. **Interaction of interconnectors and constraints.**
4. **Environmental implications.**

Optimal interconnection range

For each *Future Energy Scenario (FES)*, the results show the markets to connect to, whether reinforcement of the GB network was necessary and in which years to connect to maximise Social Economic Welfare (SEW). The results should be considered in the context of the methodology:

- Interconnector projects which connect to markets not in the optimal paths may well be beneficial, but not the most beneficial based on the assumptions in this study.
- The attractiveness of different markets varies across the scenarios. There is uncertainty as to where the best opportunities lie, due to the uncertainty of future market conditions.
- The results are not a forecast: many other factors will influence the outcome for interconnection over the next decade and beyond.
- Variations in network constraint and construction costs will have a major impact on the attractiveness of projects.

The results of the modelling are very different from previous years. The optimal paths, i.e. the additional interconnection added to the baseline level of interconnection are much lower than in last year's analysis because of the higher baseline level used. For System Transformation, there was no additional interconnection, i.e. the optimal level of interconnection is the baseline level in the original *FES* scenario.

As the baselines are much higher than last year's, and as the interconnectors that form the base case diminish the level of additional SEW further interconnection can bring, the SEW generated by additional interconnection is reduced.

The number of iterations varied across the scenarios. The optimal level of interconnection between GB and European markets for each *FES* in 2040, including the baseline levels of interconnection, is shown in Figure 6.5.

NOA / Interconnector analysis / Outcome 82

Outcome

Consumer Transformation

27.1 GW

Leading the way

27.7 GW

Steady Progression

16.9 GW

System Transformation

21.5 GW

Figure 6.5 Optimal interconnection for each FES including the base case level

The four optimal levels of interconnection shown in Figure 6.5 give a range of between 16.9 GW and 27.7 GW of interconnection capacity across the four *FES*. All four are very similar to the interconnection capacity in the *FES* 2020 scenarios, which have a range of between 15.9 GW and 27.2 GW in 2040. They have up to 2 GW additional capacity over the *FES* 2020 scenarios, driven by the potential for creating additional value.

The optimal interconnection range is between roughly 3 to 5 times the current interconnector capacity of 6 GW.

A direct comparison to last year's results is not possible as the *FES* scenario framework is different. For *FES* 2020, the levels of interconnection are nearly optimal. This is partly explained by the levels of interconnection in *FES* 2020 being partially driven by the results of *NOA* IC 2019/20, which showed substantially higher levels of interconnection than that within *FES* 2019. This results in short paths for *NOA* IC 2020/21, i.e. there is little additional value in adding interconnection over and above the levels in *FES* 2020.

Our attempts at modelling *NOA* IC 2020/21 with a baseline level of interconnection lower than that set within *FES* 2020 were unsuccessful. This highlights how important the levels of interconnection set within *FES* 2020 are to achieving a supply and demand match for every hour for each year from 2028 to 2040.

Additional interconnection is essential to achieving net zero. As levels of intermittent renewable generation increase in the scenarios, interconnectors play an increasingly important role providing flexibility in the net zero scenarios.

NOA / Interconnector analysis / Outcome 83

Outcome

The optimal level of interconnection varies considerably across the different *FES*. Consumer Transformation, Leading the Way and System Transformation, which achieve the net zero target by 2050, have the highest levels of societal change, with high levels of intermittent generation requiring greater system flexibility. This may be provided by increased electricity storage, demand side response, electrolysis or interconnection. Interconnection not only provides additional system flexibility but also opportunities for creating additional value driven by the significant differences in wholesale prices between markets. In these scenarios the new sources of flexibility beyond generation become more important to meet peak demand. When renewable generation exceeds demand such as on windy, sunny summer days, the excess supply is balanced by flexible demand side response (DSR) or electrolysis to produce hydrogen, used to charge electricity storage, or for exporting via interconnectors.

As levels of intermittent renewable generation increase, interconnectors play an increasingly important role providing flexibility in the net zero scenarios.

In System Transformation the levels of interconnection are slightly lower as there is less need for demand side flexibility. This is due to higher levels of dispatchable thermal generation powered by hydrogen providing additional system flexibility and lower levels of electrification.

Steady Progression has the lowest levels of interconnection capacity. It still has over 40 GW of natural gas fired thermal generation throughout the modelling period of 2028 to 2040, providing high levels of supply side flexibility.

Levels of electricity flexibility increase slowly up to 2030 in all scenarios, as increases in interconnection, electricity storage and demand side response are offset by reduced dispatchable thermal generation capacity. As renewable generation dominates between 2030 and 2040, further flexibility is needed to balance a net-negative carbon emission electricity system in the net zero scenarios.

Interconnection is just one of a range of technologies that will be essential to achieving the levels of electricity system flexibility necessary to achieve the net zero target by 2050. Other technologies such as dispatchable thermal generation, large scale energy storage and demand side response will be needed too.

NOA / Interconnector analysis / Outcome 84

Outcome

Last year's *NOA* IC gave a range of between 18.1 GW and 23.1 GW. The higher levels of interconnection in this year's analysis for the Consumer Transformation and Leading the Way scenarios are the result of higher levels of welfare due to more intermittent renewable generation and the requirement for increased system flexibility. Consumer Transformation, Leading the Way and System Transformation all achieve net zero greenhouse gas emissions by 2050 and a key element in achieving this is significant investment in low carbon electricity generation, with increased levels of low carbon and renewable generation compared to the *FES* 2019 scenarios. Consumer Transformation, Leading the Way and System Transformation also include greater volumes of intermittent renewable generation across Europe, providing additional welfare opportunities for balancing renewable generation volumes.

The results show there is value for additional interconnection capacity over and above that included in Ofgem's Cap and Floor Window 2, especially for the three scenarios that meet the net zero target.

Figure 6.6 shows the results in graphical format for each option, including the number of iterations, the cumulative level of interconnection capacity, the connecting country, whether any additional reinforcement was needed, the connecting zone and the connecting year.

Figure 6.6 Optimal interconnection paths for each FES

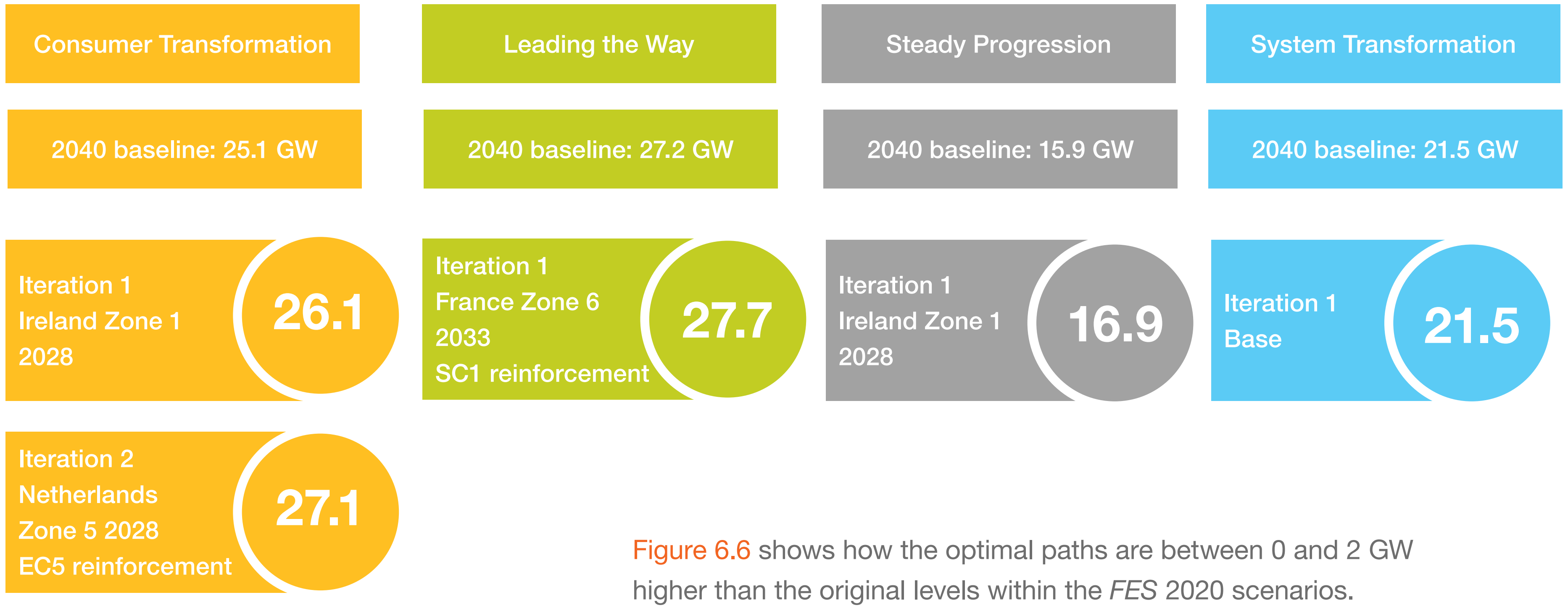


Figure 6.6 shows how the optimal paths are between 0 and 2 GW higher than the original levels within the *FES* 2020 scenarios.

NOA / Interconnector analysis / Outcome 85

Outcome

Figure 6.7 shows the level of interconnection to each European market for the four optimal paths. Two of the optimal paths result in additional interconnection to Ireland. The average Irish wholesale price is modelled as generally higher than GB, resulting in welfare generation opportunities. Also generating welfare is Ireland's synchronous generation constraint which imposes a limit on the level of demand that can be met by wind. These two factors mean British exports to Ireland exploit arbitrage and Irish exports to Britain avoid wind curtailment.

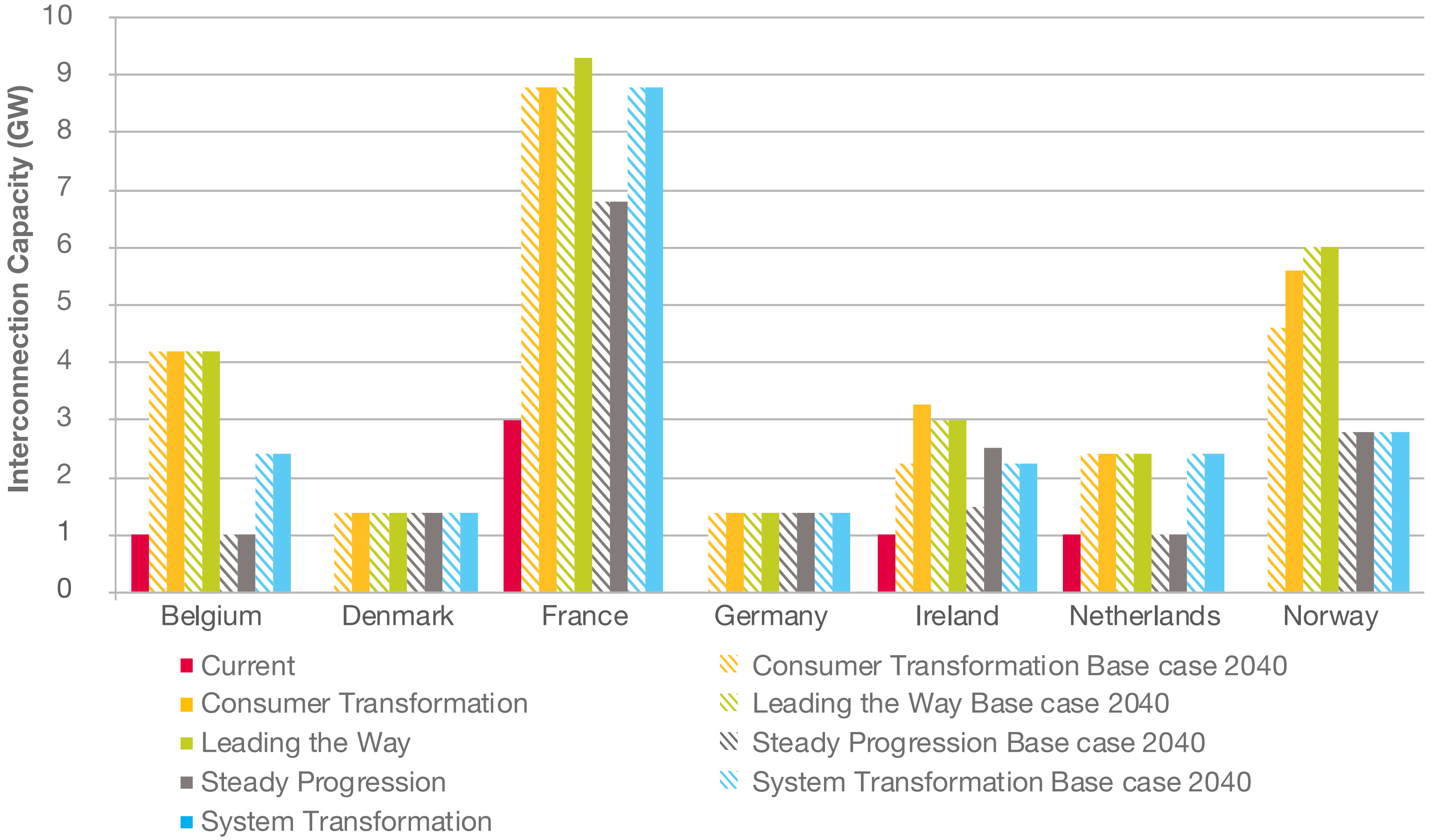


Figure 6.7 Optimal level of interconnection to each European market in 2040, for each scenario

NOA / Interconnector analysis / Outcome 86

Outcome

Figure 6.8 shows the variation in length of optimal paths across the four scenarios and the variations in net present value (NPV) relative to the base case for each iteration. It also shows the composition of each NPV broken down by welfare, CAPEX and constraints. Not surprisingly, CAPEX is always negative relative to the base case. Constraints can result in both savings and additional costs, although in Figure 6.8 all constraints are savings.

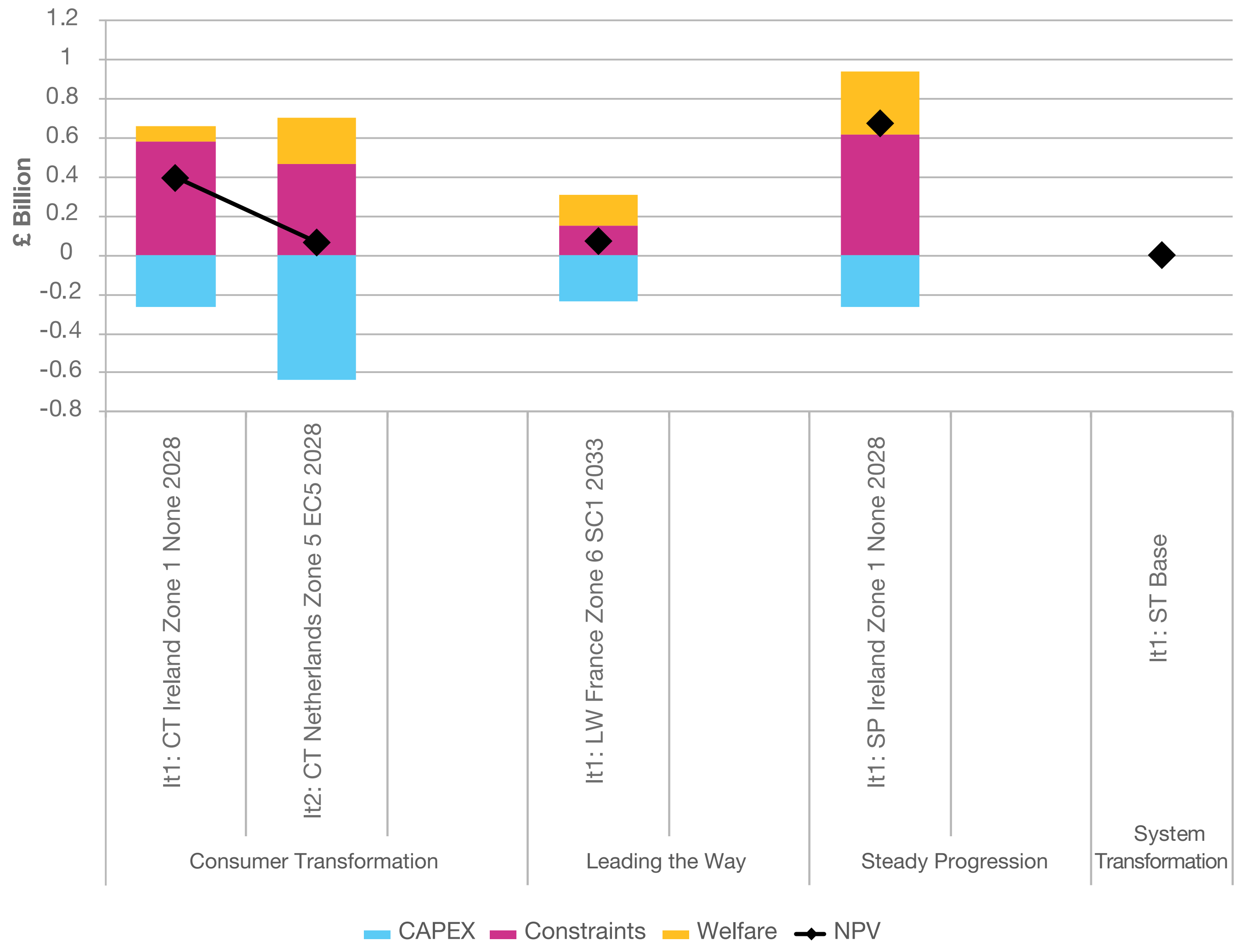
Only Consumer Transformation had an optimal path of more than one iteration, and for System Transformation, the winning study case from the first iteration was the base case, implying that no additional interconnection provided incremental value.

Figure 6.8 shows the low levels of additional welfare relative to the base case. This is because the baseline level of interconnection for each scenario was set at levels in the *FES* 2020 scenarios and as these have much higher levels than previous additions, there was very little additional SEW value created by adding more interconnection.

The additional interconnection to Ireland for Consumer Transformation iteration 1 and Steady Progression is primarily driven by the constraint savings from the interconnector and not by any additional SEW relative to the base case. Such constraint savings may well reduce in subsequent iterations of the *NOA* process as new network options are developed. Similarly, Consumer Transformation iteration 2 includes additional boundary capability for EC5 (East Anglia region) and Leading the Way includes additional boundary capability for SC1 (south coast region): the value obtained from these reinforcements may be negated in the next *NOA*.

Unlike previous years' *NOA* IC, where there were often many beneficial projects not in the optimal paths, that is they provided additional benefit relative to the base case, this year's study showed very few other projects producing positive net present value. This was again a result of using the *FES* 2020 levels of interconnection as the baseline level.

Figure 6.8 Net Present Value of each winning study case for the optimal path for each *FES*

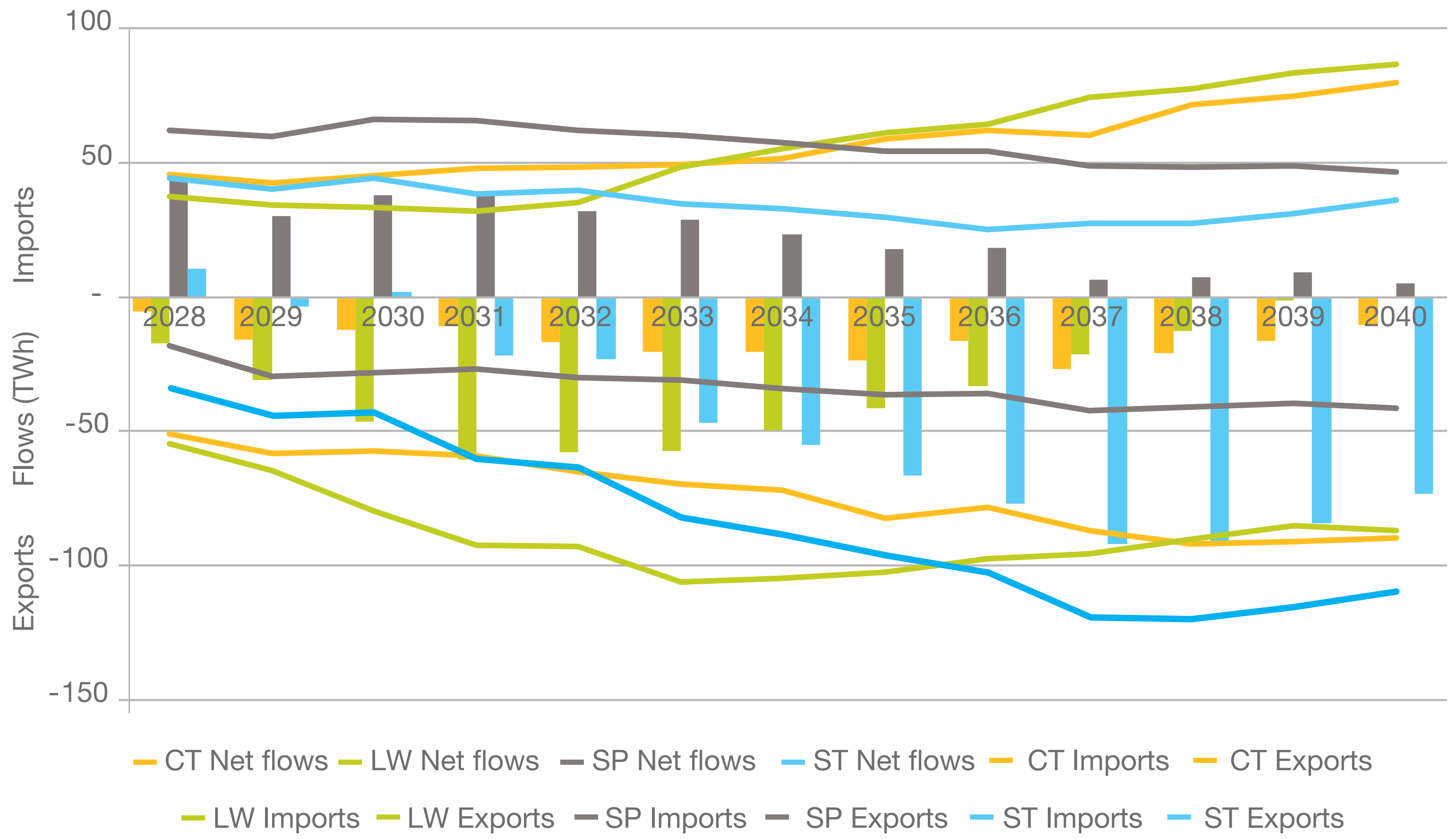


GB consumer benefit

The GB consumer gains from interconnection to cheaper wholesale electricity markets. Figure 6.9 shows annual imports and exports for each of the optimal interconnection paths.

Steady Progression maintains net annual import flows across the study period, whereas Consumer Transformation shows marginal net annual export flows, and Leading the Way and System Transformation show significant annual net export flows, but with different profiles across the years.

Figure 6.9 Annual import and export flows



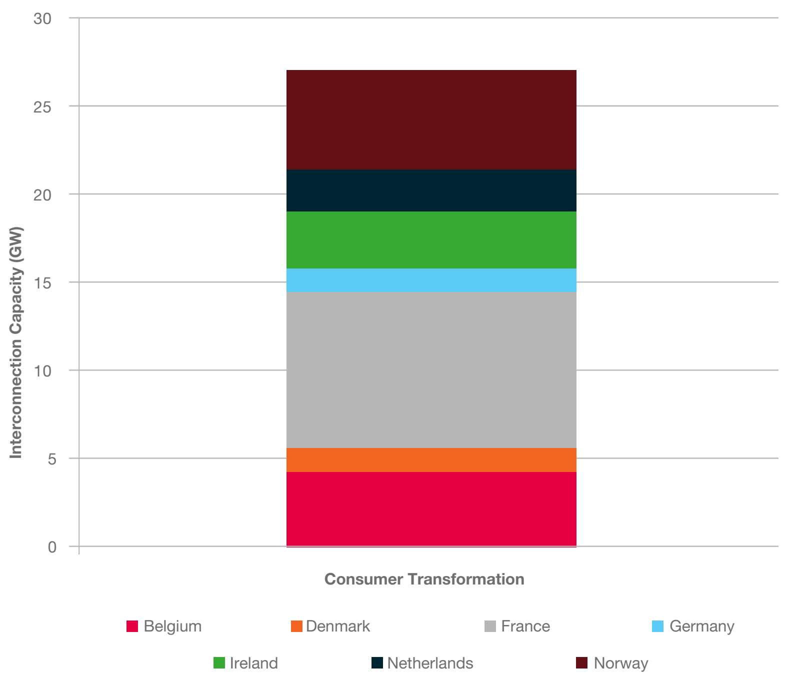
NOA / Interconnector analysis / Outcome 88

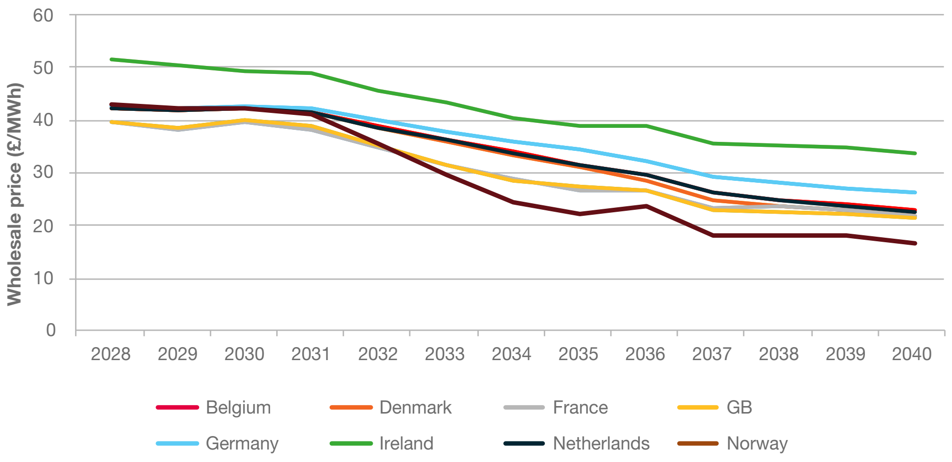
Outcome

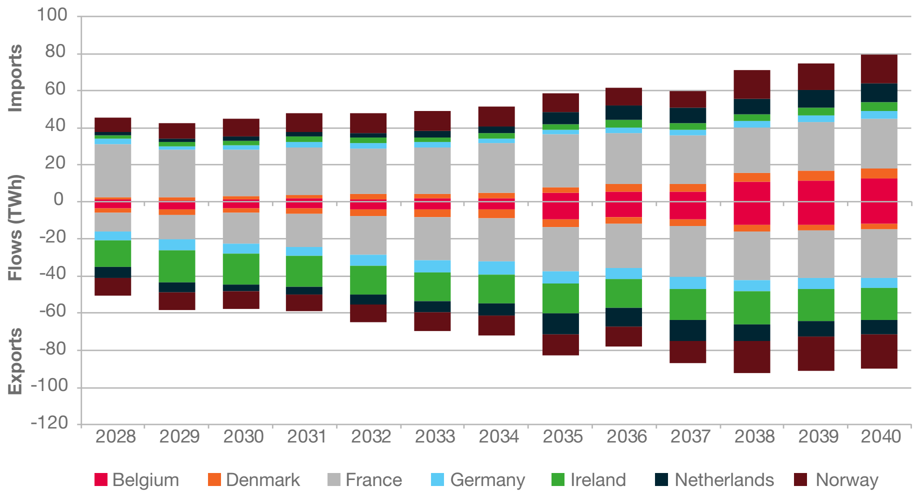
Figures 6.10 to 6.13 explore average annual wholesale prices for GB and the seven European markets for the four *FES*. The prices are not demand weighted. They also show the level of interconnection capacity as well as the annual import and export flows broken down by country.

Consumer Transformation shows a marked decrease in wholesale electricity prices across Europe, with only Norway showing lower prices than GB. This drives high export flows across the interconnectors, particularly to France, Ireland and Norway. The wholesale price differences allow arbitrage opportunities for imports to GB. Consumer Transformation shows lower levels of interconnection export than Leading the Way or System Transformation, although exports still reach over 80 TWh by 2037.

Figure 6.10 Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Consumer Transformation







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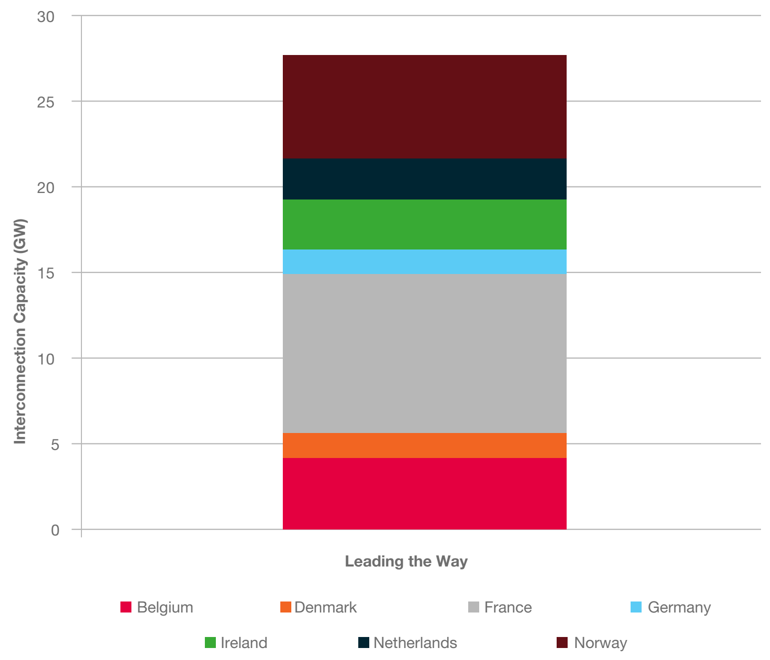
NOA / Interconnector analysis / Outcome 89

Outcome

Leading the Way shows a decline in GB and other European wholesale prices, driven by increasing levels of renewable generation. At an annual average price level, GB has some of the lowest prices in Europe, only beaten by Norway. From 2028 to the early 2030s there is a sustained ramping up of exports to the continent as increasing volumes of intermittent renewable generation are commissioned in GB, driving down prices and allowing arbitrage opportunities for renewable energy export. Exports peak in 2033 at over 100 TWh. Leading the Way shows the highest levels of exports of all the scenarios for the first half of the 2030s, but these decline slightly in the second half of the decade.

There are significant imports from both France and Norway, when prices in these two countries are lower than in GB. Throughout the 2030s there is a sustained growth in imports to GB, with Leading the Way seeing the highest levels in 2040.

Figure 6.11 Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Leading the Way



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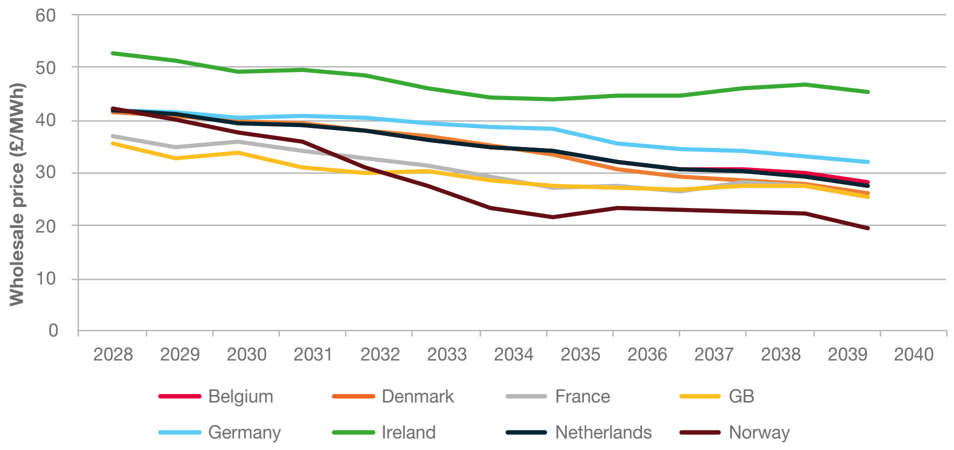

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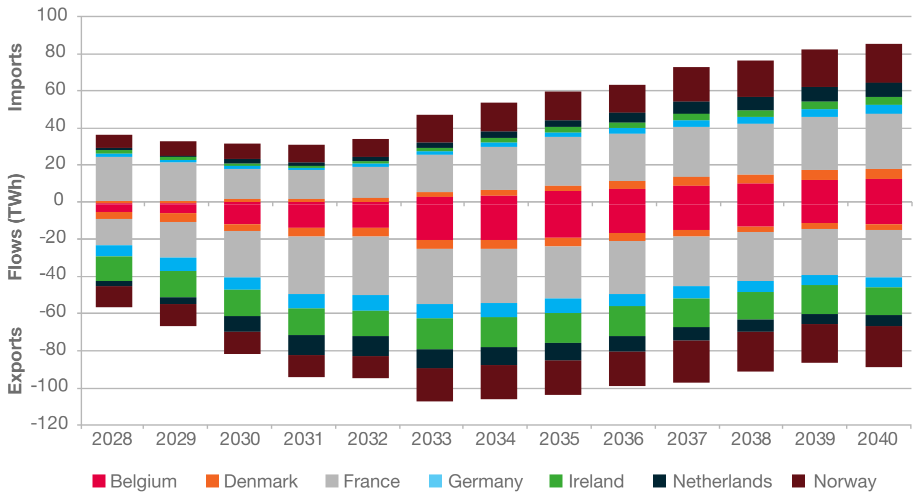

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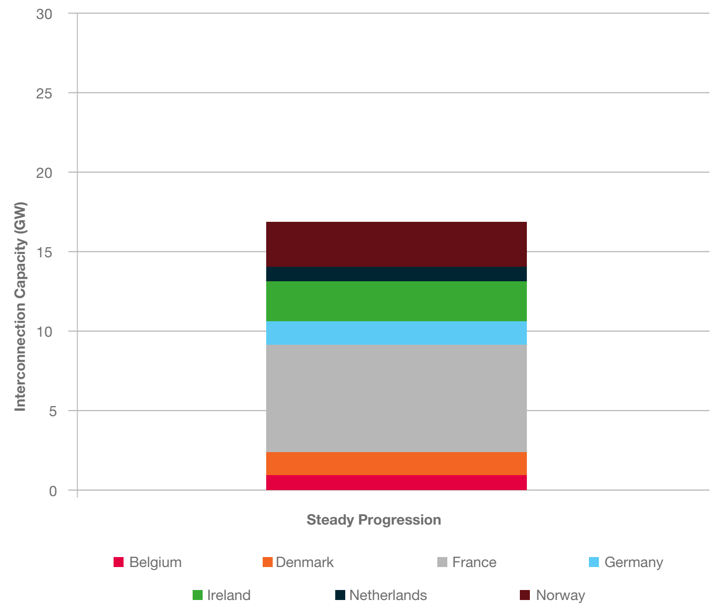
NOA / Interconnector analysis / Outcome 90

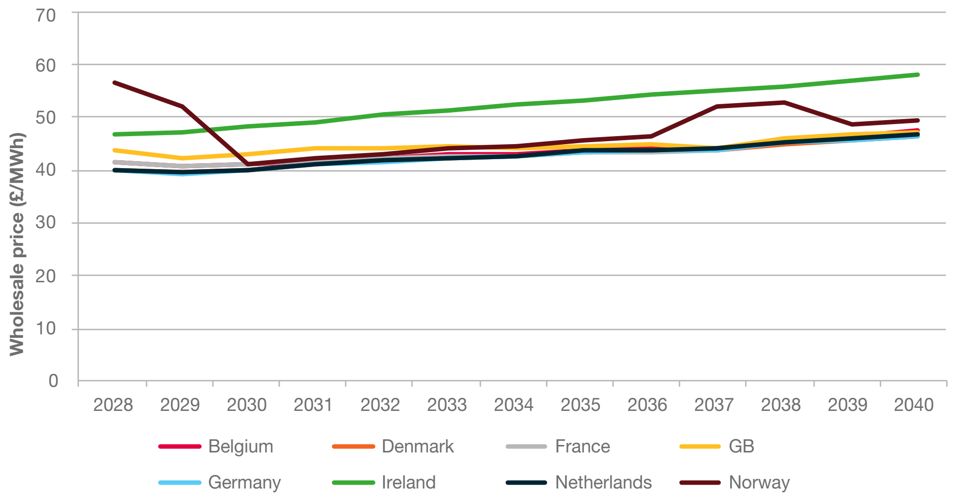
Outcome

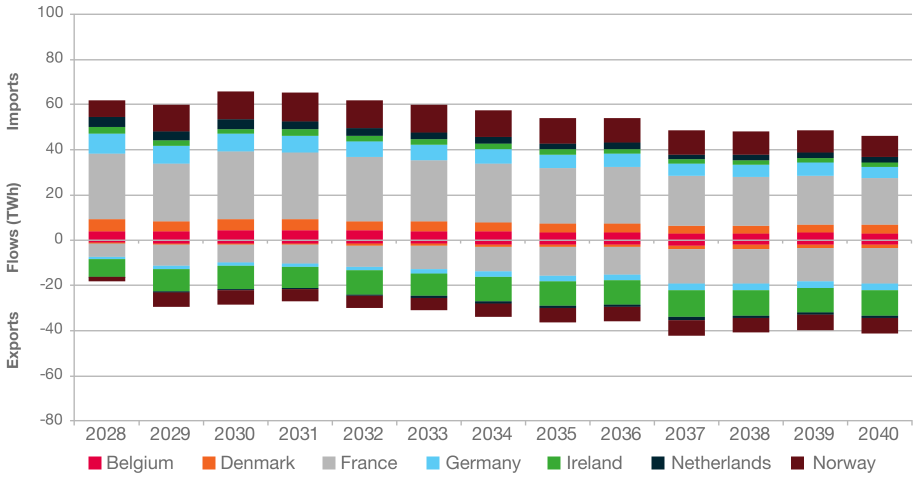
In general, Steady Progression shows GB wholesale prices to be higher than other countries, apart from Ireland. It has the highest levels of electricity prices of the four scenarios, as they are not reduced by the significant levels of renewable generation in the other three scenarios.

This leads to high import flows across the interconnectors, particularly from France, Norway and Germany. Steady Progression shows by far the lowest levels of exports of the four scenarios, as it has the lowest levels of intermittent renewable generation to drive down prices. The relatively high wholesale prices in Ireland lead to GB export arbitrage opportunities.

Figure 6.12 Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Steady Progression







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NOA / Interconnector analysis / Outcome 91

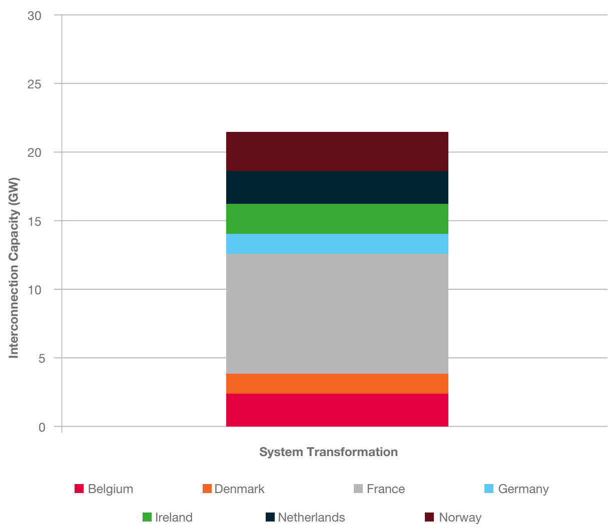
Outcome

System Transformation has some of the lowest GB and other European wholesale prices driven by increasing levels of renewable generation. Of the three scenarios that achieve net zero by 2050, System Transformation sees the lowest level of imports, as it has the highest levels of dispatchable thermal generation using hydrogen as a fuel, transported through the repurposed gas transmission and distribution networks. Throughout the 2030s exports steadily increase, and peak at roughly 120 TWh in 2038, the highest level seen across the four scenarios.

Electricity exports are highest in System Transformation because interconnectors are a source of flexibility to help balance the high levels of variable renewable generation and it has lower levels of electricity demand for electrolysis than the other net zero scenarios.

Also, the ambition to decarbonise with more centralised technologies leads to a focus on large-scale nuclear generation.

Figure 6.13 Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for System Transformation



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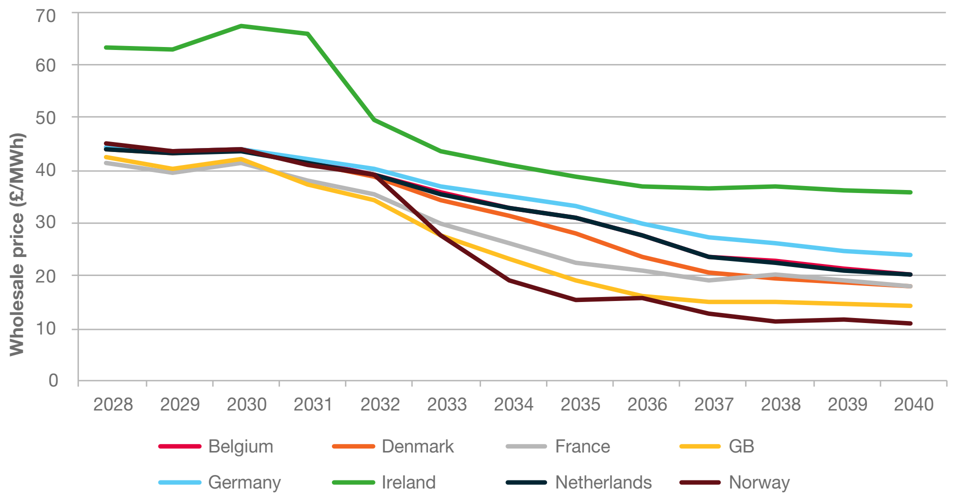

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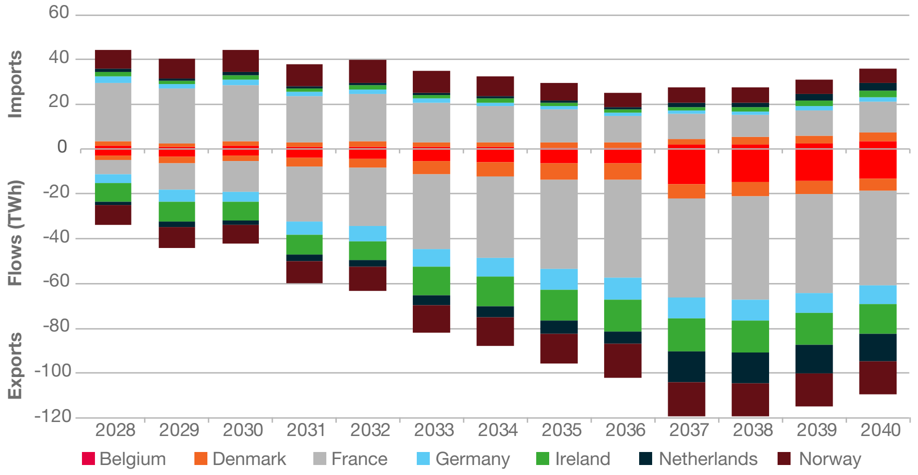

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Interaction of interconnectors and constraints

The impact of interconnectors on GB constraints costs is dependent on the location of the interconnector and the level of onshore reinforcement built to accommodate it.

Constraint costs are incurred when power in the merit order is limited by network restrictions. In this event, the System Operator will incur balancing mechanism costs from generation not able to output and offer generation elsewhere on the system to alleviate the constraint. Interconnection to different markets provides the System Operator with another balancing option. Additional interconnection to GB may either help or hinder system balancing, as balancing mechanism costs increase or decrease as network boundaries are further strained or relieved.

Flows across the GB network are from high levels of generation in the north to high levels of demand in the south. Interconnectors in the north may help alleviate constraints when exporting from GB and increase constraints when importing. Conversely, interconnectors in the south of England may reduce network constraints when importing and vice-versa.

This year, the optimal interconnection paths are short, indicating there is little opportunity for SEW value creation or constraint savings from additional interconnection. The former is due to the high level of interconnection already in the baseline for each scenario, and the latter indicates that further interconnection options do not provide significant additional constraint savings beyond that already seen in this year's *NOA*.

NOA / Interconnector analysis / Outcome 93

Environmental implications

Increased levels of interconnection bring significant benefits to GB and European consumers, through lower wholesale energy prices, greater use of renewable power and increased environmental benefits.

Reduction in CO_2 emissions

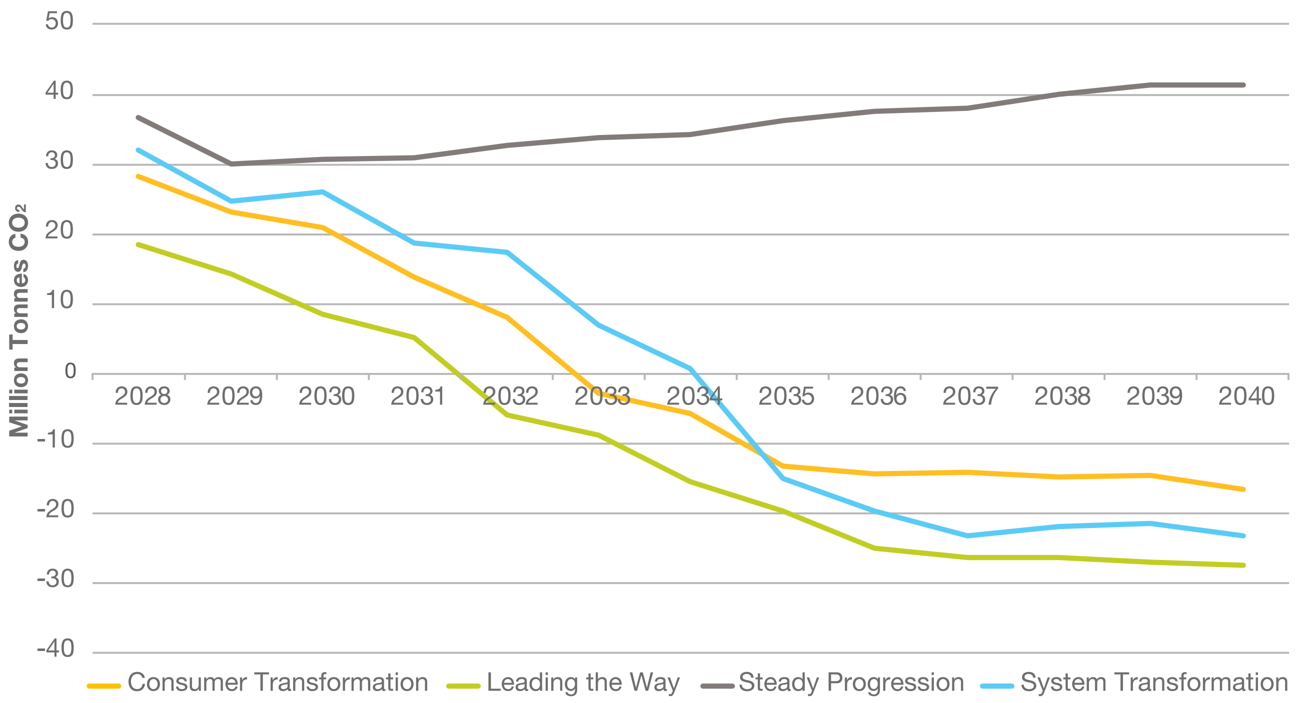
Interconnectors can increase access to renewable power, leading to reductions in CO_2. Interconnection allows surplus power from renewable generation to be exported, rather than curtailed. Figure 6.14 shows the annual CO_2 emissions from generation for each scenario for the final iteration optimal path.

In last year's *NOA* IC we compared the levels of CO_2 emissions for each scenario between the base case and the optimal path. This year, the optimal paths are so short that is of little value, so we have compared the levels of CO_2 emissions across the scenarios. The three scenarios that achieve net zero energy system emissions by 2050 all show significant decreases in CO_2 emissions in the power sector from 2028, achieving net negative emissions in the power sector by the early 2030s. Leading the Way achieves this first. Steady Progression never achieves net negative emissions in the power sector due to the significant levels of fossil fuel generation and lack of Carbon, Capture, Usage and Storage (CCUS). For Leading the Way to achieve the goal of energy system net zero by 2048, power sector emissions need to be negative by 2032.

The difference in emissions between Steady Progression and Leading the Way is roughly 70 million tonnes of CO_2 by 2040.

There is considerable uncertainty in quantifying the cost of greenhouse gas emissions, but using BEIS valuation of greenhouse gas emissions which sets a central price of carbon at £156/tonneCO_2 by 2040, this equates to over £10 bn (undiscounted) for that year.

Figure 6.14 Annual CO_2 emissions from generation for each scenario for the optimal paths



Reduction in Renewable Energy Supply (RES) curtailment

Interconnection allows surplus power from renewable generation to be exported, rather than curtailed. This may also replace more expensive fossil fuel generation, resulting in a reduction in prices and reduced curtailment of RES.

Figure 6.15 shows the annual levels of RES curtailment for Consumer Transformation and Steady Progression for the iteration one base case and for the final iteration optimal path.

Figure 6.15 shows that for Consumer Transformation, which has 106 GW of low carbon and renewable capacity by 2030, levels of RES curtailment are considerably higher than in Steady Progression, which has 82 GW of low carbon and renewable capacity by 2030. For both scenarios, in the paths with the optimal levels of additional GB interconnection, the levels of RES curtailment are lower, with Consumer Transformation roughly 24 TWh less and Steady Progression 14 TWh from 2028 to 2040. This equates to approximately 210 MW and 120 MW less RES curtailment for every hour over the thirteen-year period for Consumer Transformation and Steady Progression, respectively.

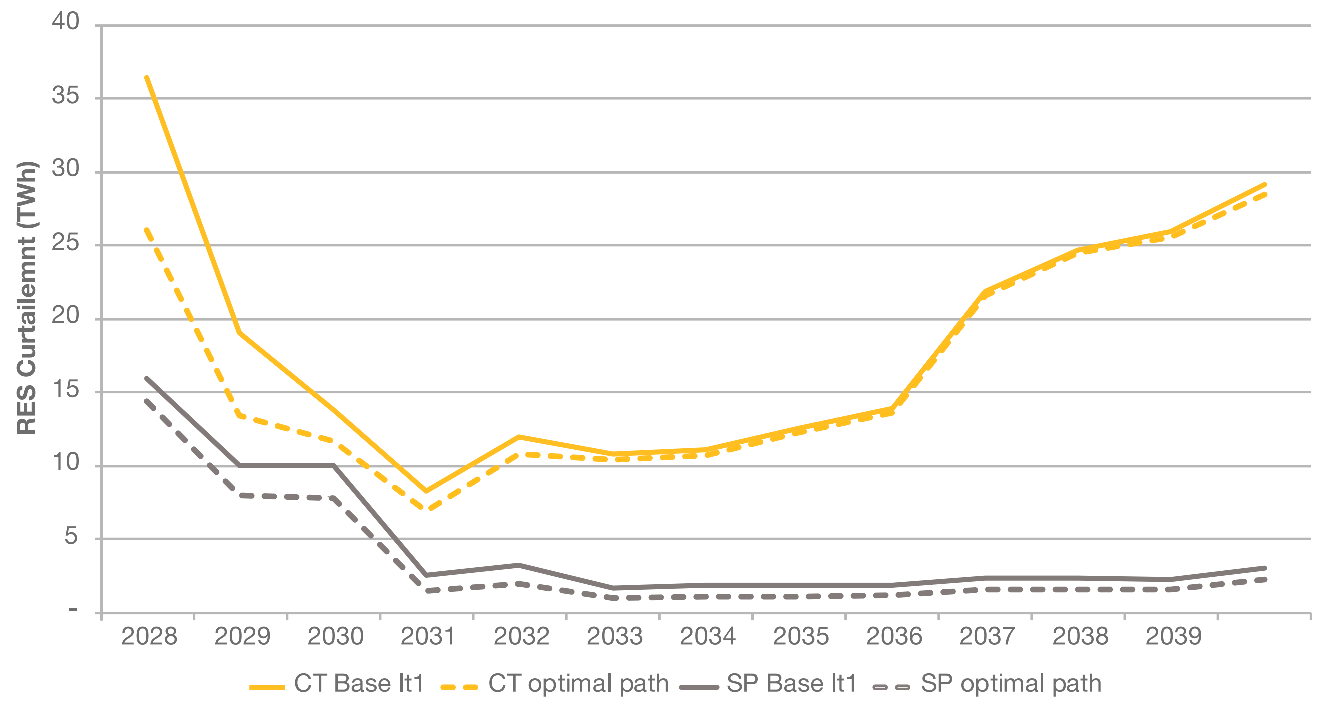


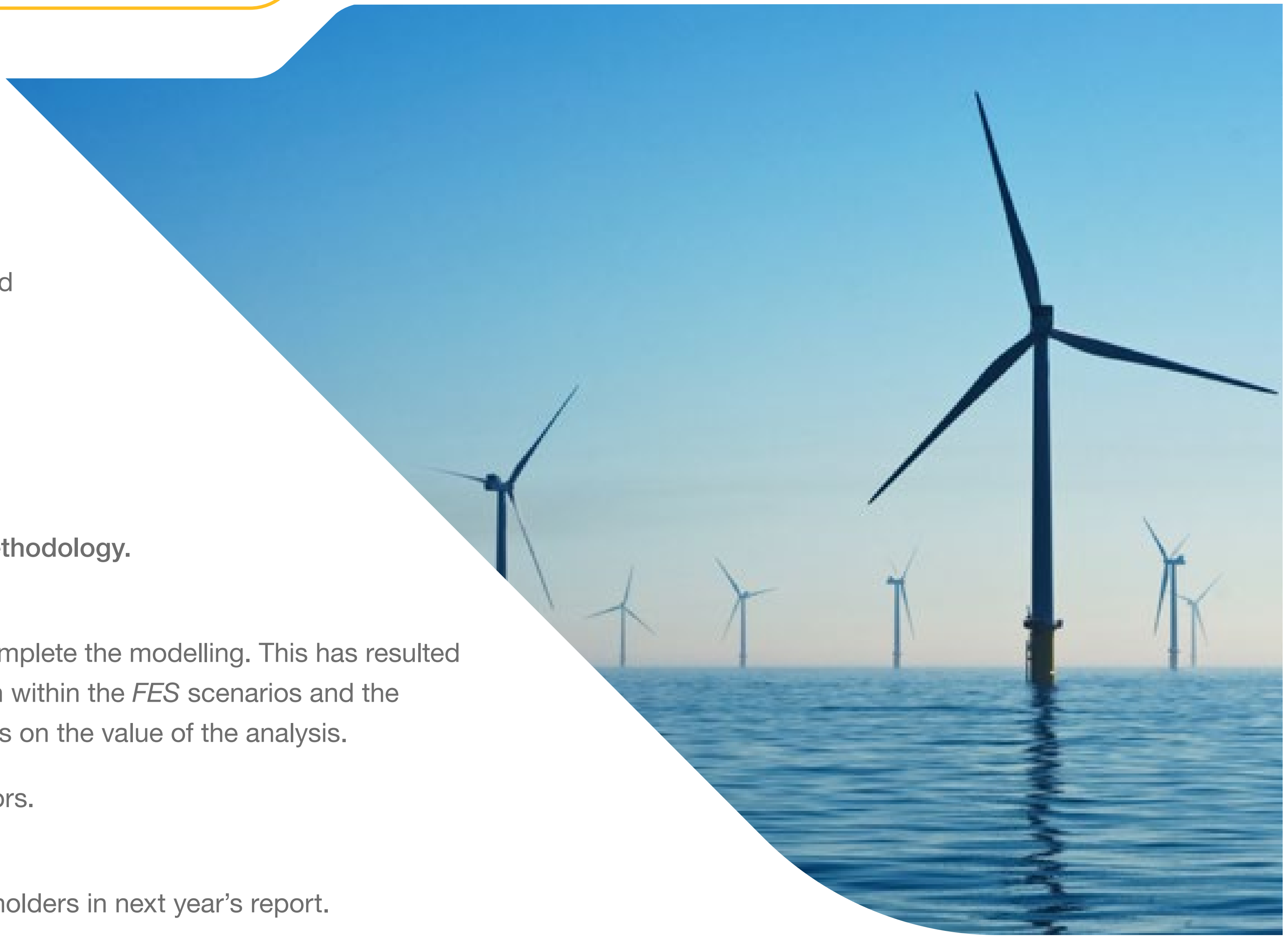
Figure 6.15 Annual levels of RES curtailment for Consumer Transformation for the base case and optimal paths

NOA / Interconnector analysis / Outcome 95

Outcome

System Operability Analysis

We have not included in this year's *NOA* IC analysis a detailed exploration of the impact of interconnectors on the ESO's requirements for system operability. Interconnector system operability analysis will feature within our National Trends and Insights report to be published in February 2021, which forms part of our System Operability Framework.



Stakeholder feedback

Have your say

We continue to rely on stakeholder feedback to develop the *NOA* for Interconnectors methodology. We want to hear your views on this year's analysis and how we can improve next year's.

This year we used the *FES* 2020 levels of interconnection as our baseline to successfully complete the modelling. This has resulted in the baseline levels and optimal paths being similar. Over time the levels of interconnection within the *FES* scenarios and the optimal paths have tended to converge. We are keen to hear your views on the impact of this on the value of the analysis.

Next year we will begin to explore the potential impacts and benefits of hybrid interconnectors. We would value your views on how we should take this work forward.

We are keen to continue to develop our *NOA* IC analysis to provide more value to our stakeholders in next year's report. What additional improvements would you like to see?

We need your help to shape next year's methodology and look forward to your involvement in 2021.

You can send us your thoughts at noa@nationalgrideso.com

NOA / Interconnector analysis / Outcome 96

Chapter 7

Stakeholder engagement

Introduction

Your feedback on the *NOA* publication helps us improve year-on-year. Our 2021 stakeholder engagement programme, which runs from when the *NOA* is published until May, is a great opportunity for you to give your views.

Your feedback is important for us to continue developing and improving the *NOA* and the *ETYS*. And because the two documents are closely related, we'll make sure the way we communicate and consult with you reflects this. We'll make sure that the *NOA* publication continues to add value by:

- collating and understanding your views and opinions
- providing opportunities for constructive debate throughout the process
- creating open and two-way communication to discuss assumptions, drivers and outputs; and
- telling you how your views have been used and reporting back on the engagement process.

The annual *NOA* review process will help us develop the publication and we encourage all parties to get involved to help us improve the publication every year.

We've redesigned our *NOA* website to provide a more intuitive and interactive experience, helping you access the results quicker and easier than before.

NOA / Stakeholder engagement / Introduction 98

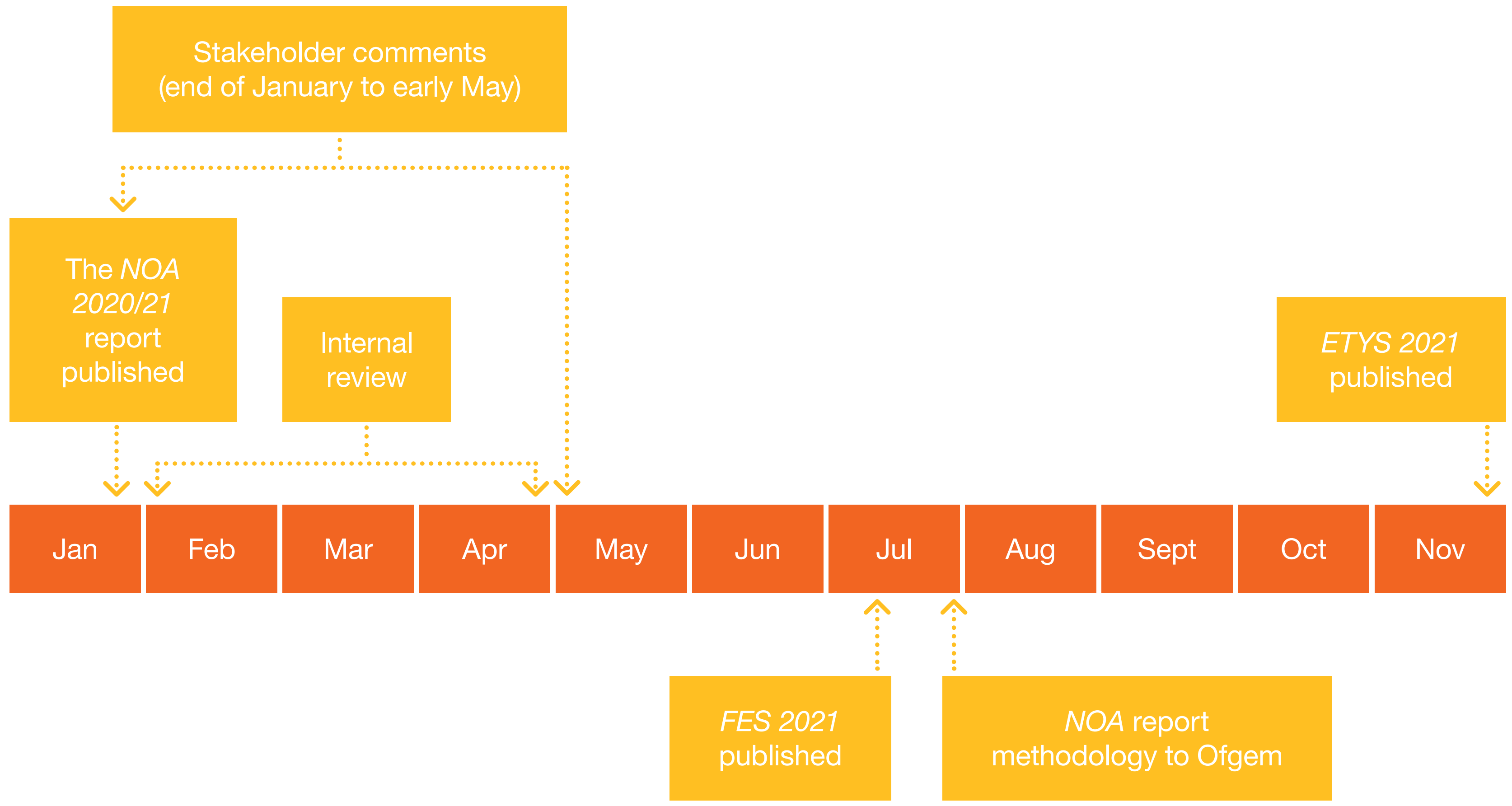
NOA methodology

Now the *NOA* is published, we'll start the review process and we look forward to having conversations with you between now and June 2021. This consultation will cover the *NOA* methodology and the look of the publication, as well as its contents. Because some parts of the *NOA* process start in May, we have already started on some of the methodology's higher-level aspirations.

Figure 7.1 shows our stakeholder activities programme and outlines our licence obligation dates.

Your feedback is important to us, and we urge you to get involved. With your early engagement, we can make sure your views are captured even before the formal consultation process begins.

Figure 7.1 *ETYS/NOA* stakeholder activities programme



NOA / Stakeholder engagement / How to get involved 99

How to get involved

Help shape the *NOA* Pathfinder projects

NOA Pathfinder projects look to resolve additional challenges on the electricity network including thermal, high voltage and stability constraints. There are three *NOA* pathfinder projects. They are:

Voltage Pathfinder	Stability Pathfinder	Constraint Management Pathfinder
Aims to find solutions to resolve regional high voltage issues.	Aims to address our immediate needs of national inertia and deliver local short circuit level needs in Scotland.	Aims to resolve network constraint issues and lower balancing costs.

- Help shape the direction of the pathfinder projects. You can do this by emailing: box.networkdevelopment.roadmap@nationalgrideso.com
- You can sign up to our mailing list to receive regular updates on progress of the *NOA* pathfinders.

NOA / Stakeholder engagement / How to get involved 100

Your feedback

We are always happy to listen to your views:

- at consultation events, such as our customer seminars
- through responses to noa@nationalgrideso.com
- at bilateral stakeholder meetings; and
- through any other means convenient for you
- you can also connect with us through social media.

We're continuing to ask readers to let us know what parts of the *NOA* are useful for them to help meet their business goals so we can continue to streamline the document. Please take the time to complete this short survey to help us understand how you use the *NOA*.

@ng_eso

National Grid ESO

National Grid ESO

NOA / Stakeholder engagement / Your feedback 101

Appendix A

Economic analysis results

Economic analysis results

NOA / Appendix A / Economic analysis results 103

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.1 Scotland and the north of England region

Code	Option description	Potential LOTI?	*NOA 2019/20* recommendation	*NOA 2020/21* recommendation	Commentary
BBNC	Beauly to Blackhillock 400kV double circuit addition (cost band: £100 million - £500 million)	Y	Do not start	Proceed	This reinforcement becomes 'critical' under three scenarios
BDUP	Uprate the Beauly to Denny 275kV circuit to 400kV		Not featured	Hold	
BLN2	Beauly to Loch Buidhe 275kV reinforcement (cost band: £100 million - £500 million)	Y	Do not start	Proceed	This reinforcement becomes 'critical' under two scenarios
BPNC[1]	A new 400kV double circuit between Blackhillock and Peterhead		Not featured	Hold	
BYRE	Reconductor Blyth to Tynemouth 275kV circuit		Not featured	Do not start	
CBEU	Creyke Beck to Keadby advance rating		Hold	Hold	
CDHW	Cellarhead to Drakelow circuits thermal uprating		Hold	Proceed	This reinforcement becomes 'critical' under three scenarios
CDP1	Power control device along Cellarhead to Drakelow		Delay	Stop	This reinforcement is no longer 'critical' under any scenario
CDP2	Power control device along Cellarhead to Drakelow		Hold	Hold	
CDP3	Additional alternative power control devices along Cellarhead to Drakelow		Do not start	Hold	
CDP4	Additional alternative power control devices along Cellarhead to Drakelow		Hold	Stop	This reinforcement is no longer 'critical' under any scenario
CDRE	Cellarhead to Drakelow reconductoring		Stop	Stop	
CENC	South east Scotland to north east England AC onshore reinforcement		Not featured	Do not start	
CGNC	A new 400kV double circuit between Creyke Beck and the south Humber region (cost band: £100 million - £500 million)	Y	Proceed	Proceed	No change
CKPC	Power control device along Creyke Beck to Keadby to Killingholme		Hold	Hold	
CLNC	New north west England to Lancashire reinforcement		Not featured	Do not start	
CMNC	South east Scotland to north west England AC onshore reinforcement (cost band: £100 million - £500 million)	Y	Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
CRPC	Power control device along Cottam to West Burton		Hold	Hold	
CS03	Commercial solution for the north of Scotland - stage 1		Not featured	Do not start	
CS04	Commercial solution for the north of Scotland - stage 2		Not featured	Do not start	
CS05	Commercial solution for Scotland and the north of England - stage 1		Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
CS06	Commercial solution for Scotland and the north of England - stage 2		Not featured	Proceed	This reinforcement is new for *NOA* 2020/21

1 In order to align with E4L5 delivery.

Economic analysis results

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Table A.1 Scotland and the north of England region (continued)

Code	Option description	Potential LOTI?	*NOA* 2019/20 recommendation	*NOA* 2020/21 recommendation	Commentary
CTP2	Alternative power control device along Creyke Beck to Thornton		Proceed	Proceed	No change
CTP3	Additional power control devices along the Creyke Beck - Thornton 1 400kV circuit		Not featured	Do not start	
CVUP	Uprating the Clydesmill to Strathaven 275kV circuits to 400kV single circuit		Not featured	Do not start	
CWPC	Power control device along Cottam to West Burton		Hold	Hold	
DEP1	Additional power control devices along the Drax - Eggborough 1 400kV circuit		Not featured	Do not start	
DEPC	Power control device along Drax to Eggborough		Hold	Hold	
DLRE	Loch Buidhe to Dounreay 275kV double circuit reconductoring		Not featured	Hold	
DLUP	Uprate the Windyhill-Lambhill-Denny North 275kV circuit to 400kV		Do not start	Hold	
DNEU	Denny North 400/275kV second supergrid transformer		Hold	Hold	
DREU	Generator circuit breaker replacement to allow Thornton to run a two-way split		Do not start	Do not start	
DWN2	Denny to Wishaw 400kV reinforcement		Do not start	Delay	A decision to invest was not deemed economical this year
DWNO	Denny to Wishaw 400kV reinforcement		Proceed	Proceed	No change
DWUP	Establish Denny North-Clydesmill-Wishaw single 400kV circuit from existing 275kV circuits		Do not start	Proceed	This reinforcement becomes 'critical' under three scenarios
E2D2	Eastern Scotland to England link: Torness to Cottam offshore HVDC		Proceed	Stop	This reinforcement is no longer 'critical' in any scenario
E2D3	Eastern Scotland to England link: Torness to Drax offshore HVDC		Do not start	Do not start	
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit (cost band: £1000 million - £1500 million)	Y	Proceed	Proceed	No change
E4D2	Eastern Scotland to England link: Peterhead to Cottam offshore HVDC		Do not start	Do not start	
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC (cost band: £2000 million - £2500 million)	Y	Proceed	Proceed	No change
E4DC	Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC		Stop	Stop	
E4L5	Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC (cost band: £2000 million - £2500 million)	Y	Proceed	Proceed	No change

NOA / Appendix A / Economic analysis results 104

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.1 Scotland and the north of England region (continued)

Code	Option description	Potential LOTI?	*NOA 2019/20* recommendation	*NOA 2020/21* recommendation	Commentary
E5L5	Eastern Scotland to England 3rd link: Blackhillock to the south Humber offshore HVDC		Do not start	Do not start	
ECU2	East coast onshore 275kV upgrade		Proceed	Proceed	No change
ECUP	East coast onshore 400kV incremental reinforcement		Proceed	Proceed	No change
ECVC	Eccles hybrid synchronous compensators and real-time rating system		Proceed	Proceed	No change
EDNC	Uprate Brinsworth and Chesterfield double circuit to 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield (cost band: £100 million - £500 million)	Y	Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
EHRE	Elvanfoot to Harker reconductoring		Stop	Hold	
FBRE	Beauly to Fyrish 275kV double circuit reconductoring		Do not start	Do not start	
FINS	East coast 132kV upgrade		Do not start	Do not start	
GWNC	A new 400kV double circuit between the south Humber area and south Lincolnshire (cost band: £500 million - £1000 million)	Y	Proceed	Proceed	No change
HAE2	Harker supergrid transformer 6 replacement		Proceed	Proceed	No change
HAEU	Harker supergrid transformer 5 and supergrid transformer 9A banking arrangement		Proceed	Proceed	No change
HFRE	Reconductor Harker to Fourstones double circuit		Do not start	Do not start	
HNNO	Hunterston East–Neilston 400kV reinforcement		Proceed	Proceed	No change
HSP3	Additional power control device along Harker to Stella West		Not featured	Do not start	
HSR1	Reconductor Harker to Stella West		Hold	Stop	
KBRE	Knocknagael to Blackhillock 275kV double circuit reconductoring		Stop	Stop	
KWHW	Keadby to West Burton circuits thermal uprating		Hold	Hold	
KWPC	Power control device along Keadby to West Burton		Hold	Hold	
LBRE	Beauly to Loch Buidhe 275kV double circuit OHL reconductoring		Hold	Hold	
LCU2	Eastern 400kV reinforcement		Not featured	Do not start	
LRNC	South Lincolnshire to Rutland reinforcement	Y	Not featured	Hold	
LWUP	Longannet 400kV reinforcement		Not featured	Do not start	

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.1 Scotland and the north of England region (continued)

Code	Option description	Potential LOTI?	*NOA* 2019/20 recommendation	*NOA* 2020/21 recommendation	Commentary
MRP1	Power control device along Penwortham to Washway Farm to Kirkby		Do not start	Do not start	
MRP2	Additional power control devices at both Harker and Penwortham		Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
NEMS	225MVAr MSCs within the north east region		Hold	Hold	
NEP1	Power control device along Blyth to Tynemouth and Blyth to South Shields		Proceed	Hold	This reinforcement is no longer 'critical' in any scenario
NEPC	Power control device along Blyth to Tynemouth and Blyth to South Shields		Hold	Hold	
NOPC	Power control device along Norton to Osbaldwick		Hold	Hold	
NOR1	Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit		Stop	Stop	
NOR2	Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit		Proceed	Stop	This reinforcement has been superceded by new reinforcement NOR5
NOR4	Reconductor 13.75km of Norton to Osbaldwick number 2 400kV circuit		Hold	Hold	
NOR5	Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit to a higher rated conductor		Not featured	Hold	
NSM1	225MVAr MSCs within the north east region		Not featured	Hold	
NSM2	225MVAr MSCs within the north east region		Not featured	Do not start	
NSM3	225MVAr MSCs within the north east region		Not featured	Do not start	
OENO	A new 400kV double circuit within Yorkshire between Eggborough and Osbaldwick		Stop	Stop	
OPN1	A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 400kV upgrades		Do not start	Do not start	
OPN2	A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades (cost band: £100 million - £500 million)	Y	Proceed	Proceed	No change
OPN4	A new alternative 400kV double circuit between the existing Norton to Osbaldwick and Poppleton and relevant 275kV upgrades		Do not start	Do not start	
OPN5	A new 400kV double circuit between the existing Norton to Osbaldwick and Poppleton and relevant 275kV and 400kV upgrades		Not featured	Do not start	
PFRE	Reconductor Penwortham to Washway Farm 275kV double circuit		Not featured	Do not start	

NOA / Appendix A / Economic analysis results 106

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.1 Scotland and the north of England region (continued)

Code	Option description	Potential LOTI?	*NOA* 2019/20 recommendation	*NOA* 2020/21 recommendation	Commentary
PMU1	Yorkshire reinforcement upgrade 1		Not featured	Do not start	
PMU2	Yorkshire reinforcement upgrade 2		Not featured	Do not start	
PSDC	Spittal to Peterhead HVDC reinforcement		Not featured	Do not start	
PWMS	Two 225MVAr MSCs at Penwortham		Hold	Hold	
SBDC	Spittal to Blackhillock HVDC reinforcement		Not featured	Hold	
SBRE	Reconductor South Shields to West Boldon 275kV circuit		Not featured	Do not start	
SHNS	Upgrade substation in the south Humber area		Proceed	Proceed	No change
SLU2	Loch Buidhe to Spittal 275kV reinforcement		Not featured	Do not start	
SNHW	Spennymoor to Norton circuit thermal uprating		Not featured	Do not start	
SSHW	Stella West to Spennymoor circuit thermal uprating		Not featured	Hold	
TBRE	Reconductor Tynemouth to West Boldon 275kV circuit		Not featured	Do not start	
TDP2	Additional power control device along Drax to Thornton		Hold	Hold	
TDPC	Power control device along Drax to Eggborough		Hold	Hold	
TDR1	Reconductor Drax to Thornton 2 circuit		Not featured	Hold	
TDR2	Reconductor Drax to Thornton 1 circuit		Not featured	Hold	
TFPC	Power control device on Tealing to Westfield circuit		Not featured	Hold	
TGDC	Eastern subsea HVDC Link from south east Scotland to south Humber area (cost band: £1500 million - £2000 million)	Y	Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
THDC	Alternative staged eastern subsea HVDC link from Torness to Hawthorn Pit		Not featured	Do not start	
THS1	Installation of a single series reactor at Thornton substation		Proceed	Proceed	No change
TKU2	Alternative east coast onshore phase 2 reinforcement		Not featured	Do not start	
TKUP	East coast onshore 400kV phase 2 reinforcement		Do not start	Do not start	
TLNO	Torness to north east England AC onshore reinforcement		Proceed	Stop	This reinforcement has been superceded by new reinforcement CMNC

NOA / Appendix A / Economic analysis results 107

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.1 Scotland and the north of England region (continued)

Code	Option description	Potential LOTI?	*NOA* 2019/20 recommendation	*NOA* 2020/21 recommendation	Commentary
TTNC	New north east England to north Yorkshire reinforcement		Not featured	Do not start	
TUEU	Tummel reconfiguration		Do not start	Do not start	
WHTI	Tee-in of the West Boldon to Hartlepool circuit at Hawthorn Pit		Proceed	Proceed	No change
WLTI	Windyhill–Lambhill–Longannet 275kV circuit turn-in to Denny North 275kV substation		Delay	Proceed	This reinforcement becomes 'critical' under three scenarios
WORE	Reconductor West Boldon to Offerton 275kV circuit		Not featured	Do not start	
WRRE	Reconductor West Burton to Ratcliffe-on-Soar circuit		Do not start	Hold	

NOA / Appendix A / Economic analysis results 108

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.2 South and east of England region

Code	Option description	Potential LOTI?	*NOA 2019/20* recommendation	*NOA 2020/21* recommendation	Commentary
AENC	A new 400kV double circuit in north East Anglia (Cost band: £100 million - £500 million)	Y	Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
ATNC	A new 400kV double circuit in south East Anglia (Cost band: £100 million - £500 million)	Y	Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
BFHW	Bramley to Fleet circuits thermal uprating		Hold	Hold	
BFPC	Power control device along Bramley to Fleet		Not featured	Hold	
BFRE	Bramley to Fleet reconductoring		Hold	Hold	
BMM2	225MVAr MSCs at Burwell Main		Proceed	Proceed	No change
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh main circuit		Proceed	Proceed	EISD submitted for *NOA* 2020/21 is one year earlier
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route		Proceed	Hold	This reinforcement is no longer 'critical' under any scenario
BTNO	A new 400kV double circuit between Bramford and Twinstead (Cost band: £100 million - £500 million)		Proceed	Proceed	No change
BWRE	Reconductor Barking to West Ham double circuit		Do not start	Hold	
CS07	Commercial solution for East Anglia - stage 1		Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
CS08	Commercial solution for East Anglia - stage 2		Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
CS09	Commercial solution for the south coast - stage 1		Not featured	Do not start	
CS10	Commercial solution for the south coast - stage 2		Not featured	Do not start	
CTRE	Reconductor remainder of Coryton South to Tilbury circuit		Hold	Proceed	This reinforcement becomes 'critical' under all scenarios
ESC1	Second Elstree to St John's Wood 400kV circuit		Hold	Hold	
FMHW	Feckenham to Minety circuit thermal uprating		Not featured	Hold	
FMPC	Power control device along Feckenham to Minety		Not featured	Hold	
FMRE	Feckenham to Minety circuit reconductoring		Not featured	Do not start	
FWPC	Power control device along Feckenham to Walham		Not featured	Hold	

NOA / Appendix A / Economic analysis results 109

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.2 South and east of England region (continued)

Code	Option description	Potential LOTI?	*NOA 2019/20* recommendation	*NOA 2020/21* recommendation	Commentary
HBUP	Uprate Bridgewater to 400kV and reconductor the route to Hinkley		Hold	Stop	
HENC	Hertfordshire reinforcement		Not featured	Do not start	
HWUP	Uprate Hackney, Tottenham and Waltham Cross 275kV to 400kV	Y	Stop	Proceed	This reinforcement becomes 'critical' under all scenarios. Change is due to updated technical data provided for *NOA* 2020/21
IFHW	Feckenham to Ironbridge circuit thermal uprating		Not featured	Hold	
IFR1	Feckenham to Ironbridge circuit reconductoring		Not featured	Do not start	
MBHW	Bramley to Melksham circuits thermal uprating		Proceed	Hold	This reinforcement is no longer 'critical' under any scenario
MBRE	Bramley to Melksham reconductoring		Hold	Hold	
NBRE	Reconductor Bramford to Norwich double circuit		Hold	Hold	
NIM1	225MVAr MSCs at Ninfield		Not featured	Hold	
NIM2	225MVAr MSCs at Ninfield		Not featured	Hold	
NOM1	225MVAr MSCs at Norwich		Hold	Hold	
NOM2	225MVAr MSCs at Norwich		Hold	Hold	
NTP1	Power control device along North Tilbury		Proceed	Hold	This reinforcement is no longer 'critical' under any scenario
PEM1	225MVAr MSCs at Pelham		Hold	Proceed	This reinforcement becomes 'critical' under two scenarios
PEM2	225MVAr MSCs at Pelham		Hold	Proceed	This reinforcement becomes 'critical' under two scenarios
RHM1	225MVAr MSCs at Rye House		Hold	Proceed	This reinforcement becomes 'critical' under one scenario
RHM2	225MVAr MSCs at Rye House		Hold	Proceed	This reinforcement becomes 'critical' under one scenario
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit		Proceed	Proceed	No change
SCD1	New offshore HVDC link between Suffolk and Kent option 1 (Cost band: £1000 million - £1500 million)	Y	Proceed	Proceed	No change
SCD2	New offshore HVDC link between Suffolk and Kent option 2		Hold	Stop	
SCN1	New 400kV transmission route between south London and the south coast		Stop	Stop	

NOA / Appendix A / Economic analysis results 110

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.2 South and east of England region (continued)

Code	Option description	Potential LOTI?	*NOA* 2019/20 recommendation	*NOA* 2020/21 recommendation	Commentary
SEEU	Reactive series compensation protective switching scheme		Proceed	Hold	This reinforcement is no longer 'critical' under any scenario
SER1	Elstree to Sundon reconductoring		Proceed	Proceed	No change
SER2	Elstree–Sundon 2 circuit turn-in and reconductoring		Hold	Hold	
TENC	Thames Estuary reinforcement (Cost band: £100 million - £500 million)	Y	Not featured	Proceed	This reinforcement is new for *NOA* 2020/21
TGP1	Power control device along Tilbury to Grain		Not featured	Hold	
THRE	Reconductor Hinkley Point to Taunton double circuit		Hold	Hold	
TKP1	Power control device along Tilbury to Kingsnorth		Not featured	Hold	
TKRE	Tilbury to Grain and Tilbury to Kingsnorth upgrade	Y	Proceed	Hold	This reinforcement is no longer 'critical' under any scenario
WAM1	225MVAr MSCs at Walpole		Hold	Hold	
WAM2	225MVAr MSCs at Walpole		Hold	Hold	
WSEU	Thermal upgrade for Sundon and Wymondley 400kV substation		Not featured	Hold	
WSR1	Sundon-Wymondley circuit 1 reconductoring		Not featured	Hold	
WSR2	Sundon-Wymondley circuit 2 reconductoring		Not featured	Hold	
WTUP	Uprate Tilbury to Waltham Cross route from 275kV to 400kV		Not featured	Do not start	
WYTI	Wymondley turn-in		Hold	Hold	

NOA / Appendix A / Economic analysis results 111

Economic analysis results

Tables A.1–3 present the results from our cost–benefit analysis. The results present the recommendations from last year's *NOA* for comparison and indicate whether an option meets the criteria as a LOTI project. We also include cost bands for options with a "Proceed" recommendation that satisfy the competition criteria. These options and their cost bands have been highlighted.

Table A.3 Wales

Code	Option description	Potential LOTI?	*NOA* 2019/20 recommendation	*NOA* 2020/21 recommendation	Commentary
MIC1	Cable replacement at Severn Tunnel	Y	Not featured	Hold	
PTC1	Pentir to Trawsfynydd cable replacement	Y	Not featured	Hold	
PTNO	North Wales reinforcement	Y	Not featured	Delay	A decision to invest was not deemed economical this year
WCC1	Cable replacement at Hinksey		Not featured	Hold	

NOA / Appendix A / Economic analysis results 112

Appendix B

LOTI projects

B.1 Eastern network reinforcement

1. Background

The scope of reinforcements included for the eastern network in the northern region includes offshore HVDC links as well as onshore reinforcement. These projects increase capability on one or more of the MITS boundaries, B1a, B2, B4, B5, B6, B7, B7a and B8. The objective is to increase the north-to-south transfer capability on the east coast of the Scottish and northern England transmission system between boundaries B1a in the Scottish Hydro Electric Transmission (SHE Transmission) area and B8 in the National Grid Electricity Transmission (NGET) area. This will safely enable greater volumes of north-to-south power flows arising from predominantly new renewable generation in Scotland. This includes key boundaries between SHE Transmission and SP Transmission (B4) and between SP Transmission (SPT) and NGET (B6). Several reinforcements are proposed in accordance with the NETS SQSS[1] and under the Transmission Owners' obligations in their transmission licences.

We have assessed six permutations of the early subsea HVDC link options for potential landing points within the north of England:

- E4DC – Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC
- E4D2 – Eastern Scotland to England link: Peterhead to Cottam offshore HVDC
- E4D3 – Eastern Scotland to England link: Peterhead to Drax offshore HVDC
- E2DC – Eastern subsea HVDC link from Torness to Hawthorn Pit
- E2D2 – Eastern Scotland to England link: Torness to Cottam offshore HVDC
- E2D3 – Eastern Scotland to England link: Torness to Drax offshore HVDC

We also added a further option this year to test optimal capacity of the E2DC link, where a staged approach to delivering a 2.8GW link as an alternative to the assumed 2GW of the above, in the form of THDC option. This is due in part to the increasing levels of generation expected local to the Torness area in SPT's area.

The links from Peterhead along with associated onshore works, can increase transfer capability on boundaries B1a down to B8[2]. The links from Torness increase transfer capability on boundaries B6 down to B8[3].

The scope of the eastern onshore reinforcements involves increasing the capacity of the existing eastern onshore circuits between Blackhillock and Kincardine that cross B1a, B2 and B4, by initially augmenting their capability at 275kV. Further uplift in capacity will be delivered by uprating these circuits to operate at 400kV. Both projects have consistently been identified as 'critical' and are included within the RIIO-T2 base allowance. Additionally, onshore network reinforcement is included to develop the network in the central belt of Scotland and increase the capability of the B5 boundary by establishing a new 400kV corridor between Denny and Wishaw in the SPT network.

To reflect the significant increase in system transfer requirements driven by the new Net Zero *Future Energy Scenarios*, several additional options were included. These include additional onshore reinforcements, as well as further offshore HVDC links between the north east of Scotland (Peterhead) and England and between the south east of Scotland (in the Torness area) and England:

- E4L5 – Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC
- E5L5 – Eastern Scotland to England 3rd link: Blackhillock to the south Humber offshore HVDC
- TGDC - Eastern subsea HVDC link from south east Scotland to south Humber area
- TLNO – Torness to north east England AC onshore reinforcement

1 The NETS SQSS is the National Electricity Transmission System Security and Quality of Supply Standard. GB Transmission Owners have licence obligations to develop their transmission systems in accordance with the NETS SQSS.
2 Depending on onshore location in the north of England.
3 Depending on onshore location in the north of England.

LOTI projects

- CMNC – South east Scotland to north west England AC onshore reinforcement
- CENC – South east Scotland to north east England AC onshore reinforcement
- CLNC – New north west England to Lancashire reinforcement
- TTNC – New north east England to north Yorkshire reinforcement

The additional HVDC links from Peterhead and Blackhillock can increase transfer capability on boundaries B1a down to B8[4]. The additional HVDC link from Torness increases transfer capability on boundaries B6 down to B8[5].

The recommendation from the 2020/21 *NOA* process is to progress the following reinforcements for the eastern network in the northern region this year to maintain the earliest in-service date (EISD):

- ECU2 - East coast onshore 275kV upgrade
- ECUP - East coast onshore 400kV incremental reinforcement
- E2DC – Eastern subsea HVDC link: Torness to Hawthorn Pit
- E4D3 – Eastern Scotland to England link: Peterhead to Drax offshore HVDC
- DWNO - Denny to Wishaw 400kV reinforcement
- E4L5 – Eastern Scotland to England 3rd link: Peterhead to the south Humber Offshore HVDC
- TGDC – Eastern subsea HVDC link from south east Scotland to south Humber area
- CMNC – South east Scotland to north west England AC onshore reinforcement

The need to reinforce the transmission network is driven by the growth of mainly renewable generation and interconnectors in the SHE Transmission, SPT and NGET (north England) areas, including offshore windfarms and interconnectors situated in the Moray Firth, in the Firth of Forth and off the north east coast of England. Required transfers for boundaries B4, B6, B7, B7a and B8 for the four 2020 *Future Energy Scenarios* can be found in sections 3.1 and 3.2 (in chapter 3) of the *ETYS* 2020. The figures also show current network capabilities across the boundaries, as well as the annual power flow for each scenario. Expected future power flows are greatly above current network capability. Further information on how to interpret these boundary graphs is included in this year's *ETYS*. The difference between the required transfers and the network capability shows a need for further network reinforcement, which is assessed economically against cost of constraints via the *NOA* process.

2. Option development

Reinforcement options have been developed in the eastern network in the northern region to improve boundary capability across boundaries B1a to B8. These consider onshore and offshore solutions and are at varying levels of development. To reflect the significant increase in system transfer requirements for this year, we have proposed additional options which include additional onshore reinforcements and further offshore HVDC links between the North of Scotland and England and between the South East of Scotland and England.

2.1 Notable Options

(a) East coast onshore 275kV upgrade (ECU2)

Establish a new 275kV substation at Alyth, including shunt reactive compensation, extend Tealing 275kV substation and install two phase shifting transformers; re-profile the 275kV circuits between Kintore, Alyth and Kincardine, and Tealing, Westfield and Longannet, and uprate the cable sections at Kincardine and Longannet. This option provides additional transmission capacity across boundaries B1a, B2 and B4 and is included within the RIIO-T2 base allowance.

(b) East coast onshore 400kV incremental reinforcement (ECUP)

Following ECU2, establish a new 400kV substation at Kintore, uprate Alyth substation for 400kV operation, re-insulate the 275kV circuits between Blackhillock, Peterhead,

4 Depending on onshore location in the north of England.
5 Depending on onshore location in the north of England.

LOTI projects

Rothienorman, Kintore, Fetteresso, Alyth and Kincardine for 400kV operation and install phase shifting transformers at Blackhillock. This provides additional transmission capacity across boundaries B1a, B2 and B4 and is included within the RIIO-T2 base allowance.

(c) Denny to Wishaw 400kV reinforcement (DWNO)

Construct a new 400kV double circuit from Bonnybridge to Newarthill and reconfigure associated sites to establish a fourth north-to-south double circuit supergrid route through the Scottish central belt.

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

Ahead of the completion of DWNO, there may be benefit in completing option DWUP, using existing 275kV overhead line circuits ahead of the construction of a new double circuit, reconfigured to establish a 400kV single circuit between Denny North, Clydesmill and Wishaw. If completed in combination with DWNO the result is two new additional 400kV circuits over B5, establishing a total of three 400kV circuits over B5.

(d) Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC (E4DC)

Construct a new offshore 2GW HVDC subsea link from Peterhead to Hawthorn Pit (north of England), including AC/DC converter stations and associated AC onshore works at both ends of the link. At Hawthorn Pit, works include a new 400kV Hawthorn Pit substation, uprating of the Hawthorn Pit–Norton circuit and associated circuit reconfiguration works in the area. This provides additional transmission capacity across boundaries, B1a, B2, B4, B5, B6, B7, and B7a.

(e) Eastern Scotland to England link: Peterhead to Cottam offshore HVDC (E4D2)

Construct a new offshore 2GW HVDC subsea link from Peterhead to Cottam (north Nottinghamshire), including AC/DC converter stations and associated AC onshore works at both ends of the link. The works at Cottam connect into a spare bay at Cottam 400kV substation. This provides additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, B7a and B8.

(f) Eastern Scotland to England link: Peterhead to Drax offshore HVDC (E4D3)

Construct a new offshore 2GW HVDC subsea link from Peterhead to Drax (Yorkshire), including AC/DC converter stations and associated AC onshore works at both ends of the link. At Peterhead, work includes the upgrade of the 275kV circuits along the Blackhillock–Rothienorman–Peterhead route to 400kV operation. Work at Drax involves connecting into a new bay at the 400kV substation and may also include associated fault level mitigation. This gives additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, B7a and B8.

(g) Eastern subsea HVDC link from Torness to Hawthorn Pit

Construct a new offshore 2GW HVDC subsea link from the Torness area to Hawthorn Pit, including AC/DC converter stations and associated AC works. The AC onshore works in the Torness area include extension of the pre-existing 'Branxton 400kV substation' by two 400kV GIS bays to provide connection to the 'Branxton Converter Station'. At Hawthorn Pit a new 400kV Hawthorn Pit substation will be needed, along with uprating the Hawthorn Pit–Norton circuit and associated circuit reconfiguration works. This provides additional transmission capacity across boundaries B6, B7 and B7a.

(h) Eastern Scotland to England link: Torness to Cottam offshore HVDC (E2D2)

Construct a new offshore 2GW HVDC subsea link from the Torness area to Cottam, including

NOA / Appendix B / LOTI projects 116

LOTI projects

AC/DC converter stations and associated AC works at Torness and Cottam. The AC onshore works around Torness include extension of the pre-existing 'Branxton 400kV substation' by two 400kV GIS bays to connect to the 'Branxton Converter Station'. The AC onshore works at Cottam connect into a spare bay at the 400kV substation. This provides additional transmission capacity across boundaries B6, B7, B7a and B8.

(i) Eastern Scotland to England link: Torness to Drax offshore HVDC (E2D3)

Construct a new offshore 2GW HVDC subsea link from the Torness area to Drax, including AC/DC converter stations and associated AC works at Torness and Drax. AC onshore works around Torness include extension of the pre-existing 'Branxton 400kV substation' by two 400kV GIS bays connecting to the 'Branxton Converter Station'. Work at Drax includes connecting into a new bay at the 400kV substation and may also include associated fault level mitigation. This provides additional transmission capacity across boundaries B6, B7, B7a and B8.

(j) Alternative staged eastern subsea HVDC link from Torness to Hawthorn Pit (THDC)

Construct a two-stage 2.8GW HVDC subsea link from Torness to Hawthorn Pit, in two 1.4GW stages. The AC onshore works around Torness include extension of the pre-existing 'Branxton 400kV substation' by two 400kV GIS bays to connect to the 'Branxton Converter Station'. At Hawthorn Pit work includes a new 400kV substation, uprating of the Hawthorn Pit–Norton circuit and associated circuit reconfiguration works. This provides additional transmission capacity across boundaries B6, B7 and B7a.

(k) Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC (E4L5)

Following completion of both the first (E2DC) and second (E4D3) eastern HVDC links from Scotland to the north east of England construct a second offshore 2GW HVDC subsea link from Peterhead terminating at a substation in the south Humber area. Works to include AC/DC converter stations and associated AC onshore works at both ends of the link. The required works at the Peterhead end include a new 400kV double circuit between Blackhillock and Peterhead via New Deer (BPNC). In south Humber works include substation equipment and circuit upgrades once the best location has been identified. This provides additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, B7a and B8.

(l) Eastern Scotland to England 3rd link: Blackhillock to the south Humber offshore HVDC (E5L5)

Following completion of both the first (E2DC) and second (E4D3) Eastern HVDC Links from Scotland to the north east of England construct a 2GW HVDC subsea link from Blackhillock terminating at a substation in the south Humber area. Works to include AC/DC converter stations and associated AC onshore works at both ends of the link. Work in south Humber includes substation equipment and circuit upgrades once the best location has been identified. This provides additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, B7a and B8.

(m) Eastern subsea HVDC link from south east Scotland to south Humber area (TGDC)

Following completion of both the first (E2DC) and second (E4D3) Eastern HVDC Links from Scotland to the north east of England construct a 2GW HVDC subsea link from the Torness area terminating at a substation in the south Humber area. Works to include AC/DC converter stations and AC onshore works at both ends of the link. This provides additional transmission capacity across boundaries B6, B7, B7a and B8.

(n) South east Scotland to north west England AC onshore reinforcement (CMNC)

Install a new 400kV double circuit from a substation in the south-east of the SPT area to a substation in NGET's north west area, and install new substation equipment. This forms a new east-west circuit crossing the B6 boundary and is also required to facilitate large renewable connection applications in the Scottish borders, which cannot be supported without major new built transmission assets.

NOA / Appendix B / LOTI projects 117

LOTI projects

(o) South east Scotland to north east England AC onshore reinforcement (CENC)

Install a new 400kV double circuit from a substation in the south-east of the SPT area to a substation in NGET's north east area, and new substation equipment. This forms a new circuit crossing the B6 boundary and is also required to facilitate large renewable connection applications in the Scottish borders, which cannot be supported without major new built transmission assets.

(p) Torness to north east England AC onshore reinforcement (TLNO)

Install a new double circuit from a new 400kV substation in the Torness area to the transmission system in north east England. Construct a new 400kV double circuit from the Torness area to a suitable connection point in north east England, including additional substation equipment. This provides additional thermal capacity across boundaries B6, B7 and B7a.

2.2 Lead options

In the 2020/21 *NOA*, ECU2, ECUP, E2DC, DWNO (or the alternative staged approach). E4D3, E4L5, TGDC and CMNC have been identified as the most efficient and beneficial reinforcements.

(a) East coast onshore 275kV upgrade (ECU2)

ECU2 has a "Proceed" recommendation in *NOA* 2020/21. It is justified in all four 2020 *FES* and has been identified as 'critical' for four consecutive years. It reinforces boundary B1a to B4 and is the earliest reinforcement option to release B4 boundary constraints with its EISD of 2023. ECU2 is included in the RIIO-T2 base allowance.

(b) East coast onshore 400kV incremental reinforcement (ECUP)

ECUP is in the 'optimal' path and 'critical' in all four scenarios. As a further onshore network upgrade to ECU2 on the east coast, it unlocks system constraints from B2 to B4, especially boundary B4. It has a "Proceed" recommendation and is also included in the RIIO-T2 base allowance.

(c) Eastern subsea HVDC link from Torness to Hawthorn Pit (E2DC)

E2DC is in the 'optimal' path and 'critical' in all four *FES* 2020. It unlocks transmission constraints across boundary B5 to B7a from 2027 onwards. With help of B7a and B8 reinforcements transporting Scottish energy further south, E2DC is required as early as possible to maximise its value.

(d) Eastern Scotland to England link: Peterhead to Cottam offshore HVDC (E4D3)

E4D3 is identified in the 'optimal' path and 'critical' in all four 2020 *FES*. An eastern Link from Peterhead has been 'critical' for five years, with E4D3 being the recommended option for the last three years. It provides additional boundary capability between B1a and B8.

(e) Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC (E4L5)

E4L5 is identified in the 'optimal' reinforcement path and 'critical' across all four of the 2020 *FES*. It has been Identified as 'critical' for the last two years. Following completion of both the first (E2DC) and second (E4D3) eastern HVDC Links E4L5 together with associated onshore reinforcement works satisfies the additional system transfer requirements, providing further boundary capability between B1a and B8.

(f) Eastern subsea HVDC link from south east Scotland to south Humber area (TGDC)

TGDC was included for the first time this year and is identified in the 'optimal' reinforcement path and 'critical' across all four of the 2020 *FES*. Following completion of both the first (E2DC) and second (E4D3) eastern HVDC Links, it provides further boundary capability between B6 and B8, as well as facilitating new generation connections in the local area at the north end of the link.

NOA / Appendix B / LOTI projects 118

LOTI projects

(g) South east Scotland to north west England AC onshore reinforcement (CMNC)

CMNC has been developed this year for the first time as NOA5 indicated the need for further onshore options over the B6 boundary. It has been identified as 'optimal' and 'critical' in all four *FES*, replacing TLNO from NOA5, and provides capability over B6.

3. Status

3.1 Initial Onshore reinforcement

The East coast onshore projects in the SHE Transmission and SPT areas are scheduled for delivery in 2023 for the 275kV works and 2026 for the 400kV uprate. These projects are both included within the RIIO-T2 base allowance, and are being developed on that basis.

3.2 First and Second Eastern HVDC Links from Scotland to north east of England

A joint team from the three onshore TOs has continued to assess the *NOA* options in more detail as part of an SWW initial needs case submitted to the regulator in October 2020. This team is working towards submission of the final SWW needs case in late 2021. This will consider system requirements, project development and delivery, and technologies. The TOs are working with the ESO who provide a detailed cost benefit analysis of the reinforcement options to help identify optimum delivery dates.

Subsea survey work has started for the link from Torness. A similar survey for the link from Peterhead is scheduled to start in Q1/early Q2 2021. Planning permission for the 400kV substation at Peterhead has been granted and a preferred location identified. The connection point at Torness in SPT's area has been assessed and a preferred convertor station site selected for further development. The southern landing points of the links and associated AC onshore works continue to be progressed with the Torness link connecting into Hawthorn Pit via a converter station. The Peterhead route will terminate in the Drax area with the converter located nearby. It is expected that the construction of the HVDC projects will take place between 2024 and 2029.

3.3 Further Eastern HVDC Links and associated Onshore reinforcement

For a second year the *NOA* has indicated that a second link from the north east of Scotland (Peterhead) and a new onshore circuit over B6 is needed. A further HVDC link from the Torness area has also been recommended. This provides the TOs and the ESO with a clear indication of significant reinforcement requirements following the delivery of the first two eastern HVDC links. The development of all links will continue to be coordinated with the development of the offshore network, to ensure the overall best solution for the consumer.

NOA / Appendix B / LOTI projects 119

B.2 Beauly to Blackhillock reinforcement

1. Background

Significant volumes of new, mainly renewable generation are expected to connect to the SHE Transmission network, resulting in much greater bulk power transfer requirements on all major SHE Transmission boundaries.

Generation volumes are forecast to increase across most fuel types, but particularly offshore wind towards the end of this decade and into the 2030s. Much of this offshore wind is likely to connect to the far north of the SHE Transmission network and contributes to the increased transfer requirement of the B1a boundary which separates the north and north west of Scotland from the southern and eastern regions.

In addition, under periods of high north-to-south power transfer a double circuit loss of the main western corridor of the SHE Transmission network, specifically the Beauly to Denny 400/275kV OHL, significantly stresses the circuits between Beauly and Blackhillock.

Under this contingency, power must flow through these circuits and across the B1a boundary to reach the eastern corridor of the network. Under these network conditions a Beauly to Blackhillock reinforcement works well with the future reinforced eastern network.

2. Options development

We assessed two options to increase transmission capacity between Beauly and Blackhillock and across B1a. They considered new build 400kV infrastructure and reconductoring the existing 275kV circuit with a High Temperature Low Sag conductor.

2.1 Leading option

The *NOA* 2020/21 recommends BBNC as the leading option for reinforcing the transmission network that connects the Eastern and Western corridors. It establishes a new 400kV double circuit between Beauly and Blackhillock substations and extension of the 400kV busbar arrangement at both sites to allow additional circuit breaker bays.

3. Economic assessment

In *NOA* 2019/20 BBNC was given a “Stop” recommendation. It was not ‘optimal’ in any scenario due to lower constraints across Scottish boundaries. The energy flow across Scottish boundaries under *FES* 2020 has been increased significantly. BBNC provides additional boundary B1 to B4 capability from 2030s, which makes it ‘optimal’ in all scenarios and ‘critical’ in all four *FES* scenarios except System Transformation. It has received a “Proceed” recommendation following least worst regret analysis.

4. Status

The option ultimately taken forward to a LOTI Initial Needs Case submission will be subject to further optioneering and stakeholder consultation as well as being informed by the LOTI cost-benefit analysis to ensure the solution is ‘optimal’.

NOA / Appendix B / LOTI projects 120

B.3 North of Beauly reinforcement

1. Background

Significant volumes of new, mainly renewable generation are expected to connect to the SHE Transmission network, leading to major increases to the bulk power transfer requirements of all major SHE Transmission boundaries.

Generation volumes are expected to increase across most fuel types but specifically offshore wind towards the end of the decade and into the 2030s. Most of this is likely to connect to the far north of the SHE Transmission network and leads to an increased transfer requirement of the B0 boundary which separates the network north of Beauly from the remaining Main Interconnected Transmission System (MITS) in the SHE Transmission area. North of Beauly encompasses the north of the Highlands, Caithness, Sutherland and Orkney.

2. Options development

We assessed several options to increase transmission capacity across B0. These included replacing 132kV circuits with higher capacity 275kV circuits, reconductoring existing 275kV circuit routes with High Temperature Low Sag conductors and new offshore HVDC circuits between Spittal in the far North and landing points in both Morayshire and the North East.

2.1 Leading option

The *NOA* 2020/21 recommends BLN2 as the leading option. This involves replacing the Beauly to Shin to Loch Buidhe 132kV double circuit overhead line with a higher capacity 275 kV double circuit overhead line, including new transformers at Shin and substation extensions at Beauly and Loch Buidhe.

3. Economic assessment

BLN2 provides incremental boundary capability from B0 to B4 (SHE-T area). It is required on its EISD of 2030 in Leading the Way and Consumer Transformation scenarios, and one year later in System Transformation. It is not required in Steady Progression due to the lower generation in this region under that scenario. Based on the single year Least Worst regret analysis, it is recommended to “Proceed”.

4. Status

The current scope of the leading option BLN2 is as per SHE Transmission reinforcement scheme (SHE-RI-058) as described in the Transmission Works Report published by the ESO.

The complete scope of the option taken forward to a LOTI Initial Needs Case submission will be subject to further optioneering and stakeholder consultation as well as being informed by the LOTI cost-benefit analysis to ensure the solution is ‘optimal’.

NOA / Appendix B / LOTI projects 121

B.4 London and south east network reinforcement

1. Background

The London and south east region have a high concentration of both power demand and generation, with much of the demand in London and growing generation capacity in the Thames Estuary and East Anglia. Interconnectors to Europe also operate along the south coast of England and East Anglia and heavily influence power flows in the region by importing and exporting to continental Europe. The coastline and waters around East Anglia are attractive for offshore wind projects and nuclear generation is also expected in the region.

The future growth of renewable generation capacity in East Anglia is expected to give rise to a high volume of constraints if the East Anglia boundary (EC5) is not reinforced. Furthermore, the increase of interconnection capacity on the south coast, combined with the build-up of renewable generation in East Anglia and the north, is expected to drive more consistent north-to-south flows through the region to meet demand in London and export power to Europe through interconnectors on the south coast.

If they are not reinforced, these flows are expected to give rise to constraints on the London Export (LE1) and south coast export (SC1rev) boundaries in the long term. At times when the south coast interconnectors are importing, however, the south coast import boundaries (SC1, SC2 and SC3) could also give rise to some constraints.

2. Options Development

Several reinforcement options have been developed to improve transmission capacity across the south coast, London and East Anglia. These options include uprating transmission routes, constructing new routes, new substations and installing reactive power compensation at key locations.

2.1 Leading options

Similar to *NOA* 2019/20 last year, the *NOA* 2020/21 recommends SCD1 as the leading option. This was submitted by NGET for analysis for the first time in 2019. It consists of constructing a 2 GW offshore HVDC link and associated substation works between Suffolk and Kent. This will significantly increase the transmission capacity on system boundaries SC1, SC1rev, SC2, LE1 and EC5.

2.2 Other options

Other recommendations from this year's *NOA* process to "Proceed" the following reinforcements for the south east region:

- Upgrade Hackney, Tottenham and Waltham Cross 275kV to 400kV (HWUP)
- Tilbury to Grain and Tilbury to Kingsnorth upgrade (TKRE)
- A new 400kV double circuit between Bramford and Twinstead (BTNO)
- New offshore HVDC link between Suffolk and Kent option 1 (SCD1)
- A new 400kV double circuit in south East Anglia (ATNC)
- Thames Estuary reinforcement (TENC)
- A new 400kV double circuit in north East Anglia (AENC)

3. Economic Assessment

The *NOA* 2020/21 analysis suggests SCD1 provides significant economic benefit. It is 'critical' in Customer Transformation and Leading the Way, being required on its EISD of 2029. However, Steady Progression doesn't need it until 2030, and System Transformation until 2031. As it was not 'critical' in all scenarios, a single year least worst regret (LWR) was performed and it was given a "Proceed" recommendation.

The economic benefit comes largely from the capability it provides to LE1 and EC5 which are the two most constrained boundaries in the south. It also contributes to reducing the constraints on SC1Rev in later years when the interconnectors are exporting.

One alternative option, SCD2, has the drawbacks compared to SCD1, of an EISD

NOA / Appendix B / LOTI projects 122

that's one year later (2030 for SCD2), and being mutually exclusive with another new route for *NOA* 2020/21, ATNC. ATNC is a new onshore circuit in south East Anglia, is a lower-cost reinforcement and provides significant capability, which is essential for improving the capability for EC5 and LE1. This means SCD2 is not on the 'optimal' path for *NOA* 2020/21, as was the case for *NOA* 2019/20.

The other alternative, SCN1, also considered in *NOA* 2019/20, is cheaper than both SCD1 and SCD2, but only provides capability for the south coast boundaries and doesn't help EC5 and LE1 north of London, and so was not in the 'optimal' path in *NOA* 2020/21.

4. Status

NGET has reviewed several design variations of SCD1 since the "Proceed" recommendation was given by *NOA*. This encompasses other reinforcements around London and East Anglia to attain the full benefit of the leading option on other system boundaries. Preliminary work to identify the optimal substations at both ends and other accompanying reinforcements with "Proceed" signal *NOA* this year is ongoing. System access for several ongoing projects around London and East Anglia is challenging due to the high connection works contracted around this area. NGET will continue working with stakeholders to address these challenges. The SWW Initial Needs Case submission is due early next year.

B.5 York, Humber and Lincolnshire reinforcements

1. Background

The reinforcements included for the network across northern and central England provide capability on one or more of the MITS boundaries B7, B7a, B8 and B9.

The objective is to increase the north-to-south transfer capability to safely enable greater volumes of predominantly new renewable generation to flow from Scotland and northern England down to central England.

2. Options development

Several reinforcement options have been developed to improve boundary capability in both northern and central England. To reflect the significant increase in system transfer requirements driven by the new Net Zero *Future Energy Scenarios*, additional options have been included for assessment.

2.1 Notable options

a) A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 400kV upgrades (OPN1)

Construct a new 400kV double circuit in Yorkshire to facilitate power transfer across boundaries. This new circuit connects near Poppleton and ties in to the Norton to Osbaldwick 400kV circuit. The scope includes 400kV circuit upgrades and substation works to increase power transfers. This option provides additional transmission capacity across boundaries B7, B7a and B8.

b) A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades (OPN2)

Construct a new 400kV double circuit in Yorkshire to allow power transfer across the relevant boundaries. This new circuit connects near Poppleton and ties in to the Norton to Osbaldwick 400kV circuit. The scope covers 275kV upgrades and substation works to increase power transfers. This option provides additional transmission capacity across boundaries B7, B7a and B8.

c) A new 400kV double circuit between the existing Norton to Osbaldwick and Poppleton and relevant 275kV upgrades (OPN4)

Construct a new 400kV double circuit in Yorkshire to enable power transfer across the relevant boundaries. This connects near Poppleton and ties in to the Norton to Osbaldwick 400kV circuit. The scope includes 275kV upgrades and substation works to increase power transfers. This option provides additional transmission capacity across boundaries B7, B7a and B8.

d) A new 400kV double circuit between the existing Norton to Osbaldwick and Poppleton and relevant 275kV and 400kV upgrades (OPN5)

Construct a new 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. This new circuit connects near Poppleton and ties in to the Norton to Osbaldwick 400kV circuit. Upgrades to the 275kV upgrades and substation works are included to increase power transfers. This reinforcement option provides additional transmission capacity across boundaries B7, B7a and B8.

e) A new 400kV double circuit within Yorkshire between Eggborough and Osbaldwick (OENO)

Construction of a new 400kV route and substation works for power transfer across the relevant boundaries.. This reinforcement provides additional transmission capacity across boundaries B7, B7a and B8.

f) A new 400kV double circuit between Creyke Beck and the south Humber (CGNC)

Construct a new 400kV double circuit in Yorkshire with substation works to facilitate power transfer requirements across the relevant boundaries. This option provides additional transmission capacity across boundaries B7, B7a and B8.

g) A new 400kV double circuit between the south Humber and South Lincolnshire (GWNC)

Construct a new 400kV double circuit with substation works in Lincolnshire to facilitate power transfer across the relevant boundaries. This provides additional transmission capacity across boundaries B7, B7a, B8 and B9.

h) South Lincolnshire to Rutland reinforcement (LRNC)

Construct a new 400kV double circuit together with substation works from South Lincolnshire to Rutland to allow power transfer across the relevant boundaries. This provides additional transmission capacity across boundaries B8 and B9.

i) Uprate the Brinsworth and Chesterfield to double circuit 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield (EDNC)

This is to alleviate high power flows in and around East Anglia and the Humber area and provide additional transmission capacity across boundaries B8 and B9.

2.2 Lead options

In *NOA* 2020/21, OPN2, CGNC, GWNC, LRNC and EDNC are the most efficient options giving the greatest benefits.

a) A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades (OPN2)

OPN2 has a "Proceed" recommendation in *NOA* 2020/21 and is 'critical' in all four *FES* scenarios. It has been recommended in the last two *NOA*s and provides boundary capability across B7, B7a and B8. It is critical to deliver alongside an eastern link to Hawthorn Pit (E2DC) as it unlocks transmission constraints from Scotland through the north of England.

NOA / Appendix B / LOTI projects 124

LOTI projects

b) A new 400kV double circuit between Creyke Beck and the south Humber (CGNC)

CGNC has a "Proceed" recommendation in *NOA* 2020/21 and is 'critical' in all four *Future Energy Scenarios* (*FES*). It has been recommended in the last two *NOA*s and provides boundary capability across B7, B7a and B8, while supporting the connection of renewable generation in Yorkshire and delivering transmission capacity to the east side of the network.

c) A new 400kV double circuit between the south Humber area and South Lincolnshire (GWNC)

GWNC has a "Proceed" recommendation in *NOA* 2020/21 and is 'critical' in all four *FES* scenarios. It has been recommended in the last two *NOA*s and provides boundary capability across B7, B7a, B8 and B9. It supports the connection of renewable generation in Yorkshire and Lincolnshire, delivering transmission capacity to the east side of the network.

d) South Lincolnshire to Rutland reinforcement (LRNC)

LRNC has a "Hold" recommendation in *NOA* 2020/21 and is 'optimal' in three of the four *FES* scenarios. It has been assessed for the first time in *NOA* and provides boundary capability across B8 and B9. It supports the connection of renewable generation in Lincolnshire and ensures transmission capacity in East Anglia is not reduced.

e) Uprate Brinsworth and Chesterfield to double circuit to 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield

EDNC has a "Proceed" recommendation in *NOA* 2020/21 and is 'optimal' in three of the four *FES* scenarios. It has been assessed for the first time in *NOA* and provides boundary capability across B8 and B9. It supports the increasing north-to-south requirements of the transmission network driven by the net zero targets.

3. Status

A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades (OPN2)

NGET has completed strategic optioneering for this project to identify the optimal options, which have been included in *NOA* to determine the most economical option. Work is currently being undertaken to support a planning application later next year, which will enable construction to begin in 2025 and the project to meet its EISD of 2027. An initial needs case is planned to be submitted to the regulator early this year.

Humber and Lincolnshire (CGNC, GWNC, LRNC, EDNC)

These projects form a wider Humber strategy which both reinforce the system and support offshore generation connections. These projects are currently in scoping, with preliminary work to identify the optimal reinforcement combinations, as well as other accompanying reinforcements required. The design of these options is being coordinated and assessed in conjunction with one another.

NOA / Appendix B / LOTI projects 125

Appendix C

List of options

List of options

This table shows the options assessed in this *NOA* publication, together with their four-letter codes. The four-letter codes appear throughout the report in tables and charts.

We have added a unique icon which represents the category. You can find out more about the various options in Chapter 3 - 'Proposed options'.

Please click here to navigate back to the interactive map in the Chapter 4 - 'Recommendations for each option' section of the report.

AENC **A new 400kV double circuit in north East Anglia** Status: Scoping Boundaries affected: LE1; EC5I; EC5E Region: South	Construct a new 400kV double circuit in north East Anglia to facilitate power transfer requirements across the relevant boundaries. Substation works is required to accommodate the new circuits.
ATNC **A new 400kV double circuit in south East Anglia** Status: Scoping Boundaries affected: SC1Rev; LE1; EC5E Region: South	Construct a new 400kV double circuit in south East Anglia to facilitate power transfer requirements across the relevant boundaries. Substation works is required to accommodate the new circuits.
BBNC **Beauly to Blackhillock 400kV double circuit addition** Status: Project not started Boundaries affected: B1aE; B1aF; B1aI; B2E; B2F; B2I; B4E; B4F; B4I Region: North	Construct a new 400kV double circuit between Beauly and Blackhillock. At both sites extend the 400kV busbar arrangements to allow for the connection of two additional bays.
BDUP **Uprate the Beauly to Denny 275kV circuit to 400kV** Status: Scoping Boundaries affected: B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5 Region: North	Uprating of the 275kV side of the existing Beauly-Denny circuit to 400kV operation between SHE Transmission and SPT. Substation works will be required at Beauly, Fasnakyle, Fort Augustus, Kinardochy, Braco West and Denny North. The Errochty I/T scheme (implemented under ECU2) shall be amended to trip the 400/132kV supergrid transformer(SGTs) at Kinardochy under loss of the 400kV double circuit south of Kinardochy.
BFHW **Bramley to Fleet circuits thermal uprating** Status: Project not started Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev Region: South	Thermal upgrade of the Bramley to Fleet circuits to allow them to operate at higher temperatures, and increase their thermal rating.

NOA / Appendix C / List of options 127

List of options

BFPC

Power control device along Bramley to Fleet
Status: Project not started
Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev
Region: South

Install a power control device along the Bramley to Fleet 400kV overhead line route. This would improve the capability to control the power flows across the South Coast area of the transmission network.

BFRE

Bramley to Fleet reconductoring
Status: Project not started
Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev
Region: South

Replace the conductors in the Bramley to Fleet circuits with higher-rated conductors to increase their thermal ratings.

BLN2

Beauly to Loch Buidhe 275kV reinforcement
Status: Scoping
Boundaries affected: B0; B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Replace the Beauly to Shin to Loch Buidhe 132kV double circuit overhead line with a higher capacity 275kV double circuit overhead line, including new transformers at Shin and substation extensions at Beauly and Loch Buidhe.

BMM2

225MVAr MSCs at Burwell Main
Status: Design/development and consenting
Boundaries affected: SC1Rev; LE1; EC5I; EC5E
Region: South

Two new 225 MVAr switched capacitors (MSCs) at Burwell Main would provide voltage support to the East Anglia area as system flows increase in future.

BPNC

A new 400kV double circuit between Blackhillock and Peterhead
Status: Project not started
Boundaries affected: B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Establish a new 400kV double circuit overhead line from Peterhead to Blackhillock via New Deer. Peterhead and Blackhillock substations will require extension to accomodate termination of the new double circuit. This reinforcement is required as onshore works to facilitate the 2nd eastern HVDC link from Peterhead (*NOA* option reference E4L5).

BPRE

Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit
Status: Project not started
Boundaries affected: SC1Rev; EC5I; EC5E
Region: South

Replace the conductors of the newly formed second Bramford to Braintree to Rayleigh Main circuit that has not already been reconductored with higher-rated conductors. This would increase the circuit's thermal rating following the new 400kV double circuit between Bramford and Twinstead.

BRRE

Reconductor remainder of Bramford to Braintree to Rayleigh route
Status: Project not started
Boundaries affected: SC1Rev; LE1; EC5I; EC5E
Region: South

Replace the conductors in the limiting sections of the existing Bramford to Braintree to Rayleigh overhead line that have not already been reconductored with higher-rated conductors, to increase the circuits overall thermal rating.

BTNO

A new 400kV double circuit between Bramford and Twinstead
Status: Scoping
Boundaries affected: SC1Rev; LE1; EC5I; EC5E
Region: South

Construct a new 400kV double circuit between Bramford substation and Twinstead tee point to create double circuits that run between Bramford to Pelham and Bramford to Braintree to Rayleigh Main. It would increase power export capability from East Anglia into the rest of the transmission system.

BWRE

Reconductor Barking to West Ham double circuit
Status: Project not started
Boundaries affected: SC1Rev; LE1
Region: South

Replace the conductors in the Barking to West Ham single circuit with higher-rated conductors.

BYRE

Reconductor Blyth to Tynemouth 275kV circuit
Status: Project not started
Boundaries affected: B7aI
Region: North

Replace the conductor in the Blyth to Tynemouth circuit with higher-rated conductors to increase the circuit's thermal rating.

List of options

CBEU

Creyke Beck to Keadby advance rating
Status: Project not started
Boundaries affected: B7al; B8
Region: North

Using weather data, enhance the rating of the Creyke Beck to Keadby 400kV overhead line to enable higher average power flows.

CDHW

Cellarhead to Drakelow circuits thermal uprating
Status: Project not started
Boundaries affected: B8
Region: North

Thermal upgrade of both Cellarhead to Drakelow 400kV circuits to allow them to operate at higher temperature and rating.

CDP1

Power control device along Cellarhead to Drakelow
Status: Project not started
Boundaries affected: B8
Region: North

Install a power control device along the Cellarhead to Drakelow 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

CDP2

Power control device along Cellarhead to Drakelow
Status: Project not started
Boundaries affected: B8
Region: North

Install a power control device along the Cellarhead to Drakelow 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

CDP3

Additional alternative power control devices along Cellarhead to Drakelow
Status: Project not started
Boundaries affected: B8
Region: North

Install an additional alternative power control devices along the Cellarhead to Drakelow 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

CDP4

Additional alternative power control devices along Cellarhead to Drakelow
Status: Project not started
Boundaries affected: B8
Region: North

Install an additional alternative power control device along the Cellarhead to Drakelow 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

CDRE

Cellarhead to Drakelow reconductoring
Status: Scoping
Boundaries affected: B8
Region: North

Replace the conductors on the existing double circuit from Cellarhead to Drakelow with higher-rated conductors to increase their thermal rating.

CENC

South east Scotland to north east England AC onshore reinforcement
Status: Project not started
Boundaries affected: B6SPT; B6I
Region: North

Construct a new 400kV double circuit from in south east Scotland to north east England, to facilitate power transfer requirements across the relevant boundaries. Suitable connection points at each end will be identified, as well as relevant substation works required to accommodate the new circuit.

CGNC

A new 400kV double circuit between Creyke Beck and the south Humber region
Status: Project not started
Boundaries affected: B7al; B8
Region: North

Construct a new 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. Substation works is required to accommodate the new circuits.

CKPC

Power control device along Creyke Beck to Keadby to Killingholme
Status: Project not started
Boundaries affected: B7al; B8; B9
Region: North

Install a power control device along the Creyke Beck to Keadby to Killingholme 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

NOA / Appendix C / List of options 129

List of options

CLNC **New north west England to Lancashire reinforcement** Status: Project not started Boundaries affected: B6l Region: North	Construct a new 400kV double circuit from north west England to Lancashire, to facilitate power transfer requirements across the relevant boundaries. Suitable connection points at each end will be identified, as well as relevant substation works required to accommodate the new circuit.
CMNC **South east Scotland to north west England AC onshore reinforcement** Status: Project not started Boundaries affected: B6SPT; B6l Region: North	Construct a new 400kV double circuit from in south east Scotland to north west England, to facilitate power transfer requirements across the relevant boundaries. Suitable connection points at each end will be identified, as well as relevant substation works required to accommodate the new circuit.
CRPC **Power control device along Cottam to West Burton** Status: Project not started Boundaries affected: B8 Region: North	Install a power control device along the Cottom to Ryhall 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.
CS03 **Commercial solution for the north of Scotland - stage 1** Status: Project not started Boundaries affected: B2; B4 Region: North	This ESO-led commercial solution provides benefit across several boundaries in the north of Scotland.
CS04 **Commercial solution for the north of Scotland - stage 2** Status: Project not started Boundaries affected: B2; B4 Region: North	This ESO-led commercial solution provides benefit across several boundaries in the north of Scotland.
CS05 **Commercial solution for Scotland and the north of England - stage 1** Status: Project not started Boundaries affected: B6; B7a Region: North	This ESO-led commercial solution provides benefit across several boundaries in the north of England.
CS06 **Commercial solution for Scotland and the north of England - stage 2** Status: Project not started Boundaries affected: B6; B7a Region: North	This ESO-led commercial solution provides benefit across several boundaries in the north of England.
CS07 **Commercial solution for East Anglia - stage 1** Status: Project not started Boundaries affected: EC5 Region: South	This ESO-led commercial solution provides boundary benefit across the East Anglia region.
CS08 **Commercial solution for East Anglia - stage 2** Status: Project not started Boundaries affected: EC5 Region: South	This ESO-led commercial solution provides boundary benefit across the East Anglia region.
CS09 **Commercial solution for the south coast - stage 1** Status: Project not started Boundaries affected: SC1; SC3 Region: South	This ESO-led commercial solution provides boundary benefit in the south coast.

NOA / Appendix C / List of options 130

List of options

CS10

Commercial solution for the south coast - stage 2
Status: Project not started
Boundaries affected: SC1; SC3
Region: South

This ESO-led commercial solution provides boundary benefit in the south coast.

CTP2

Alternative power control device along Creyke Beck to Thornton
Status: Project not started
Boundaries affected: B7aI; B8
Region: North

Install an alternative power control device along the Creyke Beck to Thornton 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

CTP3

Additional power control devices along the Creyke Beck - Thornton 1 400kV circuit
Status: Project not started
Boundaries affected: B8
Region: North

Install additional power control devices along the Creyke Beck to Thornton 1 400kV circuit. This is to help alleviate high power flows in the Humber area.

CTRE

Reconductor remainder of Coryton South to Tilbury circuit
Status: Scoping
Boundaries affected: SC1Rev; LE1
Region: South

Replace the conductors on the remaining sections of the Coryton South to Tilbury circuit, which have not recently been reconductored with higher-rated conductors. These would increase the circuit's thermal rating.

CVUP

Uprating the Clydesmill to Strathaven 275kV circuits to 400kV single circuit
Status: Project not started
Boundaries affected: B5
Region: North

Following LWUP or DWUP, reconfigure and reconductor the 275kV circuits between Clydesmill and Strathaven to establish a 400kV single circuit, including substation works at Clydesmill and Strathaven. The new circuit connects the new 400kV circuit into Clydesmill into the existing 400kV east-west corridor improving power flows.

CWPC

Power control device along Cottam to West Burton
Status: Project not started
Boundaries affected: B8; B9
Region: North

Install a power control device along the Cottam to West Burton 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

DEP1

Additional power control devices along the Drax - Eggborough 1 400kV circuit
Status: Project not started
Boundaries affected: B7aI; B8
Region: North

Install additional power control devices along the Drax to Eggborough 1 400kV circuit. This is to help balance the flows and alleviate overloading of circuit due to system faults.

DEPC

Power control device along Drax to Eggborough
Status: Project not started
Boundaries affected: B7aI; B8
Region: North

Install a power control device along the Drax to Eggborough 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

DLRE

Loch Buidhe to Dounreay 275kV double circuit reconductoring
Status: Project not started
Boundaries affected: B0; B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Reconductor the Loch Buidhe to Dounreay 275kV double circuit overhead line with a high temperature low sag conductor. This option is conditional on SHE Transmission business approval for the use of a high temperature conductor on the 275kV network and suitability of the conductor for use on the existing L3 tower structures.

NOA / Appendix C / List of options 131

List of options

DLUP

Uprate the Windyhill-Lambhill-Denny North 275kV circuit to 400kV
Status: Project not started
Boundaries affected: B1al; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Following WLTI and DNEU, increase the operating voltage of the Windyhill to Lambhill to Denny 275kV circuit by the establishment of a new 400kV gas insulated substation at Windyhill, the installation of a new 400/275kV transformer at Windyhill 400kV substation, a new 400/275kV transformer at Lambhill substation and transferring existing 275kV circuit onto the existing Denny 400kV substation.

DNEU

Denny North 400/275kV second supergrid transformer
Status: Scoping
Boundaries affected: B1al; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Installation of a new 400/275kV 1000MVA supergrid transformer (SGT2) at Denny North 400kV substation.

DREU

Generator circuit breaker replacement to allow Thornton to run a two-way split
Status: Project not started
Boundaries affected: B7al; B7aE; B8
Region: North

This reinforcement is to replace generator owned circuit breakers with higher-rated equivalents including substation equipment. This would allow higher fault levels, which in turn improves load sharing on circuits connecting to the substation.

DWN2

Denny to Wishaw 400kV reinforcement
Status: Design/development and consenting
Boundaries affected: B1al; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Following DWUP or LWUP, construct a new 400kV double circuit from Bonnybridge to north of Newarthill. One side of the new double circuit will operate at 400kV, the other at 275kV. This reinforcement will establish Denny to Bonnybridge, Bonnybridge to Wishaw, and a Denny to Newarthill to Easterhouse 275kV circuit in addition to new 400kV route establish in preceding scheme. Resulting in two new 400kV corridors in Scotland, providing additional north-to-south capability.

DWNO

Denny to Wishaw 400kV reinforcement
Status: Design/development and consenting
Boundaries affected: B1al; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Construct a new 400kV double circuit from Bonnybridge to Newarthill, and reconfigure associated sites to establish a fourth north-to-south double circuit supergrid route through the Scottish central belt. One side of the new double circuit will operate at 400kV, the other at 275kV. This reinforcement will establish Denny to Bonnybridge, Bonnybridge to Wishaw, Wishaw to Strathaven No.2 and Wishaw to Torness 400kV circuits, and a Denny to Newarthill to Easterhouse 275kV circuit.

DWUP

Establish Denny North-Clydesmill-Wishaw single 400kV circuit from existing 275kV circuits
Status: Project not started
Boundaries affected: B1al; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Establish a new 400kV single circuit between Denny North, Clydesmill and Wishaw by reconfiguration of the existing Longannet to Easterhouse/Clydesmill 275kV circuits and existing de-energised circuit between Easterhouse and Newarthill and the existing Newarthill to Wishaw circuit. Provides additional capability in Scotland via a new 400kV corridor.

E2D2

Eastern Scotland to England link: Torness to Cottam offshore HVDC
Status: Scoping
Boundaries affected: B6I; B6SPT; B7al; B8
Region: North

Construction of a new offshore 2 GW HVDC subsea link from Torness area to Cottam to provide additional transmission capacity. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Torness and Cottam.

E2D3

Eastern Scotland to England link: Torness to Drax offshore HVDC
Status: Scoping
Boundaries affected: B6SPT; B6I; B7al; B8
Region: North

Construction of a new offshore 2 GW HVDC subsea link from Torness area to Drax to provide additional transmission capacity. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Torness and Drax.

NOA / Appendix C / List of options 132

List of options

E2DC

Eastern subsea HVDC link from Torness to Hawthorn Pit
Status: Scoping
Boundaries affected: B6SPT; B6I; B7aI; B8
Region: North

Construct a new offshore 2 GW HVDC subsea link from the Torness area to Hawthorn Pit to provide additional transmission capacity. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Torness and Hawthorn Pit.

E4D2

Eastern Scotland to England link: Peterhead to Cottam offshore HVDC
Status: Design/development and consenting
Boundaries affected: B1aE; B1aF; B1aI; B2E; B2F; B2I; B4E; B4F; B4I; B5; B6I; B6SPT; B7aI; B8
Region: North

Construct a new offshore 2GW bipole HVDC subsea link from Peterhead in the north east of Scotland to Cottam along the east side of England. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Peterhead and Cottam.

E4D3

Eastern Scotland to England link: Peterhead to Drax offshore HVDC
Status: Design/development and consenting
Boundaries affected: B1aE; B1aF; B1aI; B2E; B2F; B2I; B4E; B4F; B4I; B5; B6I; B6SPT; B7aI; B8
Region: North

Construct a new offshore 2 GW bipole HVDC subsea link from Peterhead in the north east of Scotland to Drax in the Yorkshire area of England. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Peterhead and Drax.

E4DC

Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC
Status: Design/development and consenting
Boundaries affected: B1aE; B1aF; B1aI; B2E; B2F; B2I; B4E; B4F; B4I; B5; B6I; B6SPT; B7aI; B8
Region: North

Construct a new offshore 2GW bipole HVDC subsea link from Peterhead in the north east of Scotland to Hawthorn Pit in the north of England. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Peterhead and Hawthorn Pit.

E4L5

Eastern Scotland to England 3rd link: Peterhead to the south Humber offshore HVDC
Status: Optioneering
Boundaries affected: B1aE; B1aF; B1aI; B2E; B2F; B2I; B4E; B4F; B4I; B5; B6I; B6SPT; B7aI; B8
Region: North

Following a first HVDC link from Peterhead to England, construct an additional offshore 2GW bipole HVDC link from Peterhead to a location in the south Humber area. The link will involve substation works and HVDC converter stations at both Peterhead and south Humber. Circuit upgrades will also be required in the south Humber area.

E5L5

Eastern Scotland to England 3rd link: Blackhillock to the south Humber offshore HVDC
Status: Optioneering
Boundaries affected: B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5; B6SPT; B6I; B7aI; B8
Region: North

Following a first HVDC link from Peterhead to England, construct an additional offshore 2GW bipole HVDC link from Blackhillock to a location in the south Humber area. The link will involve substation works and HVDC converter stations at both Blackhillock and south Humber. Circuit upgrades will also be required in the south Humber area.

ECU2

East coast onshore 275kV upgrade
Status: Planning / consenting
Boundaries affected: B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Establish a new 275kV substation at Alyth; re-profile the 275kV circuits between Kintore, Fetteresso, Alyth and Kincardine; and Tealing, Westfield and Longannet; and uprate the cable sections at Kincardine and reconfigure at Longannet to match the enhanced rating. Extend Tealing 275kV substation and install two phase shifting transformers. Install shunt reactive series compensation at the new Alyth substation.

ECUP

East coast onshore 400kV incremental reinforcement
Status: Planning / consenting
Boundaries affected: B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

The option builds on the east coast onshore 275kV upgrade (ECU2) and upgrades 275kV infrastructure on the east coast for 400kV operation. Complete the construction of the new 400kV substation at Kintore (substation part developed under the north east 400kV reinforcement) and uprate Alyth substation (constructed under ECU2) for 400kV operation. Re-insulate the 275kV circuits between Kintore, Fetteresso, Alyth and Kincardine for 400kV operation. Install phase-shifting transformers at Blackhillock on the 275kV circuits from Knocknagael. Install 400/275kV transformers at Kincardine and Alyth and 400/132kV transformers at Fetteresso.

NOA / Appendix C / List of options 133

List of options

ECVC

Eccles hybrid synchronous compensators and real-time rating system
Status: Scoping
Boundaries affected: B6SPT; B6I; B6E; B6F; B7aI; B7aE
Region: North

Installation of two hybrid synchronous compensators at Eccles 400kV substation, and a real-time ratings system on the 400kV overhead line circuits between Moffat and Harker and Gretna and Harker and 400kV cable circuits between Crystal Rig and Torness.

EDNC

Uprate Brinsworth and Chesterfield to double circuit 400kV and a new 400kV double circuit between Ratcliffe and Chesterfield
Status: Project not started
Boundaries affected: B9; B8
Region: North

Upgrade the Brinsworth to Chesterfield 400kV double circuit and a new 400kV double circuit between Ratcliffe and Chesterfield. This is to help alleviate high power flows in and around East Anglia and the Humber area.

EHRE

Elvanfoot to Harker reconductoring
Status: Scoping
Boundaries affected: B6SPT; B6I; B7aI; B7aE
Region: North

Replace the double circuit conductors in the Elvanfoot to Harker circuits with a higher-rated conductor to increase their thermal ratings.

ESC1

Second Elstree to St John's Wood 400kV circuit
Status: Project not started
Boundaries affected: SC1Rev; LE1; EC5E
Region: South

New second 400kV cable transmission circuit from Elstree to St. Johns Wood in the existing tunnel, and carry out associated work, including modifying Elstree 400kV and St. John's Wood 400kV substations. This will improve the power flow into London.

FBRE

Beauly to Fyrish 275kV double circuit reconductoring
Status: Project not started
Boundaries affected: B0
Region: North

Reconductor the Beauly to Fyrish 275kV double circuit overhead line with a high temperature low sag conductor. This option is conditional on SHE Transmission business approval for the use of a high temperature conductor on the 275kV network and suitability of the conductor for use on the existing L3 tower structures.

FINS

East coast 132kV upgrade
Status: Scoping
Boundaries affected: B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Create a new grid supply point near Fiddes connected to the 275kV double circuit overhead line between Kintore and Tealing. Construct a new 132kV double circut from Tealing to Brechin and rationalise the present Fiddes, Brechin, Tarland and Craigiebuckler network configuration.

FMHW

Feckenham to Minety circuit thermal uprating
Status: Project not started
Boundaries affected: SC1Rev
Region: South

Thermal upgrade of the Feckenham to Minety to allow them to operate at higher temperatures, and increase their thermal rating.

FMPC

Power control device along Feckenham to Minety
Status: Project not started
Boundaries affected: B9; SC1Rev
Region: South

Install a power control device along the Feckenham to Minety 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

FMRE

Feckenham to Minety circuit reconductoring
Status: Project not started
Boundaries affected: SC1Rev
Region: South

Replace the conductors in the Feckenham to Minety circuit with higher-rated conductors.

FWPC

Power control device along Feckenham to Walham
Status: Project not started
Boundaries affected: B9; SC1Rev
Region: South

Install a power control device along the Feckenham to Walham 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

NOA / Appendix C / List of options 134

List of options

GWNC

A new 400kV double circuit between the south Humber area and south Lincolnshire
Status: Project not started
Boundaries affected: B7al; B8; B9
Region: North

Construct a new 400kV double circuit in Lincolnshire to facilitate power transfer requirements across the relevant boundaries. Substation works is required to accommodate the new circuits.

HAE2

Harker supergrid transformer 6 replacement
Status: Design/development and consenting
Boundaries affected: B6l; B6E; B7al; B7aE
Region: North

Replacing an existing transformer at Harker substation with a new one of higher rating to prevent overloading following transmission system faults.

HAEU

Harker supergrid transformer 5 and supergrid transformer 9A banking arrangement
Status: Design/development and consenting
Boundaries affected: B6l; B6E; B6F; B7al; B7aE
Region: North

Banking of existing transformers supergrid transformer 5 and supergrid transformer 9A at Harker substation and connecting directly to the Fourstones – Harker 275kV circuit to help alleviate overloading of supergrid transformers following transmission system faults.

HBUP

Uprate Bridgewater to 400kV and reconductor the route to Hinkley
Status: Design/development and consenting
Boundaries affected: B13
Region: South

Upgrade the Hinkley Point to Bridgewater 275kV circuits to 400kV including insulator and conductor replacement. Connect the circuits to the new Hinkley Point 400kV substation.

HENC

Hertfordshire reinforcement
Status: Project not started
Boundaries affected: LE1
Region: South

Construct new 400kV double circuit from Hertfordshire from Waltham Cross 400kV substation. These works would further provide additional transmission capacity between London and the south coast.

HFRE

Reconductor Harker to Fourstones double circuit
Status: Project not started
Boundaries affected: B7al
Region: North

Replace the conductors in the Harker to Fourstone single circuit with higher-rated conductors.

HNNO

Hunterston East–Neilston 400kV reinforcement
Status: Optioneering
Boundaries affected: B6SPT
Region: North

Modification of the Hunterston East to Devol Moor 400kV circuit to establish a second Hunterston East to Neilston 400kV circuit, and development of a new 400/275kV supergrid transformer 4 at Neilston 400kV substation, increasing the fault level in the Hunterston area.

HSP3

Additional power control device along Harker to Stella West
Status: Project not started
Boundaries affected: B6E; B6F
Region: North

Install additional power control devices along the Harker to Stella West route. This would improve the capability to control the power flow from east-to-west of the transmission network.

HSR1

Reconductor Harker to Stella West
Status: Project not started
Boundaries affected: B7al; B7aE
Region: North

Replace the conductors in the Harker to Stella West single circuit with higher-rated conductors.

HWUP

Uprate Hackney, Tottenham and Waltham Cross 275kV to 400kV
Status: Design/development and consenting
Boundaries affected: SC1Rev; LE1; EC5l; EC5E
Region: South

Hackney, Tottenham and Waltham Cross substation uprate from 275kV to 400kV, and the double circuit route connecting them. This will strengthen the power flow into London, via Rye House, down to Hackney.

NOA / Appendix C / List of options 135

List of options

IFHW

Feckenham to Ironbridge circuit thermal uprating
Status: Project not started
Boundaries affected: SC1Rev
Region: South

Thermal upgrade of the Feckenham to Ironbridge circuit to allow them to operate at higher temperatures, increasing its thermal rating.

IFR1

Feckenham to Ironbridge circuit reconductoring
Status: Project not started
Boundaries affected: SC1Rev
Region: South

Replace the conductors in the Feckenham to Ironbridge circuit with higher-rated conductors.

KBRE

Knocknagael to Blackhillock 275kV double circuit reconductoring
Status: Project not started
Boundaries affected: B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Reconductor the Knocknagael to Blackhillock 275kV double circuit overhead line with a high temperature low sag conductor. This option is conditional on SHE Transmission business approval for the use of a high temperature conductor on the 275kV network and suitability of the conductor for use on the existing L3 tower structures.

KWHW

Keadby to West Burton circuits thermal uprating
Status: Project not started
Boundaries affected: B8
Region: North

Thermal upgrade of the Keadby to West Burton circuits to allow them to operate at higher temperatures, and increase their thermal rating.

KWPC

Power control device along Keadby to West Burton
Status: Project not started
Boundaries affected: B7aI; B8; B9
Region: North

Install a power control device along the Keadby to West Burton 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

LBRE

Beauly to Loch Buidhe 275kV double circuit OHL reconductoring
Status: Project not started
Boundaries affected: B0; B1aI; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Reconductor the Beauly to Loch Buidhe 275kV double circuit overhead line with a high temperature low sag conductor. This option is conditional on SHE Transmission business approval for the use of a high temperature conductor on the 275kV network and suitability of the conductor for use on the existing L3 tower structures.

LCU2

Eastern B5 400kV reinforcement
Status: Project not started
Boundaries affected: B5
Region: North

Reconfiguration of existing 275kV circuits between Longannet and Currie via Kincardine, and Currie and Cockenzie via Smeaton and Kaimes, reprofiling one side of the existing overhead line double circuit to 400kV operation. Establishes a new 400kV corridor north-to-south, tying into existing east-west 400kV circuits.

LRNC

South Lincolnshire to Rutland reinforcement
Status: Project not started
Boundaries affected: B9
Region: North

Construct a new 400kV double circuit from South Lincolnshire to Rutland to facilitate power transfer requirements across the relevant boundaries. Substation works are required to accommodate the new circuits.

LWUP

Longannet 400kV reinforcement
Status: Project not started
Boundaries affected: B2I; B2E; B2F; B4I; B4E; B4F; B5
Region: North

Establishment of 400kV GIS substation at the existing Longannet substation site. Installation of two 400/275kV 1000MVA supergrid transformers to connect into 275kV substation. Reconfiguration and uprating of existing 275kV network circuits to establish 400kV connections between Longannet, Alyth, Denny North and Wishaw 400kV substations.

MBHW

Bramley to Melksham circuits thermal uprating
Status: Project not started
Boundaries affected: B12a; B13; SC1Rev; SC1.5Rev
Region: South

Thermal Upgrade of both Bramley to Melksham 400kV circuits to allow them to operate at higher temperature and rating.

List of options

MBRE

Bramley to Melksham reconductoring
Status: Project not started
Boundaries affected: B12a; B13; SC1Rev; SC1.5Rev
Region: South

Replace the conductors in the Bramley to Melksham circuits with higher-rated conductors to increase their thermal ratings.

MIC1

Cable replacement at Severn Tunnel
Status: Project not started
Boundaries affected: SW1
Region: West

Upgrade the cable in the Imperial Park to Melksham circuit passing through the Severn Tunnel with a larger cable section. This will give higher circuit rating.

MRP1

Power control device along Penwortham to Washway Farm to Kirkby
Status: Project not started
Boundaries affected: B7al
Region: North

Install an additional power control device along the Penwortham to Washway Farm to Kirkby 275kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

MRP2

Additional power control devices at both Harker and Penwortham
Status: Project not started
Boundaries affected: B6E; B6F; B7aE; B7aF
Region: North

Install additional power control devices at both Harker and Penwortham. This would improve the capability to control the power flow in both these areas of the transmission network.

NBRE

Reconductor Bramford to Norwich double circuit
Status: Project not started
Boundaries affected: SC1Rev; LE1; EC5I; EC5E
Region: South

The double circuit that runs from Norwich to Bramford would be reconductored with a higher-rated conductor.

NEMS

225MVAr MSCs within the north east region
Status: Scoping
Boundaries affected: B6I; B7aI; B7aE
Region: North

Three new 225 MVAr switched capacitors (MSCs) at Norton, Osbaldwick and Stella West 400kV substations would provide voltage support to the east side of the transmission network as system flows increase in future.

NEP1

Power control device along Blyth to Tynemouth and Blyth to South Shields
Status: Project not started
Boundaries affected: B7al
Region: North

Install an additional power control device along the Blyth to Tynemouth and Blyth to South Shields 275kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

NEPC

Power control device along Blyth to Tynemouth and Blyth to South Shields
Status: Project not started
Boundaries affected: B7al
Region: North

Install a power control device along the Blyth to Tynemouth and Blyth to South Shields 275kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

NIM1

225MVAr MSCs at Ninfield
Status: Scoping
Boundaries affected: SC1; SC2
Region: South

One new 225 MVAr switched capacitor (MSC) at Norwich would provide voltage support East Anglia area as system flows increase in the future.

NIM2

225MVAr MSCs at Ninfield
Status: Scoping
Boundaries affected: SC2
Region: South

One new 225 MVAr switched capacitor (MSC) at Norwich would provide voltage support East Anglia area as system flows increase in the future.

NOA / Appendix C / List of options 137

List of options

NOM1

225MVAr MSCs at Norwich
Status: Project not started
Boundaries affected: EC5I
Region: South

One new 225 MVAr switched capacitor (MSC) at Norwich would provide voltage support East Anglia area as system flows increase in the future.

NOM2

225MVAr MSCs at Norwich
Status: Project not started
Boundaries affected: EC5I
Region: South

One new 225 MVAr switched capacitor (MSC) at Norwich would provide voltage support East Anglia area as system flows increase in future.

NOPC

Power control device along Norton to Osbaldwick
Status: Project not started
Boundaries affected: B7aI
Region: North

Install a power control device along the Norton to Osbaldwick 400kV circuit overhead line route. This would improve the capability to control the power flows across the east and west of the transmission network.

NOR1

Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit
Status: Scoping
Boundaries affected: B7aI; B7aE
Region: North

Replace some of the conductors in the Norton to Osbaldwick double circuit with higher-rated conductors to increase the circuits' thermal ratings.

NOR2

Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit
Status: Project not started
Boundaries affected: B7aI; B7aE
Region: North

Replace some of the conductors in Norton to Osbaldwick 1 circuit with higher-rated conductors to increase the circuit's thermal rating.

NOR4

Reconductor 13.75km of Norton to Osbaldwick number 2 400kV circuit
Status: Project not started
Boundaries affected: B7aI
Region: North

Replace some of the conductors in Norton to Osbaldwick 2 circuit with higher-rated conductors to increase the circuit's thermal rating.

NOR5

Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit to a higher rated conductor
Status: Project not started
Boundaries affected: B7aI
Region: North

Replace some of the conductors in Norton to Osbaldwick 1 circuit with an even higher-rated conductor to increase the circuit's thermal rating.

NSM1

225MVAr MSCs within the north east region
Status: Project not started
Boundaries affected: B7aI; B7aE
Region: North

Three new 225 MVAr switched capacitors (MSCs) at Norton and Spennymoor 400kV substations would provide voltage support to the east side of the transmission network as system flows increase in future.

NSM2

225MVAr MSCs within the north east region
Status: Project not started
Boundaries affected: B7aI; B7aE
Region: North

Two new 225 MVAr switched capacitors (MSCs) at Norton and Spennymoor 400kV substations would provide voltage support to the east side of the transmission network as system flows increase in future.

NSM3

225MVAr MSCs within the north east region
Status: Project not started
Boundaries affected: B7aI
Region: North

A new 225 MVAr switched capacitor (MSC) at Norton 400kV substation would provide voltage support to the east side of the transmission network as system flows increase in future.

NOA / Appendix C / List of options 138

List of options

	NTP1 **Power control device along North Tilbury** Status: Project not started Boundaries affected: SC1Rev; LE1 Region: South	Install a power control device along the North Tilbury 400kV overhead line route. This would improve the capability to control the power flows east of the transmission network.
	OENO **A new 400kV double circuit within Yorkshire between Eggborough and Osbaldwick** Status: Scoping Boundaries affected: B7aI; B8 Region: North	Construct a new 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. Substation works may be required to accommodate the new circuits.
	OPN1 **A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 400kV upgrades** Status: Project not started Boundaries affected: B7aI; B8 Region: North	Construct a new 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. This new circuit connects near Poppleton and tee-in to the existing Norton to Osbaldwick 400kV circuit. 400kV circuit upgrades are delivered as part of the scope to increase power transfers. Substation works are also required.
	OPN2 **A new 400kV double circuit between the existing Norton to Osbaldwick circuit and Poppleton and relevant 275kV upgrades** Status: Project not started Boundaries affected: B7aI; B8 Region: North	Construct a new 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. This new circuit connects near Poppleton and tee-in to the existing Norton to Osbaldwick 400kV circuit. 275kV upgrades are delivered as part of the scope to increase power transfers. Substation works are also required.
	OPN4 **A new alternative 400kV double circuit between the existing Norton to Osbaldwick and Poppleton and relevant 275kV upgrades** Status: Project not started Boundaries affected: B7aI; B8 Region: North	Construct a new alternative 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. This new circuit connects near Poppleton and tee-in to the existing Norton to Osbaldwick 400kV circuit. 275kV upgrades are delivered as part of the scope to increase power transfers. Substation works are also required.
	OPN5 **A new 400kV double circuit between the existing Norton to Osbaldwick and Poppleton and relevant 275kV and 400kV upgrades** Status: Project not started Boundaries affected: B7aI; B8 Region: North	Construct a new 400kV double circuit in Yorkshire to facilitate power transfer requirements across the relevant boundaries. This new circuit connects near Poppleton and tee-in to the existing Norton to Osbaldwick 400kV circuit. 275kV upgrades are delivered to facilitate a new 400kV substation as part of the scope to increase power transfers. Substation works are also required.
	PEM1 **225MVAr MSCs at Pelham** Status: Project not started Boundaries affected: LE1; EC5I; EC5E Region: South	One new 225 MVAr switched capacitor (MSC) at Pelham would provide voltage support through East Anglia and north London as system flows increase in the future.
	PEM2 **225MVAr MSCs at Pelham** Status: Project not started Boundaries affected: LE1; EC5I; EC5E Region: South	One new 225 MVAr switched capacitor (MSC) at Pelham would provide voltage support through East Anglia and north London as system flows increase in the future.
	PFRE **Reconductor Penwortham to Washway Farm 275kV double circuit** Status: Project not started Boundaries affected: B7aE Region: North	Replace the conductor in the Penwortham to Washway Farm double circuit with higher-rated conductors to increase the circuit's thermal rating.
	PMU1 **Yorkshire reinforcement upgrade 1** Status: Project not started Boundaries affected: B7aI Region: North	Upgrade the existing 275kV route and associated upgrades, completed under OPN2, to 400kV.

NOA / Appendix C / List of options 139

List of options

PMU2

Yorkshire reinforcement upgrade 2
Status: Project not started
Boundaries affected: B7al
Region: North

Upgrade the existing 275kV route and associated upgrades, completed under OPN5, to 400kV.

PSDC

Spittal to Peterhead HVDC reinforcement
Status: Project not started
Boundaries affected: B0; B1aE; B1aF; B1al
Region: North

Construct a 2GW HVDC subsea link from a new 400kV substation at Spittal to the existing 400kV substation at Peterhead. The onshore works involve construction of 400kV substations at Dounreay, Thurso and Spittal and rebuilding of the existing Dounreay to Thurso to Spittal 275kV double circuit overhead line to 400kV.

PTC1

Pentir to Trawsfynydd cable replacement
Status: Scoping
Boundaries affected: NW2
Region: West

Upgrade the cable section on the existing Pentir to Trawsfynydd circuit to allow this to operate at higher temperatures and increase the circuits thermal rating.

PTNO

North Wales reinforcement
Status: Project not started
Boundaries affected: NW2
Region: West

Construct a second circuit in north Wales, making use of the existing transmission infrastructure to facilitate power transfer requirements across the relevant boundaries. Associated substation works are required at each end.

PWMS

Two 225MVAr MSCs at Penwortham
Status: Project not started
Boundaries affected: B7al
Region: North

Two new 225 MVAr switched capacitors (MSCs) at Penwortham substations would provide voltage support in the Mersey area as system flows increase in the future.

RHM1

225MVAr MSCs at Rye House
Status: Scoping
Boundaries affected: LE1; EC5E
Region: South

One new 225 MVAr switched capacitors (MSCs) at Rye House would provide voltage support through East Anglia and north London as system flows increase in the future.

RHM2

225MVAr MSCs at Rye House
Status: Project not started
Boundaries affected: LE1; EC5E
Region: South

One new 225 MVAr switched capacitors (MSCs) at Rye House would provide voltage support through East Anglia and north London as system flows increase in the future.

RTRE

Reconductor remainder of Rayleigh to Tilbury circuit
Status: Scoping
Boundaries affected: SC1Rev; LE1
Region: South

Replace the conductors on the remaining sections of the Rayleigh to Tilbury circuit, which have not recently been reconductored with higher-rated conductors. These would increase the circuit's thermal rating.

SBDC

Spittal to Blackhillock HVDC reinforcement
Status: Project not started
Boundaries affected: B0; B1aE; B1aF; B1al
Region: North

Construct a 2GW HVDC subsea link from a new 400kV substation at Spittal to the existing 400kV substation at Blackhillock. The onshore works involve construction of 400kV substations at Dounreay, Thurso and Spittal and rebuilding of the existing Dounreay to Thurso to Spittal 275kV double circuit overhead line to 400kV.

SBRE

Reconductor South Shields to West Boldon 275kV circuit
Status: Project not started
Boundaries affected: B7al
Region: North

Replace the conductor in the South Shields to West Boldon circuit with higher-rated conductors to increase the circuit's thermal rating.

SCD1

New offshore HVDC link between Suffolk and Kent option 1
Status: Project not started
Boundaries affected: B8; B9; SC1Rev; SC1.5Rev; SC2Rev; SC3; LE1; EC5I; EC5E
Region: South

Construct a new offshore 2GW HVDC circuit between Suffolk and Kent.

NOA / Appendix C / List of options 140

List of options

SCD2

New offshore HVDC link between Suffolk and Kent option 2
Status: Project not started
Boundaries affected: SC1Rev; LE1; EC5E
Region: South

Construct a second new offshore 2GW HVDC circuit between Suffolk and Kent, parallel with SDC1.

SCN1

New 400kV transmission route between south London and the south coast
Status: Scoping
Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev
Region: South

Construct a new transmission route from the south coast to south London, and carry out associated work. These works would provide additional transmission capacity between the south of London and the south coast.

SEEU

Reactive series compensation protective switching scheme
Status: Scoping
Boundaries affected: SC2
Region: South

Provide a new communications system, and other equipment, to allow existing reactive equipment to be switched in or out of service very quickly following transmission system faults. This would allow better control of system voltages following faults.

SER1

Elstree to Sundon reconductoring
Status: Project not started
Boundaries affected: SC1Rev; LE1
Region: South

Replace the conductors from Elstree to Sundon circuit 1 with higher-rated conductors to increase their thermal rating.

SER2

Elstree–Sundon 2 circuit turn-in and reconductoring
Status: Project not started
Boundaries affected: SC1Rev; LE1; EC5E
Region: South

Turn-in the Elstree to Sundon circuit 2, which currently passes the Elstree 400kV substation, to connect to it and replace the conductor with a higher-rated conductor. This would ensure better load flow sharing and increase the thermal rating.

SHNS

Upgrade substation in the south Humber area
Status: Project not started
Boundaries affected: B7al; B8
Region: North

Substation upgrade of the 400kV South Humber substation equipment.

SLU2

Loch Buidhe to Spittal 275kV reinforcement
Status: Project not started
Boundaries affected: B0; B1al; B1aE; B1aF; B2I; B2E; B2F; B4I; B4E; B4F
Region: North

Replace the existing Loch Buidhe to Spittal 132kV double circuit overhead line via Brora and Dunbeath with a higher capacity 275kV double circuit overhead line. Extension/reconfiguration works will be required at both Loch Buidhe and Spittal substations to accommodate the 275kV double circuit. At Brora and Dunbeath grid supply points (GSPs) replace the existing 132/33kV grid transformers (GTs) with 275/33kV GTs to connect the new 275kV overhead line to the existing 33kV network.

SNHW

Spennymoor to Norton circuit thermal uprating
Status: Project not started
Boundaries affected: B7al
Region: North

Thermal upgrade of the Spennymoor to Norton circuits to allow them to operate at higher temperatures and increase their thermal rating.

SSHW

Stella West to Spennymoor circuit thermal uprating
Status: Project not started
Boundaries affected: B7al
Region: North

Thermal upgrade of the Stella West to Spennymoor circuits to allow them to operate at higher temperatures and increase their thermal rating.

List of options

TBRE

Reconductor Tynemouth to West Boldon 275kV circuit
Status: Project not started
Boundaries affected: B7al
Region: North

Replace the conductor in the Tynemouth to West Boldon circuit with higher-rated conductors to increase the circuit's thermal rating.

TDP2

Additional power control device along Drax to Thornton
Status: Project not started
Boundaries affected: B8
Region: North

Install an additional power control device along the Drax to Thornton 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

TDPC

Power control device along Drax to Eggborough
Status: Project not started
Boundaries affected: B8
Region: North

Install a power control device along the Drax to Thornton 400kV overhead line route. This would improve the capability to control the power flows from north-to-south of the transmission network.

TDR1

Reconductor Drax to Thornton 2 circuit
Status: Project not started
Boundaries affected: B7al; B7aE; B8
Region: North

Replace the conductor in the Drax – Thornton 2 circuit with higher-rated conductors to increase the circuit's thermal rating. This will increase the power flow across the boundary.

TDR2

Reconductor Drax to Thornton 1 circuit
Status: Project not started
Boundaries affected: B7al; B7aE; B8
Region: North

Replace the conductor in the Drax – Thornton 1 circuit with higher-rated conductors to increase the circuit's thermal rating. This will increase the power flow across the boundary.

TENC

Thames Estuary reinforcement
Status: Project not started
Boundaries affected: SC1Rev; SC3; LE1; EC5E
Region: South

Construct a new 400kV double circuit bridging the Thames Estuary to facilitate power transfer requirements across the relevant boundaries. Substation works are required to accommodate the new circuits.

TFPC

Power control device on Tealing to Westfield circuit
Status: Project not started
Boundaries affected: B4l; B4F; B4E
Region: North

Install a power flow control device on the Tealing to Westfield 275kV circuit 1 at Tealing substation to optimise the power flow across the Tealing to Westfield 275kV double circuits 1 and 2, under a double circuit loss of the Alyth to Kincardine 400kV double circuit.

TGDC

Eastern subsea HVDC Link from south east Scotland to south Humber area
Status: Project not started
Boundaries affected: B6l; B6SPT; B7al
Region: North

Construct a new offshore 2GW HVDC subsea link from south east Scotland to the south Humber area in England to provide additional transmission capacity. Suitable connection points at each end will be identified, with the onshore works involving the construction of AC/DC converter stations and the associated AC works in both Scotland and England. This is in addition to a first HVDC link from the Torness area.

TGP1

Power control device along Tilbury to Grain
Status: Project not started
Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev; SC3Rev
Region: South

Install a power control device along the Tilbury to Grain 400kV overhead line route. This would improve the capability to control the power flows in the south east region of the transmission network.

THDC

Alternative staged eastern subsea HVDC link from Torness to Hawthorn Pit
Status: Scoping
Boundaries affected: B6SPT; B6l; B7al; B8
Region: North

Construct a staged a 2.8GW new offshore HVDC subsea link from the Torness area to Hawthorn Pit to provide additional transmission capacity. The onshore works involve the construction of AC/DC converter stations and the associated AC works at Torness and Hawthorn Pit. Intention to deliver project over in two 1.4GW stages, with the first 1.4GW link available for service ahead of completion of 2nd.

NOA / Appendix C / List of options 142

List of options

	THRE **Reconductor Hinkley Point to Taunton double circuit** Status: Scoping Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev Region: South	Replace the conductors in the Hinkley Point to Taunton circuits with higher-rated conductors to increase the circuits' thermal ratings.
	THS1 **Installation of a single series reactor at Thornton substation** Status: Optioneering Boundaries affected: B7aI; B7aE; B8 Region: North	Installation of a single 2400MVA series reactor at Thornton substation. These would connect the parts of the site at present operated disconnected from one another to limit fault levels. The reactors would allow some flow sharing between the different parts of the site and reduce thermal overloads on connected circuits.
	TKP1 **Power control device along Tilbury to Kingsnorth** Status: Project not started Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev; SC3Rev Region: South	Install a power control device along the Tilbury to Kingsnorth 400kV overhead line route. This would improve the capability to control the power flows in the south east region of the transmission network.
	TKRE **Tilbury to Grain and Tilbury to Kingsnorth upgrade** Status: Scoping Boundaries affected: SC1Rev; SC1.5Rev; SC2Rev; SC3; SC3Rev; LE1; EC5E Region: South	Replace the conductors in the Tilbury to Grain and Tilbury to Kingsnorth circuits with higher-rated conductors, and replace the associated cables with larger cables of a higher rating, including Tilbury, Grain and Kingsnorth substation equipment. This will increase the circuits' thermal ratings.
	TKU2 **Alternative east coast onshore phase 2 reinforcement** Status: Project not started Boundaries affected: B4E; B4F; B4I; B5; B2E; B2F; B2I Region: North	Establish further 400kV infrastructure on the east coast following ECUP. Re-profile the existing Kintore to Tealing 275kV double circuit to enable a higher operating temperature. Establish a new 400kV substation at Tealing, including new 400/275kV transformers. Re-insulate the existing Alyth to Tealing 275kV double circuit OHL for 400kV operation. Reinsulate a single side of the existing 275kV double circuit between Tealing and Longannet via Westfield to 400kV operation, installing a new 400/275kV transformer at Westfield.
	TKUP **East coast onshore 400kV phase 2 reinforcement** Status: Project not started Boundaries affected: B2I; B2E; B2F; B4I; B4E; B4F; B5 Region: North	Establish further 400kV infrastructure on the east coast following ECUP. Rebuild the Kintore to Tealing 275kV double circuit for 400kV operation and establish a new 400kV substation at Tealing, including new 400/275kV transformers. Re-insulate the existing Alyth to Tealing 275kV double circuit OHL for 400kV operation. Re-insulate the existing Tealing to Longannet 275kV route through Glenrothes, Westfield and Mossmorran for 400kV operation. Install 400/275kV transformers at Glenrothes and new 400/132kV transformers at Westfield and Mossmorran.
	TLNO **Torness to north east England AC onshore reinforcement** Status: Scoping Boundaries affected: B6SPT; B6I Region: North	This option provides additional transmission capacity by installing a new 400kV double circuit from a 400kV substation in the Torness area to a suitable connection point in north east England, including required additional substation equipment at both ends.

NOA / Appendix C / List of options 143

List of options

	TTNC **New north east England to north Yorkshire reinforcement** Status: Project not started Boundaries affected: B6l Region: North	Construct a new 400kV double circuit from north east England to north Yorkshire, to facilitate power transfer requirements across the relevant boundaries. Suitable connection points at each end will be identified, as well as relevant substation works required to accommodate the new circuit.
	TUEU **Tummel reconfiguration** Status: Scoping Boundaries affected: B4l; B4E; B4F Region: North	Relocate the existing Tummel 275/132kV supergrid transformers to the new Kinardochy 275KV substation and remove the existing Tummel substation. Connect to the existing Errochty circuits with new 132kV cables.
	WAM1 **225MVAr MSCs at Walpole** Status: Project not started Boundaries affected: EC5l; EC5E Region: South	One new 225 MVAr switched capacitor (MSC) at Walpole would provide voltage support the north London area as system flows increase in the future.
	WAM2 **225MVAr MSCs at Walpole** Status: Project not started Boundaries affected: EC5l; EC5E Region: South	One new 225 MVAr switched capacitor (MSC) at Walpole would provide voltage support the north London area as system flows increase in the future.
	WCC1 **Cable replacement at Hinksey** Status: Project not started Boundaries affected: SC1Rev; SW1 Region: West	Upgrade the cable section in the Cowley to Walham 400kV circuit at Hinksey to increasing the circuits' thermal ratings.
	WHTI **Tee-in of the West Boldon to Hartlepool circuit at Hawthorn Pit** Status: Design/development and consenting Boundaries affected: B6l; B7al; B7aE Region: North	Tee-in of the West Boldon to Hartlepool circuit, which currently passes the Hawthorn Pit site to connect to it. This would create a new 3 ended circuit, Hartlepool to Hawthorn Pit to West Boldon 275kV circuit. This would ensure better load flow sharing and increased connectivity in the north east 275kV ring.
	WLTI **Windyhill–Lambhill–Longannet 275kV circuit turn-in to Denny North 275kV substation** Status: Design/development and consenting Boundaries affected: B5 Region: North	Turn the Windyhill to Lambhill to Longannet 275kV circuit into Denny North 275kV Substation to create a 275kV Windyhill to Lambhill to Denny North circuit and a Denny North to Longannet No.2 275kV circuit.
	WORE **Reconductor West Boldon to Offerton 275kV circuit** Status: Project not started Boundaries affected: B7al Region: North	Replace the conductor in the West Boldon to Offerton circuit with higher-rated conductors to increase the circuit's thermal rating.
	WRRE **Reconductor West Burton to Ratcliffe-on-Soar circuit** Status: Project not started Boundaries affected: B8 Region: North	Replace the conductors in the West Burton to Ratcliffe-on-Soar circuit with higher-rated conductors to increase the circuit's thermal ratings.
	WSEU **Thermal upgrade for Sundon and Wymondley 400kV substation** Status: Project not started Boundaries affected: LE1; EC5E Region: South	Upgrade the 400kV Sundon and Wymondley substation equipment to increase its thermal capacity, supporting future load flow within the area.
	WSR1 **Sundon-Wymondley circuit 1 reconductoring** Status: Project not started Boundaries affected: EC5E Region: South	Replace the conductors in the Sundon to Wymondley circuit 1 with higher-rated conductors.

List of options

	WSR2 **Sundon-Wymondley circuit 2 reconductoring** Status: Project not started Boundaries affected: EC5E Region: South	Replace the conductors in the Sundon to Wymondley circuit 2 with higher-rated conductors.
	WTUP **Uprate Tilbury to Waltham Cross route from 275kV to 400kV** Status: Project not started Boundaries affected: LE1 Region: South	Upgrade Waltham Cross, Tilbury and Warley 400kV substation, turn-in Elstree to Warley circuit into Waltham Cross 400kV substation and uprate Warley to Tilbury circuit to 400kV from 275kV. These works would further provide additional transmission capacity between London and the south coast.
	WYTI **Wymondley turn-in** Status: Design/development and consenting Boundaries affected: LE1; EC5E Region: South	Modify the existing circuit that runs from Pelham to Sundon. Turn-in the circuit at Wymondley to create two separate circuits that run from Pelham to Wymondley and from Wymondley to Sundon to improve the balance of flows.

NOA / Appendix C / List of options 145

Appendix D

Meet the *NOA* team

Meet the *NOA* team

Julian Leslie

Head of Networks,
Electricity System Operator
Julian.Leslie@nationalgrideso.com

The Networks team addresses the engineering challenges of operating the electricity network by studying from the investment options stage in a changing energy landscape through to network access just a day ahead of real-time.

Nicholas Harvey

Network Development Manager
Nicholas.Harvey@nationalgrideso.com

The Network Development team delivers an efficient GB and offshore electricity transmission system by understanding present capabilities and working out the best options to meet the requirements of possible *Future Energy Scenarios*.

Network Development

We develop a holistic strategy for the NETS. This includes the following key activities:

- Testing the *FES* against models of the GB NETS to identify potential transmission requirements and publishing in the *ETYS*.
- Supporting Needs Case studies of reinforcement options as part of the SWW process.
- Supporting cost-benefit studies of different connections designs.
- Developing long-term strategies for a secure and efficient GB transmission network against the changing industry needs.

You can contact us to discuss about:

The *Network Options Assessment*

Jason Hicks
Technical Economic Assessment Manager
Jason.Hicks@nationalgrideso.com

Cost-benefit analysis and the *Network Options Assessment*

Paul Wakeley
Economic Assessment Manager
Paul.Wakeley@nationalgrideso.com

The *Electricity Ten Year Statement*

James Whiteford
GB System Capability Manager
James.Whiteford@nationalgrideso.com

Supporting parties

Strategic network planning and production of the *NOA* requires support and input from many people.
These include:

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

Don't forget you can also email us with your views on the *NOA* at:
noa@nationalgrideso.com

NOA / Appendix D / Meet the NOA team 147

Appendix E

Glossary

Average cold spell (ACS)
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.

BID3
BID3 is an economic dispatch optimisation model supplied by AFRY Management Consulting. It can simulate all European power markets simultaneously including the impact of interconnection between markets. BID3 has been specifically developed for National Grid to model the impact of electricity networks in GB, allowing the System Operator to calculate constraint costs it would incur to balance the system, post-gate closure.

Boundary allowance
An allowance in MW to be added in whole or in part to transfers arising out of the NETS SQSS economy planned transfer condition, to take some account of year-round variations in levels of generation and demand. This allowance is calculated by an empirical method described in Appendix F of the security and quality of supply standards (SQSS).

Boundary transfer capacity
The maximum pre-fault power that the transmission system can carry from the region on one side of a boundary to the region on the other side of the boundary while ensuring acceptable transmission system operating conditions will exist following one of a range of different faults.

Cost-benefit analysis (CBA)
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.

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.

Critical
The option is optimal on its earliest in-service date (EISD) in at least one scenario.

Department of Business, Energy & Industrial Strategy (BEIS)
A UK government department. The Department of Business, Energy & Industrial Strategy (BEIS) works to make sure the UK has secure, clean, affordable energy supplies and promote international action to mitigate climate change.

Distribution Network Operator (DNO)
Distribution network operators own and operate electricity distribution networks.

Double circuit overhead line
In the case of the onshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span in SHE Transmission's system or NGET's transmission system or for at least two miles in SP Transmission system. In the case of an offshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span.

Earliest In Service Date (ESID)
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.

Future Energy Scenarios (FES)
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.

Gigawatt (GW)
1,000,000,000 watts, a measure of power.

Gigawatt hour (GWh)
1,000,000,000 watt hours, a unit of energy.

Great Britain (GB)
A geographical, social and economic grouping of countries that contains England, Scotland and Wales.

NOA / Appendix E / Glossary 149

High voltage alternating current (HVAC)
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.

High voltage direct current (HVDC)
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.

Interconnector
Electricity interconnectors are transmission assets that connect the GB market to Europe and allow suppliers to trade electricity between markets.

Large Onshore Transmission Investment (LOTI)
This is a funding mechanism for the TOs as part of the RIIO-2 price control that allows TOs to bring forward investment projects worth more than £100m that have not been funded in the price control settlement.

Load factor
The average power output divided by the peak power output over a period of time.

Marine technologies
Tidal streams, tidal lagoons and energy from wave technologies (see www.emec.org.uk)

Megawatt (MW)
1,000,000 watts, a measure of power.

Megawatt hour (MWh)
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.

Main Interconnected Transmission System (MITS)
This comprises all the 400kV and 275kV elements of the onshore transmission system and, in Scotland, the132kV elements of the onshore transmission system operated in parallel with the supergrid, and any elements of an offshore transmission system operated in parallel with the supergrid, but excludes generation circuits, transformer connections to lower voltage systems, external interconnections between the onshore transmission system and external systems, and any offshore transmission systems radially connected to the onshore transmission system via single interface points.

National Electricity Transmission System (NETS)
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).

National Electricity Transmission System Operator (NETSO)
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 Electricity Transmission Ltd (SHE Transmission) in the north of the country and Scottish Power Transmission SP Transmission in the south.

National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS)
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.

National Grid Electricity Transmission plc (NGET)
National Grid Electricity Transmission plc (No. 2366977) whose registered office is 1-3 Strand, London, WC2N 5EH.

NOA / Appendix E / Glossary 150

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.

Network Options Assessment (NOA)
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)*.

Office of Gas and Electricity Markets (OFGEM)
The UK's independent National Regulatory Authority, a non-ministerial government department. Their principal objective is to protect the interests of existing and future electricity and gas consumers.

Offshore
This term means wholly or partly in offshore waters.

Offshore transmission circuit
Part of an offshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables, overhead lines and DC converters but excludes busbars and onshore transmission circuits.

Onshore
This term refers to assets that are wholly on land.

Onshore transmission circuit
Part of the onshore transmission system between two or more circuit-breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes busbars, generation circuits and offshore transmission circuits.

Optimal
The option is economically justified in at least one scenario.

Peak demand
The maximum power demand in any one fiscal year: Peak demand typically occurs at around 5:30pm on a week-day between December and February. Different definitions of peak demand are used for different purposes.

Photovoltaic (PV)
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.

Social Economic Welfare (SEW)
Social Economic Welfare (SEW) is a common cost-benefit indicator when analysing projects of public interest. It captures the overall benefit, in monetary terms, to society from a given course of action.

NOA / Appendix E / Glossary 151

SP Transmission
Scottish Power Transmission Limited (No. SC189126) whose registered office is situated at 1 Atlantic Quay, Robertson Street, Glasgow G2 8SP.

System requirements form (SRF)
Set of templates that are completed by the TOs and submitted to NGESO which contain details on the options to be assessed in the *NOA*. To find out more, please read the *NOA* Methodology report.

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.

Supergrid transformer (SGT)
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 Operability
The ability to maintain system stability and all of the asset ratings and operational parameters within pre-defined limits safely, economically and sustainably.

System Operability Framework (SOF)
The SOF identifies the challenges and opportunities which exist in the operation of future electricity networks and identifies measures to ensure the future operability.

Electricity System Operator (ESO)
An entity entrusted with transporting electric energy on a regional or national level, using fixed infrastructure. Unlike a TO, the ESO may not necessarily own the assets concerned. For example, National Grid ESO operates the electricity transmission system in Scotland, which is owned by Scottish Hydro Electricity Transmission and Scottish Power.

System stability
With reduced power demand and a tendency for higher system voltages during the summer months, fewer generators will operate and those that do run could be at reduced power factor output. This condition has a tendency to reduce the dynamic stability of the NETS. Therefore network stability analysis is usually performed for summer minimum demand conditions as this represents the limiting period.

Strategic Wider Works (SWW)
This is a funding mechanism as part of the RIIO-T1 price control that allows TOs to bring forward large investment projects that have not been funded in the price control settlement.

Transmission circuit
This is either an onshore transmission circuit or an offshore transmission circuit.

Transmission entry capacity (TEC)
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.

Transmission Owners (TO)
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.

Transmission System Operators (TSO)
An entity entrusted with transporting energy in the form of natural gas or power on a regional or national level, using fixed infrastructure.

NOA / Appendix E / Glossary 152

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NOA / Disclaimer 153

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