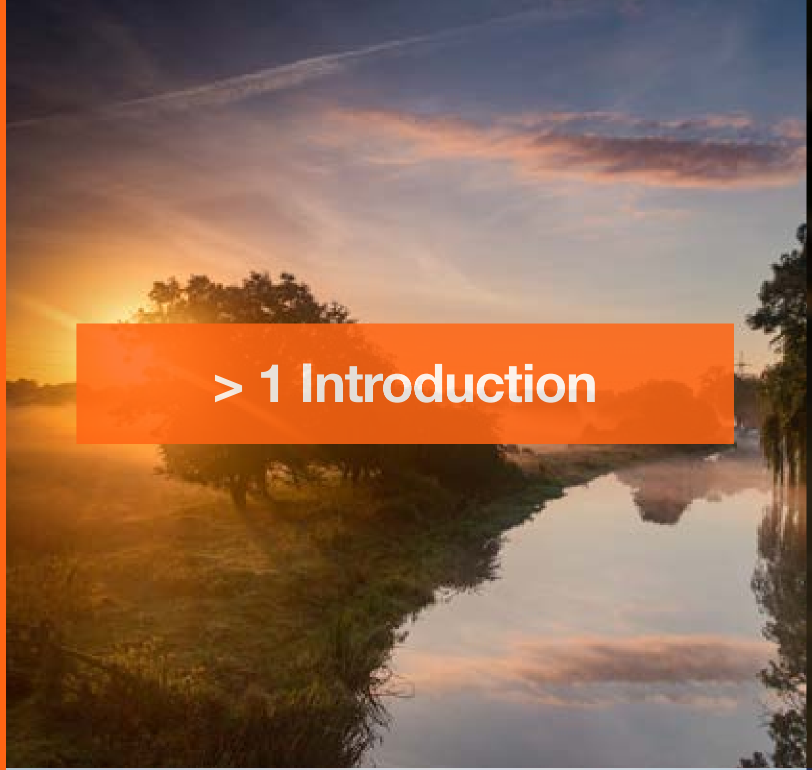
Network Options Assessment

January 2020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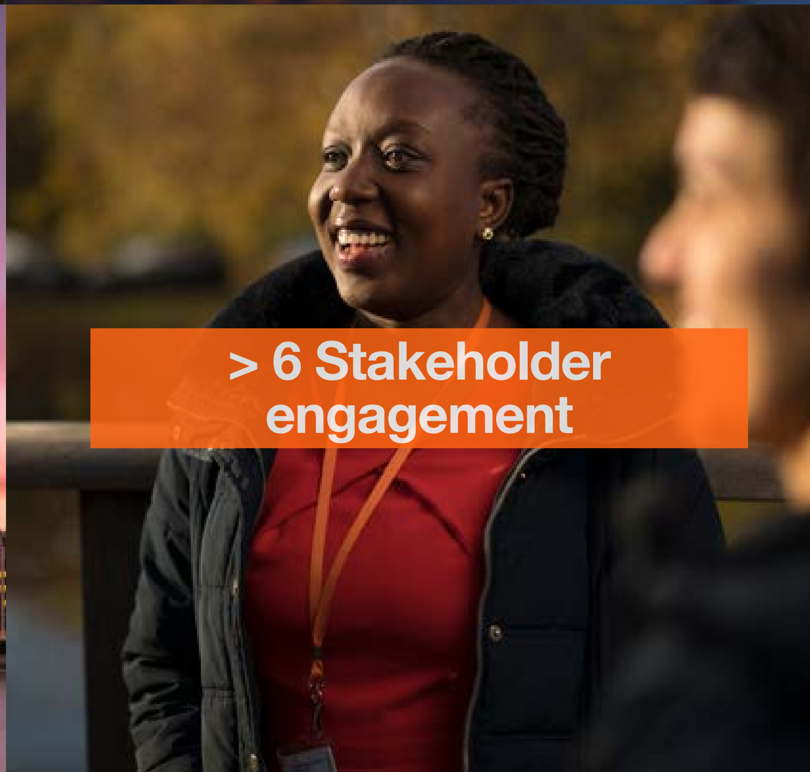
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Foreword

Last year saw a major milestone in the UK's energy revolution as the Government passed laws to end its contribution to global warming by 2050. As the Electricity System Operator (ESO), we also set a target, of having the capability to operate a zero carbon network by 2025. Our *Network Options Assessment (NOA)* publication, along with our other ESO publications, continues to embrace these ambitions and lead our industry towards a secure, sustainable and affordable energy future.

The *NOA* is a key part of the ESO role. It describes the major projects we are considering to meet the future needs of GB's electricity transmission system as outlined in the *Electricity Ten Year Statement (ETYS) 2019*, and recommends which investments in the year ahead would best futureproof the GB transmission network for their role at the heart of our energy system.

We are pleased to present the 5th *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 our recommendations on the data and analysis of the *2019 FES* and *ETYS*. Our latest methodology was approved by Ofgem in October 2019.

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.

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.

Julian Leslie
Head of Networks,
Electricity System Operator

Executive summary

The *NOA* is our recommendation for which reinforcement projects should receive investment during the coming year. We reach our conclusions using the *FES 2019*, *ETYS 2019*, and following the latest NOA report methodology approved by Ofgem. Below, we present a summary of the key points of the *NOA 2019/20*.

147 assessed options

Proceed	42
Delay	2
Hold	47
Do not start or Stop	56
NOA I/C	18.1 to 23.1 GW

£11.1bn* Total Cost

£203m Investing in 2020/21

3 Number of ESO-led commercial solutions Saving consumers up to £950m

*this includes the costs only for E2DC and not E2D2. These projects are mutually exclusive and therefore only one will be delivered in full.

Executive summary

We identified a need for four Anglo-Scottish reinforcements to accommodate the increasing north-to-south power flows. The final recommendation for which, if any, of these reinforcements should progress to construction is subject to the Strategic Wider Works (SWW) assessment, which investigates wider ranges of sensitivities.

We anticipate the south coast will have a growing volume of interconnection capacity over the next decade. In *NOA 2018/19* the increasing flows between GB and other countries triggered the need for a new transmission line between south London and the south east coast. This year, analysis showed that a new transmission route to be delivered in 2028 between Suffolk and Kent would benefit a wider range of boundaries, resulting in a higher economic benefit. As a result, we recommend this option to be investigated as an SWW with other available options.

In addition to the asset-based reinforcements proposed by the TOs, we included four ESO-led commercial solutions. We believe there is a significant benefit in pursuing three of these and will refine them via market testing this year.

This year's interconnector analysis suggests a total interconnection capacity range of between 18.1 to 23.1 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.

This *NOA* also identifies which options we recommend to proceed are likely to meet Ofgem's criteria for onshore competition. We also expand this assessment to any new or modified contracted connection projects for generator and demand connections. The competition assessment is in accordance with the Ofgem agreed methodology and the outcomes are described in Chapter 4 – 'Investment recommendations'.

You can find an overview of our investment recommendations with their optimal delivery year, including all the options where a decision must be made this year and some key changes to last year's recommendations, in table 0.1.

Many other factors outside the scope of this analysis will influence the outcome for GB interconnection over the next decade and beyond.

We are waiting on the final outcome of the EU-Exit negotiations and what this will mean for interconnector trading arrangements. We expect interconnectors to continue playing a long-term role in the UK's diverse energy mix. While some of the trading arrangements may need to change in both a deal or no-deal scenario, systems and processes can be amended to make sure power can still flow between the UK and Europe.

Executive summary

Table 0.1
Summary of investment recommendations

Key: Two Degrees | Community Renewables | Consumer Evolution | Steady Progression

Option code	Option description	EISD	TD	CR	CE	SP	NOA 2018/19 recommendation	NOA 2019/20 recommendation	Reason
BMM2	225 MVAr MSCs at Burwell Main	2022	2022	2022	2022	2022	Proceed	Proceed	No change
BNRC	Bolney and Ninfield additional reactive series compensation	2023	2023	2023	2023	2023	Proceed	Proceed	No change
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit	2029	2029	2029	2039	2029	Hold	Proceed	This reinforcement becomes critical under three scenarios
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route	2024	2024	2024	2024	2024	Hold	Proceed	This reinforcement becomes critical under all scenarios
BTNO	A new 400 kV double circuit between Bramford and Twinstead	2028	2028	2028	2028	2028	Proceed	Proceed	No change
CDP1	Power control device along Cellarhead to Drakelow	2023	2023	2028	2027	2027	Not featured	Delay	New reinforcement
CDRE	Cellarhead to Drakelow reconductoring	2022	N/A	N/A	N/A	N/A	Proceed	Stop	This reinforcement has been superceded by new alternatives CDP1, CDP2 and CDP4
CGNC	A new 400 kV double circuit between Creyke Beck and the South Humber	2031	2031	2031	2031	N/A	Not featured	Proceed	New reinforcement
CS35	Commercial solution for Scotland and the north of England	2023	2023	2023	2024	2023	Not featured	Proceed	New reinforcement
CS51	Commercial solution for East Anglia	2024	2024	2027	N/A	2033	Not featured	Proceed	New reinforcement
CS53	Commercial solution for the south coast	2023	2023	2024	2023	2023	Not featured	Proceed	New reinforcement
CTP2	Alternative power control device along Creyke Beck to Thornton	2024	2024	2029	2029	2027	Not featured	Proceed	New reinforcement

Option code	Option description	EISD	TD	CR	CE	SP	NOA 2018/19 recommendation	NOA 2019/20 recommendation	Reason
DWNO	Denny to Wishaw 400 kV reinforcement	2028	2028	2028	2028	2028	Proceed	Proceed	No change
E2D2	Eastern Scotland to England link: Torness to Cottam offshore HVDC	2028	2028	2028	N/A	N/A	Do not start	Proceed	This reinforcement becomes critical under two scenarios
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit	2027	N/A	N/A	2027	2027	Proceed	Proceed	No change
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC	2029	2029	2029	2029	2029	Proceed	Proceed	No change
E4L5	Eastern Scotland to England 3rd link: Peterhead to South Humber offshore HVDC	2031	2031	2031	2031	2031	Not featured	Proceed	New reinforcement
ECU2	East coast onshore 275 kV upgrade	2023	2023	2023	2023	2023	Proceed	Proceed	No change
ECUP	East coast onshore 400 kV incremental reinforcement	2026	2026	2026	2026	2026	Proceed	Proceed	No change
ECVC	Eccles synchronous series compensation and real-time rating system	2026	2026	2026	2026	2026	Hold	Proceed	This reinforcement becomes critical under all scenarios
FLR3	Reconductor Fleet to Lovedean circuit	2020	2020	2020	2020	2020	Not featured	Proceed	New reinforcement
GRRA	Grain running arrangement change	2020	2020	2020	2020	2020	Hold	Proceed	This reinforcement becomes critical under all scenarios
GWNC	A new 400 kV double circuit between South Humber and South Lincolnshire	2031	2031	2031	2031	2031	Not featured	Proceed	New reinforcement
HAE2	Harker supergrid transformer 5 replacement	2023	2023	2023	2028	2024	Proceed	Proceed	No change

Executive summary

Table 0.1 (continued)
Summary of investment recommendations

Key: Two Degrees | Community Renewables | Consumer Evolution | Steady Progression

Option code	Option description	EISD	TD	CR	CE	SP	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation	Reason
HAEU	Harker supergrid transformer 6 replacement	2022	2022	2022	2022	2022	Proceed	Proceed	No change
HNNO	Hunterston East to Neilston 400kV reinforcement	2023	2023	2023	2023	2023	Proceed	Proceed	No change
HSP1	Power control device along Fourstones to Harker to Stella West	2020	2020	2020	2020	2020	Not featured	Proceed	New reinforcement
KLRE	Kemsley to Littlebrook circuits uprating	2020	2020	2020	2020	2020	Proceed	Proceed	No change
LNPC	Power control device along Lackenby to Norton	2020	2020	2020	2020	2020	Not featured	Proceed	New reinforcement
LNRE	Reconductor Lackenby to Norton single 400kV circuit	2023	2028	2028	2029	2028	Proceed	Hold	This reinforcement is no longer critical under any scenario
MBHW	Bramley to Melksham circuits thermal uprating	2023	2025	2023	2026	2026	Not featured	Proceed	New reinforcement
MRPC	Power control device along Penwortham to Kirkby	2020	2020	2020	2020	2020	Not featured	Proceed	New reinforcement
NEMS	225MVAr MSCs within the north east region	2022	2028	2028	2029	2028	Proceed	Hold	Generation mix changes
NEP1	Power control device along Blyth to Tynemouth to Blyth to South Shields	2024	2024	N/A	2024	2024	Not featured	Proceed	New reinforcement
NOR2	Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit	2022	2022	2022	2023	2022	Hold	Proceed	This reinforcement becomes critical under three scenarios
NTP1	Power control device along North Tilbury	2023	2023	2023	2023	2023	Not featured	Proceed	New reinforcement
OENO	Central Yorkshire reinforcement	2028	N/A	N/A	N/A	N/A	Proceed	Stop	This reinforcement has been superceded by new reinforcement OPN2
OPN2	A new 400kV double circuit between Osbaldwick and Poppleton and relevant 275kV upgrades	2027	2028	2028	2027	2027	Not featured	Proceed	New reinforcement
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit	2021	2021	2021	2021	2021	Proceed	Proceed	No change
SCD1	New offshore HVDC link between Suffolk and Kent Option 1	2028	2028	2028	2029	2034	Not featured	Proceed	New reinforcement
SCN1	New 400kV transmission route between south London and the south coast	2029	N/A	N/A	N/A	N/A	Proceed	Stop	This reinforcement has been superceded by new reinforcement SCD1
SEEU	Reactive series compensation protective switching scheme	2022	2022	2022	2022	2022	Proceed	Proceed	No change
SER1	Elstree to Sundon reconductoring	2023	2023	2023	2023	2023	Delay	Proceed	This reinforcement becomes critical under all scenarios
SHNS	Upgrade substation in the South Humber area	2031	2031	2031	2031	2031	Not featured	Proceed	New reinforcement
THS1	Install series reactors at Thornton	2023	2023	2023	2023	2023	Proceed	Proceed	No change
TKRE	Tilbury to Grain and Tilbury to Kingsnorth upgrade	2026	2026	2026	2026	2026	Stop	Proceed	This reinforcement becomes critical under all scenarios
TLNO	Torness to north east England AC onshore reinforcement	2036	2036	2036	2036	N/A	Do not start	Proceed	This reinforcement becomes critical under three scenarios
WHTI	Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit	2021	2021	2021	2021	2021	Proceed	Proceed	No change
WLTI	Windyhill to Lambhill to Longannet 275kV circuit turn-in to Denny North 275kV substation	2021	2023	2021	2023	2022	Hold	Delay	This reinforcement is only critical under one scenario

Executive summary
Have your say

Your views are important in helping us continue to develop and improve the *NOA*. Chapter 6 – 'Stakeholder engagement' describes how you can contact us.

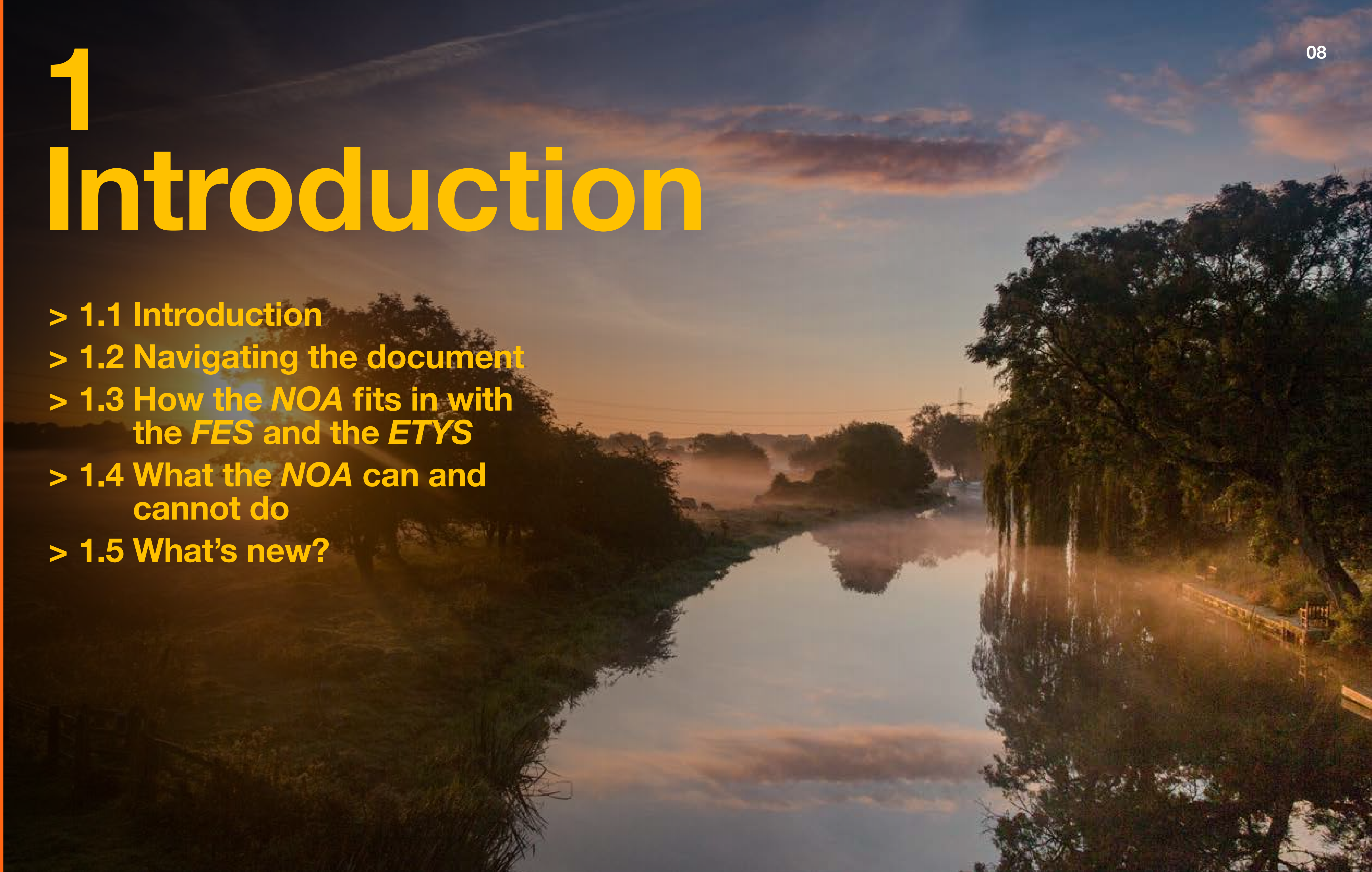
Future energy publications
National Grid ESO has an important role in leading the energy debate across our industry and working with you to make sure that together we secure our shared energy future. As the Electricity System Operator (ESO), we are perfectly placed as an enabler, informer and facilitator. 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 *Future Energy Scenarios (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 *Future Energy Scenarios (FES)*, *Electricity Ten Year Statement (ETYS)*, and *Network Options Assessment (NOA)* publications. Your input can help shape these publications and inform the energy debate.

Have your say

1 Introduction



1.1 Introduction
About this document

This chapter introduces the *Network Options Assessment (NOA)* and summarises the new features in the report.

The *NOA 2019/20* is the fifth to be published. As ever, we welcome your feedback which we will use to develop future editions.

The *NOA* helps us develop an efficient, coordinated and economic electricity transmission system consistent with the National Electricity Transmission System (NETS) Security and Quality of Supply Standard (SQSS). We use it to identify and recommend major NETS reinforcement projects for Great Britain's Transmission Owners (TOs) to meet the future network requirements, as defined in the *Electricity Ten Year Statement (ETYS)*. It also identifies which projects meet the criteria proposed by the industry regulator, Ofgem, for onshore competition.

These projects include both major NETS reinforcements and future generator and demand connections to the transmission system[1]. This report is underpinned by the data in our future energy scenarios (FES), which means that the *NOA* and the *ETYS* have a consistent starting point and give a full picture for assessing the potential development of the electricity transmission network.

Chapter 5 includes our interconnection analysis. This informs the industry of the potential benefits of future interconnection, with the goal of encouraging the development of efficient levels of interconnection capacity between GB and other markets.

This year's NOA Interconnector analysis includes additional improvements to the methodology. We've revised the interconnector baseline level methodology to provide a fairer representation of the starting point for interconnection capacity. Interconnectors have the potential to reduce carbon emissions, reduce renewable energy curtailment and improve system operability or lower the costs of providing system security.

Chapter 2 includes the NOA report methodology which details how the NOA process works. We started the NOA report methodology in early 2019, working with the onshore TOs and Ofgem. We consulted on the initial draft of the *NOA 2019/20* methodology in May 2019.

After further discussions and refinement, the methodology was submitted to Ofgem in July 2019 and then published on our website. It was approved by Ofgem in October 2019.

We've provided more context and explanation of the results, and highlighted how they differ from other analysis, such as the ***Ten-Year Network Development Plan (TYNDP)***. These improvements have been driven by stakeholder feedback and approved by Ofgem.

[1] Ofgem closed its statutory consultation on changes to Standard Licence Condition C27 of electricity transmission in January 2020. The changes proposed new requirements for the ESO to assess projects recommended for further development in the NOA and projects for future generator and demand connections, for their eligibility for competition.

1.2 Navigating the document

We've structured the *NOA* document in a logical way 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 a good overview 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. This is a good description of the types of options being proposed by the TOs.

Chapter 4

'Investment recommendations'
presents our investment recommendations for 2019/20. It also summarises the eligibility assessment for competition in onshore electricity transmission.

Chapter 5

'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. This year, we also examine the impact of interconnectors on operational costs.

Chapter 6

'Stakeholder engagement'
discusses how you can give us your feedback to improve the *NOA* in future publications.

1.3 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 issues. The *FES, ETYS* and *NOA* provide an evolving and consistent voice in the development of GB's electricity network.

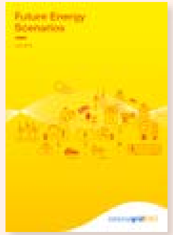
We use the *FES* to assess network requirements for power transfers across the GB NETS. The TO responds with options for reinforcing the network and the requirements are published in the *ETYS*. The *NOA* is based on our economic analysis of these options. Further explanation of this process can be found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

We summarise our economic analysis of reinforcement options by region. Based on the economic analysis, we give our recommended option or options for each of the regions. For some, we've included a summary of the Strategic Wider Works (SWW) analysis.

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.

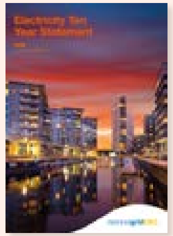
Some alternative options we've evaluated are reduced-build or operational options as explained in **Chapter 3** – 'Proposed options'. The *NOA* emphasises the need to reinforce the network, and we are keen to embrace innovative ways to do so.

Figure 1.1
***NOA* and ESO documents**



Future Energy Scenarios (FES)
July
A range of plausible and credible pathways for the future of energy from today out to 2050.

Operability Strategy Report
Regular
How the changing energy landscape will impact the operability of the electricity system.



Electricity Ten Year Statement
November
The future transmission requirements on the electricity system.

Network Options Assessment
January
The recommended options to meet reinforcement requirements on the electricity system.

1.4 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 interconnections to other European electricity grids – as well as any necessary reinforcements
- indicate whether the TOs should begin developing the Needs Case for potential SWW options
- indicate to Ofgem and other relevant stakeholders which reinforcement options and works for future generator and demand connection projects are eligible for onshore competition.

The NOA cannot…

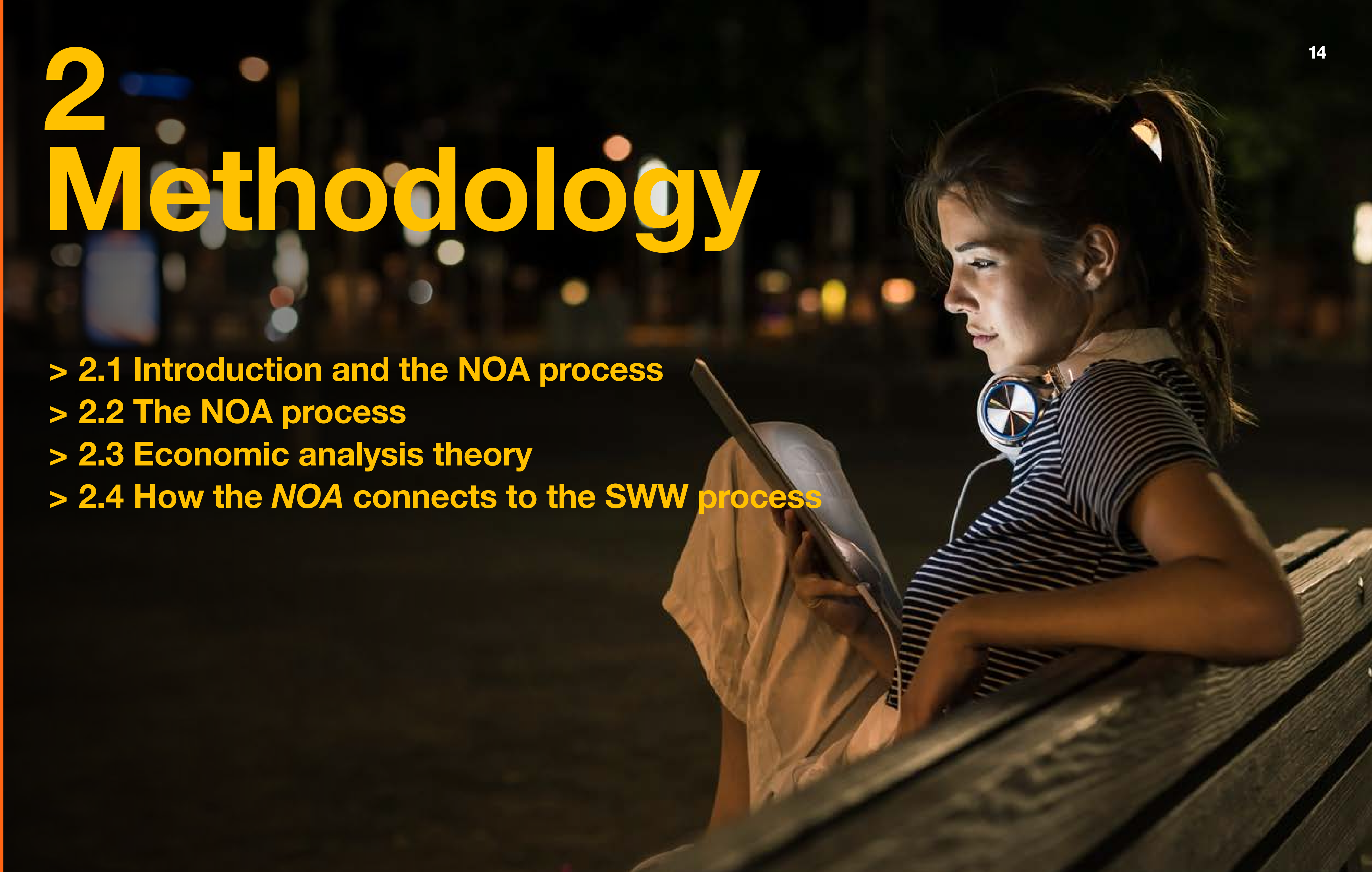
- provide recommendations for customer connection. The *NOA* only recommends the most economic reinforcement to resolve wider network issues.
- insist that reinforcement options are pursued. We can only recommend options based on our analysis. The TOs or other relevant parties are ultimately responsible 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
- list all the options that the TOs develop. Some are discarded early. The TOs develop options and consult with stakeholders on variations
- forecast or recommend future interconnection levels. It indicates the optimum level of interconnection.

1.5 What's new?

In the *NOA 2017/18*, we strengthened the NOA process by introducing a NOA Committee to scrutinise our investment recommendations. This was supported by using implied probabilities to help our decision-making for options driven by a single factor or considered sensitive.

Given the success of these, we continue to apply them this year. We've also used our stakeholders' feedback to improve the *NOA*. The following areas are new additions for the *NOA 2019/20*.

- **Interactivity and use of maps in the *NOA* report** – New features include changing the appearance to making the report more interactive for a better experience. A key innovation is the interactive map included in **Chapter 4** – 'Investment recommendations' which show the options and recommendations.
- **Publishing our system requirement forms** – We have made the **SRF** publicly available as a workbook on our **website** as a first step in our pathway to facilitate options from a broader range of participants and increase transparency in our processes. The SRF are the first step in the *NOA* process and identify the boundary transfer requirements which lead to the submission of options.
- **Changes to the *NOA* economic analysis modelling** – The *NOA 2018/19* recommended investment in two ESO-led commercial solutions. We are refining our requirements and assumptions for those solutions by considering different durations so they can be better represented in our assessment. These improvements made our models more accurate and gave more informed results.
- **The *NOA* pathfinding projects** – In 2018, we published our Network Development Roadmap for the coming years, committing to conducting pathfinding projects to explore ways of including other system needs. For example, regional reactive requirements, stability of frequency, voltage requirements for network users, year-round system requirements using a probabilistic approach, and a broader range of market participants for providing whole system solutions. We've made progress in those areas this year. For the most up-to-date information on pathfinding projects, please visit the **Network Development Roadmap webpage**.
- **Changes to the NOA for Interconnectors** – This year, we've revised the interconnector baseline level methodology to provide a fairer representation of the starting point for interconnection capacity. We've also refocused the analysis on the main iterative process, identifying the optimal level of interconnection capacity between GB and other markets. We've removed the system operability analysis, which will now be included in our ***System Operability Framework*** suite of reports. This will consider the impact of a range of technologies on system operability, rather than focus on interconnectors in isolation.
- **Changes to the handover process** – Following stakeholders' feedback on *NOA 2018/19*, we've refined our system requirements form and developed an interactive handover tool to deliver a smoother handover process of information. This yearly tool development allows us to continuously improve the TOs' experience of submitting their options to be assessed in the *NOA*, while at the same time adding an extra level of quality assurance to the NOA process.
- **New ESO data hub** – To increase our transparency we have introduced the **ESO data hub**. In future we will be looking to see how we can utilise this hub to improve the *NOA*. We always welcome suggestions so please let us know how we can further develop it to meet your needs.



2 Methodology

2.1 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. It also explains how the *NOA* ties in with the SWW process.

The NOA methodology describes how we assess major NETS reinforcements to meet the requirements identified from our analysis of the FES. This year's methodology is published on our **website**, it also includes the methodologies for interconnection analysis included in **Chapter 5** – 'Interconnection analysis' and the SWW process.

In accordance with our licence condition, major NETS reinforcements are defined in paragraph 1.28 of the **NOA report methodology** as: "a project or projects in development to deliver additional boundary capacity or alternative system benefits, as identified in the *Electricity Ten Year Statement* or equivalent document."

Some users' connection agreements have major reinforcements as their required enabling works for connection. If the *NOA* recommends a change to the delivery of these works, we will work with these users to identify if any updates are required to their agreement. Their connections will not be delayed.

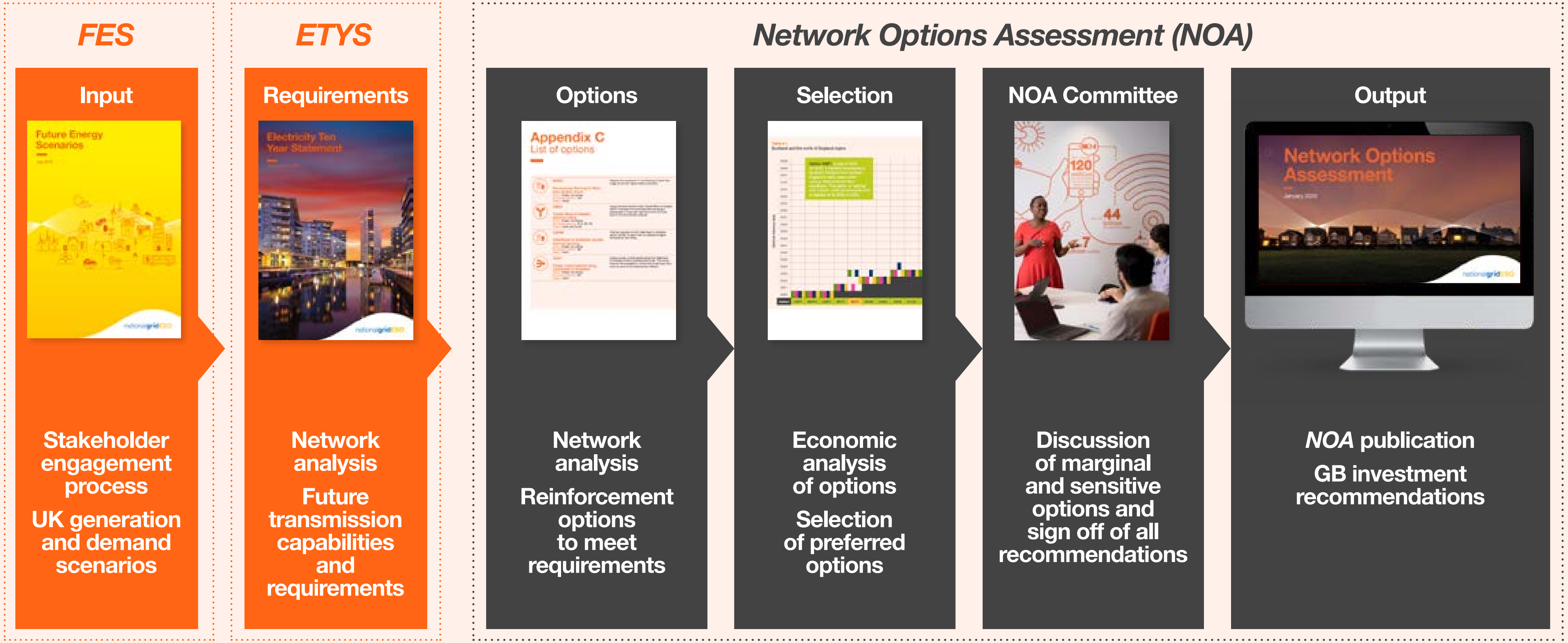
Watch our two short videos from our YouTube site that explain both the NOA process and what the future holds for the process:

NOA process

Future of the NOA process

2.2 The NOA process

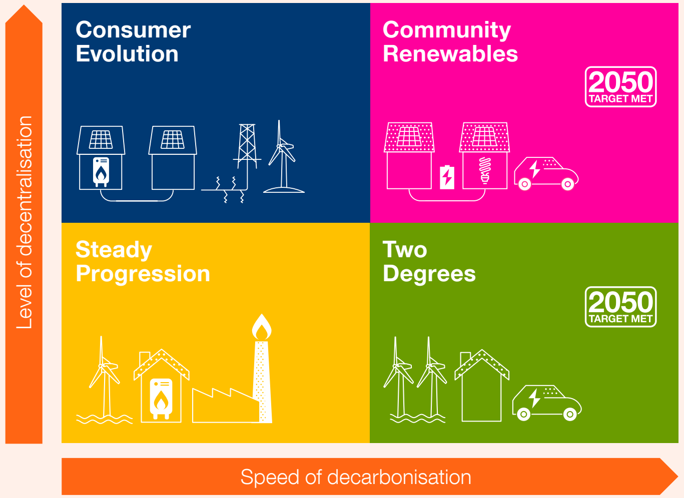
Figure 2.1
The NOA process



2.2 The NOA process

2.2.1 Future energy scenarios (FES)

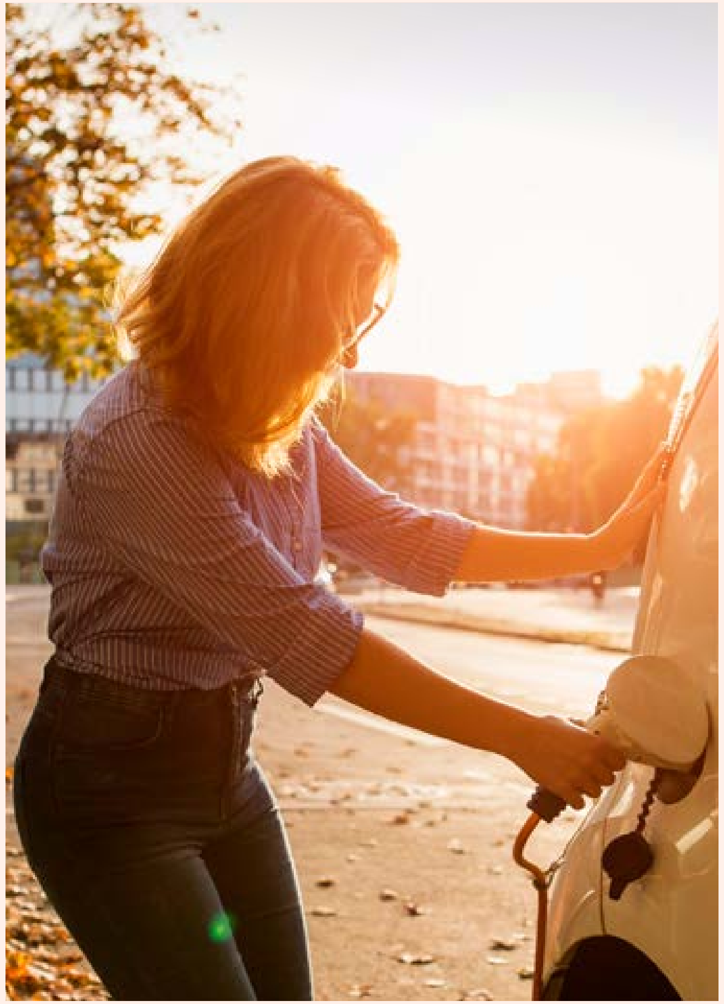
The first stage of the NOA process starts with the FES. These are a credible range of future scenarios across the whole energy system and the electricity components form the foundation for our studies and economic analysis. The four scenarios published in 2019 are:



These energy scenarios were based on two drivers ‘level of decentralisation’ and ‘speed of decarbonisation’. The *FES 2019* scenarios are unchanged from *FES 2018* and **Community Renewables** and **Two Degrees** meet the original Climate Change Act 2008 target of achieving an 80 per cent reduction in greenhouse gas emissions by 2050, compared to 1990 levels.

The new target of net zero emissions by 2050 isn’t met by any of the *FES 2019* scenarios, although the implications of this target are discussed in chapter 6 of the document. For more information on our FES, see *FES 2019*, which you can find at:

> *FES document*



2.2 The NOA process

2.2.2 *Electricity Ten Year Statement*

The *ETYS* is the second stage in the NOA process. We apply the FES to transmission system models and calculate the power flow requirements across the network. To do this, we have developed the concept of boundaries. These are a virtual split of the network into two parts.

As power transfers between these areas, we can see which parts of the network are under the most stress and where reinforcement would be most needed. Network capability and its future requirements are published in the *ETYS 2019*, which you can find at:

> *ETYS document*

> NOA webpage

2.2.3 *Network Options Assessment*

To create an electricity transmission network fit for the future, all TOs propose options to meet system capability requirements outlined by the *ETYS*, this is the third stage in the NOA process. We encourage options that include upgrading assets or creating new assets to give a wide selection of options.

As well as these build options, both the TOs and ESO can propose alternative options. These are solutions requiring very little or no build and instead maximise use of existing assets, often in innovative ways. You can find a full list of the options we analysed in **Chapter 3** – 'Proposed options'.

With these options, we move onto the fourth stage of the NOA process, 'Selection'. We use our understanding of constraint costs to carry out economic analysis. This gives us the options we believe provide the most benefit for consumers. You can find the full list of our recommended options in **Chapter 4** – 'Investment recommendations'. How we perform economic analysis is described in greater detail in the latest **NOA report methodology**.

Since the *NOA 2017/18*, we've operated the NOA Committee – consisting of ESO senior management – as an additional, transparent level of scrutiny to our NOA recommendations. In this final step, the investment recommendations from our economic analysis are presented to the NOA Committee, which focuses on marginal recommendations driven by a single scenario or driver, or recommendations which are considered to be sensitive, and challenges their single year least regret analysis with implied probabilities and other evidence.

The NOA Committee also provides wide-ranging energy industry insight, and takes into account whole system needs to support or revise marginal investment recommendations. Ahead of the NOA Committee meeting, the ESO discusses economic analysis results with both internal stakeholders and the TOs to make sure the final recommendations are robust. The TOs will be invited to present information at the NOA Committee if at least one of their options (or joint options) is to be discussed.

2.3 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 typically 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 report methodology** (paragraphs 2.61 to 2.84). This includes a detailed explanation of the cost-benefit analysis, the single year least worst regret selection process and our economic modelling tool. The latest NOA report methodology was approved by Ofgem in October 2019.

2.4 How the *NOA* connects to the SWW process

We use the NOA process to look at the costs and benefits of potential options and put forward our recommendations. If a large infrastructure option is recommended that satisfies one of the criteria below, this option is referred to as SWW. These are led by the TOs, which develop the Needs Case for such an option, with the support of the ESO.

	Option for NGET:	Option for NGET:	Option for NGET:
For England and Wales	> **£500 million**	Between **£100 million** and **£500 million**	< **£100 million**
		& supported by only 1 customer	
		& not required in most scenarios	
			& requires consent
	Considered as SWW		

	Option for SHE Transmission:	Option for SP Transmission:
For Scotland	> **£50 million**	> **£100 million**
	& output will deliver additional cross boundary (or sub-boundary) capability or wider system benefit	
	& costs cannot be recovered under any provision of the TO's price control settlement	
	Considered as SWW	

It's important to note that the relevant TO leads on developing the Needs Cases for SWW projects, and the ESO supports with the economic analysis. The TO initiates the Needs Case work for SWW projects depending on certain factors, including the forecast costs, and whether they trigger the SWW funding formula. Another important factor is the time needed to deliver the option.

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

The NOA process and SWW initial Needs Case analysis may share the same study background.

Where appropriate, we may use NOA results as part of the initial Needs Case with the agreement of the relevant TOs. We have published our methodology for the ESO process for input into TO-led SWW Needs Case submissions on our **website**.

Although SWW projects can usually be identified via the NOA process, there are also SWW projects driven by other factors, such as customer connections. The NOA report provides a summary of these SWW projects in **Appendix B** – 'SWW Projects'. However, these options provide no boundary benefit and are excluded from the NOA economic analysis. We also exclude SWW projects whose final Needs Case have been approved by Ofgem.

2.4 How the *NOA* connects to the SWW process

Prospective SWW projects excluded from this *NOA* are summarised below.

- **Scottish Islands SWW**, including Western Isles link, Shetland link, and Orkney link. Orkney link formed part of the final Needs Cases of the Scottish islands SWW. We included a summary of these SWWs in our **previous *NOA* publications** when they were being developed, even though they are reinforcements for radial connections and don't provide benefit to a particular boundary. As they advance to the approval stage, we no longer include them as potential SWWs. These projects, however, are included in our competition assessment for connections.
- **England and Wales SWW**, including Hinkley to Seabank project, and Wylfa to Pentir. The final Needs Case for Hinkley to Seabank project was approved by Ofgem in early 2018. The project is considered in the base networks and not assessed for cost and benefit in this *NOA*. Work on the Wylfa to Pentir second double circuit has now been suspended and the project is therefore excluded from assessment in the *NOA*.

3 Proposed options

3.1 Introduction

Proposed options

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 as part of the *NOA*.

We've listened to our stakeholders and provided a new look to **Chapter 3** – 'Proposed options' which now covers both the NOA options and a more concise description of the boundaries. 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** – 'SWW 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 together with commercial arrangements. We give more details of alternative options in table 2.2 in the **NOA report methodology**. 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 section 3.3 – 'The options' of this chapter.

3.2 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, day to day and year to year. Power flows across the system can be significantly impacted by changing demand and generation patterns.

The move towards renewable generation as part of decarbonisation policies and meeting emissions targets is a big factor in how constraints on boundaries are changing. You can find a fuller description of our system boundaries in this year's *ETYS*.

As more renewable generation is built in Scotland, the flows to reach demand in the English Midlands and in and around London cross boundaries B0 to B9. The urban areas in the Scottish central belt, north east England, Yorkshire and Lancashire are also high demand areas. Some of this demand is offset by local generation, such as nuclear stations at Torness and Heysham, and by ever-increasing offshore wind; however, there is still an excess of generation. New interconnectors planned to link to Norway from Peterhead (near Aberdeen) and Blyth (near Newcastle) will greatly affect the overall flows. 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.

Offshore wind farms and interconnectors also affect East Anglia and Kent. Demand in London and the surrounding area pulls more power from this new offshore wind capacity, and interconnector flows increase or reduce this flow of electricity. As a result, boundaries such as EC5, LE1 and SC3 are constrained, although interconnectors can reverse the flows on some of these boundaries. Our studies investigate the magnitude and direction of these power flows and how we can accommodate them.

We monitor boundaries in Wales and south west England for economic and efficient investments. Future offshore wind and biomass connecting in North Wales have the potential to drive increased power flows eastwards into the Midlands across NW4 boundary. The changing generation mix is unlikely to prompt investment through the NOA mechanism at present.

3.2 The system boundaries

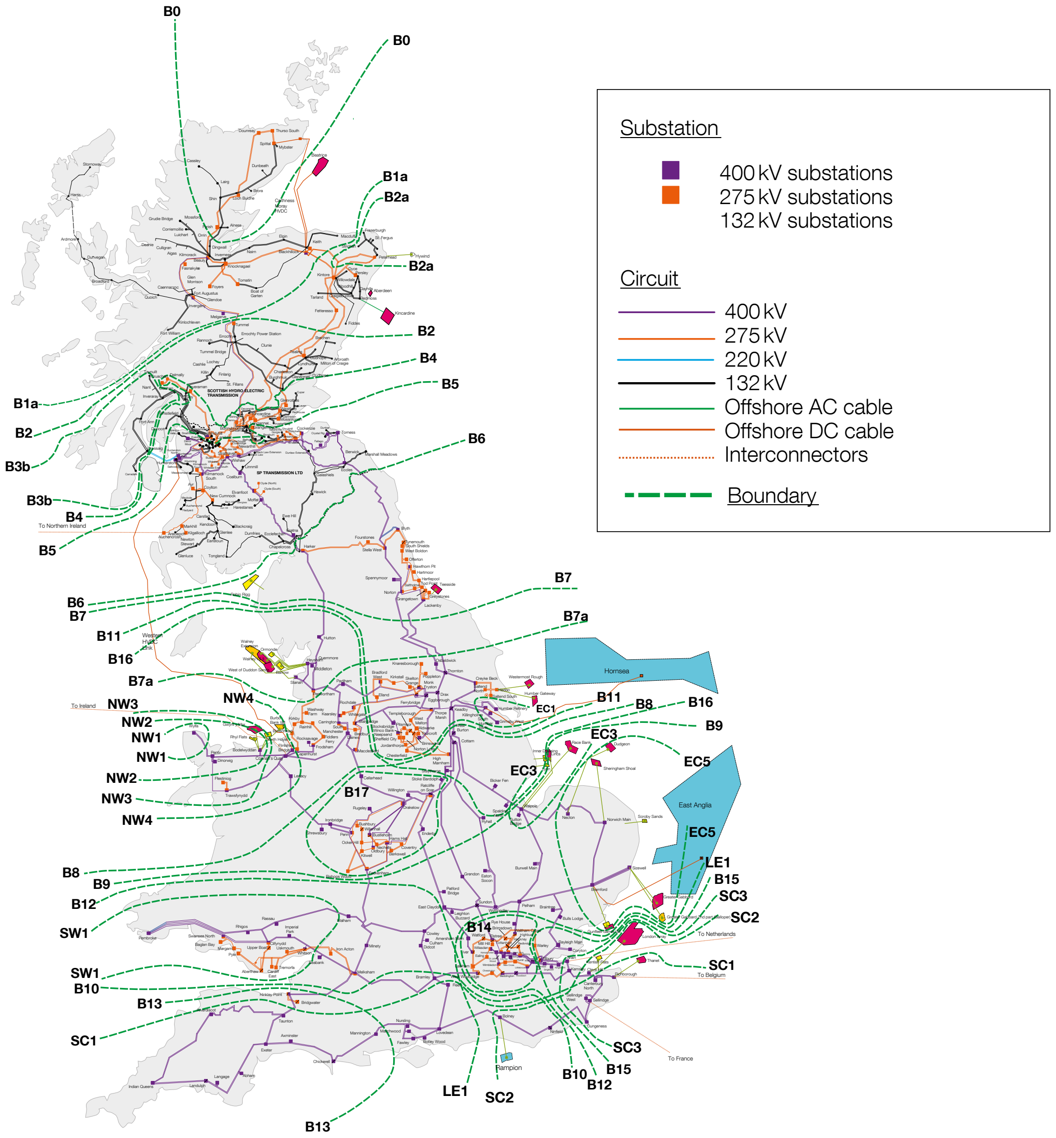


Figure 3.1 shows all the boundaries considered for this year's NOA analysis. Hover over the magnifying glass to zoom in to North and South regions respectively.

Figure 3.1 North

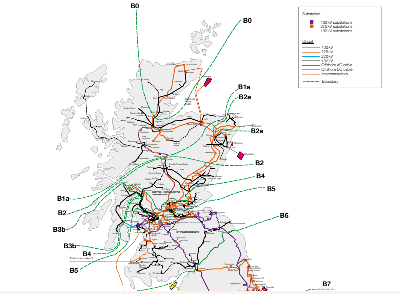
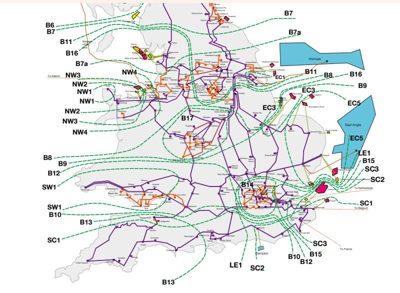


Figure 3.1 South



3.3 The options

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 broad groups: asset-based options; and ESO proposed options mentioned earlier. 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:

3.3.1 Upgrade existing circuits

Examples include replacing overhead line conductors, replacing sections of cable, or increasing the operating voltage, often from 275 kV to 400 kV. 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.

3.3.2 Develop new circuits

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

3.3.3 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.

3.3.4 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 expect new technology to become an option that uses solid-state electronics to control the flows – see references to power flow control device.

3.3 The options

3.3.5 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. As mentioned earlier, we describe alternative options in table 2.2 of the **NOA report methodology**.

3.3.6 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.

3.3.7 ESO-led commercial solutions

In the *NOA 2019/20*, 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.

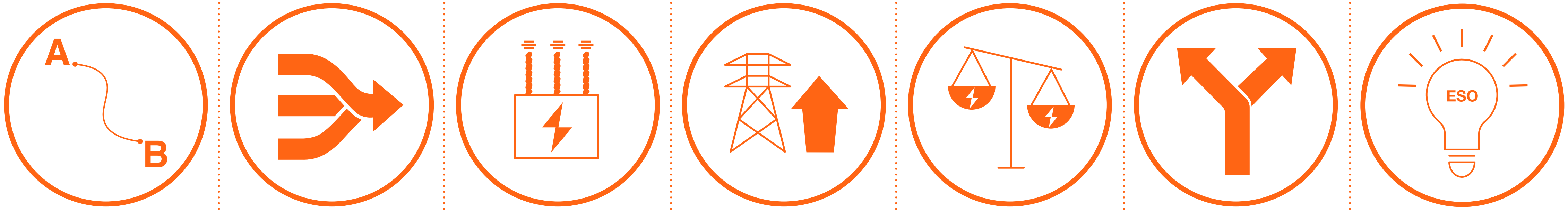
Commercial solutions can be contracted flexibly and don't have a fixed 'asset life' or duration, so we've assessed when to discontinue them. We factor the availability and arming fee into the operational costs based on our historical data.

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. We identified in this year's *NOA* that commercial solutions could save GB consumers up to £950 million between 2023 and 2033.

Figure 3.2 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.

3.3 The options

Figure 3.2
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 39	Total 29	Total 10	Total 34	Total 27	Total 4	Total 4

147
options submitted for economic analysis

3.3 The options

3.3.8 Excluded options

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

- projects with no boundary benefit (unless they are specifically included for another reason, such as links to the Scottish islands that trigger the SWW category).
- options that provide benefits, such as voltage control over the summer minimum, but no boundary capability improvement. These will be published separately as part of our pathfinding projects.
- analysis of options where the costs for the expected benefits would be prohibitive.
- long-term conceptual options submitted by the TOs to support the analysis; this is explained in more detail below.

3.3.9 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. In *NOA 2018/19*, we identified three such long-term conceptual options and provided the necessary information to the TOs regarding which needed to be developed into asset-based options proposals.

3.3.10 Offshore wider works

Our licence condition C27 obliges us to undertake early development work for offshore wider works. In 2015, we published the Integrated Offshore Transmission Project which concluded that creating an integrated offshore transmission network wasn't worthwhile. There is now more drive towards integration because of more 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. The benefits of integration are that it provides boundary capability and can connect offshore wind and interconnectors.

For *NOA 2019/20*, our approach has been to investigate the economic benefit of simple HVDC links connecting parts of the onshore system. We will investigate the benefits of connecting offshore generation as part of next year's *NOA*.

4 Investment recommendations

4.1 Introduction

Chapter 4 presents 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.

Our *NOA 2019/20* recommendations are based on robust economic analysis, then subject to further scrutiny by the NOA Committee. This will ensure development of the GB transmission network will continue to support the transition to the future energy landscape in an efficient, economical and coordinated way.

The rise in total costs from *NOA 2018/19* can be explained by three main factors. Firstly, *FES 2019* has identified further increases in offshore wind generation in the north and East Anglia. We foresee this rise as an extra 3.3 GW in the north and 3.1 GW in East Anglia between 2024 and 2029, compared to *FES 2018*, which is driving further investment.

Secondly, compared to the last *NOA*, an additional five options have moved from 'hold' to 'proceed'; as the *NOA* develops, we expect more reinforcements will be given 'proceed' recommendations as the gap between delivery and requirement closes.

Finally, the TOs have provided many new options this year to replace the long-term conceptual options we implemented last year; a number of these projects have been given 'proceed' recommendations this year.

£203m
Investing £203m this year

39
Through 39 asset-based options

£11.1bn
Total cost of £11.1bn[1]

3
Develop 3 ESO-led commercial solutions

£950m
Providing additional consumer benefits of up to £950m

[1] £11.1 billion only includes the cost for E2DC and not E2D2. These projects are mutually exclusive and therefore only one will be delivered in full.

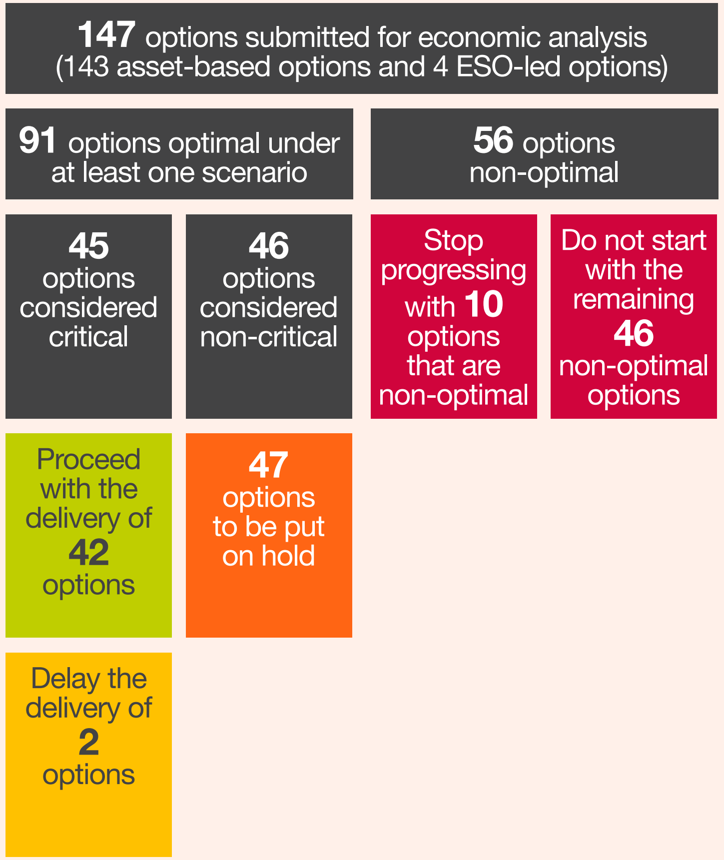
4.1 Introduction

This year we have conducted a sensitivity test on our analysis to identify the impact Contracts for Difference (CfD) could have in reducing constraint costs. CfDs are the mechanism for subsidising wind, replacing Renewable Obligation Certificates (ROC) previously used. There is limited historical evidence of how windfarms with CfDs might bid into the balancing mechanism, so we are working with academics on how bidding strategies may change. Our preliminary modelling suggests no change in the *NOA 2019/20* recommendations and reinforces our confidence in the results. We will continue to develop our modelling of wind constraint costs ahead of *NOA 2020/21*. If you would like to feed into this conversation, please contact us on **noa@nationalgrideso.com**.

In addition to the main NOA process, several pathfinding projects have been set up to address other system needs by increasing industry participation and reducing consumer costs. One of these is the constraint management pathfinder which is aimed at lowering network constraint costs by reducing residual constraints, which are those constraints that still exist after the NOA optimal paths have been recommended. These constraints are not removed by NOA recommended options, often because the major asset-based reinforcements cannot be delivered early enough. This pathfinder has focused on developing a potential new service which acts within timescales of less than 150 ms to increase demand or remove power from the network after a fault occurs in times of high constraints.

The project released a Request for Information (RFI) on 17 December 2019. The responses will inform the viability of this new service. The constraint management pathfinder is not intended to compete with any potential asset-based options, though the findings are expected to inform the development of commercial solutions that will compete with asset-based options. The service has the potential to be extended to other regions where the NOA recommended asset-based options have not been able to clear the full constraint levels, where it is economic and efficient to do so. We believe the service is most valuable where intermittent generation, most notably wind, is high.

Figure 4.1
How the options went through the process



4.2 Interpretation of the NOA outcomes

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

4.2.1 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 'non-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 non-critical and a decision can be put on hold until there is greater certainty.

4.2.2 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

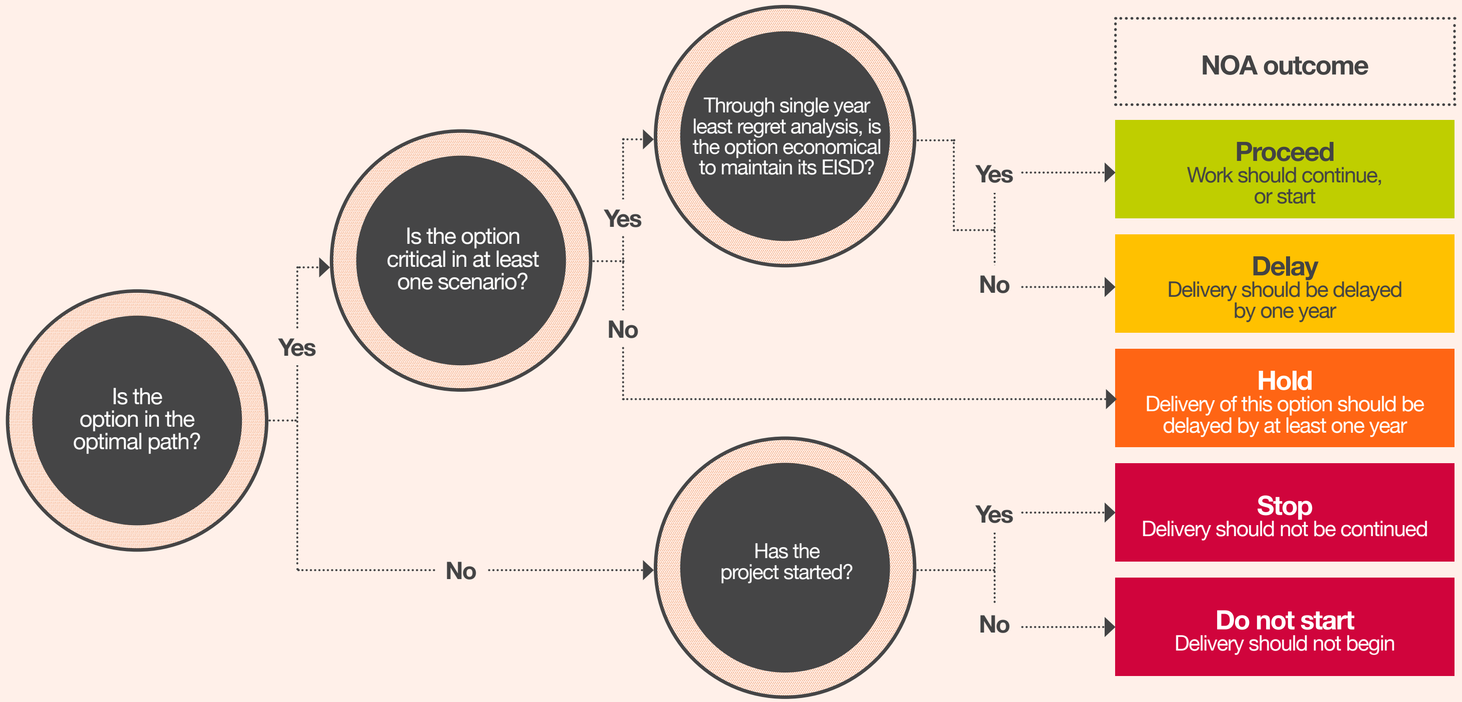
In economic analysis, the regret of an investment strategy is the net benefit difference between that strategy and the best strategy for that scenario. So, under each scenario, the best strategy will have a regret of zero, and the other strategies will have different levels of regret depending on how 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'.

4.2 Interpretation of the NOA outcomes

4.2.3 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 following outcomes:



An option we don't recommend to proceed can still be considered in any relevant SWW 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.

4.2 Interpretation of the NOA outcomes

4.2.4 Eligibility for onshore competition

Ofgem launched consultations on changes to Electricity Transmission Standard Licence Condition C27 and a statutory consultation started in December 2019. It proposed new requirements for the ESO to assess projects recommended for further development in the NOA for their eligibility for competition, and to undertake the same assessments on future generator and demand connections to the transmission system.

We believe it is sensible and pragmatic to continue to include an assessment for competition in this NOA. This includes options we recommend to proceed this year, SWW 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.

Ofgem launched a consultation in December 2019, click here to find out more.

4.3 The NOA outcomes

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

In our economic analysis, we separated the GB network into two regions: Scotland and the north of England; and the south and east of England. Wales has not been included in this year's analysis due to generational background changes. These reduce the flows across the boundaries below their current capabilities and reduce the need to reinforce the network. For a more detailed description of the boundary capability across Wales please refer to *ETYS 2019*. We present the economic analysis results on this basis.

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 and 4.2 for the two 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.

Several critical options could be progressed this year in a number of combinations, one of which will have the least worst regret across all scenarios. The options that make up this combination will be recommended to proceed.

The initial recommendations are indicated by different shadings in table 4.1 and 4.2. **56 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 section 4.4 – 'Recommendations for each option'. There may be differences between initial and final recommendations for some options. Explanations are included as part of our regional narratives. 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 section 4.4. Some options are marked as 'N/A' as they are not optimal under that particular scenario.

4.3 The NOA outcomes

4.3.1 Scotland and the north of England region

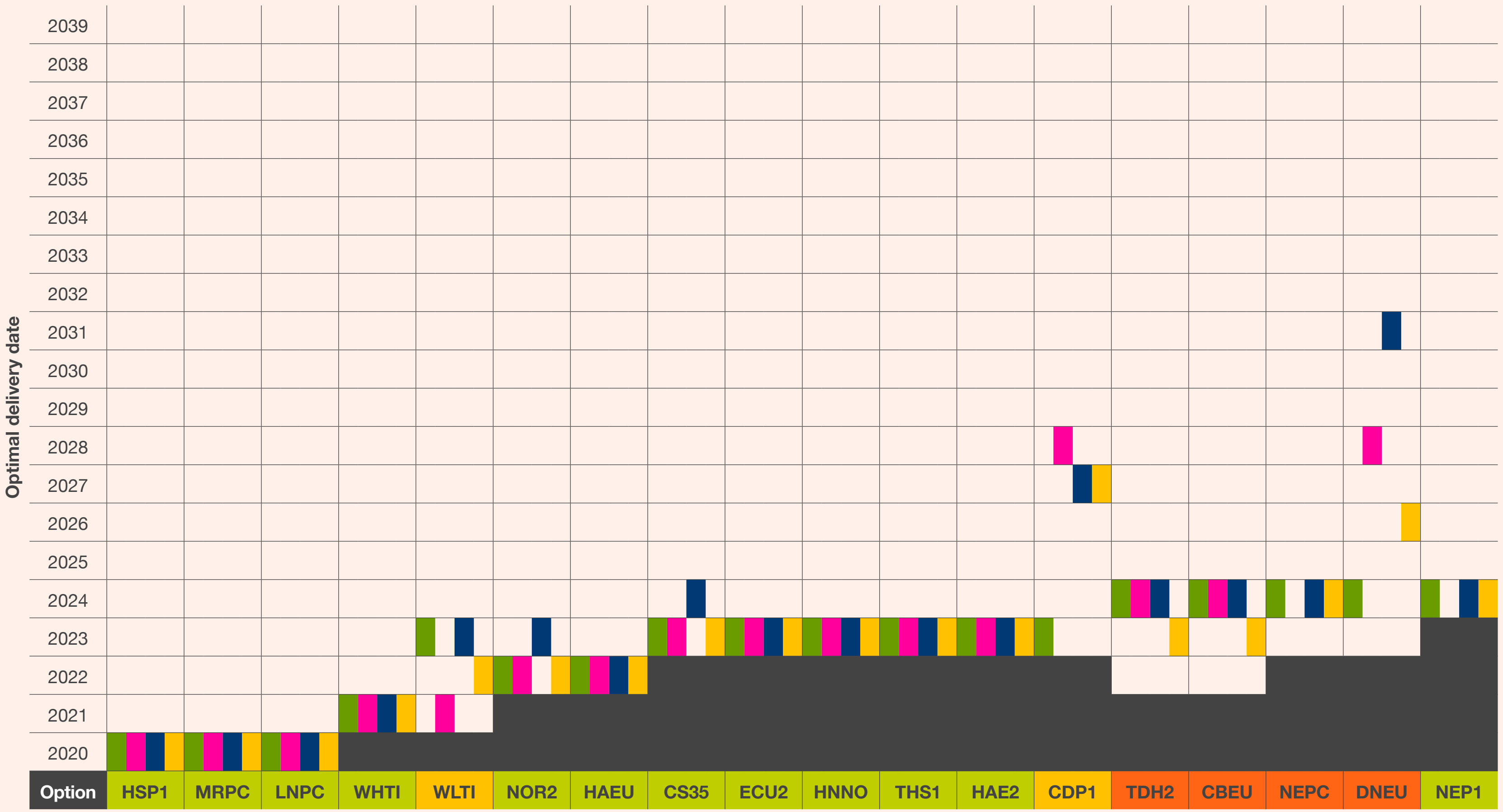
Key:

- Optimum year indicator for **Two Degrees**
- Optimum year indicator for **Community Renewables**
- Optimum year indicator for **Consumer Evolution**
- Optimum year indicator for **Steady Progression**
- EISD not yet reached
- Critical option to 'Proceed'
- Critical option to 'Delay'
- Non-critical option to 'Hold'

For more information on the reinforcements please navigate to **Appendix C**.

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

Table 4.1
Scotland and the north of England region



4.3 The NOA outcomes

4.3.1 Scotland and the north of England region

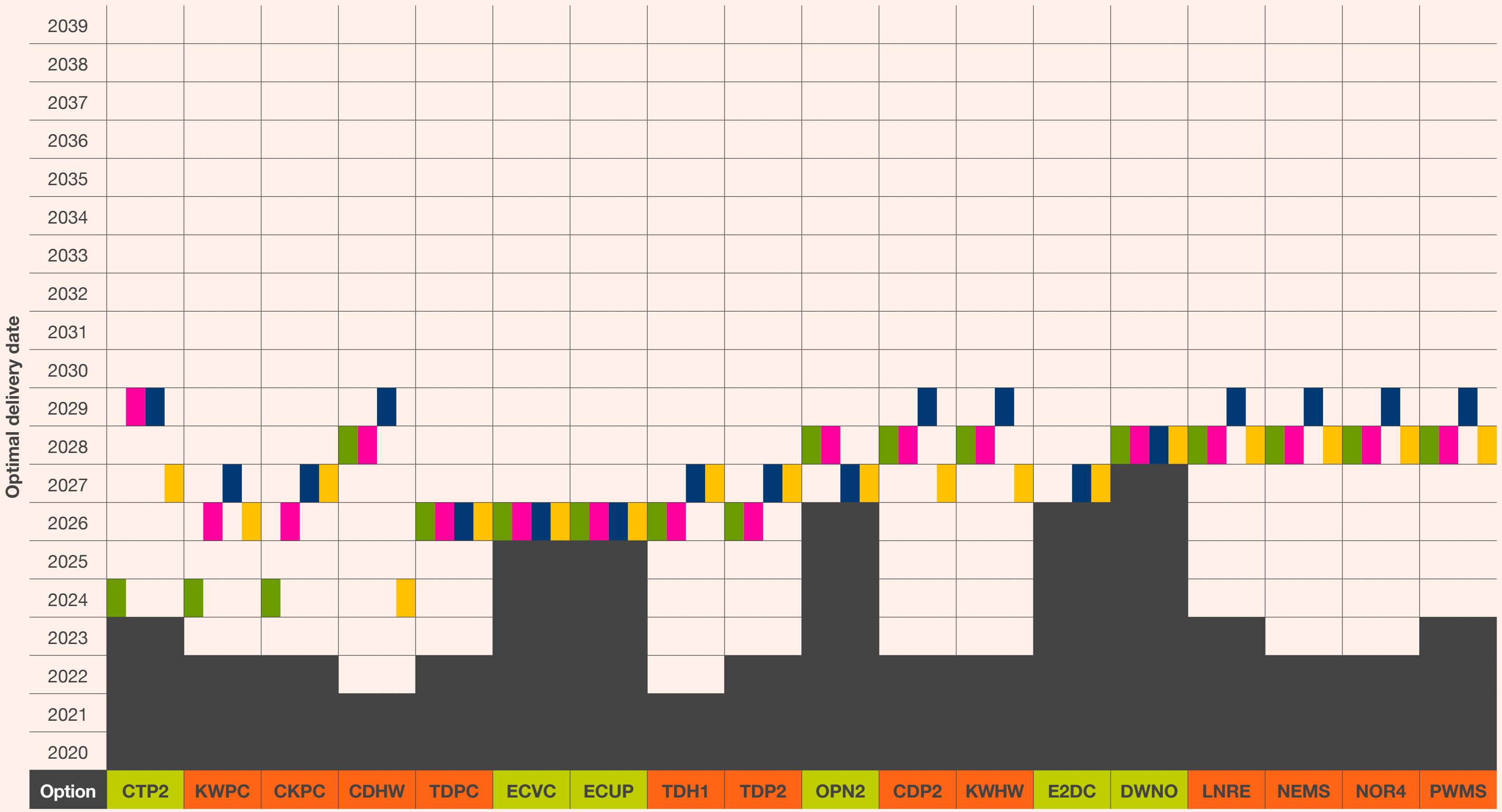
Key:

- Optimum year indicator for **Two Degrees**
- Optimum year indicator for **Community Renewables**
- Optimum year indicator for **Consumer Evolution**
- Optimum year indicator for **Steady Progression**
- EISD not yet reached
- Critical option to 'Proceed'
- Critical option to 'Delay'
- Non-critical option to 'Hold'

For more information on the reinforcements please navigate to **Appendix C**.

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

Table 4.1
Scotland and the north of England region (continued)



4.3 The NOA outcomes

4.3.1 Scotland and the north of England region

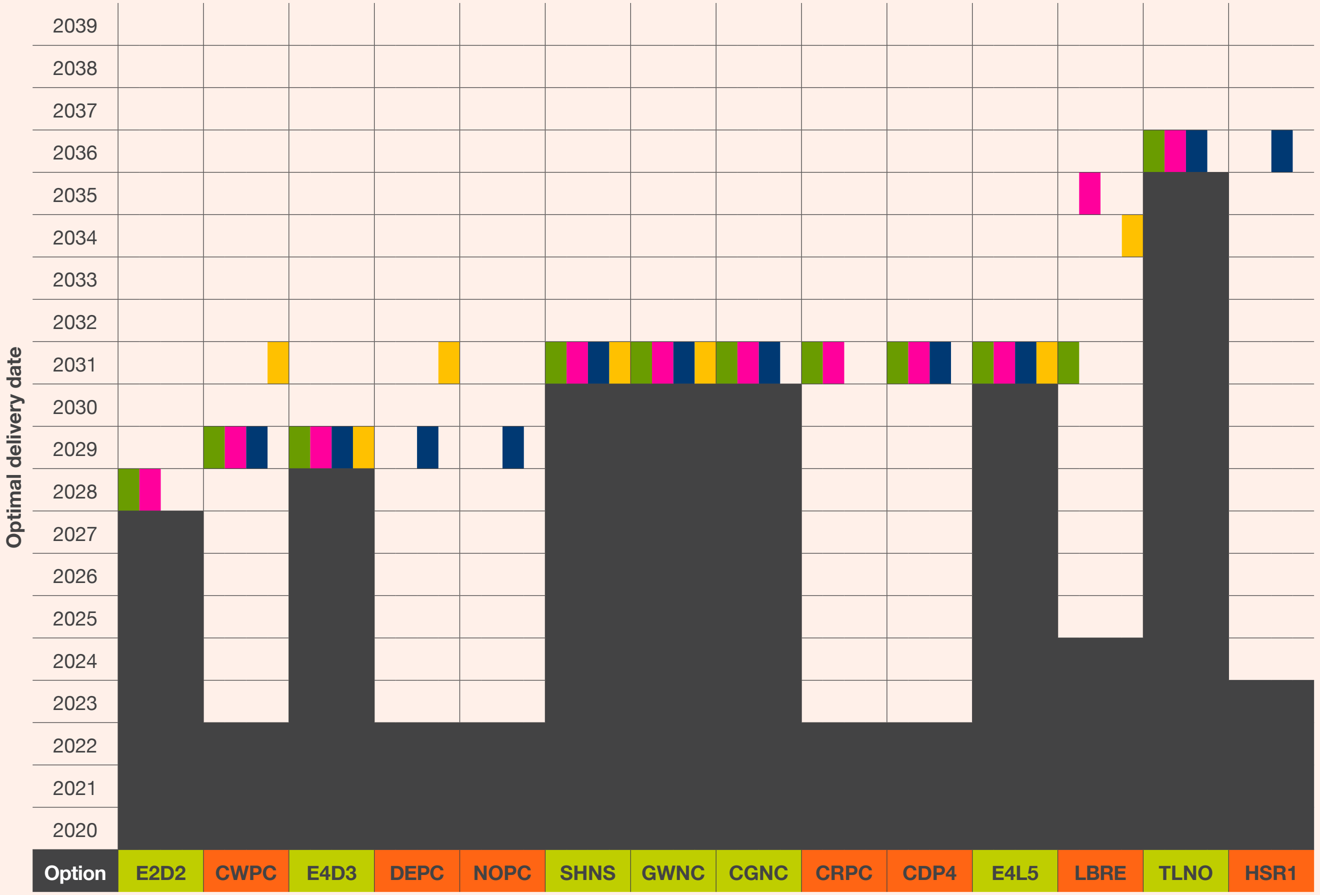
Key:

- Optimum year indicator for **Two Degrees**
- Optimum year indicator for **Community Renewables**
- Optimum year indicator for **Consumer Evolution**
- Optimum year indicator for **Steady Progression**
- EISD not yet reached
- Critical option to 'Proceed'
- Critical option to 'Delay'
- Non-critical option to 'Hold'

For more information on the reinforcements please navigate to **Appendix C**.

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

Table 4.1
Scotland and the north of England region (continued)



4.3 The NOA outcomes

For Scotland and the north of England region, we identified 50 optimal options as shown in table 4.1. Their optimum delivery dates are highlighted in different colours for different scenarios.

Of the 50 optimal options, 28 are critical and could offer more than a million different possible combinations of ‘Proceed’ and ‘Delay’ recommendations. The optimum delivery years of the following options are the same as their EISDs across all four scenarios.

These 15 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 to ‘proceed’ to maintain EISD in Scotland and north England region

Code	Option description
DWNO	Denny to Wishaw 400 kV reinforcement
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC
E4L5	Eastern Scotland to England 3rd link: Peterhead to the South Humber offshore HVDC
ECU2	East coast onshore 275 kV upgrade
ECUP	East coast onshore 400 kV incremental reinforcement
ECVC	Eccles synchronous series compensation and real-time rating system
GWNC	A new 400 kV double circuit between South Humber and South Lincolnshire
HAEU	Harker supergrid transformer 6 replacement
HNNO	Hunterston East to Neilston 400 kV reinforcement
HSP1	Power control device along Fourstones to Harker to Stella West
LNPC	Power control device along Lackenby to Norton
MRPC	Power control device along Penwortham to Kirkby
SHNS	Upgrade substation in the South Humber area
THS1	Install series reactors at Thornton
WHTI	Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit

4.3 The NOA outcomes

This leaves 13 critical options, as seen in table 4.3, and just over 8,000 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 WLTI and CDP1.

Table 4.3
'Critical' options for least regret analysis in Scotland and north England region

Code	Option description
CDP1	Power control device along Cellarhead to Drakelow
CGNC	A new 400 kV double circuit between Creyke Beck and the South Humber
CS35	Commercial solution for Scotland and the north of England
CTP2	Alternative power control device along Creyke Beck to Thornton
E2D2	Eastern Scotland to England link: Torness to Cottam offshore HVDC
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit
HAE2	Harker supergrid transformer 5 replacement
NEP1	Power control device along Blyth to Tynemouth to Blyth to South Shields
NEPC	Power control device along Blyth to Tynemouth and Blyth to South Shields
NOR2	Reconductor 13.75 km of Norton to Osbaldwick number 1 400 kV circuit
OPN2	A new 400 kV double circuit between Osbaldwick and Poppleton and relevant 275 kV upgrades
TLNO	Torness to north east England AC onshore reinforcement
WLTI	Windyhill to Lambhill to Longannet 275 kV circuit turn-in to Denny North 275 kV substation

4.3 The NOA outcomes

4.3.2 Background setting and context

Scotland and the north of England is a typical 'exporting' region where installed generation capacity is much more than enough to supply its local demand. With greater demand in central and south of England, the energy flows across the Scottish and northern English boundaries are predominantly north-to-south, which is the main driver for reinforcements to facilitate bulk power transfer.

Across all the scenarios we assessed, we've seen different levels of growth in total installed capacity in the next few decades. The similarity is that wind energy is the main contributor. Hitting the target of an 80 per cent CO_2 emission reduction in 2050, the **Two Degrees** and **Community Renewables** 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. **Consumer Evolution** and **Steady Progression** miss the 2050 target and are less demanding on transfer capability and more reinforcements are put on hold. We include our recommendation and detailed narratives for each of the reinforcements in the optimal paths on our interactive map. Here are some highlights of our recommendations:

- In the *NOA 2018/19*, we identified the need for additional transfer capabilities in the form of long-term conceptual reinforcements and communicated this to the relevant TO. For the *NOA 2019/20*, the TOs responded with new asset-based reinforcements. We have assessed these reinforcements to be beneficial and have replaced the conceptual reinforcements used in the previous *NOA*. For more information about these, see E4L5, SHNS, GWNC and CGNC on the interactive map.
- 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. We found one beneficial commercial solution in this region and recommend developing it further. For more information, see CS35 on the interactive map.
- This *NOA* included 15 eastern subsea HVDC link options between England and Scotland. These fall into three different categories based on their connection locations and some of them are mutually exclusive. From the analysis, we confirmed the need for three links to accommodate the increasing north-to-south flows. These are from:
  - Torness to northern England
  - Peterhead to northern England
  - North east Scotland to the South Humber area.

The preferences over the second and third links for the optimal paths are consistent across all scenarios. For more information see E4D3 and E4L5 on our interactive map. The analysis also suggested progressing both Torness to Hawthorn Pit (E2DC) and Torness to Cottam (E2D2) in the next investment cycle as they are favoured by different scenarios and proceeding both options sees the lowest level of regret. As the two Torness options are mutually exclusive in delivery, we would recommend prioritising the delivery of E2DC to maintain its EISD as it delivers more near-term benefits and produces a higher regret of being delayed. So we would accept a delay of E2D2's EISD up to one year for the next *NOA*. See E2DC and E2D2 on the interactive map for more information.

4.3 The NOA outcomes

In conclusion, 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 England region

Code	Option description	To meet its EISD of:
HSP1	Power control device along Fourstones to Harker to Stella West	**2020**
MRPC	Power control device along Penwortham to Kirkby	**2020**
LNPC	Power control device along Lackenby to Norton	**2020**
WHTI	Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit	**2021**
NOR2	Reconductor 13.75 km of Norton to Osbaldwick number 1 400 kV circuit	**2022**
HAEU	Harker supergrid transformer 6 replacement	**2022**
CS35	Commercial solution for Scotland and the north of England	**2023**
ECU2	East coast onshore 275 kV upgrade	**2023**
HNNO	Hunterston East to Neilston 400 kV reinforcement	**2023**
THS1	Install series reactors at Thornton	**2023**
HAE2	Harker supergrid transformer 5 replacement	**2023**
NEP1	Power control device along Blyth to Tynemouth to Blyth to South Shields	**2024**
CTP2	Alternative power control device along Creyke Beck to Thornton	**2024**

4.3 The NOA outcomes

In conclusion, 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 England region (continued)

Code	Option description	To meet its EISD of:
ECVC	Eccles synchronous series compensation and real-time rating system	**2026**
ECUP	East coast onshore 400 kV incremental reinforcement	**2026**
OPN2	A new 400 kV double circuit between Osbaldwick and Poppleton and relevant 275 kV upgrades	**2027**
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit	**2027**
DWNO	Denny to Wishaw 400 kV reinforcement	**2028**
E2D2	Eastern Scotland to England link: Torness to Cottam offshore HVDC	**2028**
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC	**2029**
SHNS	Upgrade substation in the South Humber area	**2031**
GWNC	A new 400 kV double circuit between South Humber and South Lincolnshire	**2031**
CGNC	A new 400 kV double circuit between Creyke Beck and the South Humber	**2031**
E4L5	Eastern Scotland to England 3rd link: Peterhead to the South Humber offshore HVDC	**2031**
TLNO	Torness to north east England AC onshore reinforcement	**2036**

4.3 The NOA outcomes

4.3.3 Eligibility assessment for onshore competition

Following this, we conducted eligibility assessment 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:

- A new 400 kV double circuit between Creyke Beck and the South Humber (CGNC)
- Eastern Scotland to England link: Torness to Cottam offshore HVDC (E2D2)
- Eastern subsea HVDC link from Torness to Hawthorn Pit (E2DC)
- 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)
- A new 400 kV double circuit between South Humber and South Lincolnshire (GWNC)
- Torness to north east England AC onshore reinforcement (TLNO)
- East coast onshore 275 kV upgrade (ECU2)

The east coast onshore 275 kV upgrade (ECU2) 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:

- Orkney link.
- Western Isles link.
- Shetland link.
- North Argyll substation.
- Port Ann to Crossaig reinforcement.
- Skye 2nd circuit reinforcement.

The Orkney, Western Isles, and Shetland links are three SWW projects led by SHE Transmission. SHE Transmission submitted the Final Needs Cases to Ofgem for each of these projects during 2018. Please see Ofgem's **website** for more information and updates on these projects. The Argyll, Port Ann to Crossaig and Skye projects are proposed for connections with the latter two having non-load asset replacement aspects and all three at varying stages of development.

4.3 The NOA outcomes

4.3.4 The south and east of England region

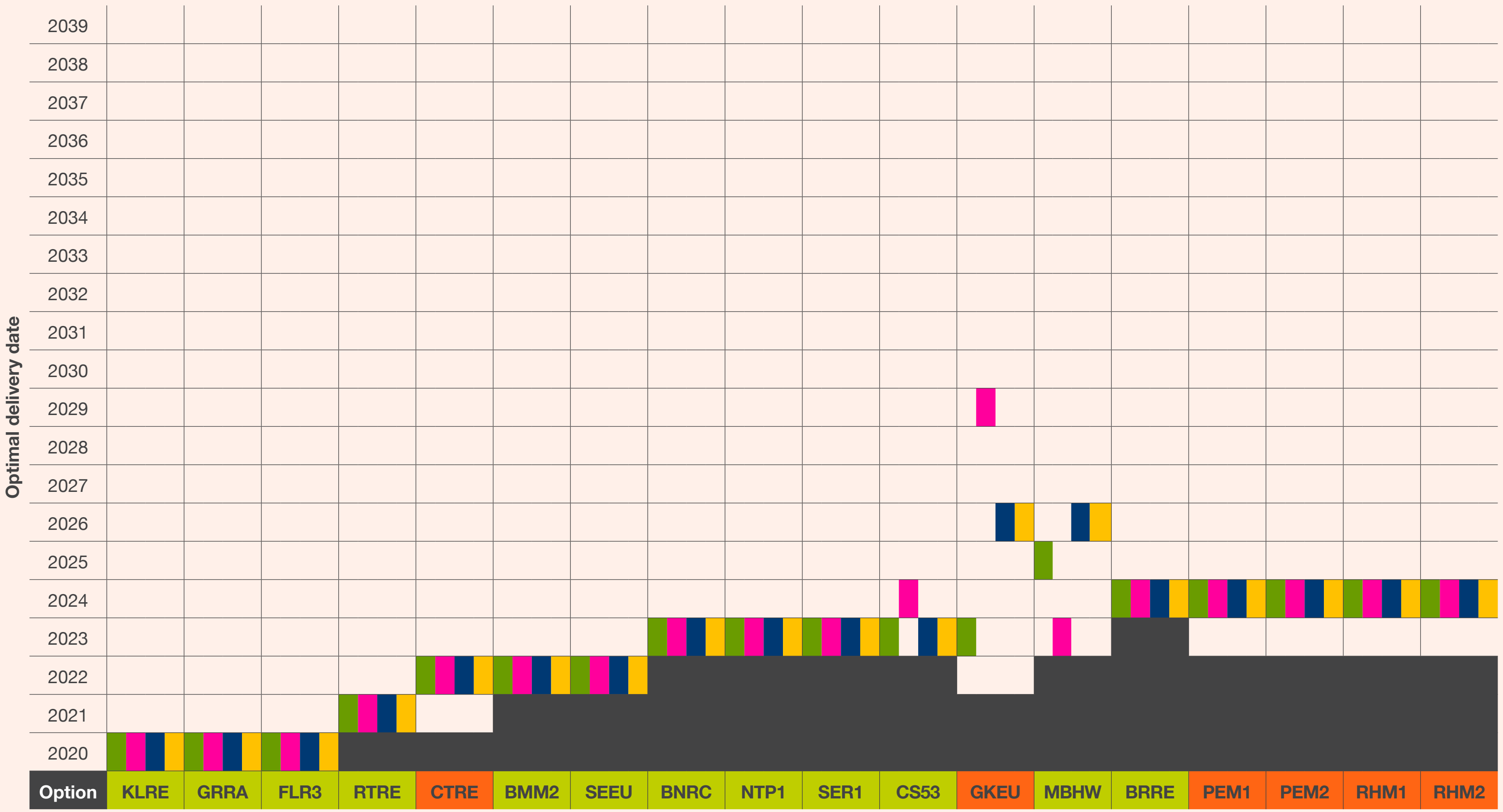
Key:

- Optimum year indicator for **Two Degrees**
- Optimum year indicator for **Community Renewables**
- Optimum year indicator for **Consumer Evolution**
- Optimum year indicator for **Steady Progression**
- EISD not yet reached
- Critical option to 'Proceed'
- Critical option to 'Delay'
- Non-critical option to 'Hold'

For more information on the reinforcements please navigate to **Appendix C**.

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

Table 4.5
The south and east of England region



4.3 The NOA outcomes

4.3.4 The south and east of England region

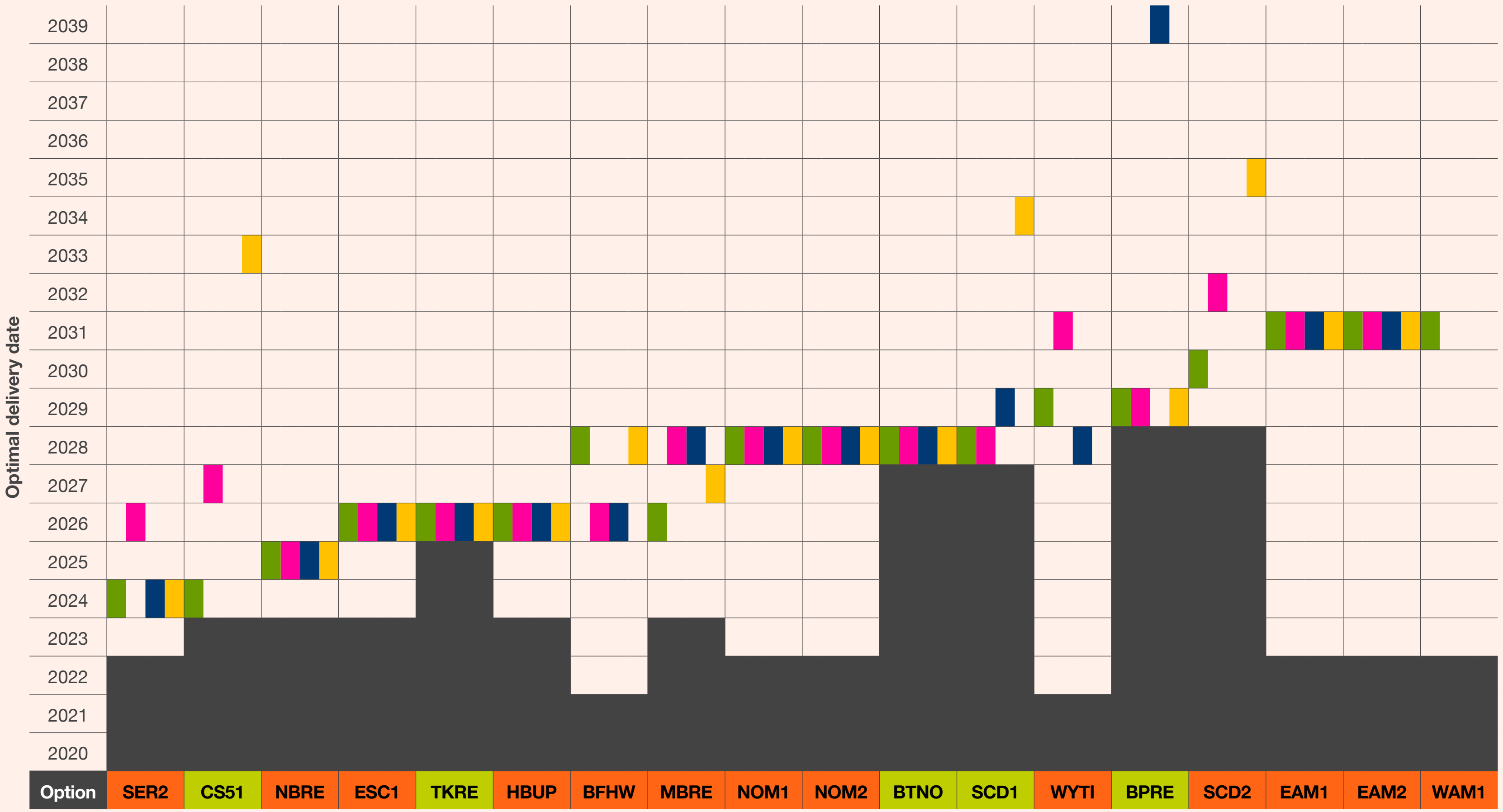
Key:

- Optimum year indicator for **Two Degrees**
- Optimum year indicator for **Community Renewables**
- Optimum year indicator for **Consumer Evolution**
- Optimum year indicator for **Steady Progression**
- EISD not yet reached
- Critical option to ‘Proceed’
- Critical option to ‘Delay’
- Non-critical option to ‘Hold’

For more information on the reinforcements please navigate to **Appendix C**.

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

Table 4.5
The south and east of England region (continued)



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4.3 The NOA outcomes

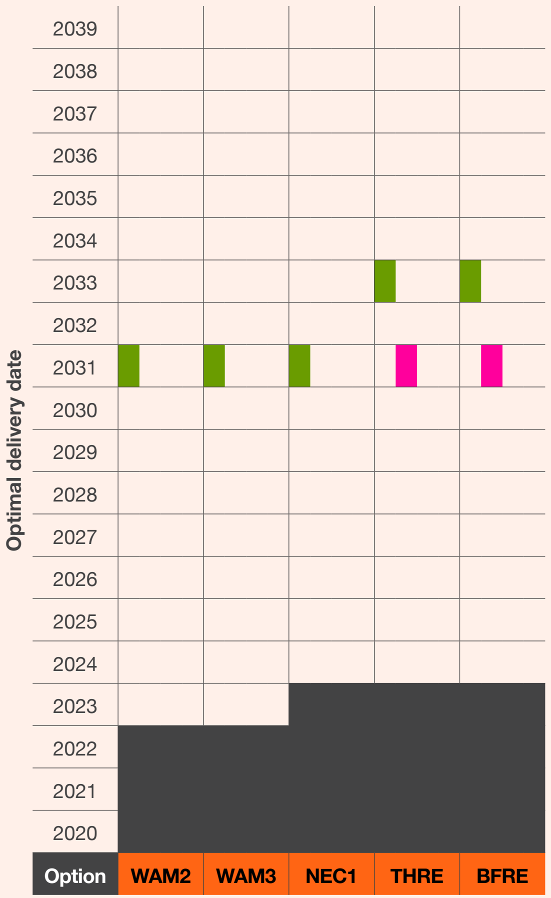
4.3.4 The south and east of England region

Key:
- Optimum year indicator for **Two Degrees**
- Optimum year indicator for **Community Renewables**
- Optimum year indicator for **Consumer Evolution**
- Optimum year indicator for **Steady Progression**
- EISD not yet reached
- Critical option to 'Proceed'
- Critical option to 'Delay'
- Non-critical option to 'Hold'

For more information on the reinforcements please navigate to **Appendix C**.

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

Table 4.5
The south and east of England region (continued)



4.3 The NOA outcomes

For the south and east of England region, we identified **41** optimal options as shown in table 4.5. Their optimum delivery dates are highlighted in different colours for different scenarios.

Of the **41** optimal options, **17** are critical and could offer over a million different possible combinations of 'Proceed' and 'Delay' recommendations. The optimum delivery years of the following options are the same as their EISDs across all four scenarios.

This means there is no need for single year least regret analysis for these **12** options, as seen in table 4.6; progressing them to maintain their EISDs is the optimum course of action under all scenarios.

Table 4.6
'Critical' options to 'proceed' to maintain EISD in south and east England region

Code	Option description
BMM2	225 MVAr MSCs at Burwell Main
BNRC	Bolney and Ninfield additional reactive series compensation
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route
BTNO	A new 400 kV double circuit between Bramford and Twinstead
FLR3	Reconductor Fleet to Lovedean circuit
GRRA	Grain running arrangement change
KLRE	Kemsley to Littlebrook circuits uprating
NTP1	Power control device along North Tilbury
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit
SEEU	Reactive series compensation protective switching scheme
SER1	Elstree to Sundon reconductoring
TKRE	Tilbury to Grain and Tilbury to Kingsnorth upgrade

4.3 The NOA outcomes

This leaves 5 critical options and 32 different possible combinations of the following reinforcements.

We performed the single year least regret analysis on all five combinations and the least regret strategy is to proceed with all critical options.

Table 4.7
'Critical' options for least regret analysis in south and east England region

Code	Option description
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit
CS51	Commercial solution for East Anglia
CS53	Commercial solution for the south coast
MBHW	Bramley to Melksham circuits thermal uprating
SCD1	New offshore HVDC link between Suffolk and Kent Option 1

4.3 The NOA outcomes

4.3.5 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 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 across the East Anglia boundary. We have included our recommendation and detailed narratives for each of the reinforcements in the optimal paths on our interactive map. Highlights of our recommendations include:

- KLRE and FLR3 reinforce two of the existing transmissions corridors bringing power from the south east coast into or around London. Both options benefit the south coast boundaries when interconnectors are importing and are required early in the reinforcement paths.
- BTNO, a new double circuit in East Anglia, supports the export of power out of the area and also reinforces the Midlands to south boundary. BTNO is critical in all scenarios due to high exports from East Anglia.
- SCD1 and SCD2, that build offshore HVDC links between Suffolk and Kent and bypass the most constrained areas. As the HVDC links can be configured to transfer power in both directions, they can benefit multiple south and east boundaries. SCD1 was optimal in all the scenarios and SCD2 was needed in three of them.
- SCN1, a new transmission route in the south coast region, can increase the total flow of power across the south coast boundaries under interconnector importing and exporting conditions. SCN1 was not included in the optimal paths in *NOA 2019/20* as the alternative SCD1 was found to provide higher overall benefit.
- HWUP, TWNC and ITUP work together to upgrade the transmission corridors across or though the north London area. Analysis suggested that these reinforcements are not required as enough transmission capacity can be provided by a combination of other reinforcements, such as SCD1 and BTNO, that are already included in the optimal paths.

Furthermore, we considered two commercial solutions in our assessment, one for the East Anglia boundary (CS51) and one for the south coast boundaries (CS53).

Commercial solutions use operational measures from commercial providers to increase the volume of power that can be securely transferred across a boundary. Although these are currently at an early development stage, they provide economic benefit. CS53 was required in the optimal paths of all four scenarios while CS51 was required in three of the four scenarios.

4.3 The NOA outcomes

In conclusion, we recommend progressing with the following reinforcements in 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:
KLRE	Kemsley to Littlebrook circuits uprating	**2020**
GRRA	Grain running arrangement change	**2020**
FLR3	Reconductor Fleet to Lovedean circuit	**2020**
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit	**2021**
BMM2	225 MVAr MSCs at Burwell Main	**2022**
SEEU	Reactive series compensation protective switching scheme	**2022**
BNRC	Bolney and Ninfield additional reactive series compensation	**2023**
NTP1	Power control device along North Tilbury	**2023**
SER1	Elstree to Sundon reconductoring	**2023**
CS53	Commercial solution for the south coast	**2023**
MBHW	Bramley to Melksham circuits thermal uprating	**2023**
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route	**2024**
CS51	Commercial solution for East Anglia	**2024**
TKRE	Tilbury to Grain and Tilbury to Kingsnorth upgrade	**2026**
BTNO	A new 400 kV double circuit between Bramford and Twinstead	**2028**
SCD1	New offshore HVDC link between Suffolk and Kent Option 1	**2028**
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit	**2029**

4.3 The NOA outcomes

4.3.6 Eligibility assessment for onshore competition

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

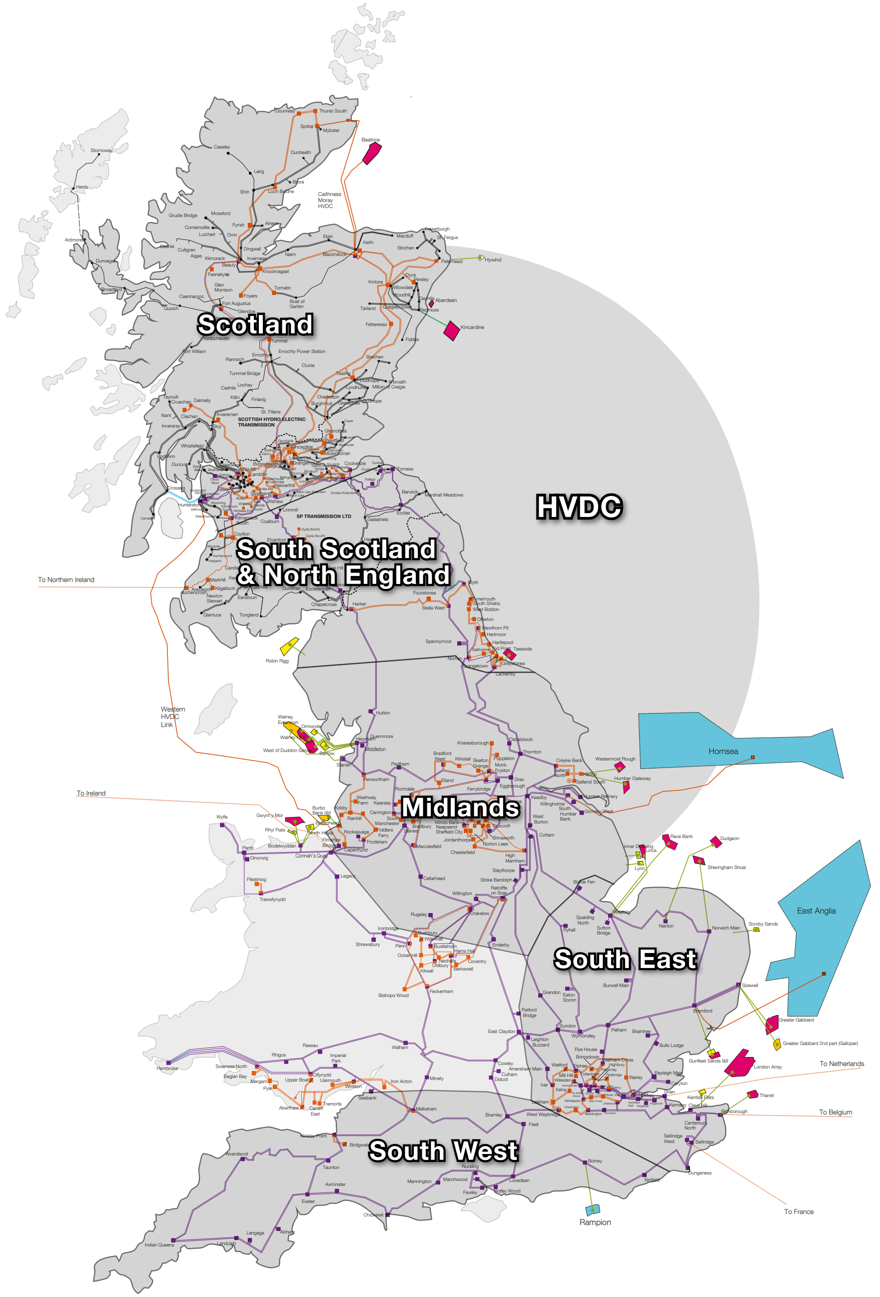
- A new 400 kV double circuit between Bramford and Twinstead (BTNO).
- New offshore HVDC link between Suffolk and Kent Option 1 (SCD1).

4.4 Recommendations for each option

This section presents the recommendation for each option assessed in *NOA 2019/20*.

In this section 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 in **section 4.2.3**.

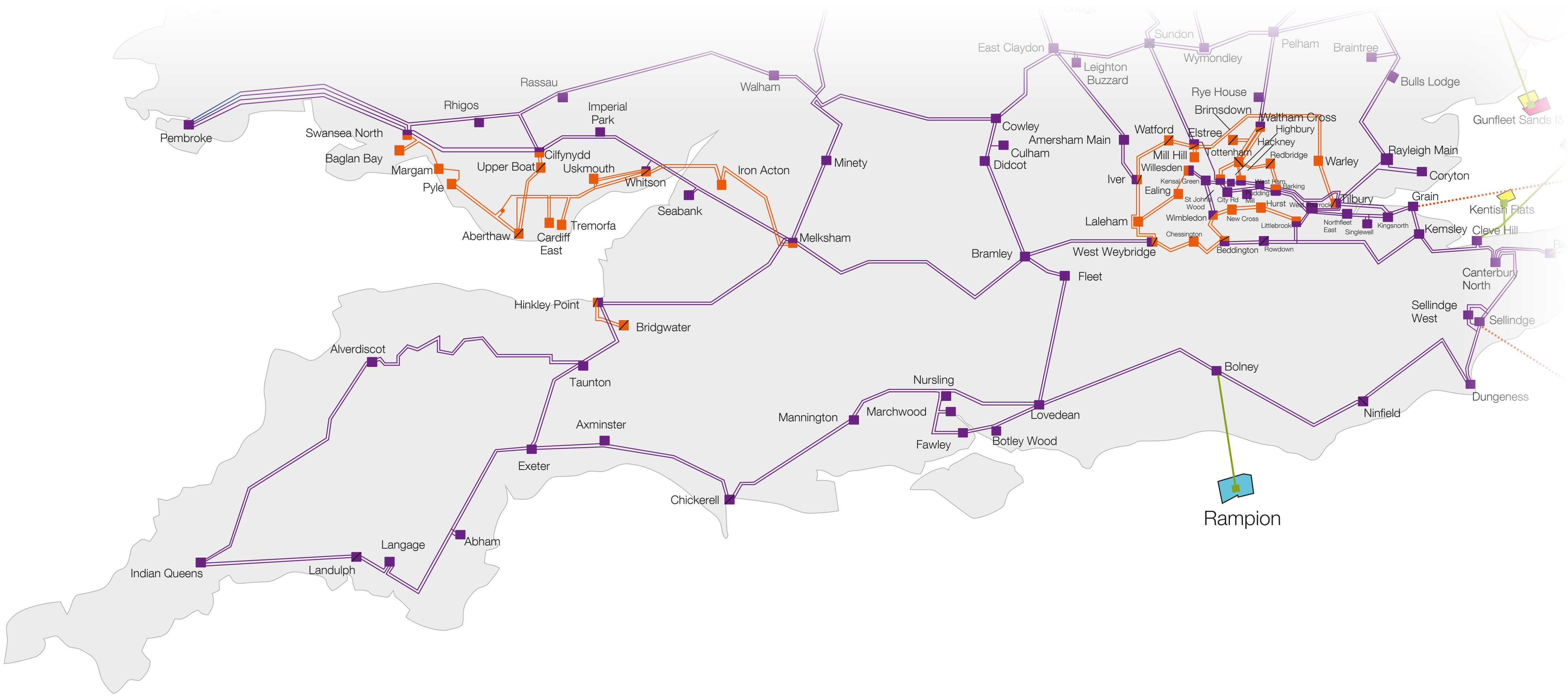
The following section provides a visual representation of the options and their recommendations. Use the menu at the bottom of each page to select the recommendations you want to see or to quickly change region. As you hover over the options on the map the table will highlight them helping to display the full results for that option. 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 and A.2 in **Appendix A** – 'Economic Analysis'.



> Boundaries

> Main map | > South West | > South East | > Midlands | > South Scotland & North England | > Scotland | > HVDC

South West



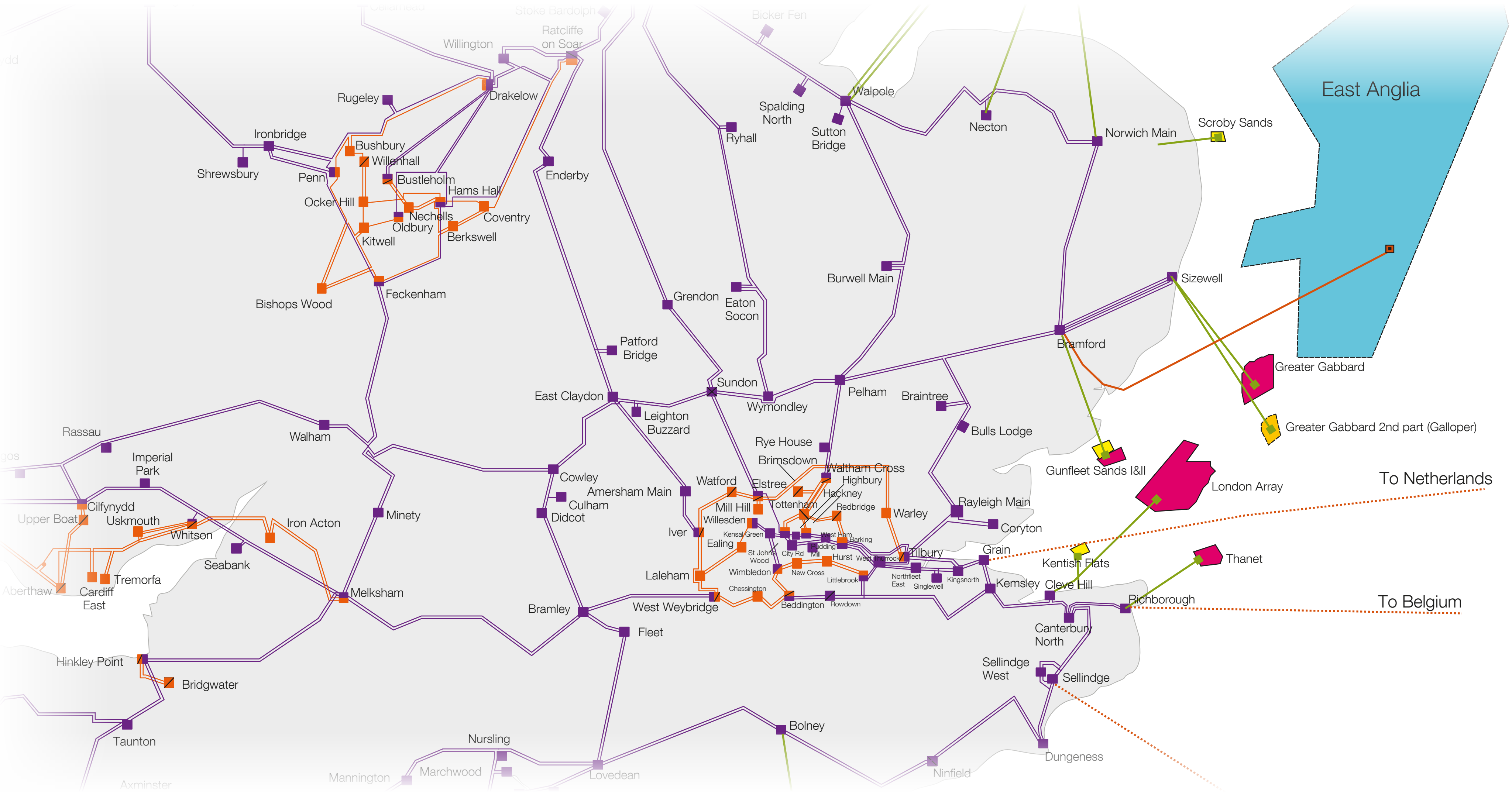
Note: all reinforcement routes and locations are for illustrative purposes only

> Click here to view details on the options

***NOA 2019/20* recommendations**

Hold Proceed

South East



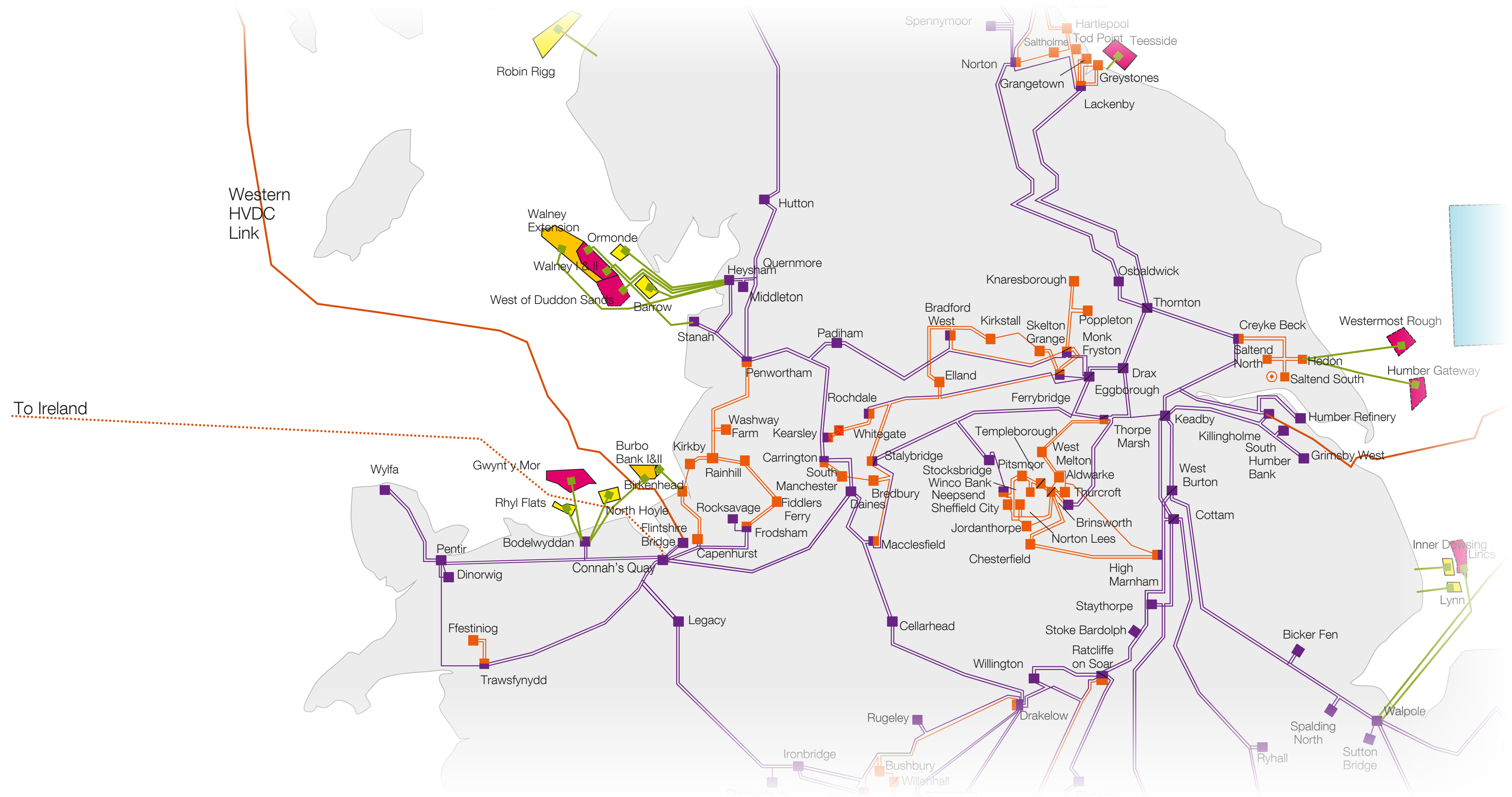
Note: all reinforcement routes and locations are for illustrative purposes only

> Click here to view details on the options

***NOA 2019/20* recommendations**

Stop Hold Proceed

Midlands



Note: all reinforcement routes and locations are for illustrative purposes only

> Click here to view details on the options

NOA 2019/20 recommendations

Stop Hold Delay Proceed

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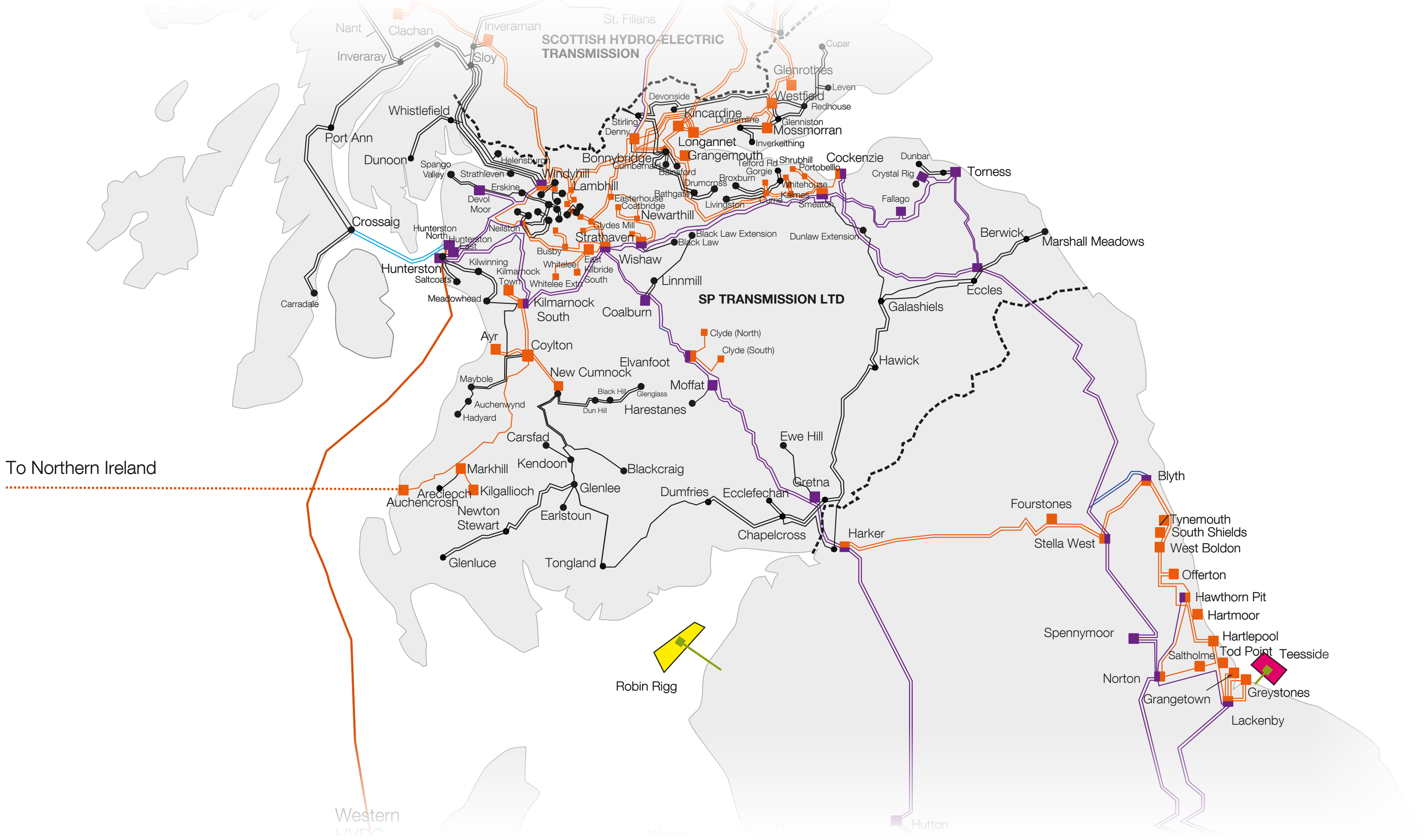
South Scotland & North England



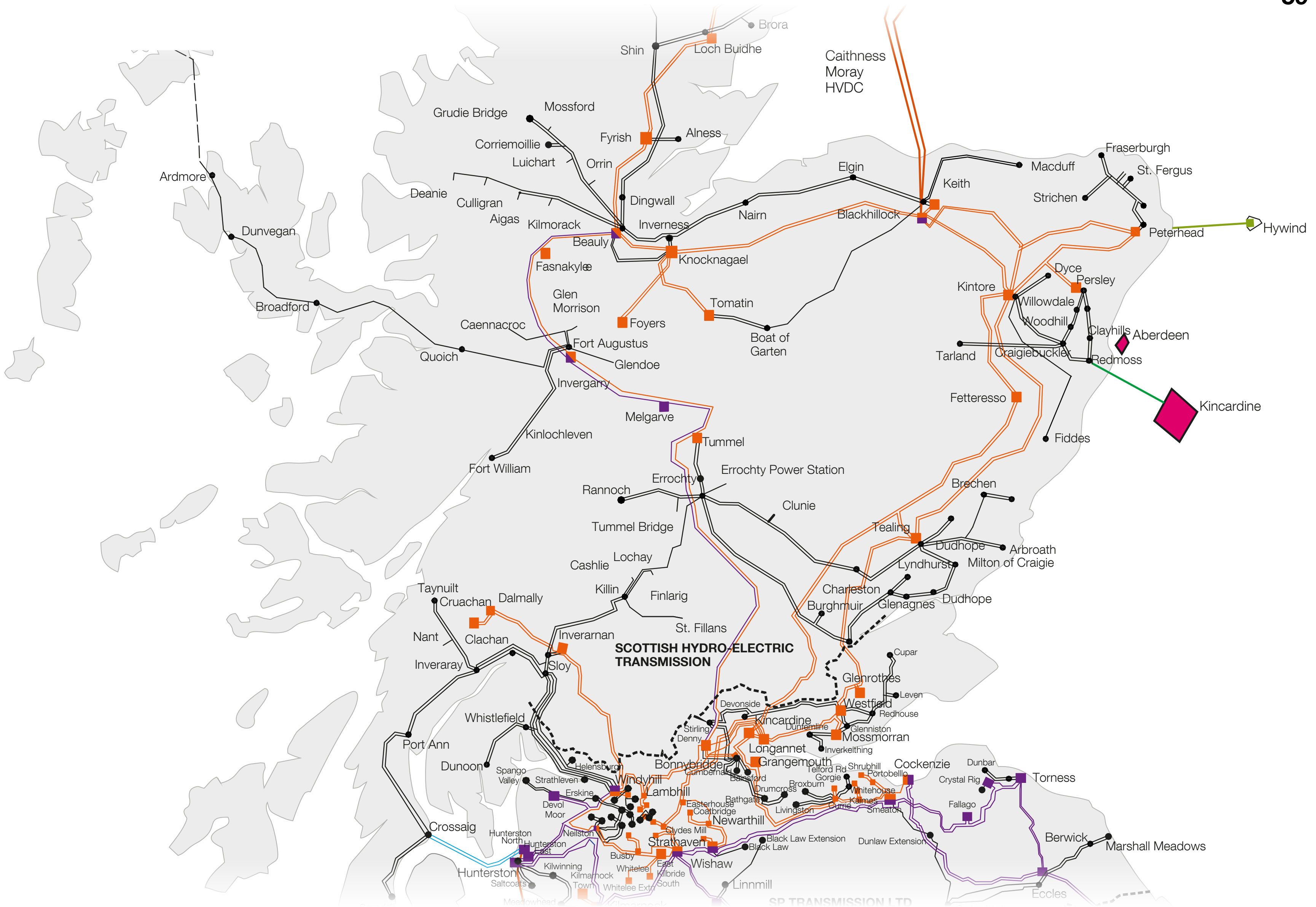
Note: all reinforcement routes and locations are for illustrative purposes only

> Click here to view details on the options

***NOA 2019/20* recommendations**

Stop Hold Proceed

Scotland



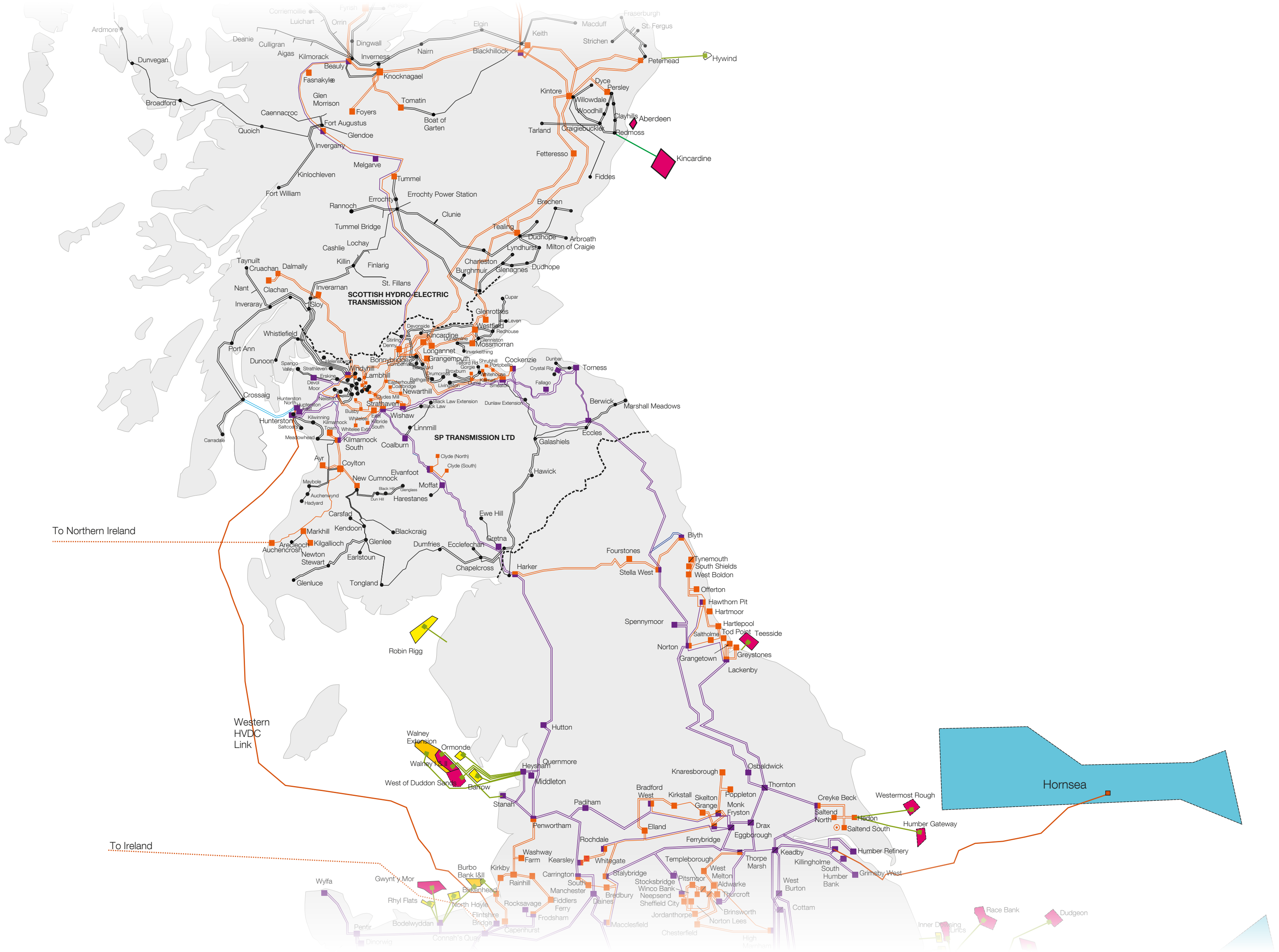
Note: all reinforcement routes and locations are for illustrative purposes only

> Click here to view details on the options

NOA 2019/20 recommendations

Stop Hold Delay Proceed

HVDC



Note: all reinforcement routes and locations are for illustrative purposes only

> Click here to view details on the options

***NOA 2019/20* recommendations**

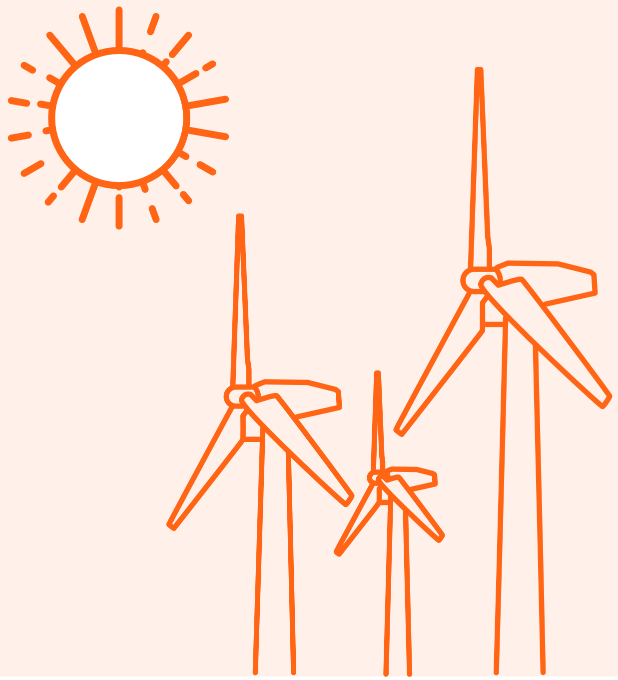
Stop Proceed

4.5 Offshore wider works

The Integrated Offshore Transmission Report, published in 2015, concluded that offshore generation was unlikely to reach levels in the timescales required to make an integrated design approach beneficial. The ESO has continued to monitor the background. The Sector Deal includes a further target to install 50 GW of offshore wind by 2050, which is met in **Two Degrees** and almost met in **Community Renewables**, giving a renewed impetus for offshore coordination.

For *NOA 2019/20*, the ESO proposed a conceptual link between Kent and Suffolk for use in the NOA analysis. A TO developed a very similar proposal, a new offshore HVDC link between Suffolk and Kent Option 1 (SCD1). This option had the benefit of more accurate costing as well as detailed power system analysis. Given these factors, it was more suitable for the ESO to adapt the TO option and consider it as a proxy for offshore coordination.

The NOA analysis found that SCD1 is optimal in all four scenarios and critical in **Two Degrees** and **Community Renewables**. The analysis also showed that another option, a new offshore HVDC link between Suffolk and Kent Option 2 (SCD2), is optimal in three scenarios (**Two Degrees**, **Steady Progression** and **Community Renewables**) although critical in none. This showed the options perform well when studied for boundary benefit alone, in other words without adding the full benefits of integration.



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5 Interconnector analysis

NOA for Interconnectors at a glance

What is NOA for Interconnectors?

The NOA for Interconnectors (NOA IC) is an assessment of how much interconnection with GB would provide the most value to consumers and other interested parties.

How does it work?

It evaluates the potential benefit of additional interconnection by considering three elements:

- Social economic welfare – the benefit to society.
- Constraint costs – the impact of the interconnector on the GB network.
- Capital expenditure costs – of both the interconnector and any associated network reinforcements.

NOA IC calculates the optimal level of interconnection by evaluating these three elements for a range of interconnector options from GB to seven European countries for each future energy scenario.

What are the high-level results?

- This year's analysis identifies many potential opportunities for additional interconnection to create value for GB and Europe, both economically and environmentally.
- Increased levels of interconnection bring significant benefits to GB and European consumers, in terms of lower wholesale energy prices and greater use of renewable power.
- A total interconnection capacity in the range of 18.1 GW and 23.1 GW between GB and European markets by 2032 would provide the maximum benefit for GB consumers.
- This is between three and five times the current level of operational GB interconnection of 5 GW.

Optimal interconnection capacity for each future energy scenario

Consumer Evolution	Community Renewables	Steady Progression	Two Degrees
18.1 GW	23.1 GW	18.1 GW	23.1 GW

5.1 Introduction

Chapter 5 presents our latest interconnection analysis. It highlights the potential benefits of efficient levels of interconnection capacity between GB and other markets. The analysis does not attempt to quantify the impact of the UK's future trading relationship negotiations with the EU. The outcome of these negotiations may impact the future efficiency of interconnection and potentially impact investment in future interconnection projects as a result.

5.1.1 The purpose of this analysis

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

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 cannot do:

- assess the viability of current or future projects: the final insights are largely independent of specific projects
- provide any project-specific information.

5.1.2 *NOA* and NOA IC

The *NOA's* purpose is to recommend to Transmission Owners across Britain 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 for the NOA IC analysis: this maximises consistency between the *NOA* and NOA IC.

5.1 Introduction

Key NOA for Interconnector analysis highlights

Value

There are many opportunities for additional GB interconnection to create value for GB and Europe, both economically and environmentally.

Benefits

Increased levels of interconnection bring significant benefits to GB and European consumers, both in terms of lower wholesale energy prices and greater use of renewable power.

23.1 GW

The analysis shows that a total interconnection capacity in the range of **18.1 GW** and **23.1 GW** between GB and European markets by 2032 would provide the maximum benefit for GB consumers.

Renewable energy

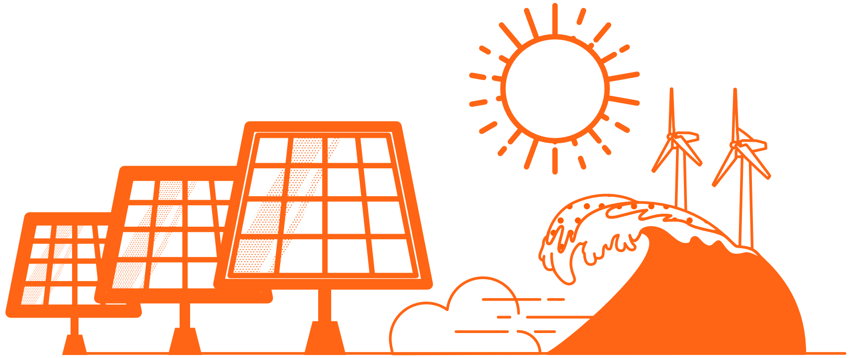
Two Degrees and **Community Renewables,** the two *FES 2019* scenarios that meet the carbon reduction target of an 80 per cent reduction in greenhouse gas emissions by 2050 compared to 1990 levels, result in the highest levels of GB interconnection, because of the high benefits due to intermittent renewable energy.

GB consumer

The analysis demonstrates that the GB consumer can benefit from more interconnection projects beyond those included within Cap and Floor Window 2.

FES 2019

While there are four optimal interconnector paths based on *FES 2019*, the analysis also shows that many of the interconnector options not on the optimal paths also add value.

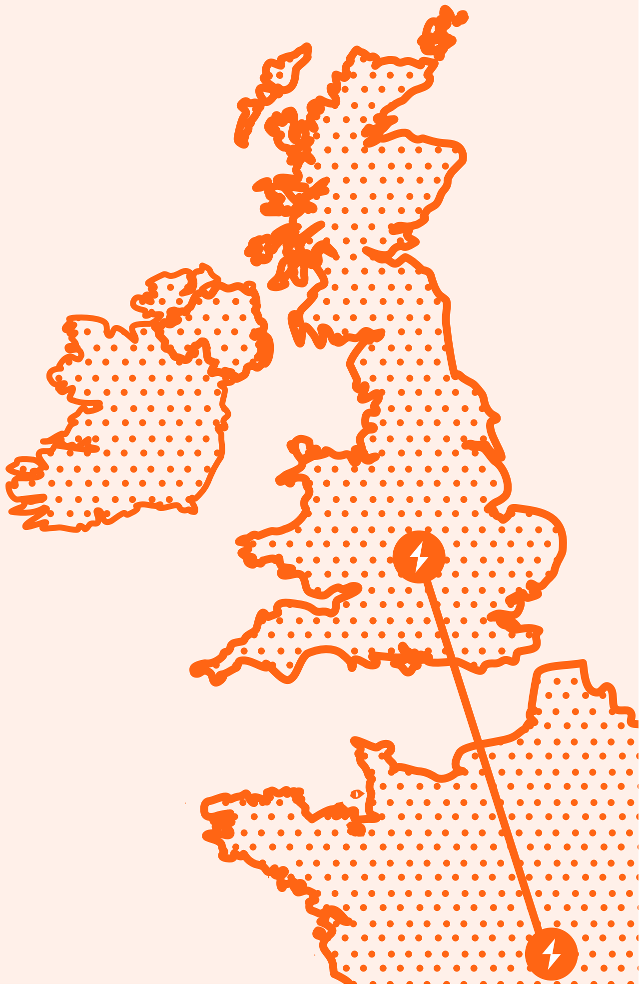


5.1 Introduction

5.1.3 Improvements to this year's analysis

For this year's analysis, we have undertaken further improvements to the methodology which were 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 to GB-based social economic welfare, capital costs and reinforcement costs. We explain in more detail the results relating to the main iterative analysis, including showing how the annual interconnector flows evolve over time.
- Based on stakeholder feedback, we have not analysed the impact interconnectors may have on other operational costs, specifically ancillary services. Our stakeholders told us NOA IC was not the best place for this type of analysis, which will instead be highlighted in other ESO sources. See **section 5.4.5** for more information.
- We have used broadly the same iterative method as last year. The studies involve a step-by-step process, where the market is modelled with a base level of interconnection. Like last year, there is no least worst regret calculation to assign one single additional interconnection option across all four scenarios. This results in four distinct optimal solutions, one for each FES. Our stakeholders told us a range of results is more useful than a single optimal solution.

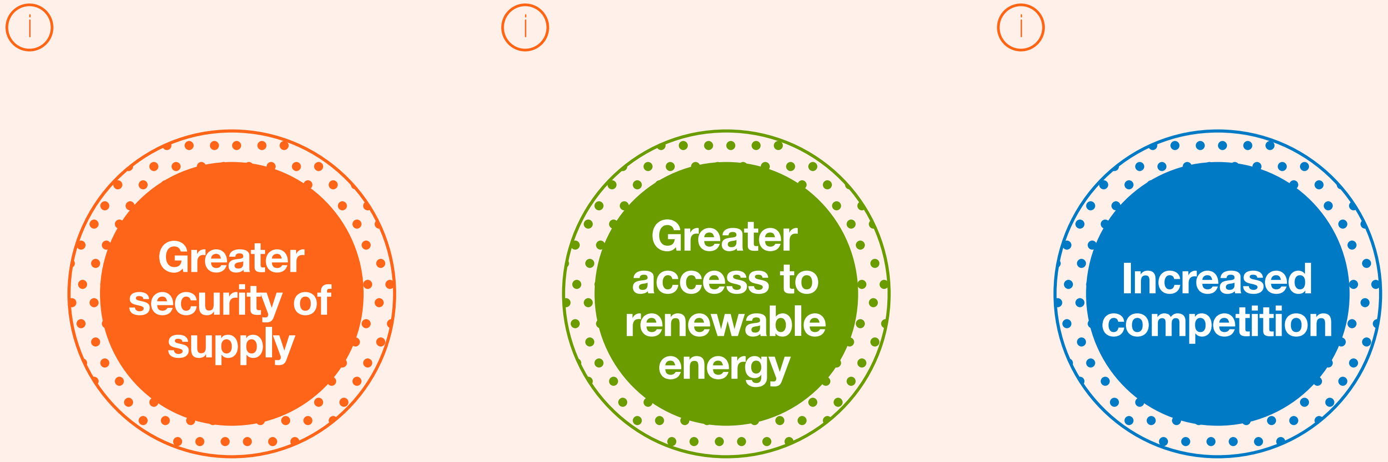


5.2 Interconnection theory

Electricity interconnectors allow the transfer of electricity between nations. Currently GB has ~5 GW of interconnection with other European markets; however, our 2019 future energy scenarios (FES) see an increase to between 12 GW in **Consumer Evolution** and 20 GW in **Two Degrees** by 2030.

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

Figure 5.1
Benefits of interconnection

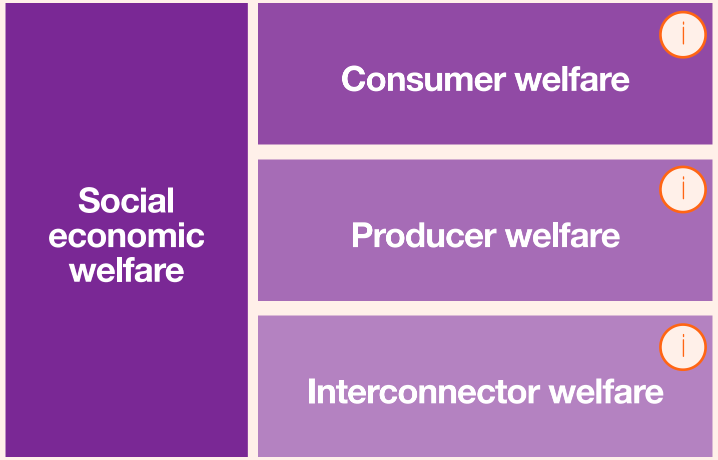


5.2 Interconnection theory

Social economic welfare (SEW) is a common indicator in cost-benefit analysis of 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 within society may lose money because of the option taken. In this analysis, SEW captures the financial benefits and detriments of market participants due to increased interconnection. Figure 5.2 shows how SEW is reached.

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 suitable markets and SEW delivered, prices between the two markets begin to converge until further interconnection brings no benefit. The interconnection capacity is optimised, having delivered maximum benefits.

Figure 5.2
Social economic welfare



5.3 Methodology

This section provides a high-level overview of the methodology used within the NOA for Interconnectors analysis, which we continue to develop using feedback from stakeholders.

5.3.1 Developments to methodology

This year, acting on stakeholders' feedback, we have focused our analysis on identifying the optimal level of interconnection capacity for GB. The key highlights are:

- The iterative process continues to focus on social economic welfare (SEW), capital costs and reinforcement costs.
- The optimal paths are based on SEW for GB and the connecting country only. This makes the direct welfare benefits of the interconnector more transparent and avoids any SEW generated by flows between other countries.
- We have continued to use the recommendations 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 continued to produce four optimal interconnection development paths: one for each future energy scenario. Stakeholders felt a range of results was more beneficial, due to the high levels of uncertainty regarding the future of the European energy market.

5.3 Methodology

5.3.2 Current and potential interconnection

As stated within the *FES 2019*, interconnection capacity increases beyond current levels in all four scenarios. Table 5.1 shows the current and planned interconnection levels which have formed the basis for this study's base interconnection capacity.

It is important to note that the baseline level of interconnection capacity used as a starting point for the modelling should not be viewed as NGESO attempting to forecast which projects currently under development will become operational. The baseline is not an assessment of the likelihood of individual projects progressing: it represents a credible aggregation of projects currently under development that can be used as a starting point for the NOA IC analysis. It is possible that not all projects currently under development will progress to completion. Other new projects may be developed and become operational.

NGESO received feedback as part of our stakeholder engagement that we should review how we set the baseline level of interconnection capacity. For NOA IC 2018/19 and previous cycles, we had included projects within the interconnector baseline against the criteria of "regulatory certainty". We received feedback that using this criterion was inappropriate for several reasons, including that it excluded certain projects with project of common interest (PCI) status and that the criteria of regulatory certainty was open to various interpretations. We also received feedback that a more appropriate methodology would be to include a broader criterion for inclusion of interconnectors and to apply an appropriate scaling factor to ensure the baseline level of interconnection facilitates a credible analysis.

For this year's NOA IC we have used, as a starting point, all interconnector projects currently operational, those under construction and those included on the **NGESO Interconnector Register**. The interconnector register lists all GB interconnector projects that have currently signed a connection agreement to connect to the GB electricity transmission system. The interconnector register is a public domain document that is updated throughout the year. Nearly all interconnector projects to GB that have PCI status are included within the interconnector register. If we add all existing operational GB interconnectors, those currently under construction and those listed on the interconnector register, this results in a figure of 21 GW: to achieve a credible baseline figure, a scaling factor of 25 per cent was applied to projects under development (but not under construction). This results in a baseline interconnection level of 13.6 GW. Note that the 25 per cent scaling factor should not be interpreted as specific projects having a 1 in 4 probability of completion: the scaling factor represents the scaling necessary to achieve a reasonable baseline level of interconnection to commence the analysis from.

For this year's analysis, we have continued to treat any Icelandic interconnection that appears within 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. It can be seen from table 5.1 that if all the projects included within the base case do successfully connect on time, then this will represent nearly a trebling in GB interconnection capacity over the next eight years.

5.3 Methodology

We welcome stakeholders' feedback on the revised interconnection baseline capacity calculation methodology. We will continue to consult with our stakeholders to revise and improve the process.

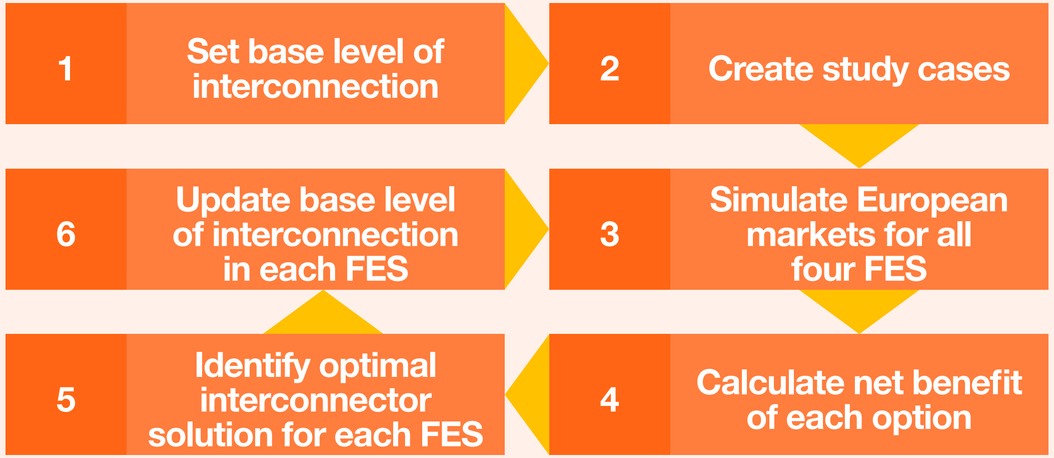
The selected method of arriving at a recommendation for capacity development is an iterative optimisation for each future energy scenario. This approach attempts to maximise the present value, equal to SEW less CAPEX less constraint costs. Figure 5.3 provides a high level overview of the process. Further details are available in the **NOA report methodology**.

Table 5.1
Current interconnection capacities and 2027 base case

	Belgium	Denmark	France	Germany	Ireland	Netherlands	Norway	Total
2019 capacity (GW)	1	0	2	0	1	1	0	**5**
2027 base case (GW)	1.7	0.7	5.8	0.7	1.3	1.3	2.2	**13.6**

Figure 5.3
Iterative process for interconnection optimisation

Hover over the numbers below to reveal more information



5.3 Methodology

The 30 study cases are shown in table 5.2. Additional interconnection is modelled to connect in 2027, 2029 and 2032, to include the effects of varying commissioning dates on SEW and constraint costs.

The iterative process for each FES finishes when it is deemed to have converged, that is when 'None' (the base case) is the option with the highest present value. Once this result is achieved, the incremental capacity will be reduced to 500 MW to analyse whether there is any benefit of a further 500 MW of interconnection.

Table 5.2
Study cases, showing interconnector connecting country, zone and reinforcement options

Interconnected country	GB connection zone	Reinforcement on boundary
None (base)	None	None
Belgium	4	EC5
Belgium	4	None
Belgium	6	None
Belgium	6	SC1+B15
Denmark	6	EC5
Denmark	6	None
Denmark	7	None
France	5	None
France	5	SC1
France	5	SC1+B15
France	5	None
France	5	SC1
Germany	4	EC5
Germany	4	None

Interconnected country	GB connection zone	Reinforcement on boundary
Germany	7	None
Ireland	1	None
Ireland	1	B6+B8
Ireland	2	None
Ireland	2	B8
Ireland	3	None
Ireland	3	SW1
Norway	1	None
Norway	1	B6+B8
Norway	2	None
Norway	2	B8
The Netherlands	4	None
The Netherlands	4	EC5
The Netherlands	6	None
The Netherlands	6	SC1+B15

5.3 Methodology

5.3.3 Estimation of interconnection construction costs

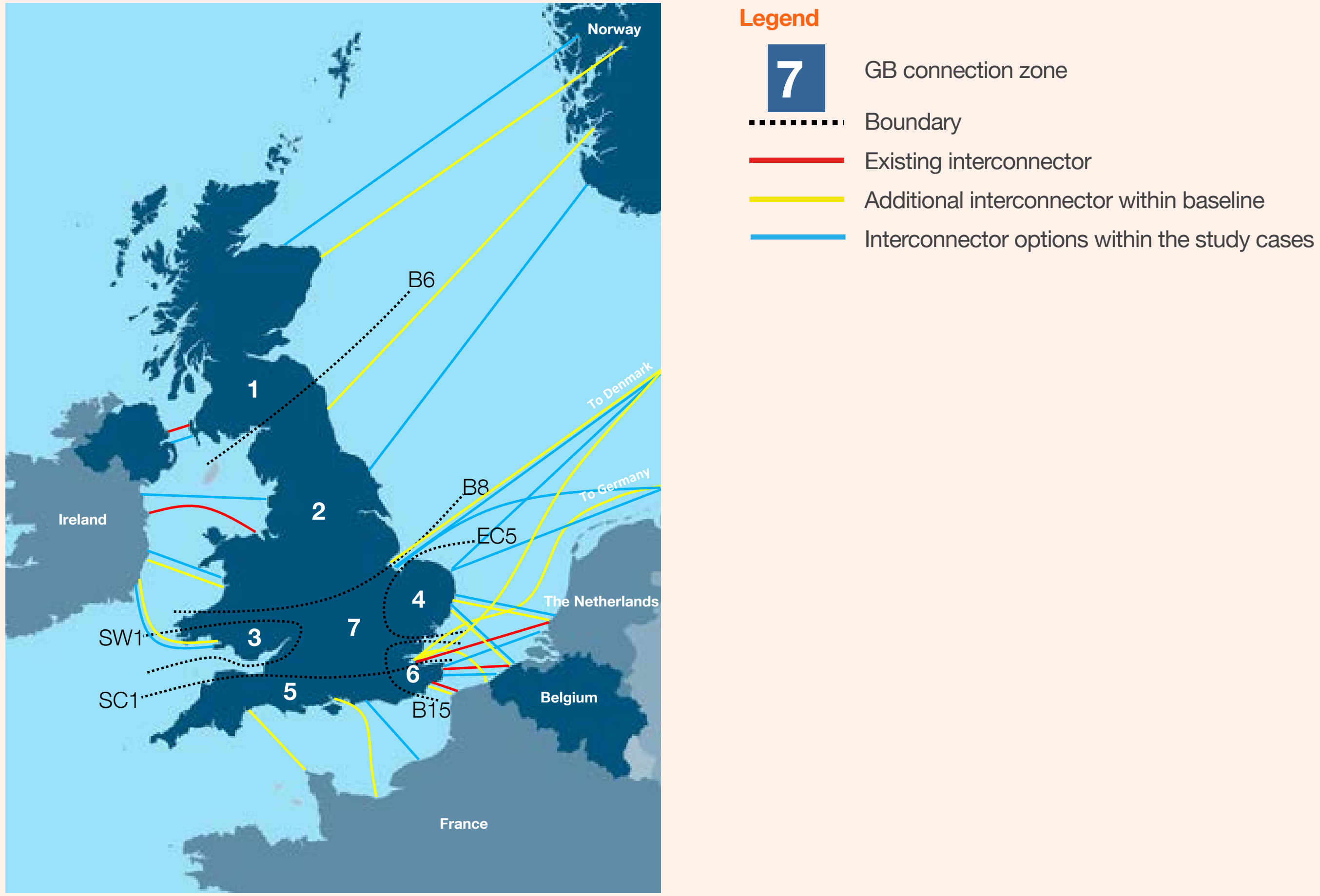
The cost of building interconnection capacity varies significantly between different projects, with key drivers including converter technology, cable length and capacity. The capital costs were derived from a publicly-available ACER (Agency for the Cooperation of Energy Regulators) **document**, based on surveys carried out on European projects, and approximations of median possible cable lengths. Costs were converted to 2019/20 prices.

5.3.4 Estimation of network reinforcement costs

We have divided the network into seven high-level zones, determined by areas of significant constraints on the network or areas of high interconnection.

Figure 5.4 highlights the GB connection zones, boundaries and interconnectors included within the base case and options modelled within the study cases.

Figure 5.4
GB network high level zones, boundaries and interconnector options



5.4 Outcome

The market studies generated SEW for each case. This section covers future interconnection that benefited the GB consumer 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.

5.4.1 Optimal interconnection range

The final results show, for each FES, the markets to connect to, whether reinforcement of the GB network was necessary and in which years to connect to maximise SEW. It is important to consider the results in the context of the methodology undertaken:

- Projects to markets not in the optimal paths may well be beneficial, but simply not the most beneficial based on the assumptions made in this study.
- The attractiveness of different markets varies across the scenarios. So 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 starting interconnection capacities shown in table 5.1 include projects already in operation or under construction and other projects currently under development, to which a scaling factor has been applied. This base case of 13.6 GW represents a near trebling of current interconnection capacity, which causes considerable price convergence between GB and mainland Europe. As the SEW generated by additional interconnection depends on the price differential between GB and European markets, the interconnectors that form the base case diminish the level of additional SEW further interconnection can bring.

The number of iterations varied across the future energy scenarios. The optimal level of interconnection between GB and European markets for each FES, including the baseline level of interconnection of 13.6 GW, is shown in figure 5.5.

5.4 Outcome

Figure 5.5
Optimal interconnection for each FES including the base case level

Consumer Evolution	Community Renewables	Steady Progression	Two Degrees
18.1 GW	23.1 GW	18.1 GW	23.1 GW

The four optimal levels of interconnection shown in figure 5.5 give a range of between 18.1 GW and 23.1 GW of interconnection capacity across the four FES. All four are higher than the interconnection capacity within the *FES 2019* scenarios, which have a range of between 12 GW and 20 GW. They have between 3.1 GW and 6.1 GW additional capacity over the *FES 2019* scenarios, driven by the potential for additional value creation.

Last year's NOA IC resulted in a range of between 18.4 GW and 21.4 GW. The longer paths in this year's analysis for the **Community Renewables** and **Two Degrees** scenarios are the result of higher levels of welfare. Both the **Community Renewables** and **Two Degrees** 2019 scenarios achieve the decarbonisation target of an 80 per cent reduction in greenhouse gas emissions by 2050 compared to 1990 levels and a key element is increased levels of offshore wind generation compared to the 2018 scenarios. Both **Community Renewables** and **Two Degrees** 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 within Ofgem's Cap and Floor Window 2.

Figure 5.6 shows the results in graphical format, including the number of iterations, the cumulative level interconnection capacity, the connecting country, whether any additional reinforcement was associated with the option, the connecting zone and the connecting year for each option.

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5.4 Outcome

Figure 5.6
Optimal interconnection paths for each FES

Baseline: 13.6 GW

Consumer Evolution		Community Renewables		Steady Progression		Two Degrees	
Ireland Zone 1 2032	14.6	Norway Zone 2 2029	14.6	Belgium Zone 4 2032 EC5 reinforcement	14.6	Norway Zone 1 2029	14.6
Germany Zone 4 2029	15.6	Ireland Zone 1 2032	15.6	Netherlands Zone 4 2029 EC5 reinforcement	15.6	Ireland Zone 1 2029	15.6
Belgium Zone 4 2029	16.6	Norway Zone 2 2032	16.6	Ireland Zone 1 2032	16.6	France Zone 6 2027	16.6
Ireland Zone 3 2029	17.6	Norway Zone 2 2032	17.6	Belgium Zone 4 2032 EC5 reinforcement	17.6	Netherlands Zone 4 2029	17.6
Norway Zone 1 2027	18.1	Ireland Zone 1 2027	18.6	Netherlands Zone 4 2027 EC5 reinforcement	18.1	Belgium Zone 6 2027	18.6
		Belgium Zone 4 2032 EC5 reinforcement	19.6			France Zone 6 2027	19.6
		Netherlands Zone 4 2029 EC5 reinforcement	20.6			Ireland Zone 1 2029	20.6
		Germany Zone 4 2032 EC5 reinforcement	21.6			Germany Zone 4 2029	21.6
		Norway Zone 2 2029	22.6			France Zone 6 2032	22.6
		France Zone 6 2029	23.1			Germany Zone 4 2032	23.1

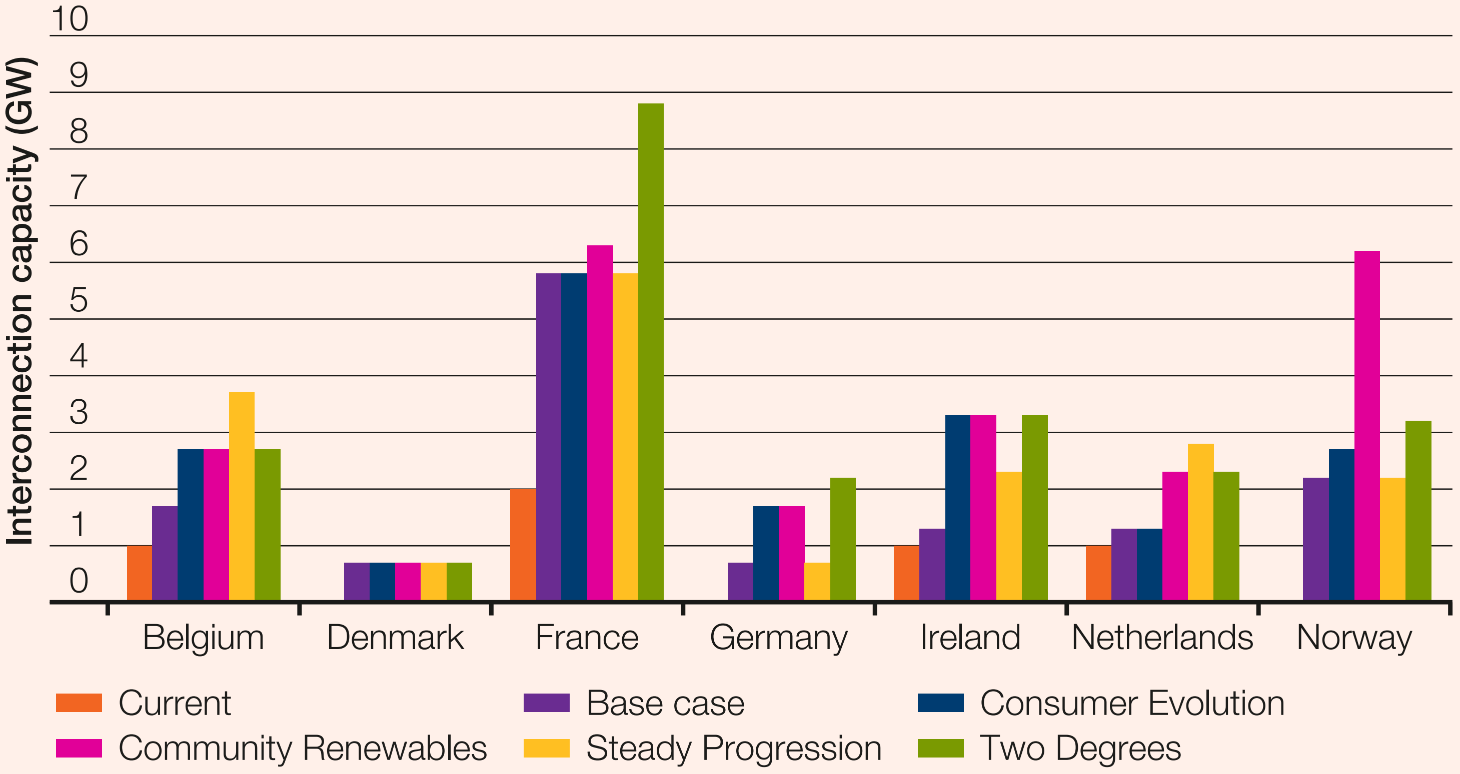
Figure 5.6 shows the range of optimal level of interconnection across the different FES. This is to be expected, as scenarios such as **Community Renewables** and **Two Degrees**, with high levels of intermittent generation and significant differences in wholesale prices between markets, provide more opportunity for welfare from additional interconnection.

5.4 Outcome

Figure 5.7 presents the level of interconnection to each European market for the four optimal paths.

Figure 5.7 shows that each optimal path for the four scenarios results in additional interconnection to Belgium and Ireland. The average Irish wholesale price is modelled, as generally higher than GB, resulting in welfare generation opportunities. Also generating welfare is relieving 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 5.7
Optimal level of interconnection to each European market



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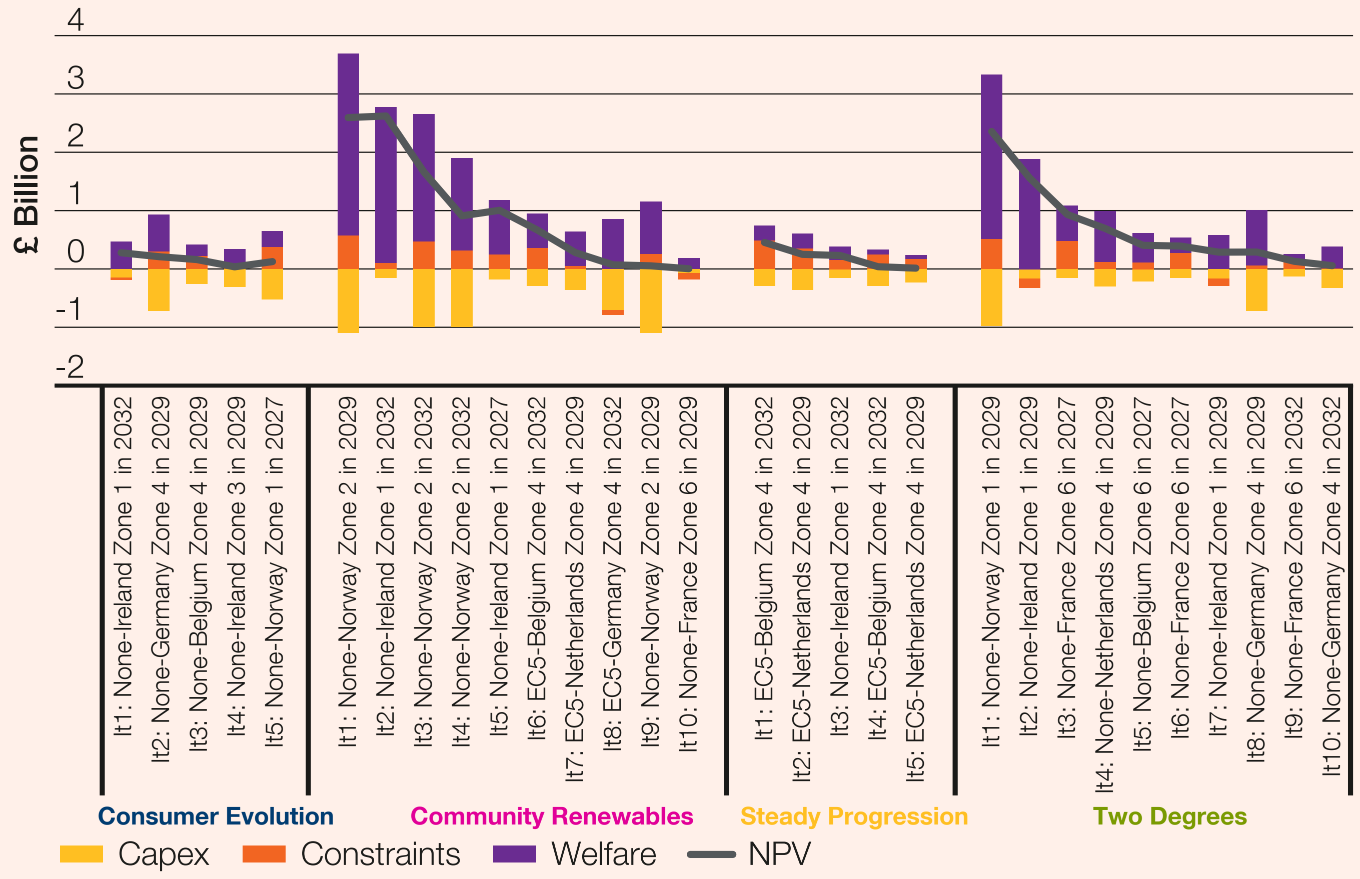
5.4 Outcome

Three of the four optimal paths also show additional interconnection above the base case level to Germany, the Netherlands and Norway. These can be explained by looking at the four optimal paths and the associated net present values relative to the base case for each FES, shown in figure 5.8.

Figure 5.8 shows the variation in length of optimal paths across the four FES and the significant variations in net present value relative to the base case for each iteration. It also shows the composition of each net present value (NPV), broken down by welfare, CAPEX and constraints. Not surprisingly, CAPEX is always negative relative to the base case, but constraints can result in both savings and additional costs, depending on the study case.

The chart highlights the longer optimal interconnection paths for the **Community Renewables** and **Two Degrees** scenarios, and the significantly higher levels of welfare generated within those paths.

Figure 5.8
Net present value of each winning study case for the optimal path for each FES



5.4 Outcome

For interconnection to Norway, the relatively high CAPEX costs are more than offset by constraint savings and in the **Community Renewables** and **Two Degrees** scenarios, significantly higher SEW benefits. Similarly, for interconnection to Germany, the additional CAPEX costs are outweighed by the additional SEW increases, albeit lower than for Norway. For the Netherlands, the relatively low additional CAPEX costs are outweighed by a combination of SEW benefits and constraint savings.

Figure 5.8 also shows how **Community Renewables** provides greater opportunities for welfare creation driven by the price difference between the GB and Norwegian markets, with the optimal solutions being interconnectors to Norway for iterations 1, 3, 4 and 9.

Only seven of the optimal solutions incorporate a boundary reinforcement, three in **Community Renewables** and four in **Steady Progression**. The low level of additional reinforcement is due to using this year's *NOA* recommendations for network reinforcements, resulting in limited additional constraint savings from additional interconnection and associated boundary reinforcement. All reinforcements are for additional capability on the EC5 boundary, suggesting this boundary could benefit from additional reinforcement above the levels included within the *FES 2019*. The EC5 boundary represents electricity flows across East Anglia, where significant levels of offshore wind are forecast to connect, which may increase congestion on the boundary.

5.4 Outcome

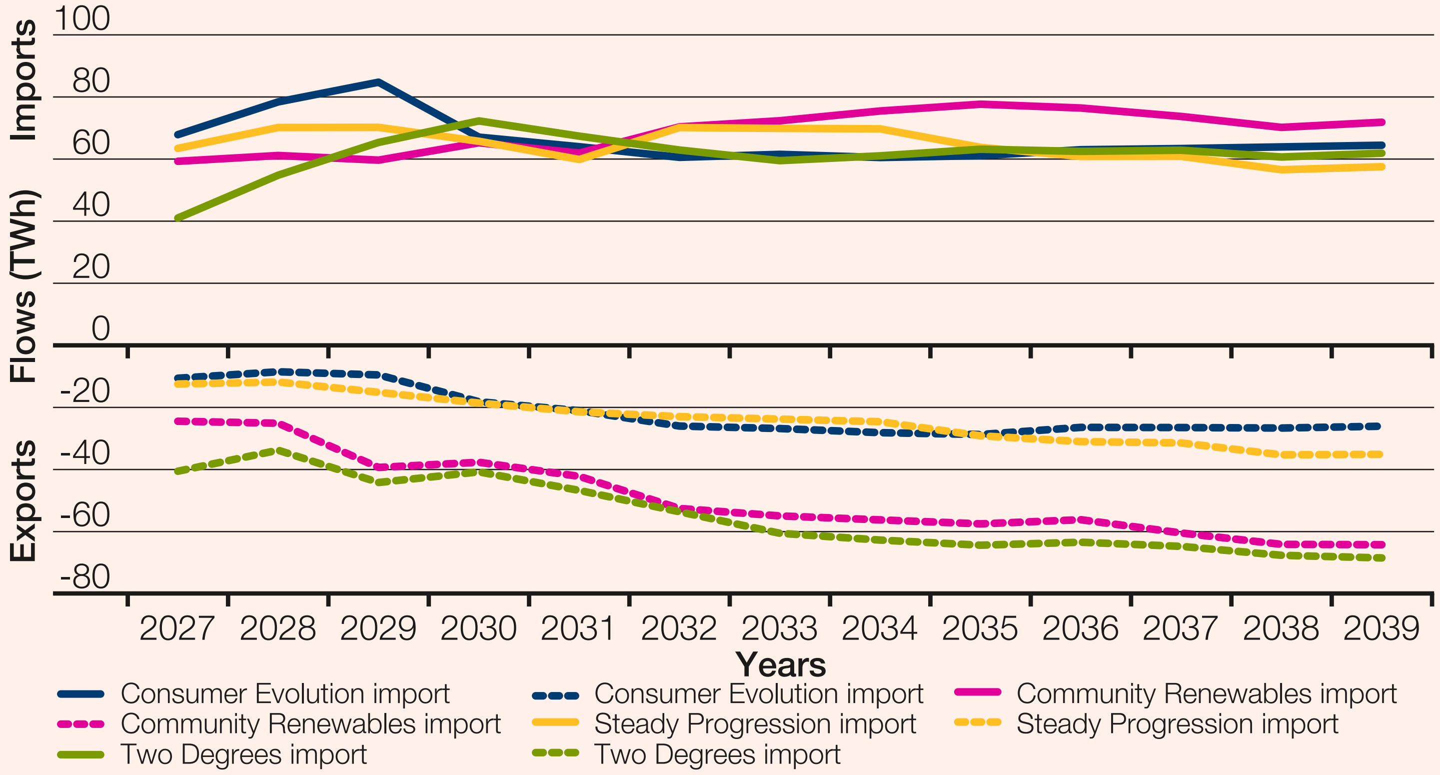
5.4.2 GB consumer benefit

The GB consumer gains from interconnection to cheaper wholesale electricity markets. Figure 5.9 shows annual imports and exports for each of the optimal interconnection paths.

Figure 5.9 shows that, like last year, **Two Degrees** sees the highest levels of exports across interconnectors for all the FES. Levels of annual exports in **Two Degrees** and **Community Renewables** are more than double those seen in **Consumer Evolution** and **Steady Progression**. All four scenarios show increasing levels of exports from 2027 as arbitrage opportunities are exploited. Import flows remain broadly flat for all four scenarios, mostly in the range of 60 TWh to 80 TWh per year.

Community Renewables and **Two Degrees**, the two scenarios that achieve the decarbonisation target of an 80 per cent reduction in greenhouse gas emissions by 2050 compared to 1990 levels, achieve roughly a net balance of imports and exports by the end of the forecast period, as high volumes of renewable generation are traded across the interconnectors.

Figure 5.9
Annual imports and export flows

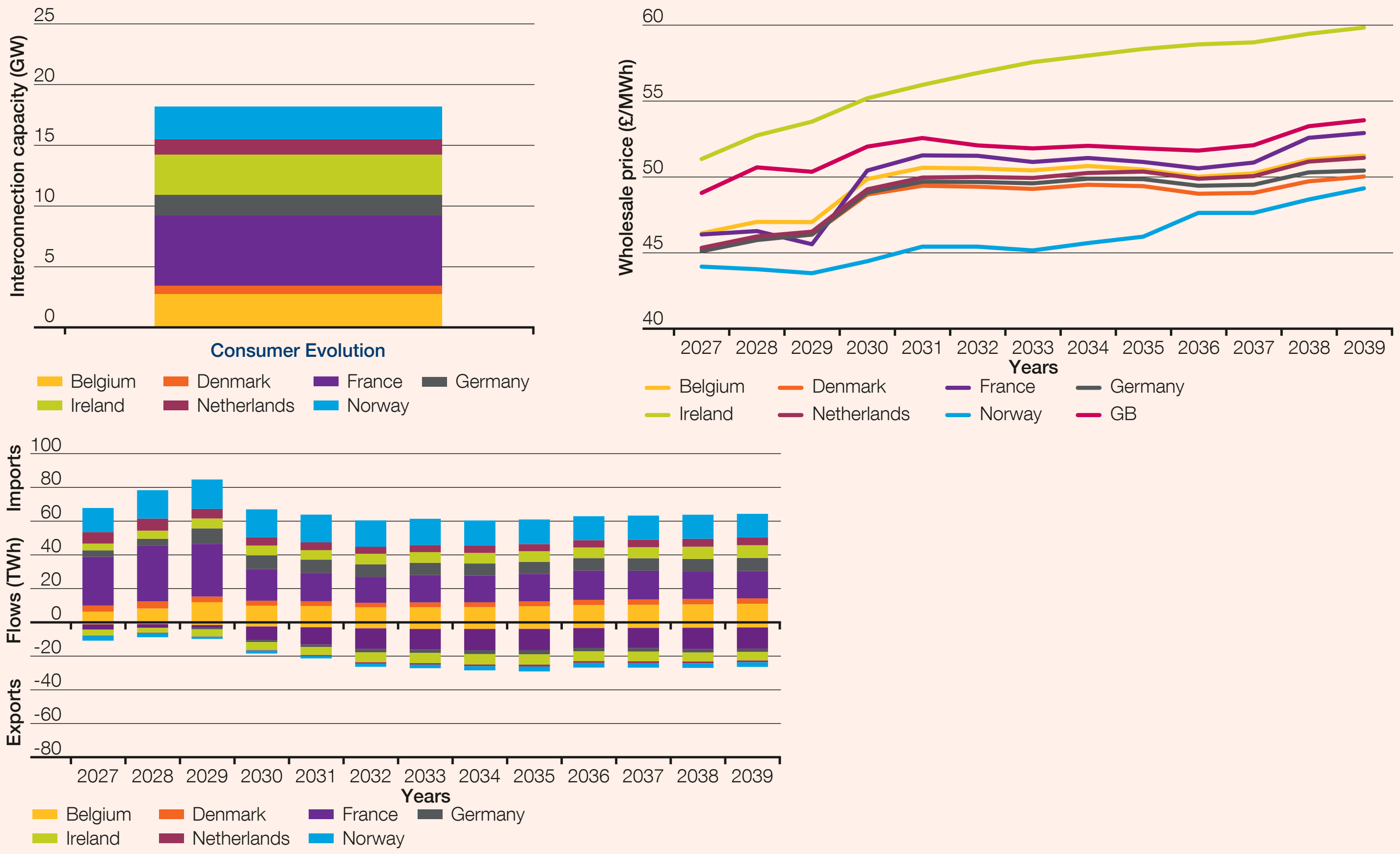


5.4 Outcome

Figures 5.10 to 5.13 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 Evolution shows a gradual increase in wholesale electricity prices across Europe, with only Ireland showing higher prices than GB. This drives high import flows across the interconnectors, particularly from France and Norway. The wholesale price differences allow arbitrage opportunities for imports to GB and drive increased welfare from additional interconnection. **Consumer Evolution** shows the lowest levels of interconnection export flows. For most of the study period, total interconnector imports are roughly three times the level of exports, although there are still high levels of exports to France during periods of high renewable electricity generation within GB.

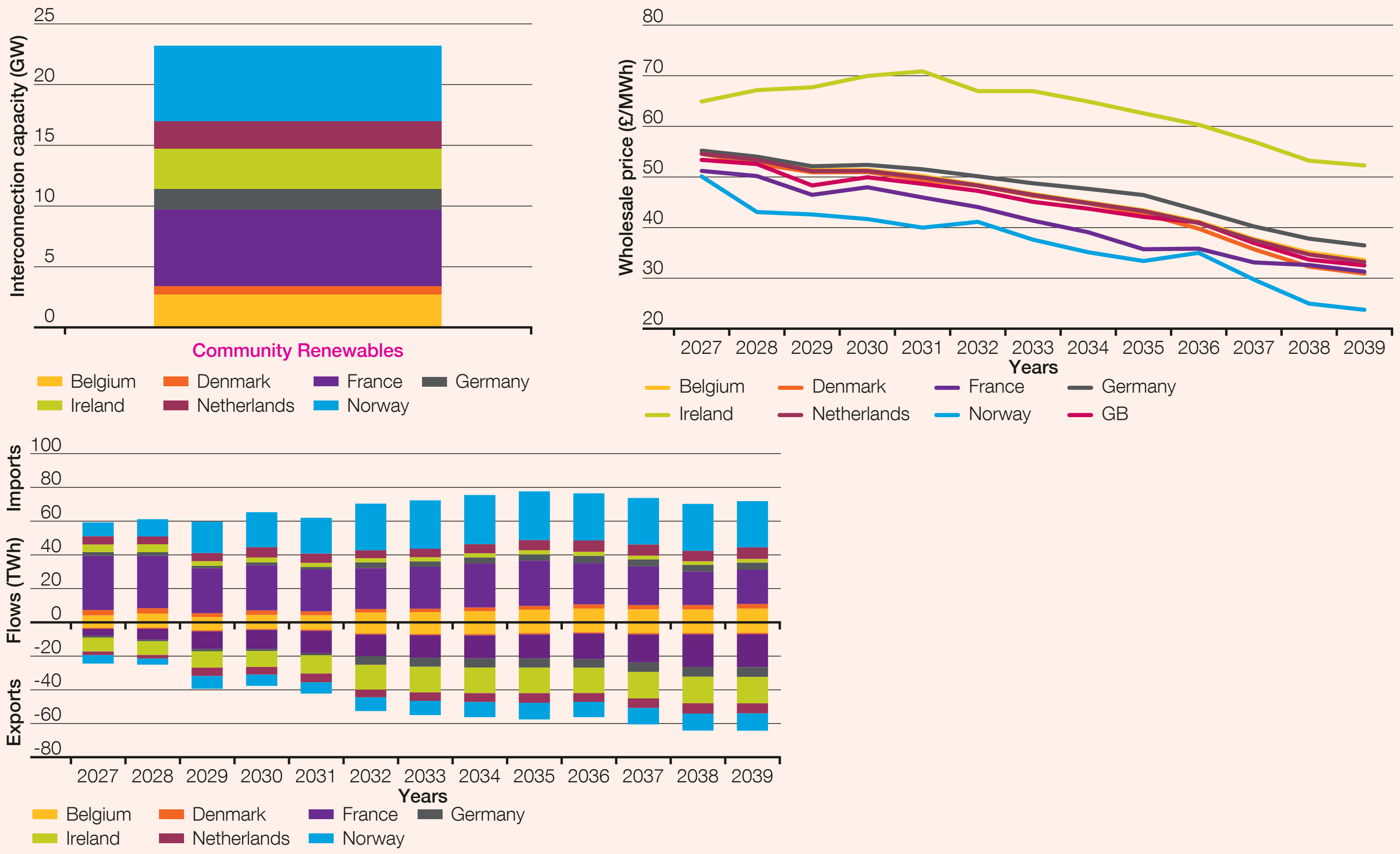
Figure 5.10
Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Consumer Evolution



5.4 Outcome

Community Renewables shows a steady decline in GB and other European wholesale prices driven by increasing levels of renewable generation. Annual wholesale prices for Norway and France are below GB, and **Community Renewables** sees the highest levels of imports from Norway of all the scenarios, as well as significant imports from France. But there are also high levels of exports, particularly to France and Ireland, when high levels of intermittent renewable generation in GB drive down GB prices and allow arbitrage opportunities for increased exports and increased welfare from additional interconnection. **Community Renewables** shows the highest levels of imports of any of the scenarios, peaking at nearly 80 TWh in 2035. By 2039 annual imports and exports are roughly in balance, at between 60 TWh and 70 TWhs.

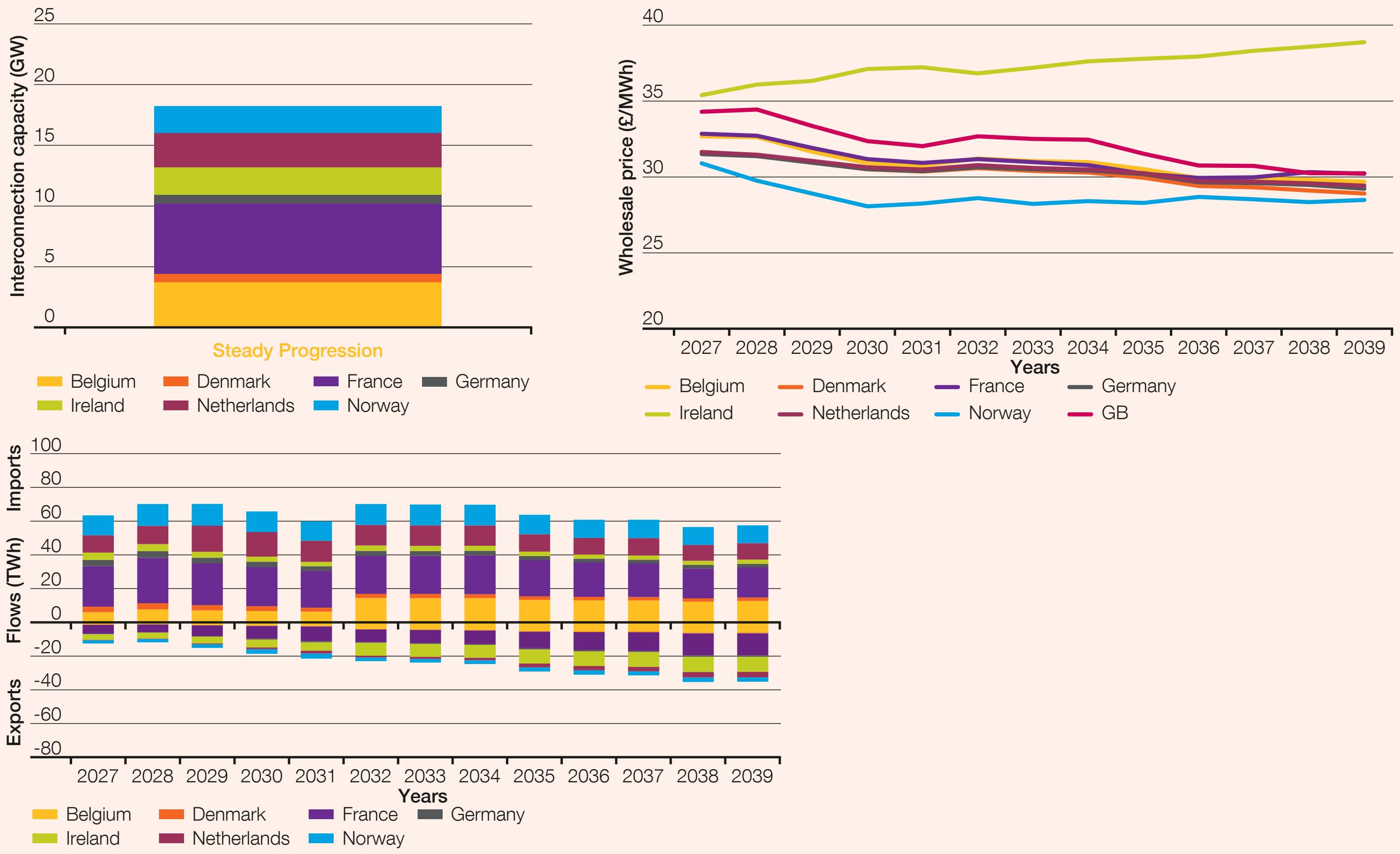
Figure 5.11
Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Community Renewables



5.4 Outcome

Steady Progression, like **Consumer Evolution**, shows GB wholesale prices to be higher than other countries, apart from Ireland. This leads to high import flows across the interconnectors, particularly from France, Norway and Belgium. **Steady Progression** shows the second lowest levels of exports. The relatively high wholesale prices in Ireland lead to GB export arbitrage opportunities.

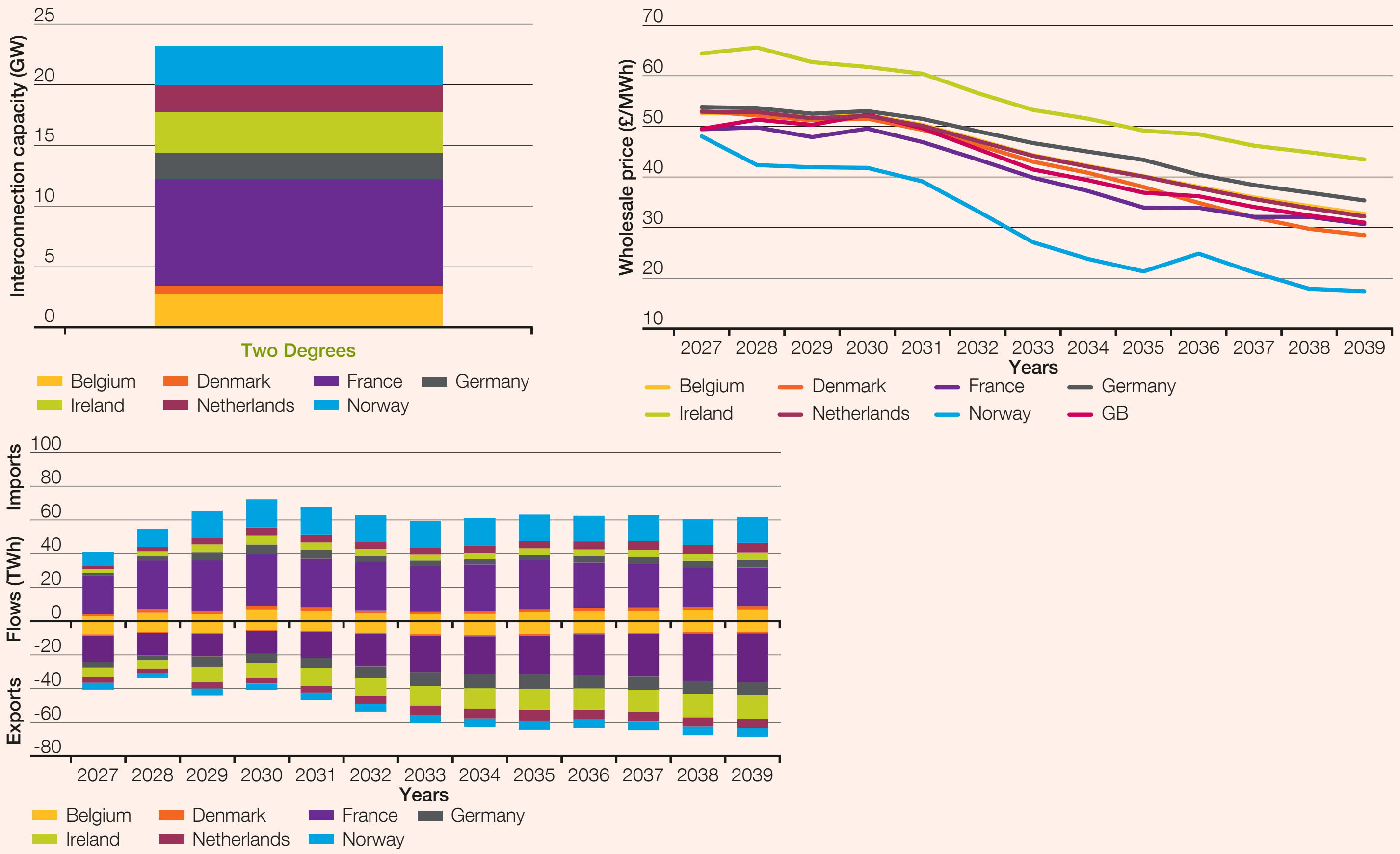
Figure 5.12
Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Steady Progression



5.4 Outcome

Two Degrees shows a significant decline in GB and other European wholesale prices, driven by increasing levels of renewable generation. There are significant imports from both France and Norway (as the lower annual French and Norwegian prices would imply), but also high levels of exports to France, Norway and Ireland when high levels of intermittent renewable generation in GB drive down our prices and allow arbitrage opportunities for renewable energy export. Figure 5.13 shows that **Two Degrees** sees the highest levels of exports across interconnectors of all the FES, slightly higher than **Community Renewables**.

Figure 5.13
Interconnection capacity, wholesale electricity prices and import and export flows for the optimal path for Two Degrees



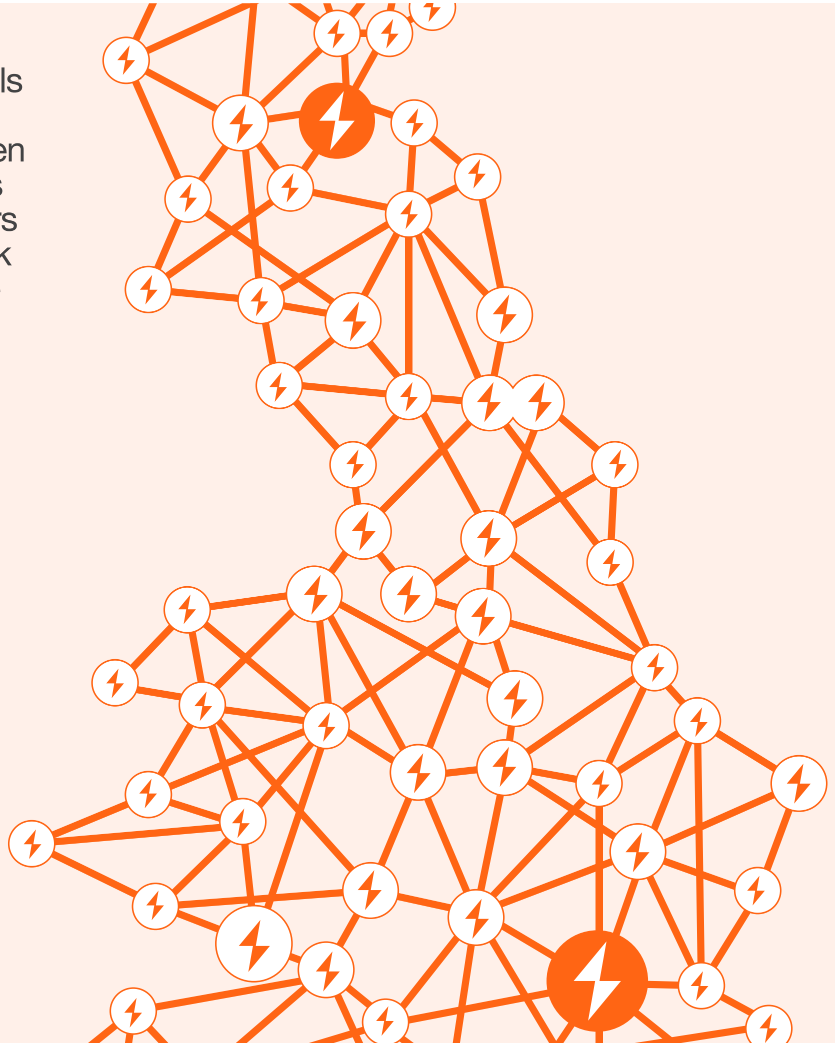
5.4 Outcome

5.4.3 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 within the merit order is limited due to 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 exacerbate constraints when exporting.



5.4 Outcome

5.4.4 Environmental implications

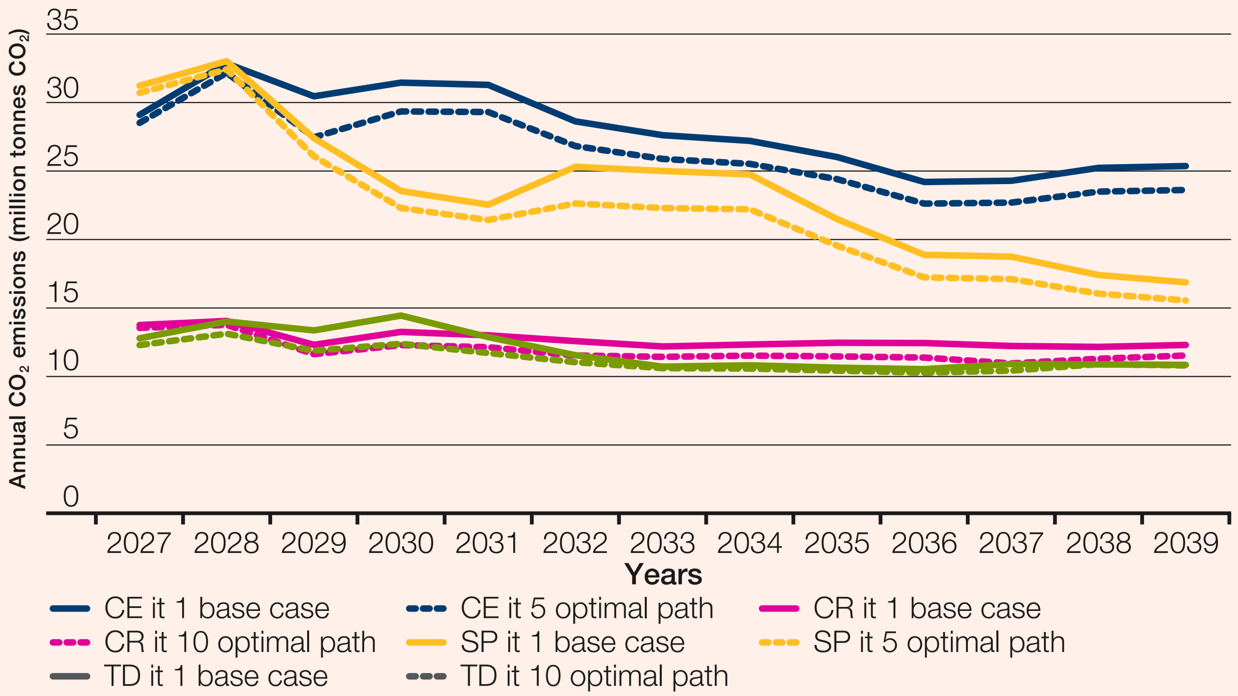
Increased levels of interconnection bring significant benefits to GB and European consumers, not only in terms of lower wholesale energy prices and greater use of renewable power, but also in terms of environmental benefits.

Reduction in CO_2 emissions

Interconnectors can increase access to renewable power, resulting in reductions in CO_2. Interconnection allows surplus power from renewable generation to be exported, rather than curtailed. Figure 5.14 shows the annual CO_2 emissions from generation for each scenario for the iteration one base case and for the final iteration optimal path.

Figure 5.14 shows that for **Consumer Evolution** and **Steady Progression**, the optimal paths (the dotted lines) show significantly lower levels of CO_2 emissions, as cleaner renewable energy is imported into the UK. For the years 2027 to 2039, this results in 21.8 and 20.6 million tonnes less of CO_2 emissions from GB generation for **Consumer Evolution** and **Steady Progression** respectively.

Figure 5.14
Annual CO_2 emissions from generation for each scenario for base case and optimal path



The savings for **Two Degrees** and **Community Renewables** are more modest, as these scenarios have a higher speed of decarbonisation. However, their optimal paths still achieve savings of 7.9 and 10.6 million tonnes of CO_2 respectively. All the reductions equate to a 5 per cent to 6.5 per cent drop over the study period.

5.4 Outcome

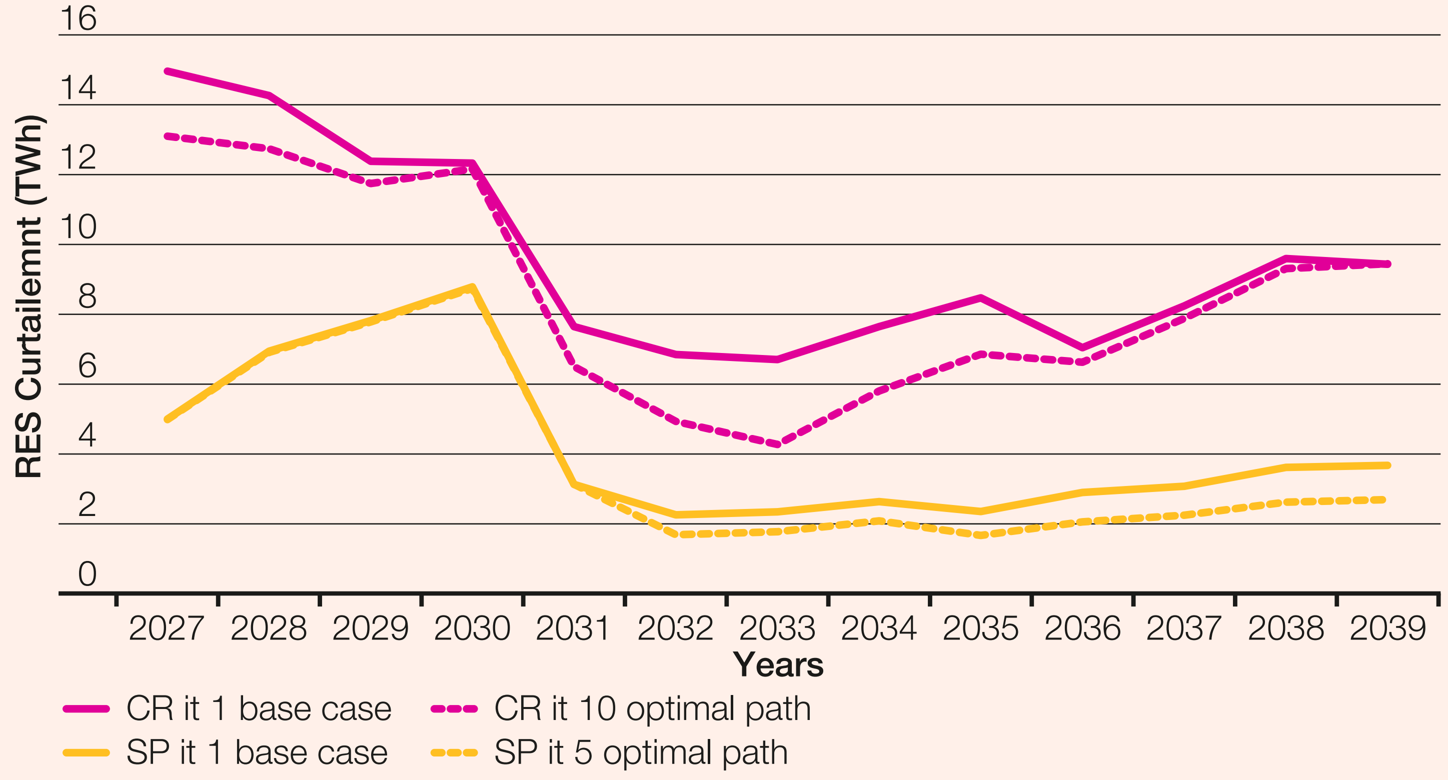
Reduction in Renewable Energy Supply (RES) curtailment

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 levels of RES.

Figure 5.15 shows the annual levels of RES curtailment for **Community Renewables** and **Steady Progression** for the iteration one base case and for the final iteration optimal path.

Figure 5.15 shows that in the **Community Renewables** scenario, which has over 100 GW of low carbon and renewable capacity by 2030, levels of RES curtailment are significantly higher than in **Steady Progression** scenario, which has only 76 GW of low carbon and renewable energy capacity. For both scenarios, in the optimal paths, that is the paths with the optimal level of additional GB interconnection, the levels of RES curtailment are lower, with **Community Renewables** resulting in roughly 14 TWh less RES curtailment and **Steady Progression** 6 TWh over the period 2027 to 2039.

Figure 5.15
Annual levels of RES curtailment for Community Renewables and Steady Progression for the base case and optimal paths



5.4 Outcome

5.4.5 System operability analysis

Last year, for the first time within the NOA IC analysis, we explored the impact interconnectors may have on the ESO's requirements for system operability.

This year we have decided not to include this. Stakeholders told us that they felt the analysis was not a good fit and that any attempt at quantifying system operability requirements should have a broader scope, rather than focusing on the potential benefits that interconnectors may provide. Another point was that analysing the impact interconnectors may have on system operability is complex, and requires a deeper analysis than was feasible within the NOA IC framework.

We will be incorporating the interconnector system operability analysis within our *System Operability Framework*, which we believe is a more logical fit. Our latest Operational Strategy Report explains the future challenges in maintaining an operable electricity system. The report provides a list of reports we will produce during 2020 covering a wide range of operability issues and challenges. Many of these will cover the impact of interconnection on system operability, but the Trends and Insights report, to be published in February 2020, will provide commentary on the operability impact of the latest FES scenarios, and will include an update to the system operability analysis included within last year's NOA IC.

5.5 NOA IC, TYNDP and PCIs

The NOA for Interconnectors analysis uses the *FES 2019*, so, the assumptions within these scenarios play an important role in determining its results. The European Network for Transmission System Operators for Electricity (ENTSO-E) also undertakes a cost-benefit analysis (**CBA**) of European interconnector projects[1], assessing amongst other things socio-economic welfare and CO_2 emissions. This forms part of the Ten Year Network Development Plan (TYNDP) process, which includes a suite of scenarios. Like the *FES*, the TYNDP scenarios are developed with stakeholder engagement and aim to reduce emissions to meet the 2050 EU targets.

The TYNDP is a two-year process that includes scenarios highlighting how the European power system may develop over the next two decades. Each project is assessed using the pan-European CBA methodology. This methodology sets out the criteria for the assessment of costs and benefits of transmission and storage projects, all of which stem from European policies on market integration, security of supply and sustainability. Projects of common interest (PCIs) are selected from the TYNDP list of transmission and storage projects. The PCI process is led by the European Commission, and for a project to qualify for PCI status it must be included within the latest TYNDP, impact at least two EU Member States, enhance market integration, increase competition, enhance security of supply and contribute to the EU's sustainability objective. PCI projects benefit from advantages including streamlined permit granting procedures and being eligible for funding from the Connecting Europe Facility, the EU's 30 billion euro fund for boosting energy, transport and digital infrastructure. PCIs can also apply for support from other EU programmes, including the European Regional Development Fund (ERDF).

The TYNDP includes an assessment of each interconnector project and the requirements for additional interconnection at a regional level. Many of the interconnector projects within the TYNDP have PCI status. To include all interconnector projects currently with PCI status at full capacity within the interconnector baseline for NOA IC would give a total interconnection capacity figure too high for any meaningful analysis. In addition, NOA IC is an economic market and network study that does not identify the relative economic benefits of specific interconnector projects currently under development. NOA IC does not attempt to pick 'winners and losers'. The current NOA IC baseline interconnection methodology includes all projects currently on the interconnector register, many of which have PCI status, with a scaling factor applied to achieve a baseline interconnection level for meaningful analysis. We believe this approach is equitable and fair.

[1] The findings of the CBAs on interconnectors undertaken as part of ENTSO-E's 2018 Ten Year Network Development Plan (TYNDP) package are available **here**.

5.6 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.

Do you believe the developments we implemented this year, such as the revised interconnector baseline capacity, have been beneficial?

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

How else can we add more value?

We need you to help shape next year's methodology, we look forward to your involvement in 2020.

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

Have your say

6 Stakeholder engagement

6.1 Introduction and continuous development

Your feedback on the *NOA* publication helps us improve the report year-on-year. Our 2020 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 NOA annual review process will help us develop the publication and we encourage all interested parties to get involved to help us improve the publication every year.

As mentioned in **Chapter 1**, we published a **long-term roadmap** for network development in 2018 with a plan to deliver further value from the *NOA*. We envisage that the findings in those additional areas will be included in our future *NOA* publications, as part of the main *NOA* report and/or as separate documents. We will share the outcomes and seek opportunities to work with a wider range of industry participants to shape our future *NOA*.

If you would like to get involved, please visit our **Network Development Roadmap web page** for more information, or email us directly at **networkdevelopment.roadmap@nationalgrideso.com**

From *NOA 2018/19*, we took on board your views and incorporated improvements and changes to this year's report.

- We have made changes to the chapter structure. Last year's **Chapter 3** – 'Boundary descriptions' has now been removed and a more concise boundary description incorporated.
- We have given the report a refreshing new look and an improved reader experience with more interactivity and visual aids, such as the first-time inclusion of a map interface to **Chapter 4** – 'Investment recommendations'. This map provides more clarity on the investment recommendation. We would really appreciate your thoughts on the new experience.
- We've made progress in our pathfinding projects since the previous *NOA* and we talk about this in the 'What's new?' section in **Chapter 1** – 'Introduction'. We'd like to know your views on the development of these projects.

6.2 Stakeholder engagement

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.

YouTube nationalgrideso

@ng_eso

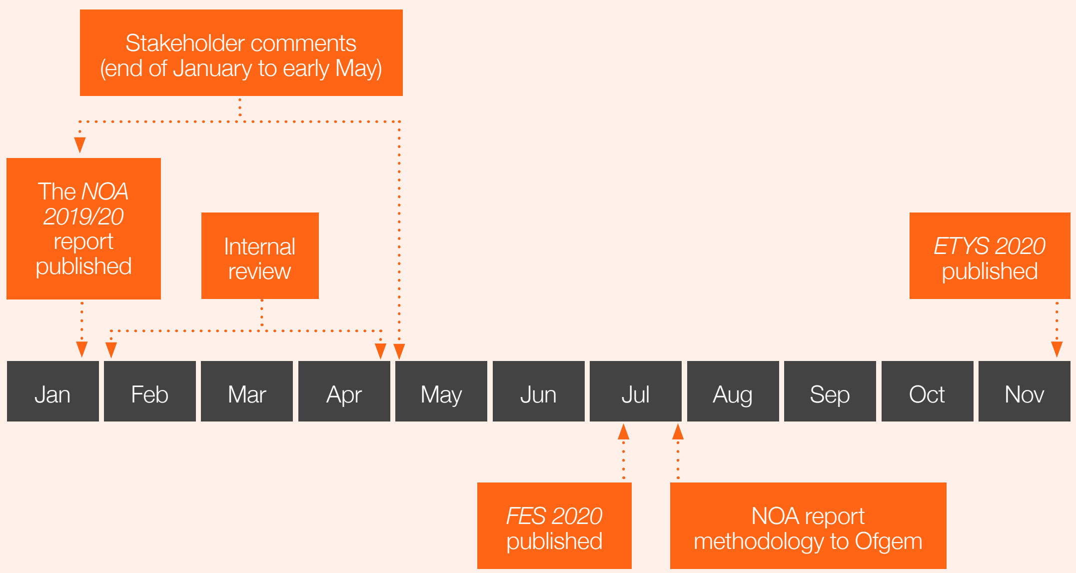
LinkedIn nationalgrideso.com

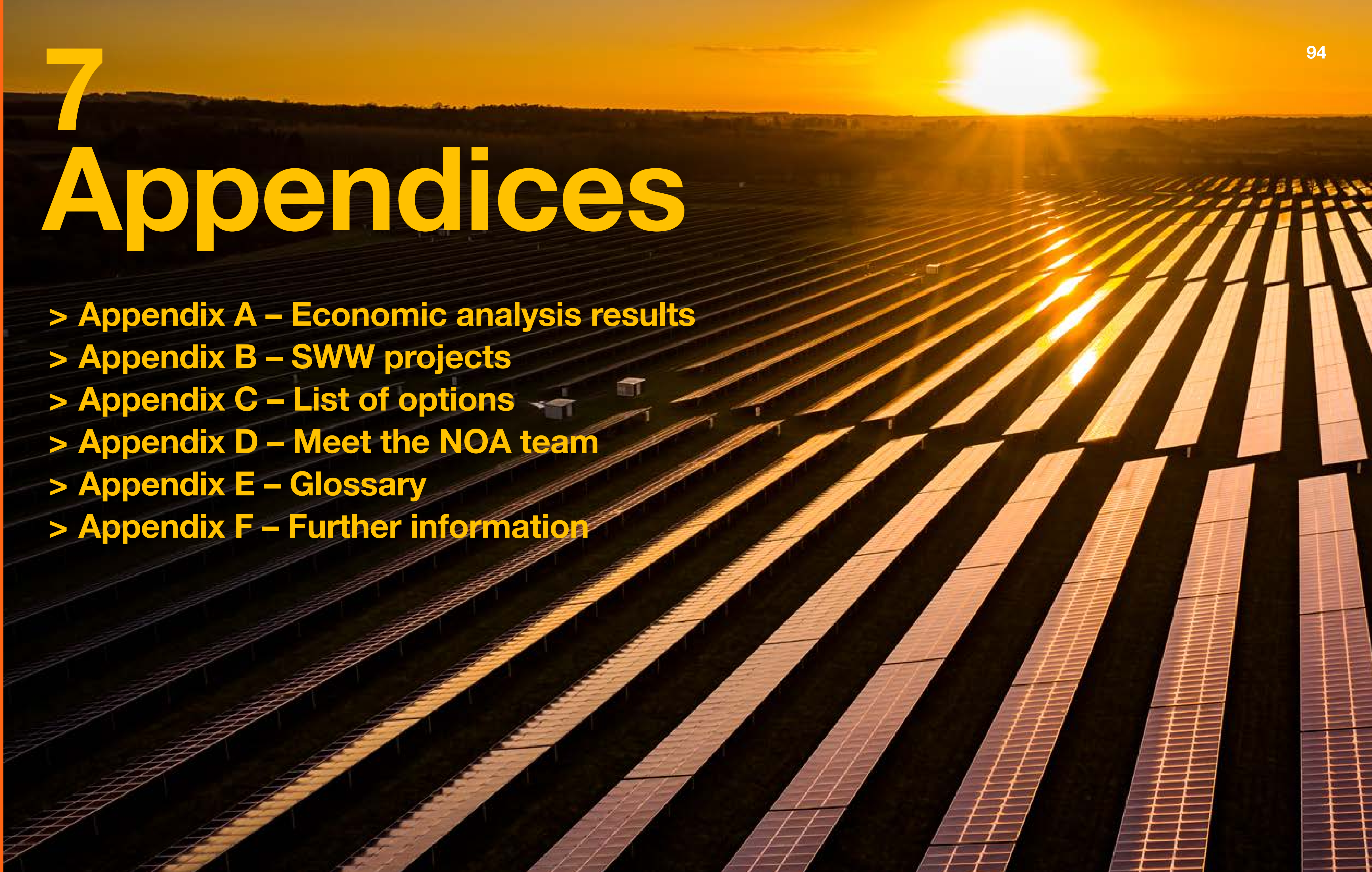
Now the *NOA* is published, we'll start the review process and look forward to having conversations with you between now and June 2020. This consultation will cover the NOA methodology and the look of the report, as well as its contents. Because some parts of the NOA process start in May, we have already started on some of the methodology's higher-level aspirations.

Figure 6.1 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 6.1
***ETYS/NOA* stakeholder activities programme**





7 Appendices

Appendix A
Economic analysis results

Tables A.1–2 present the results from our cost-benefit analysis. The results present the recommendations from last year's *NOA* for comparison and to indicate whether an option could be an SWW. We also include cost bands for options with a 'Proceed' recommendation that satisfy the competition criteria. These options and their cost bands are highlighted in orange.

The NOA recommendations are based on our economic assessment of options to deliver boundary benefits. Some options assessed may be listed as enabling works in users' connection agreements. This may be for a number of reasons. An option not receiving a 'Proceed' recommendation could still be proceeded by the TO(s) if required for other reasons than delivering boundary benefits.

Table A.1
Scotland and the north of England region

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
BBNC	Beauly to Blackhillock 400 kV double circuit addition		Not featured	Do not start
BLN2	Beauly to Loch Buidhe 275 kV reinforcement		Not featured	Do not start
CBEU	Creyke Beck to Keadby advance rating		Hold	Hold
CDHW	Cellarhead to Drakelow circuits thermal uprating		Not featured	Hold
NOR4	Reconductor 13.75 km of Norton to Osbaldwick number 2 400 kV circuit		Hold	Hold
CDP1	Power control device along Cellarhead to Drakelow		Not featured	Delay
CDP2	Power control device along Cellarhead to Drakelow		Not featured	Hold
CDP3	Alternative power control device along Cellarhead to Drakelow		Not featured	Do not start
CDP4	Alternative power control device along Cellarhead to Drakelow		Not featured	Hold
CDRE	Cellarhead to Drakelow reconductoring		Proceed	Stop
CGNC	A new 400 kV double circuit between Creyke Beck and the South Humber (cost band: [£100 million – £500 million])		Not featured	Proceed
CKPC	Power control device along Creyke Beck to Keadby to Killingholme		Not featured	Hold
CRPC	Power control device along Cottam to Ryhall		Not featured	Hold
CS34	Commercial solution for the north of Scotland		Not featured	Do not start
CS35	Commercial solution for Scotland and the north of England		Not featured	Proceed
CTP1	Power control device along Creyke Beck to Thornton		Not featured	Do not start
CTP2	Alternative power control device along Creyke Beck to Thornton		Not featured	Proceed
CWPC	Power control device along Cottam to West Burton		Not featured	Hold
DEPC	Power control device along Drax to Eggborough		Not featured	Hold
DLUP	Uprate the Windyhill to Lambhill to Denny North 275 kV circuit to 400 kV		Not featured	Do not start
DNEU	Denny North 400/275 kV 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 400 kV reinforcement		Not featured	Do not start
DWNO	Denny to Wishaw 400 kV reinforcement		Proceed	Proceed
DWUP	Establish Denny North to Clydesmill to Wishaw single 400 kV circuit from existing 275 kV circuits		Not featured	Do not start

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

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
E2D2	Eastern Scotland to England link: Torness to Cottam offshore HVDC (cost band [£2,000 million – £2,500 million])	Y	Do not start	Proceed
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: [£1,500 million – £2,000 million])	Y	Proceed	Proceed
E2L2	Eastern subsea HVDC link from Torness to Cottam with metallic return		Not featured	Do not start
E2L3	Eastern subsea HVDC link from Torness to Drax with metallic return		Not featured	Do not start
E2LC	Eastern subsea HVDC link from Torness to Hawthorn Pit with metallic return		Not featured	Do not start
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: [£2,000 million – £2,500 million])	Y	Proceed	Proceed
E4DC	Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC		Stop	Stop
E4L2	Eastern Scotland to England link: Peterhead to Cottam offshore HVDC		Not featured	Do not start
E4L3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC		Not featured	Do not start
E4L5	Eastern Scotland to England 3rd link: Peterhead to the South Humber offshore HVDC (cost band: [£3,500 million – £4,000 million])	Y	Not featured	Proceed
E4LC	Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC		Not featured	Do not start
E5L5	Eastern Scotland to England 3rd link: Blackhillock to the South Humber offshore HVDC		Not featured	Do not start
E6L5	Eastern Scotland to England 3rd link: Tealing to the South Humber offshore HVDC		Not featured	Do not start
ECU2	East coast onshore 275kV upgrade (cost band: [£100 million – £500 million])	Y	Proceed	Proceed
ECUP	East coast onshore 400kV incremental reinforcement	Y	Proceed	Proceed
ECVC	Eccles synchronous series compensation and real-time rating system		Hold	Proceed
EHRE	Elvanfoot to Harker reconductoring		Hold	Stop

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

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
FBRE	Beauly to Fyrish 275kV double circuit reconductoring		Do not start	Do not start
FINS	East coast 132kV upgrade		Not featured	Do not start
GCNC	A new 400kV double circuit between South Humber and West Lincolnshire		Not featured	Do not start
GWNC	A new 400kV double circuit between South Humber and South Lincolnshire (cost band: [£100 million – £500 million])		Not featured	Proceed
HAE2	Harker supergrid transformer 5 replacement		Proceed	Proceed
HAEU	Harker supergrid transformer 6 replacement		Proceed	Proceed
HFRE	Reconductor Harker to Fourstones double circuit		Not featured	Do not start
HNNO	Hunterston East to Neilston 400kV reinforcement		Proceed	Proceed
HSP1	Power control device along Fourstones to Harker to Stella West		Not featured	Proceed
HSP2	Power control device along Fourstones to Harker to Stella West		Not featured	Do not start
HSR1	Reconductor Harker to Stella West		Not featured	Hold
KBRE	Knocknagael to Blackhillock 275kV double circuit reconductoring		Hold	Stop
KWHW	Keadby to West Burton circuits thermal uprating		Hold	Hold
KWPC	Power control device along Keadby to West Burton		Not featured	Hold
LBRE	Beauly to Loch Buidhe 275kV **double circuit overhead line** reconductoring		Not featured	Hold
LCUP	Uprating of Longannet to 400kV operation, installation of new 400kV substation between Wishaw and Torness, and uprate existing 275kV circuit to 400kV		Not featured	Do not start
LNP1	Power control device along Lackenby to Norton		Not featured	Do not start
LNPC	Power control device along Lackenby to Norton		Not featured	Proceed
LNRE	Reconductor Lackenby to Norton single 400kV circuit		Proceed	Hold
MHPC	Power control device along Harker to Gretna and Harker to Moffat		Not featured	Do not start
MRP1	Power control device along Penwortham to Washway Farm to Kirkby		Not featured	Do not start
MRPC	Power control device along Penwortham to Kirkby		Not featured	Proceed
NEMS	225MVAr MSCs within the north east region		Proceed	Hold

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Economic analysis results

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

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
NEP1	Power control device along Blyth to Tynemouth to Blyth to South Shields		Not featured	Proceed
NEPC	Power control device along Blyth to Tynemouth and Blyth to South Shields		Not featured	Hold
NOPC	Power control device along Norton to Osbaldwick		Not featured	Hold
NOR1	Reconductor 13.75 km of Norton to Osbaldwick 400 kV double circuit		Hold	Stop
NOR2	Reconductor 13.75 km of Norton to Osbaldwick number 1 400 kV circuit		Hold	Proceed
OENO	Central Yorkshire reinforcement		Proceed	Stop
OPN1	A new 400 kV double circuit between Osbaldwick and Poppleton and relevant 400 kV upgrades		Not featured	Do not start
OPN2	A new 400 kV double circuit between Osbaldwick and Poppleton and relevant 275 kV upgrades		Not featured	Proceed
OPN3	A new 400 kV double circuit between Osbaldwick and Poppleton using cable and relevant 400 kV upgrades		Not featured	Do not start
OPN4	A new 400 kV double circuit between Osbaldwick and Poppleton using cable and relevant 275 kV upgrades		Not featured	Do not start
PWMS	Two 225 MVAr MSCs at Penwortham		Not featured	Hold
SHNS	Upgrade substation in the South Humber area		Not featured	Proceed
TDH1	Drax to Thornton 2 circuit thermal uprating and equipment upgrade		Not featured	Hold
TDH2	Drax to Thornton 1 circuit thermal uprating and equipment upgrade		Not featured	Hold
TDP2	Additional power control device along Drax to Thornton		Not featured	Hold
TDPC	Power control device along Drax to Thornton		Not featured	Hold
THS1	Install series reactors at Thornton		Proceed	Proceed
TKUP	East coast onshore 400 kV phase 2 reinforcement		Not featured	Do not start
TLNO	Torness to north east England AC onshore reinforcement (cost band: [£500 million – £1,000 million])	Y	Do not start	Proceed
TUEU	Tummel reconfiguration		Not featured	Do not start
TURC	Tummel reactive series compensation		Hold	Stop
WHTI	Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit		Proceed	Proceed
WLTI	Windyhill to Lambhill to Longannet 275 kV circuit turn-in to Denny North 275 kV substation		Hold	Delay

Appendix A
Economic analysis results

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Table A.2
South and east of England region

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
BBP1	Power control device along Bramford to Braintree		Not featured	Do not start
BFEU	Thermal upgrade for Bramley and Fleet 400kV substation		Not featured	Do not start
BFHW	Bramley to Fleet circuits thermal uprating		Hold	Hold
BFRE	Bramley to Fleet reconductoring		Do not start	Hold
BMM2	225MVAr MSCs at Burwell Main		Proceed	Proceed
BNRC	Bolney and Ninfield additional reactive series compensation		Proceed	Proceed
BPP1	Power control device along Bramford to Pelham		Not featured	Do not start
BPP2	Power control device along Braintree to Pelham		Not featured	Do not start
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit		Hold	Proceed
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route		Hold	Proceed
BTNO	A new 400kV double circuit between Bramford and Twinstead (cost band: [£100 million – £500 million])		Proceed	Proceed
BWRE	Reconductor Barking to West Ham double circuit		Not featured	Do not start
CKNC	New 400kV transmission route in Kent area		Not featured	Do not start
CS51	Commercial solution for East Anglia		Not featured	Proceed
CS53	Commercial solution for the south coast		Not featured	Proceed
CTRE	Reconductor remainder of Coryton South to Tilbury circuit		Hold	Hold
EAM1	225MVAr MSC at Eaton Socon		Not featured	Hold
EAM2	225MVAr MSC at Eaton Socon		Not featured	Hold
ESC1	Second Elstree to St John's Wood 400kV circuit		Hold	Hold
FLR3	Reconductor Fleet to Lovedean circuit		Not featured	Proceed
GKEU	Thermal upgrade for Grain and Kingsnorth 400kV substation		Hold	Hold
GKPC	Power control device along Grain to Kingsnorth		Not featured	Do not start
GRRA	Grain running arrangement change		Hold	Proceed
HBUP	Uprate Bridgewater to 400kV and reconductor the route to Hinkley		Not featured	Hold
HWUP	Uprate Hackney, Tottenham and Waltham Cross 275kV to 400kV		Hold	Stop
ITUP	Uprate Iver to Tilbury route from 275kV to 400kV		Not featured	Do not start

Appendix A
Economic analysis results

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

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
KLRE	Kemsley to Littlebrook circuits uprating		Proceed	Proceed
MBHW	Bramley to Melksham circuits thermal uprating		Not featured	Proceed
MBRE	Bramley to Melksham reconductoring		Hold	Hold
NBRE	Reconductor Bramford to Norwich double circuit		Hold	Hold
NEC1	Cable replacement at Necton 400 kV substation		Not featured	Hold
NOM1	225 MVAr MSC at Norwich		Not featured	Hold
NOM2	225 MVAr MSC at Norwich		Not featured	Hold
NTP1	Power control device along North Tilbury		Not featured	Proceed
PEM1	225 MVAr MSC at Pelham		Do not start	Hold
PEM2	225 MVAr MSC at Pelham		Do not start	Hold
RHM1	225 MVAr MSC at Rye House		Do not start	Hold
RHM2	225 MVAr MSC at Rye House		Do not start	Hold
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit		Proceed	Proceed
SCD1	New offshore HVDC link between Suffolk and Kent Option 1 (cost band: [£500 million – £1,000 million])	Y	Not featured	Proceed
SCD2	New offshore HVDC link between Suffolk and Kent Option 2		Not featured	Hold
SCN1	New 400 kV transmission route between south London and the south coast		Proceed	Stop
SEEU	Reactive series compensation protective switching scheme		Proceed	Proceed
SER1	Elstree to Sundon reconductoring		Delay	Proceed
SER2	Elstree to Sundon 2 circuit turn-in and reconductoring		Hold	Hold
THRE	Reconductor Hinkley Point to Taunton double circuit		Hold	Hold
TKRE	Tilbury to Grain and Tilbury to Kingsnorth upgrade		Stop	Proceed
TWNC	Uprate Tilbury to Waltham Cross route from 275 kV to 400 kV and new 400 kV transmission route in Hertfordshire area		Not featured	Do not start
TMEU	Thorpe Marsh substation reconfiguration		Not featured	Do not start
WAM1	225 MVAr MSC at Walpole		Not featured	Hold

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Economic analysis results

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

Option code	Option description	Potential SWW?	*NOA 2018/19* recommendation	*NOA 2019/20* recommendation
WAM2	225 MVAr MSC at Walpole		Not featured	Hold
WAM3	225 MVAr MSC at Walpole		Not featured	Hold
WYM1	225 MVAr MSC at Wymondley		Not featured	Do not start
WRRE	Reconductor West Burton to Ratcliffe-on-Soar circuit		Not featured	Do not start
WYM2	225 MVAr MSC at Wymondley		Not featured	Do not start
WYQB	Wymondley quad boosters		Hold	Stop
WYTI	Wymondley turn-in		Hold	Hold

Appendix A
Interactive map tables

South West – Proceed

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
BNRC	Bolney and Ninfield additional reactive series compensation	2023	2023	2023	2023	2023
FLR3	Reconductor Fleet to Lovedean circuit	2020	2020	2020	2020	2020
MBHW	Bramley to Melksham circuits thermal uprating	2023	2025	2023	2026	2026
SEEU	Reactive series compensation protective switching scheme	2022	2022	2022	2022	2022

South West – Hold

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
BFHW	Bramley to Fleet circuits thermal uprating	2022	2028	2026	2026	2028
BFRE	Bramley to Fleet reconductoring	2024	2033	2031	N/A	N/A
HBUP	Uprate Bridgewater to 400kV and reconductor the route to Hinkley	2024	2026	2026	2026	2026
MBRE	Bramley to Melksham reconductoring	2024	2026	2028	2028	2027
THRE	Reconductor Hinkley Point to Taunton double circuit	2024	2033	2031	N/A	N/A

South East – Proceed

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
BMM2	225MVAr MSCs at Burwell Main	2022	2022	2022	2022	2022
BPRE	Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit	2029	2029	2029	2039	2029
BRRE	Reconductor remainder of Bramford to Braintree to Rayleigh route	2024	2024	2024	2024	2024
BTNO	A new 400kV double circuit between Bramford and Twinstead	2028	2028	2028	2028	2028
CS51	Commercial solution for East Anglia	2024	2024	2027	N/A	2033
CS53	Commercial solution for the south coast	2023	2023	2024	2023	2023
GRRA	Grain running arrangement change	2020	2020	2020	2020	2020
KLRE	Kemsley to Littlebrook circuits uprating	2020	2020	2020	2020	2020
NTP1	Power control device along North Tilbury	2023	2023	2023	2023	2023
RTRE	Reconductor remainder of Rayleigh to Tilbury circuit	2021	2021	2021	2021	2021
SCD1	New offshore HVDC link between Suffolk and Kent Option 1	2028	2028	2028	2029	2034
SER1	Elstree to Sundon reconductoring	2023	2023	2023	2023	2023
TKRE	Tilbury to Grain and Tilbury to Kingsnorth upgrade	2026	2026	2026	2026	2026

South East – Hold

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
CTRE	Reconductor remainder of Coryton South to Tilbury circuit	2021	2022	2022	2022	2022
EAM1	225MVAr MSC at Eaton Socon	2023	2031	2031	2031	2031
EAM2	225MVAr MSC at Eaton Socon	2023	2031	2031	2031	2031
ESC1	Second Elstree to St John's Wood 400kV circuit	2024	2026	2026	2026	2026
GKEU	Thermal upgrade for Grain and Kingsnorth 400kV substation	2022	2023	2029	2026	2026
NBRE	Reconductor Bramford to Norwich double circuit	2024	2025	2025	2025	2025
NEC1	Cable replacement at Necton 400kV substation	2024	2031	N/A	N/A	N/A
NOM1	225MVAr MSC at Norwich	2023	2028	2028	2028	2028
NOM2	225MVAr MSC at Norwich	2023	2028	2028	2028	2028
PEM1	225MVAr MSC at Pelham	2023	2024	2024	2024	2024
PEM2	225MVAr MSC at Pelham	2023	2024	2024	2024	2024
RHM1	225MVAr MSC at Rye House	2023	2024	2024	2024	2024
RHM2	225MVAr MSC at Rye House	2023	2024	2024	2024	2024
SCD2	New offshore HVDC link between Suffolk and Kent Option 2	2029	2030	2032	N/A	2035
SER2	Elstree to Sundon 2 circuit turn-in and reconductoring	2023	2024	2026	2024	2024
WAM1	225MVAr MSC at Walpole	2023	2031	N/A	N/A	N/A
WAM2	225MVAr MSC at Walpole	2023	2031	N/A	N/A	N/A
WAM3	225MVAr MSC at Walpole	2023	2031	N/A	N/A	N/A
WYTI	Wymondley turn-in	2022	2029	2031	2028	N/A

South East – Stop

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
HWUP	Uprate Hackney, Tottenham and Waltham Cross 275kV to 400kV	2026	N/A	N/A	N/A	N/A
SCN1	New 400kV transmission route between south London and the south coast	2029	N/A	N/A	N/A	N/A
WYQB	Wymondley quad boosters	2023	N/A	N/A	N/A	N/A

Appendix A
Interactive map tables

Midlands – Proceed

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
CGNC	A new 400kV double circuit between Creyke Beck and the South Humber	2031	2031	2031	2031	N/A
CTP2	Alternative power control device along Creyke Beck to Thornton	2024	2024	2029	2029	2027
GWNC	A new 400kV double circuit between South Humber and South Lincolnshire	2031	2031	2031	2031	2031
MRPC	Power control device along Penwortham to Kirkby	2020	2020	2020	2020	2020
NOR2	Reconductor 13.75km of Norton to Osbaldwick number 1 400kV circuit	2022	2022	2022	2023	2022
OPN2	A new 400kV double circuit between Osbaldwick and Poppleton and relevant 275kV upgrades	2027	2028	2028	2027	2027
SHNS	Upgrade substation in the South Humber area	2031	2031	2031	2031	2031
THS1	Install series reactors at Thornton	2023	2023	2023	2023	2023

Midlands – Delay

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
CDP1	Power control device along Cellarhead to Drakelow	2023	2023	2028	2027	2027

Midlands – Hold

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
CBEU	Creyke Beck to Keadby advance rating	2022	2024	2024	2024	2023
CDHW	Cellarhead to Drakelow circuits thermal uprating	2022	2028	2028	2029	2024
CDP2	Power control device along Cellarhead to Drakelow	2023	2028	2028	2029	2027
CDP4	Alternative power control device along Cellarhead to Drakelow	2023	2031	2031	2031	N/A
CKPC	Power control device along Creyke Beck to Keadby to Killingholme	2023	2024	2026	2027	2027
CRPC	Power control device along Cottam to Ryhall	2023	2031	2031	N/A	N/A
CWPC	Power control device along Cottam to West Burton	2023	2029	2029	2029	2031
DEPC	Power control device along Drax to Eggborough	2023	N/A	N/A	2029	2031
KWHW	Keadby to West Burton circuits thermal uprating	2022	2028	2028	2029	2027
KWPC	Power control device along Keadby to West Burton	2023	2024	2026	2027	2026
NOPC	Power control device along Norton to Osbaldwick	2023	N/A	N/A	2029	N/A
NOR4	Reconductor 13.75km of Norton to Osbaldwick number 2 400kV circuit	2022	2028	2028	2029	2028
PWMS	Two 225MVAr MSCs at Penwortham	2023	2028	2028	2029	2028
TDH1	Drax to Thornton 2 circuit thermal uprating and equipment upgrade	2022	2026	2026	2027	2027
TDH2	Drax to Thornton 1 circuit thermal uprating and equipment upgrade	2022	2024	2024	2024	2023
TDP2	Additional power control device along Drax to Thornton	2023	2026	2026	2027	2027
TDPC	Power control device along Drax to Thornton	2023	2026	2026	2026	2026

Midlands – Stop

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
CDRE	Cellarhead to Drakelow reconductoring	2022	N/A	N/A	N/A	N/A
NOR1	Reconductor 13.75km of Norton to Osbaldwick 400kV double circuit	2022	N/A	N/A	N/A	N/A
OENO	Central Yorkshire reinforcement	2028	N/A	N/A	N/A	N/A

Appendix A
Interactive map tables

South Scotland & North England – Proceed

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
ECVC	Eccles synchronous series compensation and real-time rating system	2026	2026	2026	2026	2026
HAE2	Harker supergrid transformer 5 replacement	2023	2023	2023	2023	2023
HAEU	Harker supergrid transformer 6 replacement	2022	2022	2022	2022	2022
HSP1	Power control device along Fourstones to Harker to Stella West	2020	2020	2020	2020	2020
LNPC	Power control device along Lackenby to Norton	2020	2020	2020	2020	2020
NEP1	Power control device along Blyth to Tynemouth to Blyth to South Shields	2024	2024	N/A	2024	2024
TLNO	Torness to north east England AC onshore reinforcement	2036	2036	2036	2036	N/A
WHTI	Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit	2021	2021	2021	2021	2021

South Scotland & North England – Hold

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
HSR1	Reconductor Harker to Stella West	2024	N/A	N/A	2036	N/A
LNRE	Reconductor Lackenby to Norton single 400kV circuit	2023	2028	2028	2029	2028
NEMS	225MVAr MSCs within the north east region	2022	2028	2028	2029	2028
NEPC	Power control device along Blyth to Tynemouth and Blyth to South Shields	2023	2024	N/A	2024	2024

South Scotland & North England – Stop

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
EHRE	Elvanfoot to Harker reconductoring	2026	N/A	N/A	N/A	N/A

Scotland – Proceed

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
CS35	Commercial solution for Scotland and the north of England	2023	2023	2023	2024	2023
DWNO	Denny to Wishaw 400kV reinforcement	2028	2028	2028	2028	2028
ECU2	East coast onshore 275kV upgrade	2023	2023	2023	2023	2023
ECUP	East coast onshore 400kV incremental reinforcement	2026	2026	2026	2026	2026
HNNO	Hunterston East to Neilston 400kV reinforcement	2023	2023	2023	2023	2023

Scotland – Delay

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
WLTI	Windyhill to Lambhill to Longannet 275kV circuit turn-in to Denny North 275kV substation	2021	2023	2021	2023	2022

Scotland – Hold

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
DNEU	Denny North 400/275kV second supergrid transformer	2023	2024	2028	2031	2026
LBRE	Beauly to Loch Buidhe 275kV Double Circuit OHL reconductoring	2025	2031	2035	N/A	2034

Scotland – Stop

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
KBRE	Knocknagael to Blackhillock 275kV double circuit reconductoring	2025	N/A	N/A	N/A	N/A
TURC	Tummel reactive series compensation	2023	N/A	N/A	N/A	N/A

Appendix A
Interactive map tables

HVDC – Proceed

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
E2D2	Eastern Scotland to England link: Torness to Cottam offshore HVDC	2028	2028	2028	N/A	N/A
E2DC	Eastern subsea HVDC link from Torness to Hawthorn Pit	2027	N/A	N/A	2027	2027
E4D3	Eastern Scotland to England link: Peterhead to Drax offshore HVDC	2029	2029	2029	2029	2029
E4L5	Eastern Scotland to England 3rd link: Peterhead to the South Humber offshore HVDC	2031	2031	2031	2031	2031

HVDC – Stop

Option code	Option description	EISD	Two Degrees	Community Renewables	Consumer Evolution	Steady Progression
E4DC	Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC	2028	N/A	N/A	N/A	N/A

Appendix B
SWW projects

B.1 Eastern network reinforcement

1. Background

The scope of the reinforcements included for the eastern network in the northern region includes offshore HVDC links and onshore reinforcement. These reinforcement 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, to safely enable greater volumes of north-to-south power flows arising predominantly from new renewable generation in Scotland. This includes key boundaries between SHE Transmission and SP Transmission (B4) and between SP Transmission (SPT) and NGET (B6).

A number of reinforcements are proposed to improve the transfer capability in accordance with the NETS SQSS[1] and in line with the Transmission Owners' obligations in their transmission licences. Within *NOA 2018/19*, we considered subsea HVDC links from both Peterhead and Torness in the east of Scotland to three locations in the east of England, culminating in six options for assessment. These options are considered again in this year's NOA process; additionally, each option is also considered with the addition of a metallic earth return conductor. This would permit operation of the link at reduced capacity with one pole disabled. As a result, we have considered 12 iterations of the previously proposed subsea HVDC link options in combination, in addition to the onshore alternative, within this year's NOA process:

- E4DC – Peterhead to Hawthorn Pit
- E4D2 – Peterhead to Cottam
- E4D3 – Peterhead to Drax
- E4LC – Peterhead to Hawthorn Pit (metallic return conductor)
- E4L2 – Peterhead to Cottam (metallic return conductor)
- E4L3 – Peterhead to Drax (metallic return conductor)
- E2DC – Torness to Hawthorn Pit
- E2D2 – Torness to Cottam
- E2D3 – Torness to Drax
- E2LC – Torness to Hawthorn Pit (metallic return conductor)
- E2L2 – Torness to Cottam (metallic return conductor)
- E2L3 – Torness to Drax (metallic return conductor)
- TLNO – Eastern Scotland to England link: Torness to north east England double circuit.

All subsea HVDC link options involve the construction of a 2 GW HVDC link and associated AC onshore works at either end of the link. The NOA process only allows analysis of the economic benefit of the metallic return from a boundary capability perspective, and further assessments around reliability will be carried out during project development to fully determine the requirement of such a return path. The links from Peterhead can increase transfer capability on boundaries B1a down to B8[2]. The links from Torness increase transfer capability on boundaries B6 down to B8[2].

[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.

Appendix B
SWW projects

The eastern onshore reinforcements increase the capacity of the eastern onshore circuits between Blackhillock and Kincardine that cross B1a, B2 and B4 by initially augmenting their capability at 275kV. Uprating these circuits to operate at 400kV will deliver further capacity. The two onshore projects have consistently been identified as critical through the NOA process. Additionally, an onshore network reinforcement is included to develop the network in the central belt of Scotland and increase the capability of the B5 boundary with the establishment of a new 400kV corridor central in the SPT network.

The recommendation from the 2019/20 NOA process is to progress the following reinforcements to maintain their earliest in service date (EISD):

- East coast onshore 275kV upgrade (ECU2) – EISD of 2023
- East coast onshore 400kV incremental reinforcement (ECUP) – EISD of 2026
- Eastern Scotland to England link: Torness to Hawthorn Pit offshore HVDC (E2DC) – EISD of 2027
- Eastern Scotland to England link: Torness to Cottam offshore HVDC (E2D2) – EISD of 2028
- Eastern Scotland to England link: Peterhead to Drax offshore HVDC (E4D3) – EISD of 2029
- Denny to Wishaw 400kV reinforcement (DWNO) – EISD 2028.

Note, economic analysis this year has recommended two of the southern landing points of the HVDC link from Torness continue to be developed this year to maintain their EISDs. We will undertake further work via the SWW process to determine which of these southern landing points provides the most appropriate solution for the future of the GB network.

The need to reinforce the transmission network is driven fundamentally by the growth of predominantly 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[3] for boundaries B4, B6, B7, B7a and B8 for the four 2019 future energy scenarios can be found in sections 3.4 and 3.5 of this year's ***ETYS 2019***. The figures also show the current network capabilities across the boundaries, as well as the distribution of annual power flow for each scenario. The difference between the required transfers and network capability shows a need for further network reinforcement. The figures show expected future power flows are greatly in excess of 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.

[3] The Required Transfer figures shown take into account interconnectors connecting to the GB Transmission system in the 2019 future energy scenarios.

Appendix B
SWW projects

2. Option development

Several reinforcement options have been developed for the eastern network in the northern region to improve boundary capability across boundaries B1a to B8. These include onshore and offshore solutions and are at varying levels of development. To reflect the increase in transfers for this year and the need for long-term conceptual options in *NOA 2018/19*, we have submitted additional options to the process to provide an indication of what future reinforcements may be needed. These options include additional onshore reinforcements, as well as a further offshore HVDC link between the north 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 at Alyth. 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.

(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, Rothienorman, Kintore, Fetteresso, Alyth and Kincardine for 400kV operation and install phase shifting transformers at Blackhillock. This option provides additional transmission capacity across boundaries B1a, B2 and B4.

(c) Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC (E4DC/E4LC)

Construct a new offshore 2GW HVDC subsea link from Peterhead (north east of Scotland) to Hawthorn Pit (north of England), including AC/DC converter stations and associated AC onshore works at the Peterhead and Hawthorn Pit ends of the link. The AC onshore works at Peterhead include the upgrade of the 275kV circuits along the Blackhillock to Rothienorman to Peterhead route to 400kV operation. The AC onshore works at Hawthorn Pit include a new 400kV Hawthorn Pit substation, uprating of the Hawthorn Pit to Norton circuit and associated circuit reconfiguration works in the area. This option provides additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, and B7a. This option is assessed with and without a metallic return conductor.

(d) Eastern Scotland to England link: Peterhead to Cottam offshore HVDC (E4D2/E4L2)

Construct a new offshore 2GW HVDC subsea link from Peterhead (north east of Scotland) to Cottam (north Nottinghamshire in England), including AC/DC converter stations and associated AC onshore works at the Peterhead and Cottam ends of the link. The AC onshore works at Peterhead include upgrade of the 275kV circuits along the Blackhillock to Rothienorman to Peterhead route to 400kV operation. The AC onshore works at Cottam are to connect into a bay at Cottam 400kV substation. This option provides additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, B7a and B8. This option is assessed with and without a metallic return conductor.

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(e) Eastern Scotland to England link: Peterhead to Drax offshore HVDC (E4D3/E4L3)

Construct a new offshore 2 GW HVDC subsea link from Peterhead (north east of Scotland) to Drax (Yorkshire in England), including AC/DC converter stations and associated AC onshore works at the Peterhead and Drax ends of the link. The AC onshore works at Peterhead include upgrade of the 275 kV circuits along the Blackhillock to Rothienorman to Peterhead route to 400 kV operation. The AC onshore works at Drax include a busbar extension, a new bay at the Drax 400 kV substation and may also include associated fault level mitigation works. This option provides additional transmission capacity across boundaries B1a, B2, B4, B5, B6, B7, B7a and B8. This option is assessed with and without a metallic return conductor.

(f) Eastern Scotland to England link: Torness to Hawthorn Pit offshore HVDC (E2DC/E2LC)

Construct a new offshore 2 GW HVDC subsea link from the Torness area to Hawthorn Pit, including AC/DC converter stations and associated AC works at Torness and Hawthorn Pit. The AC onshore works around Torness include extension of the 'Branxton 400 kV substation' by two 400 kV GIS bays to provide connection to the 'Branxton Converter Station'. The AC onshore works at Hawthorn Pit include a new 400 kV Hawthorn Pit substation, uprating of the Hawthorn Pit to Norton circuit and associated circuit reconfiguration works. This option provides additional transmission capacity across boundaries B6, B7 and B7a. This option is assessed with and without a metallic return conductor.

(g) Eastern Scotland to England link: Torness to Cottam offshore HVDC (E2D2/E2L2)

Construct a new offshore 2 GW HVDC subsea link from the Torness area to Cottam, including AC/DC converter stations and associated AC works at Torness and Cottam. The AC onshore works around Torness include extension of the 'Branxton 400 kV substation' by two 400 kV GIS bays to provide connection to the 'Branxton Converter Station'. The AC onshore works at Cottam are to connect into a bay at Cottam 400 kV substation. This option provides additional transmission capacity across boundaries B6, B7, B7a and B8. This option is assessed with and without a metallic return conductor.

(h) Eastern Scotland to England link: Torness to Drax offshore HVDC (E2D3/E2L3)

Construct a new offshore 2 GW HVDC subsea link from the Torness area to Drax, including AC/DC converter stations and associated AC works at Torness and Drax. The AC onshore works around Torness include extension of the pre-existing 'Branxton 400 kV substation' by two 400 kV GIS bays to provide connection to the 'Branxton Converter Station'. The AC onshore works at Drax include a busbar extension, a new bay at the existing Drax 400 kV substation and may also include associated fault level mitigation works. This option provides additional transmission capacity across boundaries B6, B7, B7a and B8. This option is assessed with and without a metallic return conductor.

Appendix B
SWW projects

(i) Denny to Wishaw 400 kV reinforcement (DWNO)
Construct a new 400 kV 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 be operated at 400 kV, the other at 275 kV. This will establish Denny to Bonnybridge, Bonnybridge to Wishaw, Wishaw to Strathaven No.2 and Wishaw to Torness 400 kV circuits, and a Denny to Newarthill to Easterhouse 275 kV circuit. This option provides additional transmission capacity across boundary B5.

(j) Eastern Scotland to England link: Torness to north east England double circuit (TLNO)
Install a new double circuit from a new 400 kV substation in the Torness area to a connection point on the transmission system in north east England. Construct a new 400 kV double circuit from the Torness area to the SPT/NGET border. Continue construction of the double circuit to a suitable connection point in north east England, providing additional substation equipment where required.

This option provides additional thermal capacity across boundaries B6, B7 and B7a.

2.2 Leading options
In the *2019/20 NOA*, E4D3, E2DC, E2D2, ECUP, ECU2 and DWNO have been identified as the most efficient and beneficial reinforcements.

(a) Eastern subsea HVDC link from Peterhead to Drax (E4D3)
E4D3 is in the optimal path and critical in all four 2019 future energy scenarios. It has been identified as critical for two consecutive years. It provides additional boundary capability between B1a and B8.

(b) Eastern subsea HVDC link from Torness to Hawthorn Pit (E2DC)
E2DC is in the optimal path and critical in two of the four 2019 future energy scenarios, where the 2050 target of 80 per cent carbon reduction is not met. It unlocks transmission constraints across boundaries B5 to B6 from 2027. With help of B7a and B8 reinforcements transporting Scottish energy further south, E2DC is required as early as possible to maximise its value.

(c) Eastern subsea HVDC link from Torness to Cottam (E2D2)
E2D2 is in the optimal path and critical in two of the four 2019 future energy scenarios, where the 2050 target of 80 per cent carbon reduction is met. Unlike E2DC, this crosses B7, B7a and B8, so does not rely on further onshore reinforcement to transmit power further south; however, this is delivered one year later than the Hawthorn Pit option.

(d) East coast onshore 275 kV upgrade (ECU2)
ECU2 has a ‘proceed’ recommendation in *NOA 2019/20*. It is justified in all four 2019 future energy scenarios. It has been identified as critical for three consecutive years. It reinforces boundary B1a to B6, and ECU2 is the earliest option to release B4 boundary constraints with its EISD of 2023.

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(e) East coast onshore 400 kV 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 B1a to B6, especially boundary B4. ECUP has a 'proceed' recommendation.

Other options that feature in the *NOA 2019/20* analysis for Scotland and the north of England region, but which fall below the SWW threshold are likely to be considered in the SWW analysis. This is because they are interdependent to meet the common need of improving boundary transfer capability.

3. Status

A joint team among the three onshore TOs has continued to assess the NOA options in more detail as part of preparing an SWW Initial Needs Case submission to the regulator in 2020. This team is organised into workstreams to consider system requirements, project development, delivery, and differing technologies. The TOs are working with the ESO which provides a cost-benefit analysis of the options in more detail to identify the optimum sequence and delivery dates for the reinforcements.

Preliminary subsea cable routeing is complete and physical survey work is to be tendered in early 2020. For links out of Peterhead, planning permission for the 400 kV substation at Peterhead has been granted and a preferred location for this converter station identified. The connection point of Torness in SPT's area has been assessed and several options for the site have been identified to be further developed. For southern landing points of the links, the associated AC onshore works will be further optimised and included in the SWW Needs Case submission. We expect the construction of the HVDC projects will take place between 2023 and 2029. The east coast onshore projects in the SHE Transmission and SPT areas are scheduled for earlier delivery, 2023 for the 275 kV works and 2026 for the 400 kV uprate. The Scottish TOs are currently proposing to include the projects within their RIIO-T2 baseline that will be reviewed and consulted on in 2020.

Appendix B
SWW projects

B.2 South east network reinforcement

1. Background

The south east region has 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

The *NOA 2019/20* 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.

The *NOA 2018/19* previously recommended SCN1 as the leading option. This builds a new 400 kV circuit in Kent and can increase the transmission capacity of the south coast boundaries SC1 and SC2. However, it cannot increase transmission capability of EC5 and LE1 and requires additional options to reinforce the transmission corridors across and through the north of London before it can provide capability for SC1rev.

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2.2 Other options

Other recommendations from this year's NOA process include proceeding with the following reinforcements for the south east region:

- Reconductor remainder of Bramford to Braintree to Rayleigh route (BRRE) – EISD: 2024
- Reconductor the newly-formed second Bramford to Braintree to Rayleigh Main circuit (BPRE) – EISD: 2029
- A new 400kV double circuit between Bramford and Twinstead (BTNO) – EISD: 2028
- Kemsley to Littlebrook circuits uprating (KLRE) – EISD: 2020
- Reconductor Bramley to Melksham double circuit (MBHW) – EISD: 2024
- Elstree to Sundon reconductoring (SER1) – EISD: 2023
- Reconductor Fleet to Lovedean circuit (FLR3) – EISD: 2020.

ESO and NGET will also continue to investigate other options. Examples include a second HVDC circuit between Suffolk and Kent (SCD2) and commercial solutions (CS51 and CS53) as proposed this year.

3. Economic assessment

The *NOA 2019/20* analysis suggests SCD1 provides significant economic benefit. It is critical in **Two Degrees** and **Community Renewables** in 2028 and required in 2029 in **Steady Progression** and in 2034 in **Consumer Evolution**. SCD1 received a 'proceed' recommendation following the single year least worst regret (LWR) analysis.

The economic benefit of SCD1 is derived largely from the capability it provides to EC5, which is the most constrained boundary in the south east region. Its contribution towards relieving constraints on LE1 and SC1rev is also important, especially in later years when interconnector exports to mainland Europe are high.

SCD1 provided greater economic benefit than SCN1 in *NOA 2019/20,* although the capital cost of the HVDC link is higher. This is mainly due to its ability to provide capability to a wider range of boundaries and its earlier EISD.

4. Status

NGET has reviewed several design variations of SCD1, which encompass other reinforcement options to maximise system boundary benefits. Preliminary work to identify the optimal connection substations at both ends is ongoing. NGET will continue working with stakeholders towards a SWW Initial Needs Case submission. Since SCD1 is at a very initial phase of development, the ESO recommends that both SCD1 and SCN1 are subject to more detailed technical and economic analysis leading to an SWW project Initial Needs Case submission.

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> 2 Methodology
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List of options

The table below 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. The list below is divided by regions, both North and South.

This year, next to each option, 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 section 4.4.

BBNC **Beauly to Blackhillock 400 kV double circuit addition** Status: Project not started Boundaries affected: B1aI, B1aE, B1aF, B2E, B2F, B2I, B4E, B4F, B4I Region: North	Construct a new 400 kV double circuit between Beauly and Blackhillock. At both sites, extend the 400 kV busbar arrangements to allow for the connection of two additional bays.
BBP1 **Power control device along Bramford to Braintree** Status: Project not started Boundaries affected: LE1 Region: South	Install a power control device along the Bramford to Braintree 400 kV overhead line route. This would improve the capability to control the power flows east of the transmission network.
BFEU **Thermal upgrade for Bramley and Fleet 400 kV substation** Status: Project not started Boundaries affected: SC1e Region: South	Replace substation assets at Bramley and Fleet to allow the Bramley to Fleet circuits to operate at higher thermal rating following the reconductoring works. This will allow more power flow to the south.
BFHW **Bramley to Fleet circuits thermal uprating** Status: Project not started Boundaries affected: SC1e Region: South	Thermal upgrade of the Bramley to Fleet circuits to allow them to operate at higher temperatures, and increase their thermal rating.
BFRE **Bramley to Fleet reconductoring** Status: Project not started Boundaries affected: SC1e Region: South	Replace the conductors in the Bramley to Fleet circuits with higher-rated conductors to increase their thermal ratings.

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BLN2

Beauly to Loch Buidhe 275kV reinforcement
Status: Scoping
Boundaries affected: B0
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
Boundaries affected: EC5, LE1
Region: South

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

BNRC

Bolney and Ninfield additional reactive series compensation
Status: Scoping
Boundaries affected: SC1, SC1e, SC2, SC3
Region: South

Provide additional reactive series compensation equipment at Bolney and Ninfield substations, to maintain voltages within acceptable operational limits in future network operating conditions.

BPP1

Power control device along Bramford to Pelham
Status: Project not started
Boundaries affected: LE1
Region: South

Install a power control device along the Bramford to Pelham 400kV overhead line route. This would improve the capability to control the power flows east of the transmission network.

BPP2

Power control device along Braintree to Pelham
Status: Project not started
Boundaries affected: LE1
Region: South

Install a power control device along the Braintree to Pelham 400kV overhead line route. This would improve the capability to control the power flows east of the transmission network.

BPRE

Reconductor the newly formed second Bramford to Braintree to Rayleigh Main circuit
Status: Project not started
Boundaries affected: EC5
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: B9, EC5, LE1, SC1e
Region: South

Replace the conductors in the parts of the existing Bramford to Braintree to Rayleigh overhead line that have not already been reconductored with higher-rated conductors, to increase the circuit's thermal rating.

BTNO

A new 400kV double circuit between Bramford and Twinstead
Status: Scoping
Boundaries affected: B9, EC5, LE1, SC1e
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.

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BWRE

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

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

CBEU

Creyke Beck to Keadby advance rating
Status: Project not started
Boundaries affected: B7al, B8, B9
Region: North and South

Using historical weather data, Creyke Beck to Keadby 400kV overhead line enhanced thermal rating is established to cope with high flows from the north east of the transmission network.

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

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

Install an 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.

CDP4

Alternative power control device 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.

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CGNC

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

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

CKNC

New 400 kV transmission route in Kent area
Status: Project not started
Boundaries affected: SC1, SC1e
Region: South

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

CKPC

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

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

CRPC

Power control device along Cottam to Ryhall
Status: Project not started
Boundaries affected: B8
Region: North

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

CS34

Commercial solution for the north of Scotland
Status: Project not started
Boundaries affected: B2, B4
Region: North

This ESO-led commercial solution provides boundary benefit across boundaries B2 and B4 in the north of Scotland.

CS35

Commercial solution for Scotland and the north of England
Status: Project not started
Boundaries affected: B6, B7a
Region: North

This ESO-led commercial solution provides benefit across the Anglo-Scottish boundary and further south.

CS51

Commercial solution for East Anglia
Status: Project not started
Boundaries affected: EC5
Region: South

This commercial solution provides boundary benefit across the East Anglia region.

CS53

Commercial solution for the south coast
Status: Project not started
Boundaries affected: SC1, SC3
Region: South

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

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CTP1
Power control device along Creyke Beck to Thornton
Status: Project not started
Boundaries affected: B8
Region: North

Install a 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.

CTP2
Alternative power control device along Creyke Beck to Thornton
Status: Project not started
Boundaries affected: 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.

CTRE
Reconductor remainder of Coryton South to Tilbury circuit
Status: Scoping
Boundaries affected: 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.

CWPC
Power control device along Cottam to West Burton
Status: Project not started
Boundaries affected: B8, B9
Region: North and South

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.

DEPC
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 Eggborough 400kV overhead line route. This would improve the capability to control the power flows from north to south of the transmission network.

DLUP
Uprate the Windyhill to Lambhill to Denny North 275kV circuit to 400kV
Status: Project not started
Boundaries affected: B5, B6SPT
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: B1aE, B1aF, B1aI, B2E, B2F, B2I, B4E, B4F, B4I, B5
Region: North

Installation of a new 400/275kV, 1,000 MVA 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: B7aI, 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.

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DWN2

Denny to Wishaw 400 kV reinforcement
Status: Design/Development
Boundaries affected: B5, B6SPT
Region: North

Following DWUP and DWNO, construct a new 400 kV double circuit from Bonnybridge to north of Newarthill, establishing Denny to Bonnybridge 400 kV and Bonnbridge to Wishaw 400 kV in addition to Denny to Clydesmill 400 kV from DLUP.

DWNO

Denny to Wishaw 400 kV reinforcement
Status: Design/development
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I, B5, B6SPT
Region: North

Construct a new 400 kV 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 400 kV, the other at 275 kV. This reinforcement will establish Denny to Bonnybridge, Bonnybridge to Wishaw, Wishaw to Strathaven No.2 and Wishaw to Torness 400 kV circuits, and a Denny to Newarthill to Easterhouse 275 kV circuit.

DWUP

Establish Denny North to Clydesmill to Wishaw single 400 kV circuit from existing 275 kV circuits
Status: Project not started
Boundaries affected: B5, B6SPT
Region: North

Following WLTI and DNEU, establish a new 400 kV single circuit between Denny North, Clydesmill and Wishaw by reconfiguration of the existing Longannet to Easterhouse/Clydesmill 275 kV circuits and existing de-energised circuit between Easterhouse and Newarthill and the existing Newarthill to Wishaw circuit.

E2D2

Eastern Scotland to England link: Torness to Cottam offshore HVDC
Status: Scoping
Boundaries affected: B5, B6l, 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: B5, B6l, B6SPT, 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.

E2DC

Eastern subsea HVDC link from Torness to Hawthorn Pit
Status: Scoping
Boundaries affected: B5, B6l, B6SPT, B7al, 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.

E2L2

Eastern subsea HVDC link from Torness to Cottam with metallic return
Status: Scoping
Boundaries affected: B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW bipole HVDC link from Torness area to Cottam. The link will involve substation works, circuit upgrades and HVDC converter stations at both Torness and Cottam. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

E2L3

Eastern subsea HVDC link from Torness to Drax with metallic return
Status: Scoping
Boundaries affected: B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW bipole HVDC link from Torness area to Drax. The link will involve substation works, circuit upgrades and HVDC converter stations at both Torness and Drax. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

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E2LC
Eastern subsea HVDC link from Torness to Hawthorn Pit with metallic return
Status: Scoping
Boundaries affected: B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW bipole HVDC link from Torness area to Hawthorne Pit. The link will involve substation works, circuit upgrades and HVDC converter stations at both Torness and Hawthorne Pit. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

E4DC
Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC
Status: Scoping
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2l, B4E, B4F, B4l, B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW 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.

E4D2
Eastern Scotland to England link: Peterhead to Cottam offshore HVDC
Status: Scoping
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2l, B4E, B4F, B4l, B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW 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.

E4L2
Eastern Scotland to England link: Peterhead to Cottam offshore HVDC
Status: Scoping
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2l, B4E, B4F, B4l, B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW bipole HVDC link from Peterhead to Cottam. The link will involve substation works, circuit upgrades and HVDC converter stations at both Peterhead and Cottam. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

E4D3
Eastern Scotland to England link: Peterhead to Drax offshore HVDC
Status: Scoping
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2l, B4E, B4F, B4l, B5, B6l, B6SPT, B7al, 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.

E4L3
Eastern Scotland to England link: Peterhead to Drax offshore HVDC
Status: Scoping
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2l, B4E, B4F, B4l, B5, B6l, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW bipole HVDC link from Peterhead to Drax. The link will involve substation works, circuit upgrades and HVDC converter stations at both Peterhead and Drax. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

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E4L5

Eastern Scotland to England 3rd link: Peterhead to the South Humber offshore HVDC

Status: Project not started
Boundaries affected: B1aF, B1al, B1aE, B2E, B2F, B2I, B4E, B4F, B4I, B5, B6I, B6SPT, B7al, B8
Region: North

Following a first HVDC link from Peterhead to England, construct an additional offshore 2 GW bipole HVDC link from Peterhead to a location near the Humber, provisionally the substation in the South Humber. The link will involve substation works, circuit upgrades and HVDC converter stations at both Peterhead and the South Humber. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

E4LC

Eastern Scotland to England link: Peterhead to Hawthorn Pit offshore HVDC

Status: Scoping
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I, B5, B6I, B6SPT, B7al, B8
Region: North

Construct a new offshore 2 GW bipole HVDC link from Peterhead to Hawthorn Pit. The link will involve substation works, circuit upgrades and HVDC converter stations at both Peterhead and Hawthorn Pit. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

E5L5

Eastern Scotland to England 3rd link: Blackhillock to the South Humber offshore HVDC

Status: Project not started
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I, B6I, B7al, B8
Region: North

Following a first HVDC link from Peterhead to England, construct an additional offshore 2 GW bipole HVDC link from Blackhillock to a location near the Humber, provisionally the substation in the South Humber. The link will involve substation works, circuit upgrades and HVDC converter stations at both Blackhillock and the South Humber. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

E6L5

Eastern Scotland to England 3rd link: Tealing to the South Humber offshore HVDC

Status: Project not started
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I, B6I, B7al, B8
Region: North

Following a first HVDC link from Peterhead to England, construct an additional offshore 2 GW bipole HVDC link from Tealing to a location near the Humber, provisionally the substation in the South Humber. The link will involve substation works, circuit upgrades and HVDC converter stations at both Tealing and the South Humber. The link will include a metallic earth return conductor to permit operation at reduced capacity with one pole disabled.

EAM1

225 MVAr MSC at Eaton Socon

Status: Project not started
Boundaries affected: B9, LE1
Region: South

One new 225 MVAr switched capacitor (MSC) at Eaton Socon would provide voltage support to the North London area as system flows increase in future.

EAM2

225 MVAr MSC at Eaton Socon

Status: Project not started
Boundaries affected: B9, LE1
Region: South

One new 225 MVAr switched capacitor (MSC) at Eaton Socon would provide voltage support to the North London area as system flows increase in future.

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ECU2

East coast onshore 275kV upgrade
Status: Planning/consenting
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I, B5, B6SPT
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 Longannet to match the enhanced rating. Extend Tealing 275kV substation and install two phaseshifting transformers. Install shunt reactive series compensation at the new Alyth substation.

ECUP

East coast onshore 400kV incremental reinforcement
Status: Planning/consenting
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I, B5, B6SPT
Region: North

The option builds on the east coast onshore 275kV upgrade (ECU2) and upgrades the 275kV infrastructure on the east coast for 400kV operation. Establish new 400kV substations at Rothienorman and Kintore, and uprate Alyth substation (proposed under ECU2) for 400kV operation. Re-insulate the 275kV circuits between Blackhillock, Rothienorman, 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, Alyth and Kintore and install 400/132kV transformers at Fetteresso and Rothienorman.

ECVC

Eccles synchronous series compensation and real-time rating system
Status: Scoping
Boundaries affected: B5, B6l, B6SPT, B7al
Region: North

Installation of two SVCs 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.

EHRE

Elvanfoot to Harker reconductoring
Status: Scoping
Boundaries affected: B6SPT
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: LE1, SC1e
Region: South

New second 400kV cable transmission circuit from Elstree to St John's 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: B4E, B4F, B4I
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 circuit from Tealing to Brechin and rationalise the present Fiddes, Brechin, Tarland and Craigiebuckler network configuration.

FLR3

Reconductor Fleet to Lovedean circuit
Status: Construction
Boundaries affected: SC1, SC1e, SC2
Region: South

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

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GCNC

A new 400 kV double circuit between South Humber and West Lincolnshire
Status: Project not started
Boundaries affected: B7al
Region: North

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

GKEU

Thermal upgrade for Grain and Kingsnorth 400 kV substation
Status: Project not started
Boundaries affected: SC1, SC2
Region: South

Thermal upgrade of the 400 kV Grain and Kingsnorth substation equipment to increase its thermal capacity, supporting future load flow within the area.

GKPC

Power control device along Grain to Kingsnorth
Status: Project not started
Boundaries affected: SC1
Region: South

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

GRRA

Grain running arrangement change
Status: Not applicable as it is an operational solution
Boundaries affected: SC3
Region: South

Change the running arrangement configuration at Grain 400 kV substation so that it is split into two sections. Following faults, the circuit loading balance is improved.

GWNC

A new 400 kV double circuit between South Humber and South Lincolnshire
Status: Project not started
Boundaries affected: B7al, B8, B9
Region: North and South

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

HAE2

Harker supergrid transformer 5 replacement
Status: Design
Boundaries affected: B6F, B6l, B7, B7al
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 6 replacement
Status: Design
Boundaries affected: B6F, B6l, B7, B7al
Region: North

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

HBUP

Uprate Bridgewater to 400 kV and reconductor the route to Hinkley
Status: Design
Boundaries affected: B13, SC1
Region: South

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

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	Option	Description
	HFRE **Reconductor Harker to Fourstones double circuit** Status: Project not started Boundaries affected: B6l, B7al Region: North	Replace the conductors in the Harker to Fourstones single circuit with higher-rated conductors.
	HNNO **Hunterston East to Neilston 400 kV reinforcement** Status: Optioneering and consenting started Boundaries affected: B6SPT Region: North	Modification of the Hunterston East to Devol Moor 400 kV circuit to become the Hunterston East to Neilston 400 kV double circuit overhead line (overhead line), and development of a new 400/275 kV supergrid transformer (SGT4) at Neilston 400 kV substation.
	HSP1 **Power control device along Fourstones to Harker to Stella West** Status: Design Boundaries affected: B6F, B6l, B7, B7aF, B7al Region: North	Install a power control device along the Fourstones to Harker to Stella West 275 kV overhead line route. This would improve the capability to control the power flows from north to south of the transmission network.
	HSP2 **Power control device along Fourstones to Harker to Stella West** Status: Design Boundaries affected: B6l Region: North	Install a power control device along the Fourstones to Harker to Stella West 275 kV overhead line route. This would improve the capability to control the power flows from north to south of the transmission network.
	HSR1 **Reconductor Harker to Stella West** Status: Project not started Boundaries affected: B6l Region: North	Replace the conductors in the Harker to Stella West single circuit with higher-rated conductors.
	HWUP **Uprate Hackney, Tottenham and Waltham Cross 275 kV to 400 kV** Status: Design Boundaries affected: B9, LE1, SC1e Region: South	Hackney, Tottenham and Waltham Cross substation uprate from 275 kV to 400 kV, and the double circuit route connecting them. This will strengthen the power flow into London, via Rye House, down to Hackney.
	ITUP **Uprate Iver to Tilbury route from 275 kV to 400 kV** Status: Project not started Boundaries affected: LE1, SC1e Region: South	Uprate the double circuit route between Iver to Tilbury from 275 kV to 400 kV, and the associated 275 kV substations along the route. These works would further provide additional transmission capacity between the south of London and the south coast.
	KBRE **Knocknagael to Blackhillock 275 kV double circuit reconductoring** Status: Project not started Boundaries affected: B2E, B2F, B2l, B4E, B4F, B4l Region: North	Reconductor the Knocknagael to Blackhillock 275 kV 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 275 kV network and suitability of the conductor for use on the existing L3 tower structures.

Please click here to navigate back to the interactive map in section 4.4.

Appendix C
List of options

KLRE

Kemsley to Littlebrook circuits uprating
Status: Construction
Boundaries affected: SC1e, SC1, SC2, SC3
Region: South

The 400 kV circuits running from Kemsley via Longfield Tee to Littlebrook would be reconductored with higher-rated conductors.

KWHW

Keadby to West Burton circuits thermal uprating
Status: Project not started
Boundaries affected: B7al, 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: B7al, B8
Region: North

Install a power control device along the Keadby to West Burton 400 kV 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 275 kV double circuit overhead line reconductoring
Status: Project not started
Boundaries affected: B0
Region: North

Reconductor the Beauly to Loch Buidhe 275 kV 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 275 kV network and suitability of the conductor for use on the existing L3 tower structures.

LCUP

Uprating of Longannet to 400 kV operation, installation of new 400 kV substation between Wishaw and Torness, and uprate existing 275 kV circuit to 400 kV
Status: Project not started
Boundaries affected: B5, B6SPT
Region: North

Create a new 400 kV substation in the circuits between Smeaton and Wishaw. Upgrade the circuit between Loangannet and Currie from 275 kV to 400 kV and connect into the new 400 kV substation.

LNRE

Reconductor Lackenby to Norton single 400 kV circuit
Status: Project not started
Boundaries affected: B7, B7al
Region: North

Replace the conductors in the Lackenby to Norton single circuit with higher-rated conductors, and replace the cable with a larger cable of higher rating to increase the circuit's thermal rating. The two options have different conductor types that provide different ratings.

LNP1

Power control device along Lackenby to Norton
Status: Project not started
Boundaries affected: B7, B7al
Region: North

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

LNPC

Power control device along Lackenby to Norton
Status: Design
Boundaries affected: B7, B7aF, B7al
Region: North

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

Please click here to navigate back to the interactive map in section 4.4.

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List of options

MBHW
Bramley to Melksham circuits thermal uprating
Status: Project not started
Boundaries affected: B13, SC1e
Region: South

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

MBRE
Bramley to Melksham reconductoring
Status: Project not started
Boundaries affected: B13, LE1, SC1e
Region: South

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

MHPC
Power control device along Harker to Gretna and Harker to Moffat
Status: Project not started
Boundaries affected: B6l
Region: North

Install a power control device along the Harker to Gretna and Harker to Moffat 400kV overhead line route. This would improve the capability to control the power flows from north to south of the transmission network.

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.

MRPC
Power control device along Penwortham to Kirkby
Status: Design
Boundaries affected: B7aF, B7al
Region: North

Install a power control device along the Penwortham to Kirkby 275kV circuit overhead line route. This would improve the capability to control the power flows across the east and west of the transmission network.

NBRE
Reconductor Bramford to Norwich double circuit
Status: Project not started
Boundaries affected: EC5
Region: South

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

NEC1
Cable replacement at Necton 400kV substation
Status: Project not started
Boundaries affected: B9
Region: South

Upgrade cable of the Necton circuit with a larger cable section increasing the circuit's thermal ratings. This will allow higher through flows and increase the power flow.

NEMS
225MVAr MSCs within the north east region
Status: Scoping
Boundaries affected: B7, B7al, B8
Region: North

Three new 225MVAr 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.

Please click here to navigate back to the interactive map in section 4.4.

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List of options

NEP1

Power control device along Blyth to Tynemouth to 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 275 kV 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: B6l, B7al
Region: North

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

NOM1

225 MVAr MSC at Norwich
Status: Project not started
Boundaries affected: EC5
Region: South

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

NOM2

225 MVAr MSC at Norwich
Status: Project not started
Boundaries affected: EC5
Region: South

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

NOPC

Power control device along Norton to Osbaldwick
Status: Project not started
Boundaries affected: B7al, B8
Region: North

Install a power control device along the Norton to Osbaldwick 400 kV 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 13.75 km of Norton to Osbaldwick 400 kV double circuit
Status: Scoping
Boundaries affected: B7al
Region: North

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

NOR2

Reconductor 13.75 km of Norton to Osbaldwick number 1 400 kV circuit
Status: Project not started
Boundaries affected: B7al
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 13.75 km of Norton to Osbaldwick number 2 400 kV circuit
Status: Project not started
Boundaries affected: B7, B7a
Region: North

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

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NTP1

Power control device along North Tilbury

Status: Project not started
Boundaries affected: 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

Central Yorkshire reinforcement

Status: Scoping
Boundaries affected: B7al, B8, B9
Region: North and South

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

OPN1

A new 400kV double circuit between Osbaldwick and Poppleton and relevant 400kV upgrades

Status: Project not started
Boundaries affected: B7al
Region: North

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

OPN2

A new 400kV double circuit between Osbaldwick and Poppleton and relevant 275kV upgrades

Status: Project not started
Boundaries affected: B7al, B8
Region: North

Construct a new 400kV double circuit in central Yorkshire to facilitate power transfer requirements across the relevant boundaries. 275kV circuit upgrades are required in central Yorkshire. Substation works might be required to accommodate the new circuits.

OPN3

A new 400kV double circuit between Osbaldwick and Poppleton using cable and relevant 400kV upgrades

Status: Project not started
Boundaries affected: B7al
Region: North

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

OPN4

A new 400kV double circuit between Osbaldwick and Poppleton using cable and relevant 275kV upgrades

Status: Project not started
Boundaries affected: B7al, B8
Region: North

Construct a new 400kV double circuit in central Yorkshire to facilitate power transfer requirements across the relevant boundaries. 275kV circuit upgrades are required in central Yorkshire. Substation works might be required to accommodate the new circuits.

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Appendix C
List of options

PEM1

225 MVAr MSC at Pelham
Status: Project not started
Boundaries affected: B9, EC5, LE1
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 future.

PEM2

225 MVAr MSC at Pelham
Status: Project not started
Boundaries affected: B9, EC5, LE1
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 future.

PWMS

Two 225 MVAr MSCs at Penwortham
Status: Project not started
Boundaries affected: B7al, B8
Region: North

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

RHM1

225 MVAr MSC at Rye House
Status: Scoping
Boundaries affected: EC5, LE1, SC1e
Region: South

One new 225 MVAr switched capacitor (MSC) at Rye House would provide voltage support through East Anglia and North London as system flows increase in future.

RHM2

225 MVAr MSC at Rye House
Status: Project not started
Boundaries affected: EC5, LE1
Region: South

One new 225 MVAr switched capacitor (MSC) at Rye House would provide voltage support through East Anglia and North London as system flows increase in future.

RTRE

Reconductor remainder of Rayleigh to Tilbury circuit
Status: Scoping
Boundaries affected: EC5, LE1, SC1e
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.

SCD1

New offshore HVDC link between Suffolk and Kent Option 1
Status: Project not started
Boundaries affected: EC5, LE1, SC1, SC1e
Region: South

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

SCD2

New offshore HVDC link between Suffolk and Kent Option 2
Status: Project not started
Boundaries affected: EC5
Region: South

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

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SCN1

New 400 kV transmission route between south London and the south coast
Status: Scoping
Boundaries affected: SC1, SC1e
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: B9, LE1, SC1e
Region: South

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

SER2

Elstree to Sundon 2 circuit turn-in and reconductoring
Status: Project not started
Boundaries affected: LE1, SC1e
Region: South

Turn-in the Elstree to Sundon circuit 2, which currently passes the Elstree 400 kV 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 400 kV South Humber substation equipment.

TDH1

Drax to Thornton 2 circuit thermal uprating and equipment upgrade
Status: Project not started
Boundaries affected: B7al, B8
Region: North

Thermal upgrade of Drax to Thornton 2 circuit to allow it to operate at higher temperature and rating and upgrade the other associated equipment at the substations. This will increase the power flow across the boundary.

TDH2

Drax to Thornton 1 circuit thermal uprating and equipment upgrade
Status: Project not started
Boundaries affected: B7al, B8
Region: North

Thermal upgrade of Drax to Thornton 1 circuit to allow it to operate at higher temperature and upgrade the other associated equipment at the substations. This will increase the power flow across the boundary.

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 400 kV overhead line route. This would improve the capability to control the power flows from north to south of the transmission network.

Please click here to navigate back to the interactive map in section 4.4.

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TDPC
Power control device along Drax to Thornton
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.

THRE
Reconductor Hinkley Point to Taunton double circuit
Status: Scoping
Boundaries affected: SC1e
Region: South

Replace the conductors in the Hinkley Point to Taunton circuits with higher-rated conductors to increase the circuit's thermal ratings.

THS1
Install series reactors at Thornton
Status: Scoping
Boundaries affected: B7, B7al, B8
Region: North

Install series reactors 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.

TKRE
Tilbury to Grain and Tilbury to Kingsnorth upgrade
Status: Scoping
Boundaries affected: LE1, SC1, SC1e
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 circuit's thermal ratings.

TKUP
East coast onshore 400kV phase 2 reinforcement
Status: Project not started
Boundaries affected: B2E, B2F, B2I, B4E, B4F, B4I, B5, B6SPT
Region: North

Establish further 400kV infrastructure on the east coast following the east coast 400kV onshore incremental (ECUP) reinforcement, eastern HVDC link from Peterhead (E4DC/D2/D3) and from Torness (E2DC/D2/D3). Rebuild the Kintore to Tealing 275kV double circuit for 400kV operation and install new 400/275kV transformers at Tealing. Re-insulate the existing Tealing to Longannet route through Glenrothes, Westfield and Mossmorran for 400kV operation. Install 400/275kV transformers at Glenrothes and Longannet and new 400/132kV transformers at Westfield and Mossmorran.

TLNO
Torness to north east England AC onshore reinforcement
Status: Scoping
Boundaries affected: B5, B6I, B6SPT, B7al
Region: North

This option provides additional transmission capacity by installing a double circuit from a new 400kV substation in the Torness area to a suitable connection point in north east England.

TMEU
Thorpe Marsh substation reconfiguration
Status: Project not started
Boundaries affected: B9
Region: South

Reconfigure Thorpe Marsh 400kV substation to balance flows on the surrounding circuits. This would ensure better load flow sharing and increase the power flow.

TUEU
Tummel reconfiguration
Status: Scoping
Boundaries affected: B2E, B2F, B2I, B4E, B4F, B4I
Region: North

Following TURC, relocate the SGTs at Tummel to the new 275kV substation and connect to the Errochty circuits with new 132kV cables.

Please click here to navigate back to the interactive map in section 4.4.

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TURC

Tummel reactive series compensation
Status: Planning/consenting
Boundaries affected: B1aE, B1aF, B1al, B2E, B2F, B2I, B4E, B4F, B4I
Region: North

Establish a 275kV double busbar at Tummel substation and install shunt reactive series compensation.

TWNC

Uprate Tilbury to Waltham Cross route from 275kV to 400kV and new 400kV transmission route in Hertfordshire area
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. Construct new transmission route to Hertfordshire from Waltham Cross 400kV substation. These works would further provide additional transmission capacity between the south of London and the south coast.

WAM1

225MVAr MSC at Walpole
Status: Project not started
Boundaries affected: B9, LE1
Region: South

One new 225MVAr switched capacitor (MSC) at Walpole would provide voltage support to the North London area as system flows increase in future.

WAM2

225MVAr MSC at Walpole
Status: Project not started
Boundaries affected: B9, LE1
Region: South

One new 225MVAr switched capacitor (MSC) at Walpole would provide voltage support to the North London area as system flows increase in future.

WAM3

225MVAr MSC at Walpole
Status: Project not started
Boundaries affected: B9, LE1
Region: South

One new 225 MVAr switched capacitor (MSC) at Walpole would provide voltage support to the North London area as system flows increase in future.

WHTI

Turn-in of West Boldon to Hartlepool circuit at Hawthorn Pit
Status: Design
Boundaries affected: B6l, B7, B7al
Region: North

Turn-in the West Boldon to Hartlepool circuit, which currently passes the Hawthorn Pit site to connect to it. This would create new West Boldon to Hawthorn Pit and Hawthorn Pit to Hartlepool circuits. This would ensure better load flow sharing and increased connectivity in the north east 275kV ring. The two options have different delivery years.

WLTI

Windyhill to Lambhill to Longannet 275kV circuit turn-in to Denny North 275kV substation
Status: Design/development
Boundaries affected: B5, B6SPT
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.

WRRE

Reconductor West Burton to Ratcliffe-on-Soar circuit
Status: Project not started
Boundaries affected: B9
Region: South

Replace the conductors in the West Burton to Ratcliffe-on-Soar circuit with higher-rated conductors to increase the circuit's thermal ratings.

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Appendix C
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WYM1	**225 MVAr MSC at Wymondley** Status: Project not started Boundaries affected: LE1 Region: South	One new 225 MVAr switched capacitor (MSC) at Wymondley would provide voltage support to the North London area as system flows increase in future.
WYM2	**225 MVAr MSC at Wymondley** Status: Project not started Boundaries affected: LE1 Region: South	One new 225 MVAr switched capacitor (MSC) at Wymondley would provide voltage support to the North London area as system flows increase in future.
WYQB	**Wymondley quad boosters** Status: Design Boundaries affected: LE1, SC1e Region: South	Install a pair of quad boosters on the double circuits running from Wymondley to Pelham at the Wymondley 400 kV substation. The quad boosters would improve the capability to control the power flows on the North London circuits.
WYTI	**Wymondley turn-in** Status: Design Boundaries affected: B9, LE1, SC1e 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.

Please click here to navigate back to the interactive map in section 4.4.

Appendix D
Meet the NOA team

Julian Leslie
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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
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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.

Appendix D
Meet the NOA team

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:

The Network Options Assessment

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Cost-benefit analysis and the Network Options Assessment

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OR:

Network requirements and the *Electricity Ten Year Statement*

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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

Appendix E
Glossary

Throughout this document, there are terms highlighted in purple that are explained in more detail here.

BID3:
BID3 is an economic dispatch optimisation model supplied by Pöyry Management Consulting. It can simulate all European power markets simultaneously, including the impact of interconnection between markets. BID3 has been specifically developed for National Grid ESO 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.

CBA – Cost-benefit analysis:
A method of assessing the benefits of a given project in comparison to the costs. This tool can help to provide a comparative base for all projects to be considered.

Critical:
The option is 'optimal' on its earliest in service date (EISD) in at least one scenario.

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 National Grid Electricity Transmission's system or for at least two miles in SP Transmission's system. In the case of an offshore transmission system, this is a transmission line which consists of two circuits sharing the same towers for at least one span.

EISD – Earliest in service date:
The earliest date when the project could be delivered and put into service, if investment in the project was started immediately.

ESO – Electricity System Operator:
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 Electric Transmission and SP Transmission.

FES – Future energy scenarios:
They are 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.

GW – Gigawatt:
1,000,000,000 watts, a measure of power.

GWh – Gigawatt hour:
1,000,000,000 watt hours, a unit of energy.

GB – Great Britain:
A geographical, social and economic grouping of countries that contains England, Scotland and Wales.

HVAC – High Voltage Alternating Current:
Electric power transmission in which the voltage varies in a sinusoidal fashion, resulting in a current flow that periodically reverses direction. HVAC is presently the most common form of electricity transmission and distribution, since it allows the voltage level to be raised or lowered using a transformer.

HVDC – High Voltage Direct Current:
The transmission of power using continuous voltage and current as opposed to alternating current. HVDC is commonly used for point to point long-distance and/or subsea connections. HVDC offers various advantages over HVAC transmission, but requires the use of costly power electronic converters at each end to change the voltage level and convert it to/from AC.

Interconnector:
Electricity interconnectors are transmission assets that connect the GB market to Europe and allow suppliers to trade electricity between markets.

MW – Megawatt:
1,000,000 watts, a measure of power.

MWh – Megawatt hour:
1,000,000 watt hours, a measure of power usage or consumption in 1 hour.

Merit order:
An ordered list of generators, sorted by the marginal cost of generation.

MITS – Main Interconnected Transmission System:
This comprises all the 400 kV and 275 kV elements of the onshore transmission system and, in Scotland, the 132 kV elements of the onshore transmission system operated in parallel with the supergrid. It also includes any elements of an offshore transmission system operated in parallel with the supergrid. It 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.

Appendix E
Glossary

NETS – National Electricity Transmission System:
The National Electricity Transmission System comprises the onshore and offshore transmission systems of England, Wales and Scotland. It transmits high-voltage electricity from where it is produced to where it is needed throughout the country. The system is made up of high-voltage electricity wires that extend across Britain and nearby offshore waters. It is owned and maintained by regional transmission companies, while the system as a whole is operated by a single System Operator (SO).

NETSO – National Electricity Transmission System Operator:
National Grid acts as the NETSO for the whole of Great Britain while owning the transmission assets in England and Wales. In Scotland, transmission assets are owned by Scottish Hydro Electric Transmission Ltd (SHE Transmission) in the north of the country and Scottish Power Transmission (SP Transmission) in the south.

NETS SQSS – National Electricity Transmission System Security and Quality of Supply Standards:
A set of standards used in the planning and operation of the National Electricity Transmission System of Great Britain. For the avoidance of doubt, the National Electricity Transmission System is made up of both the onshore transmission system and the offshore transmission system.

NGET – National Grid Electricity Transmission plc:
National Grid Electricity Transmission plc (No. 2366977) whose registered office is 1–3 Strand, London, WC2N 5EH.

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.

NOA – Network Options Assessment:
The *NOA* is the process for assessing options for reinforcing the National Electricity Transmission System (NETS) to meet the requirements that the Electricity System Operator (ESO) finds from its analysis of the future energy scenarios (FES).

OFGEM – Office of Gas and Electricity Markets:
The UK's independent National Regulatory Authority, a non-ministerial government department. Their principal objective is to protect the interests of existing and future electricity and gas consumers.

Offshore:
This term means wholly or partly in offshore waters.

Offshore transmission circuit:
Part of an offshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables, overhead lines and DC converters but excludes busbars and onshore transmission circuits.

Onshore:
This term refers to assets that are wholly on land.

Onshore transmission circuit:
Part of the onshore transmission system between two or more circuit breakers which includes, for example, transformers, reactors, cables and overhead lines but excludes busbars, generation circuits and offshore transmission circuits.

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.

Power supply background (aka generation background):
The sources of generation across Great Britain to meet the power demand.

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.

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Glossary

SHE Transmission:
Scottish Hydro Electric Transmission (No. SC213461) whose registered office is situated at Inveralmond HS, 200 Dunkeld Road, Perth, Perthshire PH1 3AQ.

SP Transmission:
Scottish Power Transmission Limited (No. SC189126) whose registered office is situated at 1 Atlantic Quay, Robertson Street, Glasgow G2 8SP.

SRF – system requirements form:
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 report methodology.

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 275 kV and above.

SGT – supergrid transformer:
A term used to describe transformers on the NETS that operate in the 275–400 kV 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.

SOF – System Operability Framework:
The SOF identifies the challenges and opportunities which exist in the operation of future electricity networks and identifies measures to ensure the future operability.

System stability:
With reduced power demand and a tendency for higher system voltages during the summer months, fewer generators will operate and those that do run could be at reduced power factor output. This condition has a tendency to reduce the dynamic stability of the NETS. Therefore, network stability analysis is usually performed for summer minimum demand conditions as this represents the limiting period.

SWW – Strategic Wider Works:
This is a funding mechanism as part of the RIIO-T1 price control that allows TOs to bring forward large investment projects that have not been funded in the price control settlement.

Transmission circuit:
This is either an onshore transmission circuit or an offshore transmission circuit.

TEC – Transmission entry capacity:
The maximum amount of active power deliverable by a power station at its grid entry point (which can be either onshore or offshore). This will be the maximum power deliverable by all of the generating units within the power station, minus any auxiliary loads.

Transmission losses:
Power losses that are caused by the electrical resistance of the transmission system.

TOs – Transmission Owners:
A collective term used to describe the three transmission asset owners within Great Britain, namely National Grid Electricity Transmission, Scottish Hydro Electric Transmission and Scottish Power Transmission.

TSO – Transmission System Operator:
An entity entrusted with transporting energy in the form of natural gas or power on a regional or national level, using fixed infrastructure.

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Executive summary (page 03)

Proceed
Total cost of £11.1bn*
Investing £203m in 2020/21.
Number of ESO-led commercial solutions 3.
Saving consumers up to £950m
*This only includes the costs for E2DC and not E2D2. These projects are mutually exclusive and therefore only one will be delivered in full.

Delay
With a total deferred spend of £713k as a decision to invest was not deemed economical this year.

Hold
These options were 'optimal' but an investment is not required this year. The recommendation could be made when there is greater certainty in the future.

Do not start
These options are not 'optimal', and therefore delivery should not be progressed this year.

NOA I/C
Total interconnection capacity range of between 18.1 to 23.1 GW between GB and European markets.

Chapter 1 – Introduction (page 9)

[1] Ofgem closed its statutory consultation on changes to Standard Licence Condition C27 of electricity transmission in January 2020. The changes proposed new requirements for the ESO to assess projects recommended for further development in the *NOA* and projects for future generator and demand connections, for their eligibility for competition.

4.3 The NOA outcomes Table 4.1 Scotland and the north of England region (page 37)

Option HSP1 is new in *NOA 2019/20*. It benefits boundaries in southern Scotland and northern England in early years under various interconnector flow conditions. This option is 'optimal' and 'critical' under all scenarios and is needed on its EISD in 2020.

Option MRPC is new in *NOA 2019/20* and along with LNPC and WHTI benefits the northern England boundaries in the early years. The option is 'critical' under all scenarios and is needed on its EISD of 2020.

Option LNPC is new in this year's *NOA* and along with reinforcements, MRPC and WHTI, benefits the northern England boundaries in early years. The option is 'optimal' and 'critical' under all scenarios and is needed on its EISD of 2020.

Option WHTI, along with HSP1, HAEU, LNPC, and MRPC, reinforces boundaries in northern England from 2021 and provides further benefit for interconnector imports. Following the same recommendation as *NOA 2018/19*, WHTI is recommended to 'proceed' and is 'critical' in all scenarios from its EISD in 2021.

Option WLTI is a pre-requisite for ECU2 and reinforces southern Scotland and northern England boundaries. It had a recommendation in *NOA 2018/19* of 'hold'. This year, WLTI was 'critical' in one scenario, **Community Renewables**, however the single year least regret analysis showed it was not economically viable to deliver on its EISD of 2021. So its recommendation is 'delay'.

Option NOR2 provides capability in northern England from the early 2020s. NOR2 forms part of the wider option of NOR1, which includes the reconductoring from Norton to Osbaldwick of the first circuit, known as NOR2, and the second circuit, known as NOR4. This year's analysis showed only a need to reconductor the first circuit, NOR2. So this option is now 'critical' across three scenarios – **Two Degrees**, **Community Renewables** and **Steady Progression** – and must meet its EISD of 2022.

Option HAEU, along with HAE2, continues to provide benefit to the southern Scotland and northern England boundaries as seen in *NOA 2018/19*. However, as opposed to HAE2, it is more beneficial when independently delivered and is therefore 'critical' in all scenarios with a required EISD in 2022.

Option CS35 is an ESO-led commercial solution, which benefits the Anglo-Scottish and northern England boundaries in all scenarios from its EISD of 2023. The option does not displace or 'delay' any asset-based options in the 'optimal' paths, as it provides further benefits to the network in mid-2020s when other reinforcements are yet to be delivered. CS35 is 'critical' in all scenarios except **Consumer Evolution**.

Option ECU2 provides additional transmission capacity across most Scottish boundaries from as early as 2023. The option is critical in all scenarios which is consistent with the *NOA 2018/19* result.

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Option HNNO benefits boundaries in southern Scotland and provides these independently of other options in early years. HNNO was recommended to 'proceed' in *NOA 2018/19* and is still 'critical' in all four scenarios; so we recommend to 'proceed' on its EISD in 2023.

Option THS1 benefits boundaries in northern England from the early 2020s and works alongside TDH1, TDH2 and TDPC. THS1 is 'critical' in all scenarios and needed from its EISD of 2023.

Option HAE2, along with HAEU, continues to provide benefit to the southern Scotland and northern England boundaries as seen from *NOA 2018/19*. This option is 'critical' under all scenarios.

Option CDP1 is new to this year's *NOA*. It benefits north Midlands boundaries and is only considered 'critical' in **Two Degrees**. However, the single year least worst regret analysis suggested this reinforcement be 'delayed'.

Option TDH2, along with TDH1, is new in this year's *NOA* and reinforces the north Midlands boundaries. Both reinforcements are beneficial with the delivery of the second eastern subsea HVDC link, E2DC.

Option CBEU benefits northern England and north Midlands boundaries from 2023. It was in the 'optimal' path in last year's *NOA* and was required in 2025 in all four FES scenarios. CBEU is 'optimal' in all scenarios but not 'critical'.

Option NEPC is new in *NOA 2019/20* and reinforces the northern England boundaries. It is driven by the increasing Anglo-Scottish and interconnector power flows.

Option DNEU benefits the Scotland boundaries. The outcome of this reinforcement was also 'hold' in *NOA 2018/19*.

Option NEP1 is new in this year's *NOA* and builds on option NEPC. It brings further benefit in northern England boundaries from 2024. This option is seen to be 'critical' under three scenarios: **Two Degrees**, **Consumer Evolution** and **Steady Progression**.

4.3 The NOA outcomes Table 4.1 Scotland and the north of England region (page 38)

Option CTP2 is a new reinforcement to *NOA 2019/20* and brings benefits to north Midlands capability from as early as 2024. It works with several other north Midlands reinforcements, including CDP1, CKPC and KWPC. The option was 'critical' in **Two Degrees** and further analysis showed further benefit to its delivery in 2024 as opposed to deferring it until 2026.

Option KWPC is new in *NOA 2019/20* and provides north Midlands boundary capability from early 2020s. The economic benefit of this option is realised from 2024 and so is 'optimal' in all scenarios but not 'critical'.

Option CKPC is new to this year's *NOA* and forms part of the group of options: KWPC, TDPC and KWHW. It provides north Midlands boundary capability from 2024.

Option CDHW is new in *NOA 2019/20*. It benefits north Midlands and South Humber boundaries and forms part of the group of reinforcements: KWPC, CKPC, TDPC and KWHW. Whilst the boundary capability is realised from 2022, it is mainly justified from 2024, with northern England power flows being released by other reinforcements: HAEU, WHTI and NEPC. So it is 'optimal' in all scenarios but not 'critical'.

Option TDPC is new to this year's *NOA* and works alongside CKPC and KWHW to reinforce the north Midlands boundaries.

Option ECVC benefits boundaries in southern Scotland and northern England. In *NOA 2018/19,* the recommendation was to 'hold' this reinforcement; in this year's *NOA* the recommendation to 'proceed' is justified due to the benefits it provides to the southern Scotland and Anglo-Scottish boundaries.

Option ECUP builds on ECU2 and benefits the Scotland boundaries. It is 'optimal' and 'critical' in all scenarios and is to be delivered on its EISD of 2026.

Option TDH1, along with TDH2, is new in this year's *NOA* and reinforces the north Midlands boundaries. Both reinforcements are beneficial with the delivery of the second eastern subsea HVDC link, E2DC.

Option TDP2 is new to this year's *NOA* and reinforces the north Midlands boundaries. This option is additional to TDH1 and TDH2 which will provide benefit when the commissioning of the second eastern subsea HVDC link, E2DC, takes place.

Option OPN2 is new in this year's *NOA*. It is an alternative to OENO and benefits boundaries in northern England. OPN2 is 'critical' under two scenarios, **Consumer Evolution** and **Steady Progression**, to meet its EISD of 2027.

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Option CDP2 is new in *NOA 2019/20*, bringing benefits to north Midlands. In all scenarios, both CDP1 and CDP2 are 'optimal' to achieve the capabilities needed in the north Midlands from 2027. However, unlike CDP1, this option is not 'critical' under any scenario and should be put on 'hold'.

Option KWHW, along with options CKPC and TDPC, provides north Midlands boundary capability from 2024. It is also a pre-requisite for when the eastern subsea HVDC links are commissioned. Similar to HSR1, from *NOA 2018/19*, this is recommended to 'hold' until later years as other reinforcements are required instead in the earlier years to alleviate the constraints in northern boundaries.

Option E2DC benefits boundaries in southern Scotland and northern England. It connects Torness and Hawthorn Pit and is one of the three options (the other two options include E2D2 between Torness and Cottam and E2D3 between Torness and Drax) proposed for the first Anglo-Scottish eastern subsea HVDC links. Compared to the other two candidates, E2DC is much shorter and can be delivered a year earlier. This means it can provide more near-term benefits; but the downside is that it covers fewer boundaries in northern England. In **Consumer Evolution** and **Steady Progression**, where there is less renewable growth, E2DC is found most 'optimal' as the needs for transfer capability are less demanding. So the option is 'critical' in **Consumer Evolution** and **Steady Progression**, which is consistent with *NOA 2018/19* results. In **Two Degrees** and **Community Renewables**, E2DC is less 'optimal' than E2D2 in this *NOA*.

Option DWNO benefits the southern and central Scottish boundaries. The analysis showed that it was 'critical' in all scenarios and needed on its EISD of 2028.

Option LNRE reinforces the northern England boundaries. In *NOA 2018/19*, this was given a 'proceed', however this year's analysis showed other reinforcements now provide further benefit in the northern England boundaries for the early 2020s. So the option is no longer 'critical' in any of the scenarios and received a recommendation of 'hold'.

Option NEMS reinforces the northern England boundaries and was given a 'proceed' in *NOA 2018/19*. The recommendation for this year is 'hold', as analysis showed there was further benefit when delivered alongside other reinforcements in the late 2020s.

Option NOR4 benefits boundaries in northern England from the late 2020s. It is best aligned with other reinforcements such as LNRE, NEMS and PWMS after 2028. NOR4 forms part of the wider option of NOR1, which includes the reconductoring from Norton to Osbaldwick of the first circuit, known as NOR2, and the second circuit, known as NOR4. NOR4 was recommended to 'proceed' in the previous *NOA*, however this year's analysis showed there was no further benefit of delivering NOR4 on its EISD due to new power flow control devices in northern England. So this option is not 'critical' under any scenario and should be put on 'hold'.

Option PWMS is new in *NOA 2019/20* and works in combination with other northern England reinforcements to provide increased capability to the northern England boundaries.

4.3 The NOA outcomes Table 4.1 Scotland and the north of England region (page 39)

Option E2D2 benefits boundaries in southern Scotland and northern England. It connects Torness and Cottam and is one of the three options (the other two include E2DC between Torness and Hawthorn Pit and E2D3 between Torness and Drax) proposed for the first Anglo-Scottish eastern subsea HVDC links. Compared to E2DC, it lands further south, making it more beneficial to boundaries in northern England in the later years. Although it is more expensive and requires a year longer to deliver, it is still more 'optimal' than E2DC in **Two Degrees** and **Community Renewables**. In *NOA 2018/19*, the recommendation was 'Do not start', the recommendation in *NOA 2019/20* is to 'proceed' as it is now 'critical' in two scenarios, **Two Degrees** and **Community Renewables**.

Option CWPC is new to this year's *NOA* and benefits the north Midlands boundary capability from early 2020s. The option is 'optimal'; however analysis showed it should be put on 'hold' until the second eastern subsea HVDC link, E2DC, and the third eastern HVDC subsea link, E4L5, are connected.

Option E4D3 is the second eastern subsea HVDC link which follows the first link connecting between Torness and England. It provides major benefit across Scottish and northern English boundaries and is justified in all scenarios on its EISD of 2029. The option, connecting between Peterhead and Drax, is found to be more optimal than E4DC (between Peterhead and Hawthorn Pit) when delivered together with E2D2 (first

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link between Torness and Cottam). E4D3 is also more economically viable than the other alternative option, E4D2 (between Peterhead and Cottam). E4D3 is critical across all scenarios which is consistent with the *NOA 2018/19* result.

Option DEPC is new in *NOA 2019/20* and benefits the north Midlands boundary capability from 2024. It is only required when the connection of the Torness to Hawthorn Pit eastern subsea HVDC link, E2DC, is realised.

Option NOPC is new in *NOA 2019/20* and reinforces the northern England and north Midlands boundaries.

Option SHNS is new in *NOA 2019/20* and is required for the third eastern subsea HVDC link, E4L5, from Peterhead to the South Humber area. This option is 'critical' across all scenarios so needs to meet its EISD of 2031.

Option GWNC is new to this year's *NOA*. It will bring benefits when the connection of the eastern subsea HVDC link, E4L5, happens in the South Humber area. It further reinforces the north Midlands boundaries and relieves boundaries in Scotland and northern England. The option is 'optimal' and 'critical' in all scenarios and needed on its EISD in 2031.

Option CGNC, together with other options in the South Humber area – GWNC, SHNS and E4L5 – is 'critical' under the three scenarios of **Two Degrees**, **Community Renewables** and **Consumer Evolution**. It is not required by **Steady Progression** which sees fewer constraints in the South Humber area. To maximise its benefit for the connection of the third eastern subsea HVDC link, E4L5, it is recommended to be delivered on its EISD.

Option CRPC, is new in this year's *NOA*, bringing benefits to north Midlands capability and is justified in later years for **Two Degrees** and **Community Renewables** where the first eastern subsea HVDC link, E2D2, connects at Cottam.

Option CDP4 is new and benefits north Midlands capability from 2031 when the third eastern subsea HVDC link, E4L5, connects. CDP4, along with CDP2, is 'optimal', but not 'critical' under any scenario.

Option E4L5 is the third eastern subsea HVDC link, which is required following the first link between Torness and England and second link between Peterhead and England. E4L5 connects Peterhead and the South Humber area and can alleviate constraints across all major boundaries. It requires several onshore reinforcements to accommodate the power flows to England. E4L5, together with these onshore reinforcements, is 'critical' in all scenarios to be delivered on its EISD of 2031.

Option LBRE is new in *NOA 2019/20* and reinforces the northern Scotland boundaries. Due to the increased generation capacity of the northern Scotland regions, this reinforcement becomes beneficial in the 2030s.

Option TLNO benefits boundaries in southern Scotland and northern England. It had a recommendation in the *NOA 2018/19* of 'Do not start', however alongside the third eastern subsea HVDC link, E4L5, and those proposed for the South Humber area, TLNO is now justified by its further benefits on northern England boundaries. TLNO has now become 'critical' under all scenarios except **Steady Progression**.

Option HSR1 is new in this year's *NOA* and benefits southern Scotland and northern England capability in the late 2020s. This option is recommended to 'hold' as it further reinforces with the increased generation capacity in northern England.

4.3 The NOA outcomes Table 4.5 The south and east of England region (page 46)

Option KLRE benefits multiple south coast boundaries by reinforcing the network to accommodate power flows from the south east coast into London. Analysis showed the option to be 'critical' in all four scenarios.

Option GRRA provides an increase capability to the export power flows of one of the south east coast boundaries by changing the circuit connection arrangements of the Grain 400 kV substation. It is an operational measure with no capital cost or other expenditure and is 'critical' in all four scenarios.

Option FLR3 is new in *NOA 2019/20*, and has a pre-requisite option, KLRE. It provides capability to the south coast boundary for both import and export interconnector flows to Europe. This option is 'critical' in all four scenarios.

RTRE received a recommendation in *NOA 2018/19* of 'proceed'. In this year's analysis, this option was initially given a 'hold' recommendation and was 'optimal' in 2022, one year after its EISD, in all scenarios. Given the reinforcement's minimal first year spend as well as

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operational advice presented at the NOA Committee, it was agreed to overturn this recommendation from 'hold' to 'proceed'.

Option CTRE has a pre-requisite option, RTRE, and provides capability to the London Export boundary in the early years.

Option BMM2 is a pre-requisite for other reinforcements, BTNO and SCD1, to provide benefit across the East Anglia and London Export boundaries. This option was seen to be 'critical' in all four scenarios.

Option SEEU provides capability to the south east region. Analysis showed that SEEU is 'critical' in all four FES scenarios.

Option BNRC provides capability to the southern coast boundaries, especially for high interconnector imports. BNRC is 'critical' in all four scenarios.

Option NTP1 is new in *NOA 2019/20*, has pre-requisite options, BMM2 and RTRE, and provides benefit to the London Export boundary. Analysis has shown that the option is 'critical' in all four scenarios.

Option SER1 is a pre-requisite reinforcement to SER2 and provides benefits across the south coast London Export and Midlands to south boundaries during high southern interconnector export flows to Europe. SER1 was given the recommendation in *NOA 2018/19* to 'delay' and in this year's *NOA* the recommendation is to 'proceed' as analysis shows it is 'critical' in all four scenarios.

Option CS53 is an ESO-led commercial solution has a pre-requisite option, BNRC, to benefit the south and south east coast boundaries. The option was seen to be 'critical' in three scenarios, **Two Degrees**, **Consumer Evolution** and **Steady Progression**.

Option GKEU has pre-requisite options, KLRE and BNRC, and provides additional capability for the south and south east coast region for southern interconnector imports from Europe.

Option MBHW is new in *NOA 2019/20* and provides capability to south coast boundaries with increased generation capacity in the south west and south coast region. This option is 'critical' in one scenario, **Community Renewables**.

Option BRRE is a pre-requisite to reinforcements BTNO and SCD1 and provides additional capability to the East Anglia, south coast and London Export boundaries. The analysis has seen further benefit due to the increased generation capacity in the East Anglia region for interconnector exports to Europe. BRRE was recommended in *NOA 2018/19* to 'hold', this year it was seen to be 'critical' under all scenarios and so received a recommendation of 'proceed'.

Option PEM1, together with PEM2, benefits the London Export, East Anglia and Midlands to south boundaries. PEM1 received a recommendation in *NOA 2018/19* of 'Do not start' with *NOA 2019/20* giving a recommendation of 'hold' as it was found to be 'optimal' but not 'critical'.

Option PEM2, together with PEM1, benefits the London Export, East Anglia and Midlands to south boundaries. PEM2 received a recommendation in *NOA 2018/19* of 'Do not start' with *NOA 2019/20* giving a recommendation of 'hold' as it was found to be 'optimal' but not 'critical'.

Option RHM1, together with RHM2, is a pre-requisite to BPRE. The option reinforces the London Export and East Anglia regions. RHM1 received a recommendation in *NOA 2018/19* of 'Do not start' with *NOA 2019/20* giving a recommendation of 'hold' due to generation background changes leaving it 'optimal' but not 'critical'.

Option RHM2, together with RHM1, is a pre-requisite to BPRE and RTRE to reinforce the London Export and East Anglia regions. RHM2 received a recommendation in *NOA 2018/19* of 'Do not start' with *NOA 2019/20* giving a recommendation of 'hold' due to generation background changes leaving it 'optimal' but not 'critical'.

4.3 The NOA outcomes Table 4.5 The south and east of England region (page 47)

Option SER2 has a pre-requisite reinforcement, SER1, and provides benefit across the south coast and London Export boundaries during high southern interconnector export flows to Europe.

Option CS51 is an ESO-led commercial solution which benefits the East Anglia boundary. It does not displace or 'delay' any asset-based options in the 'optimal' paths, as it provides further benefits to the network, due to the increased generation capacity in the area, when reinforcements BTNO and SCD1 are yet to be delivered. It was seen to be 'critical' in **Two Degrees**.

Option NBRE has as pre-requisite options BMM2 and BRRE and benefits the East Anglia region.

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Option ESC1 provides capability to the south coast and London Export boundaries.

Option TKRE works with SCD1 to benefit multiple south coast boundaries. TKRE was given the recommendation in *NOA 2018/19* to 'stop' as it was superseded by SCN1. This year's NOA recommendation is to 'proceed' as analysis shows it is 'critical' in all four scenarios.

Option HBUP is new in this year's *NOA* and provides additional capability to the south west and south coast regions.

Option BFHW has as a pre-requisite option, BRRE, and provides capability on the south east coast region for when interconnectors are exporting to Europe.

Option MBRE reinforces the south west and south coast regions, especially for southern interconnector exports to Europe.

Option NOM1 is new in this year's *NOA*, has a pre-requisite option, BTNO, and reinforces the East Anglia region.

Option NOM2 is new in this year's *NOA* and has a pre-requisite option, BTNO, to provide additional capability to the East Anglia region.

Option BTNO is a pre-requisite to reinforcement BPRE and follows SCD1 and SCD2 to provide the highest capability to the East Anglia boundaries. The analysis showed it is 'critical' under all scenarios.

Option SCD1 is new in this year's *NOA* and provides capability to boundaries in the East Anglia, south east and south coast regions. SCD1 reinforces a wider range of boundaries than other options, such as SCN1, resulting in a high economic benefit for the HVDC link. It provides additional benefit to the export power flows from the East Anglia region, with an expected increase in generation capacity in future years. So analysis showed this option to be 'critical' in two scenarios, **Two Degrees** and **Community Renewables**.

Option WYTI benefits the south east and Midland regions.

Option BPRE, following the reinforcements SCD1 and BTNO, provides further capability in the East Anglia region whilst also supporting flows through the Midlands to southern boundaries. The analysis showed further benefit to the reinforcement due to the increases in generation capacity in the East Anglia region. BPRE was recommended in *NOA 2018/19* to 'hold', this year it was seen to be 'critical' under three scenarios, **Two Degrees**, **Steady Progression** and **Community Renewables**, and so received a recommendation of 'proceed'.

Option SCD2 is new in this year's *NOA* and follows other reinforcements, SCD1, BPRE and BTNO, to provide additional capability to the East Anglia boundary.

Option EAM1, together with EAM2, is new in this year's *NOA* and benefits the London Export boundary and the Midlands to south boundary. EAM1 enables other reinforcements, such as BTNO or SCD1, to provide capability for these boundaries under the condition of increased power flows.

Option EAM2, together with EAM1, is a new reinforcement in this year's *NOA* and provides benefit to the London Export boundary and the Midlands to south boundary. EAM2 enables other key reinforcements, such as BTNO or SCD1, to provide capability for these boundaries during increased power flows.

Option WAM1 is new in *NOA 2019/20* and, together with WAM2 and WAM3, provides additional capability from the Midlands to south boundaries.

4.3 The NOA outcomes Table 4.5 The south and east of England region (page 48)

Option WAM2 is new in *NOA 2019/20* and, together with WAM1 and WAM3, provides additional capability from the Midlands to south boundaries.

Option WAM3 is new in *NOA 2019/20* and, together with WAM1 and WAM2, provides additional capability from the Midlands to south boundaries.

Option NEC1 is new to the *NOA 2019/20* and reinforces the Midlands to south boundary due to the increased power flows in the regions.

Option THRE provides capability on the south coast boundary during high southern interconnector export flows to Europe.

Option BFRE provides capability on the south coast boundary for when interconnectors are exporting to Europe, especially with increased exports in later years. BFRE received a recommendation in *NOA 2018/19* of 'Do not start' with *NOA 2019/20* giving a recommendation of 'hold' as it was found to be 'optimal' but not 'critical'.

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5.2 Interconnection theory
Figure 5.1 Benefits of interconnection (page 61)

Greater security of supply:
Both markets can access increased levels of generation to secure their energy needs.

Greater access to renewable energy:
Increased access to intermittent renewable generation, consequently displacing domestic non-renewable generation.

Increased competition:
Increased access to cheaper generation and more consumers leads to increased competition, allowing some participants in both markets to benefit financially. These benefits are measured as social economic welfare.

5.2 Interconnection theory
Figure 5.2 Social Economic welfare (page 62)

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 for consumers in the cheaper market, as they now share their access to cheaper generation with more consumers.

Producer welfare
Increased producer welfare due to increased revenue for generators in the lower priced market, as generators can now access more customers.

Reduced producer welfare due to reduced revenue for generators in the higher priced market, as they are now competing against cheaper overseas generation.

Interconnector welfare
Revenue for interconnector business income generated from selling capacity across the interconnector.

5.3 Methodology
Figure 5.3 Iterative process for interconnection optimisation (page 65)

1. Set base level of 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 totalled 13.6 GW, as shown in table 5.1. All interconnectors that are in the NOA IC base case are included in each scenario within the model.

2. Create study cases:
To test the effect of additional capacity for each market, 1 GW of interconnection was added in each of the European markets (i.e. to each of the seven European connecting countries) to the base level of interconnection.

For each country's additional interconnector, a number of zones and reinforcement combinations were studied. In total, 30 study cases were considered, with different combinations of country, GB connection zone and reinforcement. In study cases where a reinforcement upgrade is selected, an additional 1 GW of capability is added to the relevant boundary.

The 30 study cases are shown in table 5.2. Additional interconnection is modelled to connect in 2027, 2029 and 2032, in order to understand the effects of varying commissioning dates on SEW and attributable constraint costs.

3. Simulate European markets:
Run all 30 study cases for each 2019 FES for all European countries then calculate SEW and constraint costs.

The cases are run in our BID3 economic dispatch optimisation tool. It can simulate all European power markets simultaneously from the bottom up, i.e. it can model individual power stations, and balances supply and demand on an hourly basis.

First, a dispatch, or unconstrained run is undertaken, so that supply meets demand at each point in time, assuming the transmission network is capable of sending power wherever it is needed, i.e. unconstrained.

Second, a re-dispatch, or constrained run is produced, that models constraints on the network, where generation is restricted in some areas of the country due to network capability, and hence generation is increased elsewhere to balance supply and demand. This duty is performed by the SO at minimum cost, and BID3 approximates this activity in the re-dispatch run.

Appendix F

Further information

4. Calculate net benefit of each combination:
Calculate PV = SEW – CAPEX – constraint costs
for each option of country, GB connection zone, reinforcement and connecting year for each scenario, where:

PV = result in present value terms, i.e. as costs are occurred across a range of years, discounting is employed to standardise each cost in present value

SEW = social economic welfare

CAPEX = capital costs for interconnector cable, converter station and network reinforcement, if included within the relevant option

Constraint costs = the constraint costs incurred in ensuring all boundary constraints are met.

5. Identify optimal solution:
For each FES, identify which option has the highest PV across three time periods (interconnectors commissioning in 2027, 2029 and 2032).

6. Update base level of interconnection:
Add optimal solution to base level of interconnection for each FES and repeat steps 3 to 6.

Appendix F
Index of links

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