The Great Grid Upgrade

Eastern Green Link 5 (EGL 5)

Strategic Options Report

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nationalgrid

Contents

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Executive summary

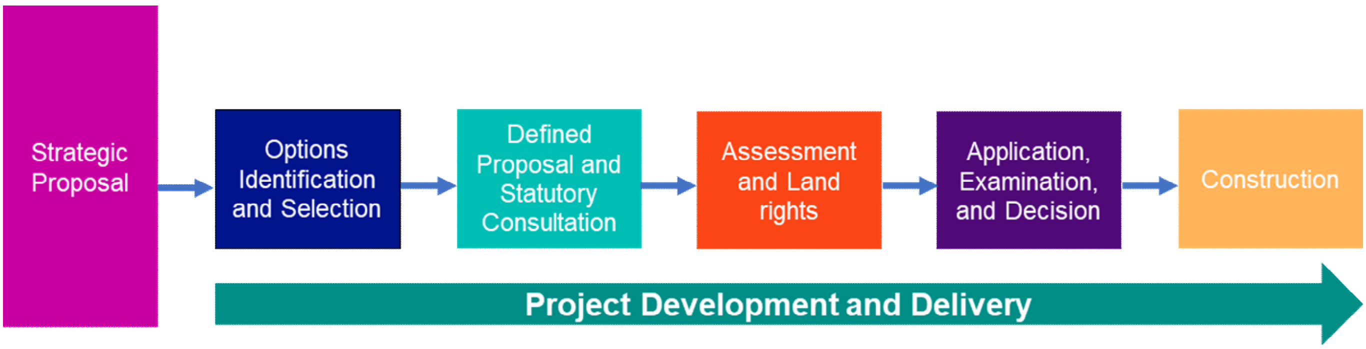
Purpose of the Strategic Options Report

This Strategic Options Report (SOR) provides an overview of the options that National Grid Electricity Transmission plc (NGET) have identified and subsequently evaluated for the strategic optioneering of the Eastern Green Link 5 (EGL 5) project (the Project). EGL 5 is a new primarily offshore high voltage electricity link, with associated onshore infrastructure, between Scotland and England.

EGL 5 is needed as the existing transmission network does not have enough capacity to securely and reliably transport the increasing amount of energy being generated in Scotland and Scottish waters, particularly from offshore wind, to population centres in the Midlands and South of England.

When the need for transmission system works are identified that would require additional consents and/or permissions, we adopt a process-based approach to consenting, the stages for which are shown below:

Figure A – NGET approach to the consenting process



This report forms part of the initial ‘Strategic Proposal’ stage.

How the electricity system is planned and operated

NGET is the owner of the transmission system in England and Wales and holds an electricity transmission licence permitting transmission ownership activities. NGET’s transmission licence requires that NGET provide an efficient, economic, and co-ordinated transmission system in England and Wales. As part of this requirement, NGET must ensure that there is sufficient transmission capacity to meet demand and generator customer requirements, along with providing for wider transmission system needs that exist or are anticipated in the future.

When planning changes to the transmission system, NGET must also have regard to the desirability of preserving amenity, in line with its duties under sections 9 and 38 of the Electricity Act 1989 (‘the Electricity Act’).

NGET is the licenced monopoly provider of electricity transmission services in England and Wales, and is regulated by the Office of Gas and Electricity Markets (Ofgem).

The National Energy System Operator (NESO), is a separate legal entity to NGET. NESO facilitates several roles on behalf of the electricity industry, including making formal offers to applicants requesting connection to the National Electricity Transmission System (NETS). NESO also manages shortfalls in capacity by reducing power flows and constraining generation, as well as making investment recommendations to Transmission Owners (TOs), including NGET, through an annual network planning cycle and other periodic reviews. This indicates which areas of the transmission system require reinforcement.

The legislation, policy and regulatory framework

Legislation

In addition to the legal duty to maintain an efficient, economic, and co-ordinated energy transmission system, NGET is subject to a number of statutory duties when developing new infrastructure, including under the:

- Electricity Act 1989
- National Parks and Access to the Countryside Act 1949
- Countryside and Rights of Way Act 2000
- Natural Environment and Rural Communities Act 2006
- Wildlife and Countryside Act 1981

UK energy policy

In 2019, the UK Government committed to achieving net zero greenhouse gas emissions by 2050. In July 2024 a General Election was held, which led to a change in UK Government, although the 2050 target for net zero greenhouse emissions remains in place. In addition, the UK Government has committed to achieving a net zero electricity system by 2030.

These commitments require the UK to move away from fossil fuels and to adopt alternative sources of energy to power homes, transport, and businesses. The Government has set out how it plans to deliver on these commitments within multiple plans including:

- British Energy Security Strategy (BESS, April 2022); and
- Powering Up Britain and Powering Up Britain: Energy Security Plan (March 2023)
- The Clean Power 20230 Action Plan: A new era of clean electricity (December 2024)

Key ambitions made within these plans to achieve net zero include:

- Up to 50 GW of offshore wind connected by 2030 including 5 GW of which will be offshore floating wind; and.
- Up to 8 nuclear reactors being progressed reaching up to 24 GW to be achieved by 2050.
- Reducing the carbon intensity of Great Britain’s generation from 171gCO_2e/kWh in 2023 to 50gCO_2e/kWh in 2030.

Key commitments that were made by the UK Government in the Powering Up Britain Strategy with regards to electricity network development include those listed below:

- For the appointed Electricity Networks Commissioner to provide recommendations to Government in June 2023 on how grid delivery can be accelerated; and,
- To work with industry and Ofgem to reform the grid connections process, including publishing a connections action plan in 2023.

Consenting regimes, national and marine planning policy

Electricity network infrastructure developments

Developing the electricity transmission system in England and Wales, subject to the type and scale of the project, may require one or more statutory consents.

This project does not automatically qualify as a Nationally Significant Infrastructure Project (NSIP) under s14 of the Planning Act 2008 ("the 2008 Act"). However, the project will request a direction pursuant to s35 of the 2008 Act from the Secretary of State (SoS) for Energy Security and Net Zero (DESNZ) during Spring 2025, to bring the project into the Development Consent Order (DCO) regime. It is intended that a DCO application for the project would include all English onshore elements of the Project, as well as the offshore elements in English waters by inclusion of a deemed marine licence within the DCO. Should a direction pursuant to s35 of the 2008 Act be issued by the SoS, the project would be directed in to the 2008 Act and therefore a DCO application would be prepared and submitted to the Planning Inspectorate who acts on behalf of the SoS for the relevant department.

Applications for a DCO have to be determined in accordance with government National Policy Statements (NPS) in most cases. NPSs set out the need and government policy relating to NSIPs.

The NPSs also form the primary basis on which DCO applications are determined by the relevant Secretary of State. Other material considerations can include local planning policies set out in relevant development plans by local planning authorities and national planning policy, for example the National Planning Policy Framework.

Six NPS for energy infrastructure were designated by the Secretary of State in January 2024. The relevant NPS for electricity transmission infrastructure developments are the Overarching National Policy Statement for Energy (EN-1), National Planning Policy Statement for Renewable Energy Infrastructure (EN-3) and the National Policy Statement for Electricity Networks Infrastructure (EN-5), which is read in conjunction with EN-1.

Part 3 of EN-1 sets out Government policy on the need for new NSIPs confirming that the UK needs a range of the types of energy infrastructure covered by the NPS and that "substantial weight" should be given to the urgent need for the types of infrastructure covered by the NPS when considering applications for DCOs.

EN-3 also has relevance to the Project, in the view of the need for the Project to reinforce boundary flows and facilitate future connections from offshore wind.

Section 1.6.3 confirms that EN-3 will apply to offshore transmission infrastructure projects in English waters which are directed into the NSIP regime under s35 of the Planning Act 2008.

Assessment principles applied by decision maker

Part 4 of EN-1 sets out the general policies that are applied in determining DCO applications relating to new energy infrastructure. Part 2 of EN-5 sets out the assessment principles in the specific context of electricity networks infrastructure.

Principles of particular importance for transmission infrastructure projects include:

- Presumption in favour of development;
- The critical national priority for low carbon infrastructure;
- Consideration of alternatives;
- Good design;
- Climate change adaptation and resilience;
- Networks DCO applications submitted in isolation;
- Electricity Act duties; and
- Adverse impacts and potential benefits

The need case for reinforcement to the transmission system

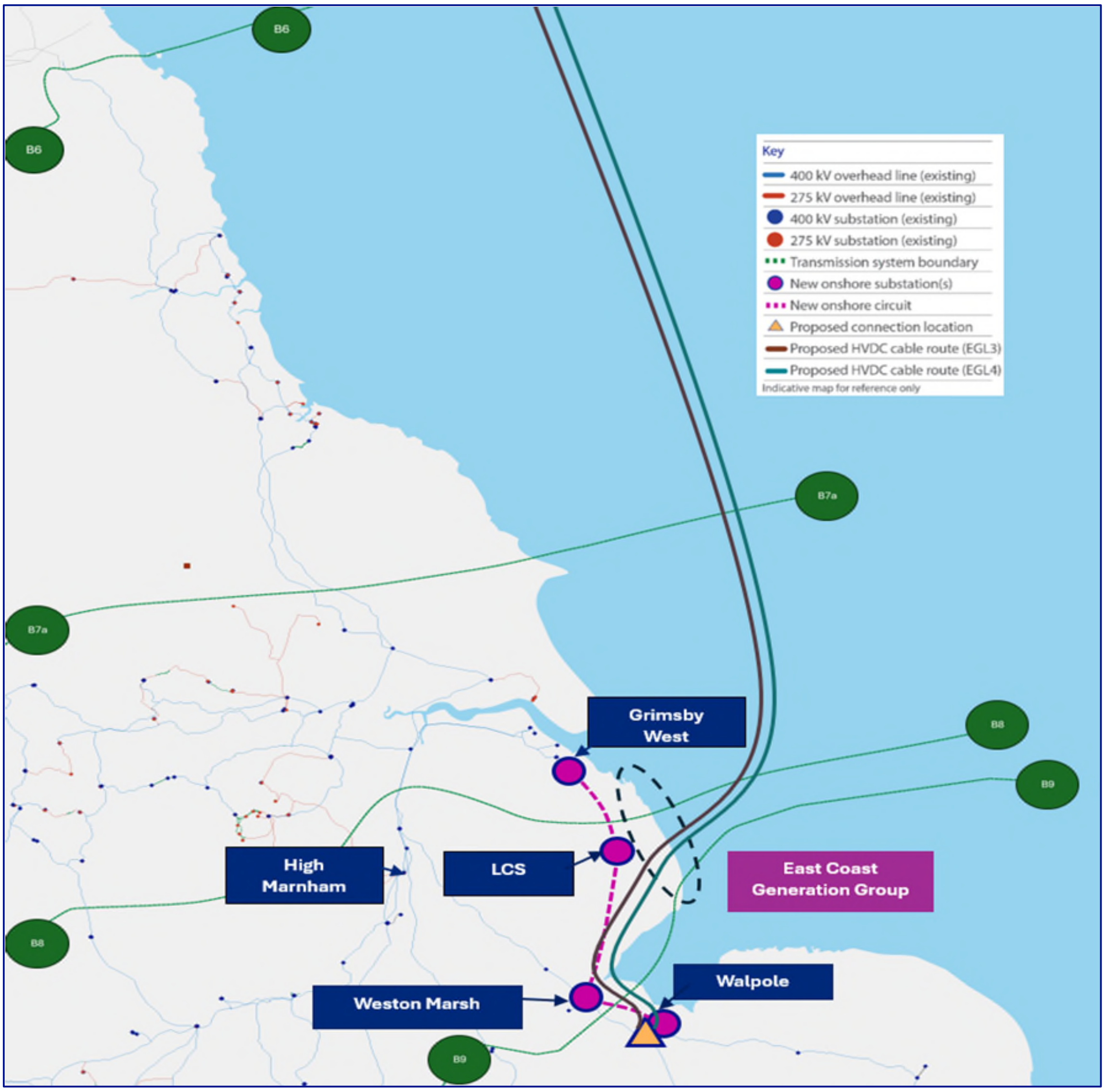
NGET must comply with section 9 of the Electricity Act and Standard Condition D3 (Transmission System Security Standard and Quality of Service) of its Transmission Licence, which requires it to develop and maintain an efficient, coordinated and economical system of electricity transmission.

When required power flows are identified that would exceed the boundary capacity of the transmission system, NGET must resolve the capacity shortfall under the terms of its Transmission Licence.

Existing transmission network

Figure B below shows the existing transmission system, the B6, B7a, B8 and B9 boundaries and the approximate location of the East Coast Generation Group.

Figure B – The East Coast Lincolnshire region transmission system including Grimsby to Walpole, EGL 3 and EGL 4 connections currently under consultation



Boundary Analysis Results

Table A below shows how the existing generation groups and boundaries perform in 2035 for the expected planned transfer flows.

Table A – Existing boundary performance by 2035 and generation group capacity to last contract date

System Boundary Export or Generation Group		2035 Post Fault Capability	2035 Post Fault Capacity	Capability Deficit (-) / Surplus (+)	Capacity Deficit (-) / Surplus (+)	Secured Event Fault
*East Coast contracts to 2035 (Generation)	14,149.0 MW	0 MW	0 MW	-14,149.0 MW	-14,149.0 MW	N/A
B6 – 2035 (boundary)	28,564.2 MW	15,783 MW	16,013 MW	-12,781.2 MW	-12,551.2 MW	Stella West – Eccles 400 kV double circuit
B7a – 2035 (boundary)	25,203.2 MW	19,700 MW	23,805 MW	-5,503.2 MW	-1,398.2 MW	Norton – Osbaldwick 400 kV double circuit
B8 – 2035 (boundary)	28,700.2 MW	23,400 MW	44,829 MW	-5,300.2 MW	+16,129 MW	North Humber to High Marnham 400 kV double circuit
B9 – 2035 (boundary)	25,093 MW	19,300 MW	28,411 MW	-5,793 MW	+3,318MW	Lincolnshire – Walpole 400 kV double circuit

- *Note - *2,730MW of generation is connecting to Weston Marsh substation with >4 transmission circuits connecting to this location.

We recognise that the deficits in Table A need to be addressed. It is noted that a capability uplift would be expected to facilitate the required boundary transfers.

From 2035 further increases in boundary requirements are expected, and this is reflected in our existing contractual commitments. To address these needs, additional reinforcements to these boundaries are expected in Central England and Wales which will supplement these system boundaries in the future. This will facilitate connections beyond 2035 when further increases in generation are expected in all regions, which will be subject to their own detailed need case assessments and option appraisals.

Need case conclusion

There are three distinct issues that need to be considered by system reinforcements that EGL 5 seeks to enhance:

- Provision of capacity and capability from Scotland across the B6 and B7a system boundaries.
- Consider provision of beneficial capability across B8 and/or B9 system boundaries.

- Neutral connection impact upon the East Coast Generation Group.

How we identified and appraised strategic options

Once the need case had been established, there was a requirement to consider the many ways in which the Project could be delivered. Before we undertook any further work, a technical compliance filter was applied to make sure that all of the potential strategic options being considered would work on the network, rejecting any that would not meet technical standards or would not work in practice. At the early stages of optioneering, a key factor was to consider locations either at or close to existing or already planned NGET substations, to minimise the infrastructure required. There are potentially many ways in which the identified need could be met, so further network modelling was carried out to understand the issues better.

The criteria for any potential strategic option to be considered further and not discontinued are one or more of the following:

- An environmental benefit;
- A technical system benefit;
- A capital and lifetime cost benefit, which includes the consideration of initial capital costs and long-term maintenance and operating costs; or
- A socio-economic benefit.

Where the benefits of options are very similar to each other, all options are captured and included for appraisal. This ensures that all possible solutions are appraised regardless of having similar capability.

The appraisal of all potential strategic options led to six being selected to take forward for detailed appraisal. These are indicated in Table B, as shown below.

Table B – Proposed strategic options for appraisal

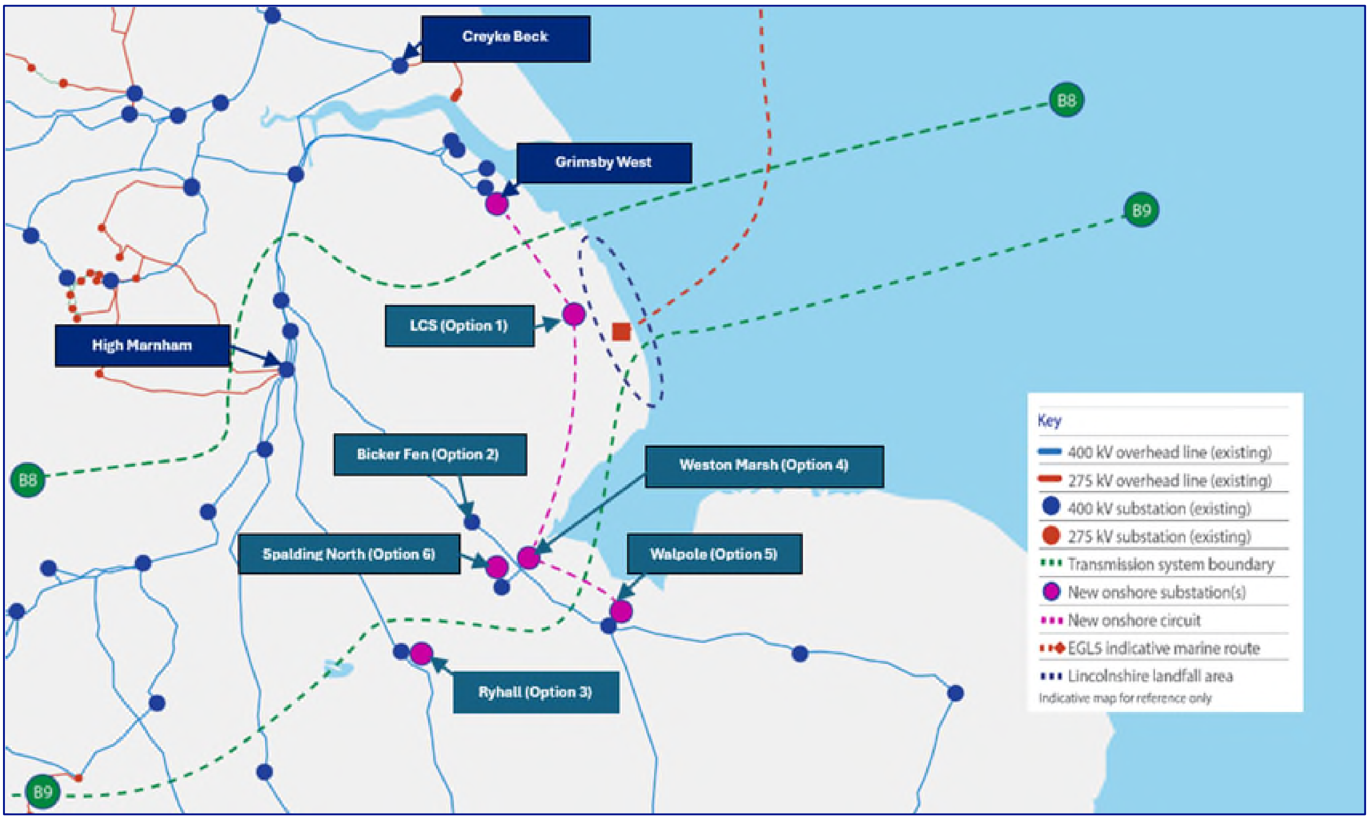
Proposed strategic option title	Option description[1]
Option 1 – Connection to New Lincolnshire Connection Substation(s) (LCS)	546 km new offshore subsea transmission connection
Option 2 – Connection to Bicker Fen	594 km new offshore subsea transmission connection
Option 3 – Connection to New Ryhall	636 km new offshore subsea transmission connection
Option 4 – Connection to New Weston Marsh	600 km new offshore subsea transmission connection

[1] The given length of each “offshore subsea transmission connection” refers to the full length of the project, including onshore infrastructure,

Proposed strategic option title	Option description[1]
Option 5 – Connection to New Walpole	624 km new offshore subsea transmission connection
Option 6 – Connection to New Spalding North	606 km new offshore subsea transmission connection

Figure C below shows the indicative location overview of all strategic options, the B8 and B9 boundaries and the approximate location of the Lincolnshire landfall area.

Figure C – Indicative overview of all strategic options



Review of recommended technology option

Following NESO recommendations for the connection of a new HVDC link in the Humber area, we considered whether an AC based onshore option could be used to address the identified need.

Overall, this option is less preferable as it is expected to result in a greater level of negative environmental and socio-economic impact compared to the subsea HVDC options. Further, it provides limited benefit over those options.

The results of our appraisal of strategic options

We have determined that the preferred strategic option to best address the Project need case and take forward at this stage is Option 1 (LCS). The selection of Option 1 (LCS) as the preferred option is justified by the following points summarising the environmental and socio-economic, technical, and cost appraisal:

- From an environmental and socio-economic perspective, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 1 (LCS). The potential impact on statutory designations is mainly limited to the marine route/landfall and therefore common to all options
- One of the key differentiators between options relates to overall route length which can impact the extent of environmental and socio-economic effects, with Option 1 (LCS) requiring the shortest cable route length.
- From a technical perspective, Option 1 (LCS) resolves the technical need case increasing capacity across the B6, B7a and B8 boundaries. Whilst it does not cross boundary B9 it does provide benefit to it. It also has neutral impact to the East Coast Generation Group.
- From a cost perspective, Option 1 (LCS), with HVDC as the recommended technology, has an estimated capital cost of £2,237.5m and a lifetime circuit cost of £2,437m. Option 1 (LCS) presents the lowest capital and lifetime cost across all options taken forward for appraisal. From a cost perspective, these considerations add significant weight to the interim preference of this option. HVDC technology is well established and does not add uncertainty or constructability risk to the Project.

Conclusions and next steps

This SOR presents the findings of our strategic options appraisal process and is intended to provide a clear justification for our preferred strategic option for the Project. This report demonstrates that we have utilised the need case to consider the potential ways in which the Project could be delivered by generating a number of potential strategic options.

To meet the need for provision of capacity and capability across the B6 and B7a and beneficial capability across B8 and/or B9 system boundaries with neutral connection impact upon the East Coast Generation Group, our proposal at the current stage is to take forward Option 1 (LCS). We will continue to review the work, including any notable changes in circumstances, and will have regard to consultation responses.

The selection of Option 1 (LCS) as the final preferred option is justified above; reference can be made to the previous sections of this executive summary. The Project will now be taken forward to the next stage of development.

This involves preliminary routing and siting work, identification of a preliminary preferred route corridor and siting choice for the converter station and preparation of a graduated swathe, which indicates a more likely location for the development. This will be consulted on at consultation to seek feedback from consultees and help shape the further development of the Project.

1. Introduction

1.1 Purpose of the Strategic Options Report

1.1.1 This Strategic Options Report (SOR) has been prepared by National Grid Electricity Transmission plc (NGET) as part of the ongoing strategic options appraisal and decision-making process involved in promoting new transmission projects. It presents the findings of our options appraisal process and is intended to provide a clear justification and evidence for our decision-making of a preferred strategic option for the EGL 5 Project (the Project). EGL 5 is a new primarily offshore high voltage electricity link, with associated onshore infrastructure, between Scotland and England. EGL 5 is needed as the existing transmission network does not have enough capacity to securely and reliably transport the increasing amount of energy generated in Scotland and Scottish waters, particularly from offshore wind, to population centres in the Midlands and South of England. This report has been prepared in accordance with Our Approach to Consenting[2].

1.1.2 The Government has committed to achieving clean power by 2030, subject to security of supply. The way electricity is generated in the UK is changing rapidly, with a transition to cheaper, cleaner, and more secure forms of energy like new offshore windfarms. We need to make changes to the network of overhead lines (OHLs), pylons, cables, and other infrastructure that transports electricity around the country, so that everyone has access to the clean electricity from these new renewable sources. Details on the need for the Project is described in Chapter 4 of this report.

1.1.3 The consideration of strategic options is part of a process to inform the selection of the preferred option and the Project that is proposed to be consented through the consents application approach set out in Section 3.5. That process will be influenced by considerations of other emerging energy projects and by evolving customer requirements.

1.1.4 As we continue to develop our plans and as our proposals evolve, we keep strategic options under review, taking account of consultation feedback and any changes that might influence the appraisal of technical, environmental, socio-economic, and cost considerations.

1.1.5 As set out in Our Approach to Consenting the following are the key stages in the project development and delivery process for major infrastructure projects:

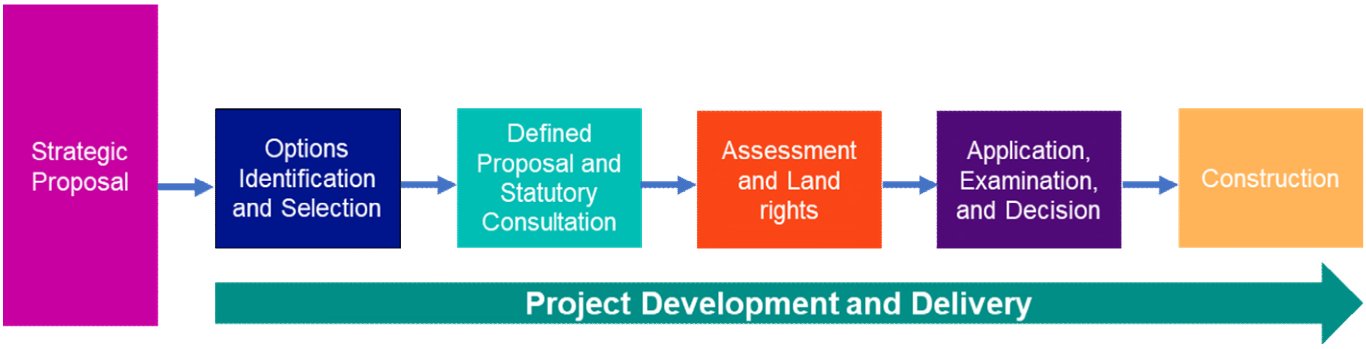
- Strategic Proposal;
- Options Identification and Selection;
- Defined Proposal and Statutory Consultation;
- Assessment and Land Rights;
- Application, Examination and Decision; and

[2] Our Approach to Consenting, National Grid, April 2022
www.nationalgrid.com/electricity-transmission/document/142336/download

- Construction.

1.1.6 The identification of a strategic proposal establishes the scope of the project which commences with Options Identification and Selection. This document forms part of the "Strategic Proposal" and is at the very start of the process as shown in Figure 1.1.

Figure 1.1 – Approach to the consenting process



1.1.7 This report is a key output from the initial stage of our approach to the consenting process, and provides information about scheme development, to support consultation.

1.1.8 As the Project proposals continue to evolve, strategic options will be kept under review, taking account of consultation feedback and any changes that might influence the appraisal of technical, environmental, socio-economic and cost considerations.

1.2 Structure of this Report

1.2.1 The report is structured as follows:

- Chapter 1: Introduction
- Chapter 2: How the electricity system is planned and operated
- Chapter 3: The legislative, policy and regulatory framework
- Chapter 4: The need case for reinforcement of the transmission system
- Chapter 5: Options identification and selection process
- Chapter 6: The results of our appraisal of strategic options
- Chapter 7: Comparison of the appraisal of the strategic options
- Chapter 8: Interaction with other projects
- Chapter 9: Conclusions and next steps

1.2.2 This document is also supported by a detailed set of appendices setting out our obligations, technology assumptions and cost appraisal methodology as follows:

- Appendix A: Glossary
- Appendix B: Summary of National Grid Electricity Transmission legal obligations
- Appendix C: Technology overview
- Appendix D: Economic appraisal
- Appendix E: Mathematical principles used for AC loss calculation

- Appendix F: Beyond 2030 publication
- Appendix G: Onshore alternative option

1.2.3 This SOR is part of an iterative process, investigating prospective opportunities. The conclusions of this report will, in due course, be supplemented by feedback from consultation exercises, along with other elements such as design evolution. Consistent with Our Approach to Consenting, we will continue to assess relevant technical, environmental, socio-economic and cost factors as part of ongoing appraisals.

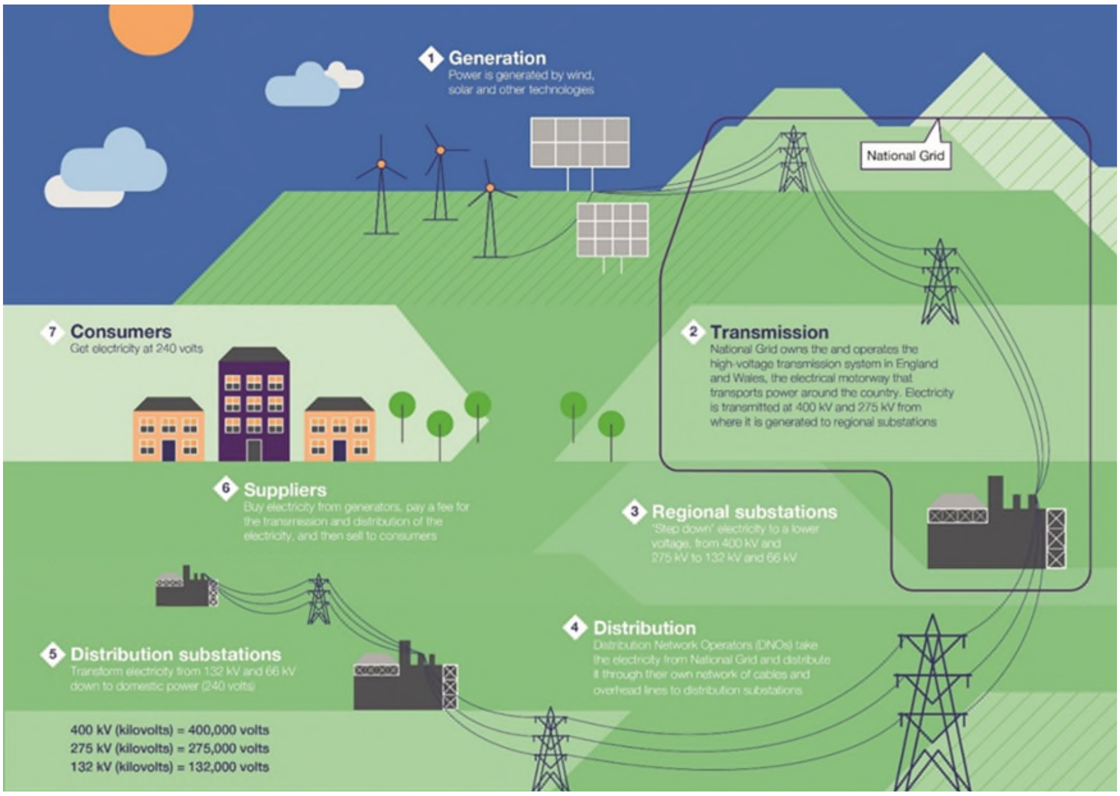
2. How the electricity transmission system is planned and operated

2.1 The transmission system

2.1.1 The electricity transmission system is a means of transmitting electricity around the country from where it is generated to where it is needed. The existing transmission system in Great Britain operates at 400 kV and 275 kV and transports bulk supplies of electricity from generating stations to demand centres. Lower voltage distribution systems operate at 132 kV and below in England and Wales and are mainly used to transport electricity from substations (interface points with the transmission system) to the majority of end customers as presented in Figure 2.1.

> *What is demand?*
>
> *Demand is electricity used by domestic and non-domestic consumers, for example the electricity used within the home or by businesses.*

Figure 2.1 – The electricity system from generator to consumer



2.1.2 There are three Transmission Owners (TOs) for the Great Britain network. NGET is the TO for the transmission network in England and Wales. SP Energy Networks is the TO for Southern Scotland and Scottish and Southern Electricity Networks (SSEN) is the TO for Northern Scotland and Scottish Islands Groups.

2.1.3 The generation directly connected to the electricity transmission system tends to be of two types: low carbon energy (nuclear, wind farms, solar, hydro) and large fossil fuel powered generation. This is also supplemented by new storage technologies such as battery storage.

2.1.4 Substations provide points of connection to the transmission system for power generation stations, distribution networks, transmission connected demand customers (e.g., large industrial customers) and interconnectors. Circuits connect substations on the transmission system. The system is mostly composed of double-circuits (in the case of OHLs carried on two sides of a single pylon) and single-circuits.

What are interconnectors?

Interconnectors are transmission links that connect the electricity networks in two countries to allow for the transfer of electricity across borders. Currently the Great Britain system has interconnectors with France, Netherlands, Belgium and other countries.

2.1.5 Much of the transmission system was originally constructed in the 1960s. Incremental changes to the transmission system have subsequently been made to meet increasing customer demand and to connect new power generation stations and interconnectors with other countries' transmission systems.

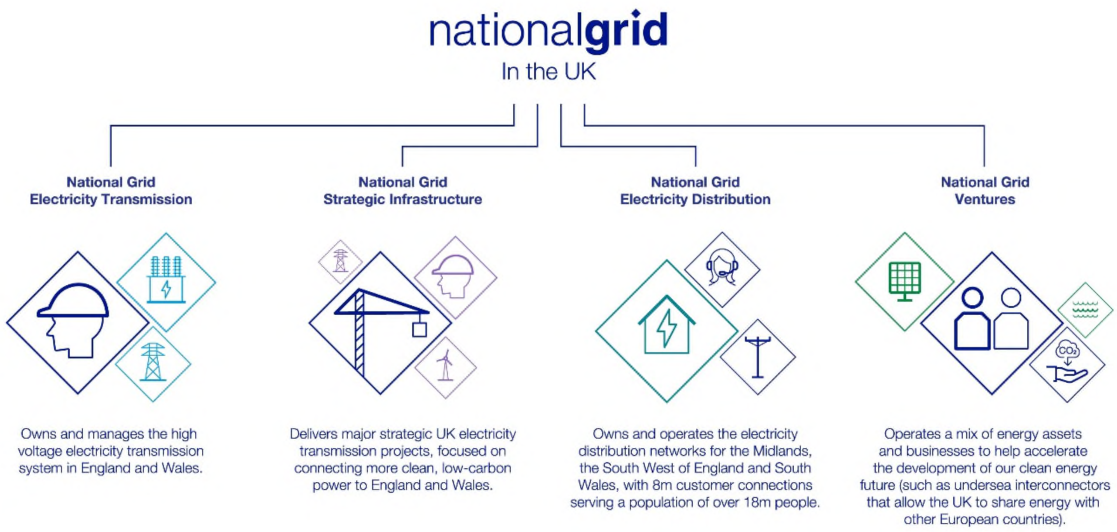
2.1.6 A single electricity market serves the whole of Great Britain. In this competitive wholesale market, generators and suppliers trade electricity on a half hourly basis. Generators produce electricity and sell it in the wholesale market. Suppliers purchase electricity in the wholesale market and supply to end customers.

2.1.7 Electricity can also be traded on the single market in Great Britain by generators and suppliers in other European countries. Interconnectors with transmission systems in France, Belgium, Denmark, the Netherlands and other countries are used to import electricity to and/or export electricity from Great Britain's transmission system.

2.2 Roles and responsibilities

2.2.1 In maintaining and operating the electricity transmission system, there are multiple parties involved. The following sections provide an overview of the roles and responsibilities for the DESNZ, the Office of Gas and Electricity Markets (Ofgem), NGET and National Energy System Operator (NESO).

Figure 2.2 – Roles and Responsibilities within National Grid



2.3 The role of National Grid Electricity Transmission

2.3.1 NGET, as the TO, builds, owns, and maintains the high voltage transmission system in England and Wales and is part of the National Grid Group of companies.

2.3.2 Our transmission system consists of approximately 7,200 km of OHLs and 700 km of underground cabling, operating at 400 kV and 275 kV. In general, 400 kV circuits have a higher power carrying capability than 275 kV circuits. These OHL and underground cable circuits connect around 340 transmission substations forming a highly interconnected transmission system.

2.3.3 Transmission of electricity in Great Britain requires permission by a licence granted under Section 6(1)(b) of the Electricity Act 1989 (as amended) (the Electricity Act). NGET has been granted a transmission licence (the Transmission Licence) and is therefore bound by legal obligations, which are primarily set out in the Electricity Act and the Transmission Licence.

2.3.4 Our legal obligations include duties under Section 9, Section 38 and Schedule 9 of the Electricity Act. In summary, these require us to:

- Develop and maintain an efficient, co-ordinated, and economical system of electricity transmission. This requires us to invest in upgrading the electricity transmission system, delivering new infrastructure such as OHLs and substations that will connect increasing amounts of low carbon power as required to meet future demand and supply as well as wider Energy Policy. This includes working with NESO to help large energy projects connect to the transmission system so their electricity can flow through the network and power homes and businesses.
- When formulating proposals for the installation of electric line or the execution of any other works for or in connection with the transmission or supply of electricity, have regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and

- When formulating such proposals, do what it reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects.

2.4 The role of the Department for Energy Security and Net Zero

2.4.1 The Department for Energy Security and Net Zero (DESNZ) is the ministerial department with primary responsibility for energy. It sets the policy landscape for the United Kingdom. Details of the Government energy policy are described in Chapter 3.

2.4.2 The Secretary of State (SoS) for DESNZ is the ultimate decision maker for new electricity transmission network proposals under the Planning Act 2008 (as amended).

2.4.3 During Spring 2025, this Project will request a direction pursuant to s35 of the 2008 Act from DESNZ to bring the project into the Development Consent Order (DCO) regime. It is intended that a DCO application for the Project would include all English onshore elements of the Project, as well as the offshore elements in English waters by inclusion of a deemed marine licence within the DCO. Should a direction pursuant to s35 of the 2008 Act be issued by the SoS, the Project would be directed into the 2008 Act and therefore a DCO application would be prepared and submitted to the Planning Inspectorate who acts on behalf of the SoS for the relevant department.

2.4.4 Applications for DCOs are submitted to and examined by the Planning Inspectorate and determined by the SoS for DESNZ. Further details are available in Section 3.5

What is net zero?

UK Government's commitment to reduce greenhouse gas emissions to net zero by 2050 as per the Climate Change Act 2008 (2050 Target Amendment) Order 2019. Net zero means any emissions that cannot be avoided would be balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere

2.5 The role of Ofgem

2.5.1 Ofgem (the Office of Gas and Electricity Markets) is the regulator for gas and electricity markets in Great Britain. It is a non-ministerial Government department and an independent National Regulatory Authority, whose role is to protect consumers as a greener, fairer, energy system is delivered.

2.5.2 Ofgem works with Government, industry, and consumer groups to help deliver net zero from an energy perspective at the lowest cost possible to consumers. For NGET, this means reviewing the need case and the associated investment required to deliver large infrastructure projects.

2.5.3 To deliver the investments proposed within the Holistic Network Design (HND), Ofgem has introduced a new regulatory framework known as Accelerated Strategic Transmission Investment (ASTI). This aims to facilitate achieving Government targets by streamlining the regulatory approval and funding process for projects which require acceleration. The HND provides a recommended offshore and onshore design for a

2030 electricity network, that facilitates the Government's ambition for 50GW of offshore wind by 2030. More details on this can be found on the NESO website[3].

2.5.4 In Ofgem's December 2022 decision on accelerating onshore electricity transmission investment[4], it was confirmed that EGL 5 is not currently included in the published list of ASTI projects. NGET working with SSEN plans to submit a delivery plan to Ofgem for review and consideration of EGL 5 being included in the ASTI projects list or within a future regulatory framework to deliver new transmission networks identified as required by NESO.

2.5.5 Should EGL 5 not be included in the ASTI framework, or equivalent, Ofgem will provide instruction to NGET on the regulatory regime which is to be applied to the Project.

2.6 The role of the National Energy System Operator

2.6.1 National Energy System Operator (NESO) is the electricity system operator for Great Britain. NESO ensures electricity is always where it is needed, and the transmission network remains stable and secure in its operation.

2.6.2 As of 1st of October 2024, NESO became a public body owned by the DESNZ. It was formerly part of National Grid PLC and called the Electricity System Operator (ESO).

2.6.3 NESO has been established to act as the independent organisation responsible for planning Britain's energy system, operating the electricity network and offering expert advice to the sector's decision-makers.

2.6.4 Generators apply to NESO when they wish to connect to the network and NESO leads, working with the TOs, to consider how the network may need to evolve to deliver a cleaner greener future. NESO is currently reforming their connection processes to meet the increasing number of projects wanting to connect to the transmission system.

2.6.5 NESO, in undertaking this role, engages with NGET for England and Wales as well as the two TOs in Scotland, SSEN and SP Energy Networks.

2.6.6 NESO delivers multiple roles across the electricity system. These are explained in sections below.

- Electricity market balancing: NESO ensures that electricity demand and supply is balanced on a second-by-second basis and manages any shortfalls in boundary capacity by reducing power flows and constraining generation.

> *What is a boundary?*
>
> *A boundary notionally splits the system into two parts, crossing critical circuit paths that carry power between the areas where power flow limitations may be encountered. NESO can manage any shortfall in boundary capacity by reducing the power flows. This is achieved by constraining generation and paying for generators to reduce output.*

[3] A Holistic Network Design for Offshore Wind, NESO, July 2022
https://www.neso.energy/publications/beyond-2030/holistic-network-design-offshore-wind

[4] Decision on accelerating onshore electricity transmission development, Ofgem, December 2022
https://www.ofgem.gov.uk/publications/decision-accelerating-onshore-electricity-transmission-investment

- Future Energy Scenarios: NESO undertakes an annual process to publish the Future Energy Scenarios (FES) which takes energy industry views as part of a consultation process and develops a set of possible energy growth scenarios to 2050. In developing FES, NESO takes into consideration the latest pipeline of connections as detailed within the Transmission Entry Capacity (TEC) Register.
- Network planning: ESO also facilitated an annual process to publish the Electricity Ten Year Statement (ETYS) setting out the network performance and requirements for all transmission in Great Britain over the next 10 years based on the data from the FES. ESO used the ETYS to publish annually the Network Options Assessment (NOA), which considers the economic case for options to reinforce the transmission system and makes economic recommendations. The NOA undertakes a Cost Benefit Analysis (CBA) process to determine when it is right to take forward options proposed by TOs to increase network capacity. This considers the capital costs of the proposal, delivery timescales and constraint costs (as explained in Chapter 5) avoided by delivering the proposal. This establishes when a proposed reinforcement becomes the most economical way to deliver value to Great Britain's energy consumers.
- Network Planning Review (NPR): The Pathway to 2030 Holistic Network Design (HND) and the recommendations set out in the most recent Network Options Assessment (NOA) prepared by ESO were the first steps towards a more centralised, strategic network planning approach that is critical for delivering affordable, clean and secure power, with a view to achieving net zero.
- NESO is currently transitioning from the NOA to a more comprehensive approach, a Centralised Strategic Network Plan (CSNP). The CSNP will aim to foster the holistic development of the NETS, marking a new era in our network planning.
- Connections: NESO facilitates several roles on behalf of the electricity industry, including making formal offers to connection applicants to the electricity transmission system. NGET is obligated to provide the physical connections to the elements of the electricity transmission system that NGET own.

2.6.7 The planning activities undertaken by NESO are currently being updated to support the delivery of the Government's net-zero commitment. In 2022, ESO published the HND setting out an integrated approach to transmission network design that supports the large-scale delivery of electricity generated from offshore wind by 2030.

2.6.8 As it stands, the HND recommendations are not sufficient by themselves to reinforce the transmission system, as more electricity will be generated than the network can efficiently support and transport. Therefore, the UK Government requested ESO to further develop the HND and enable a set of recommendations to allow a greater amount of offshore wind generation to connect to the network.

2.6.9 The further development of the HND, known as HND FUE (HND Follow Up Exercise), was published by ESO in 2024, in a report titled 'Beyond 2030'. More detail is provided in Appendix F.

3. The legislative, policy and regulatory framework

3.1 Overview

3.1.1 We are under a legal duty to maintain an efficient, economic, and co-ordinated energy transmission system. This section of the report provides further detail of the legal duties and the wider policy context to which we operate within including Government energy policy and national planning policy. This includes ensuring that the delivery of energy is affordable, our networks are resilient, and enable transition to a net zero carbon economy having regard to the environment and society that we operate in.

3.2 Why is NGET required to reinforce the transmission system?

3.2.1 Our duties are placed upon us by the Electricity Act 1989 ('the Electricity Act') and under the terms of our Transmission Licence. Those duties, and terms of particular relevance to the development of the proposed connection described in this report are set out below.

3.2.2 As part of our Transmission Licence requirements, the transmission infrastructure needs to be capable of providing and maintaining a minimum level of security and quality of supply and of transporting electricity from and to customers. We are required to ensure that the transmission system remains capable as customer requirements change.

3.2.3 The capacity of the transmission system is based on the physical ability of electrical circuits to carry power. Each circuit has a defined capacity and the total capacity of the circuits in a region or across a boundary is the sum of all of the capacity of all the circuits.

3.2.4 The capability of the transmission system is the natural flow of energy that can occur in the infrastructure comprising the network. Due to the physical properties of the transmission system, this is often not as great as the theoretical capacity of the infrastructure in question.

3.2.5 The transmission system needs to cater for demand, generation and interconnector changes. These customers can apply to NESO for new or modified connections to the transmission system. The relevant transmission owner must then assess the generation group to ensure that the transmission system is sufficient in the area to accommodate the existing and proposed generation. Upon completion of the assessment, NESO will make a formal offer of connection.

3.2.6 Where power flows are constrained by the transmission system across a specific number of circuits, this is termed a ‘boundary’ by NESO. Such boundaries are used in the ETYS to identify constraints which may require changes to the transmission system in the next 10 years. Where the ‘boundary capacity’ is exceeded against the standards of the Security and Quality of Supply Standard (SQSS), we must resolve the capacity shortfall.

What is the SQSS?

It is an industry standard that sets out the criteria and methodology for planning and operating the onshore and offshore electricity transmission system. It details the planning criteria for the connection of generation and demand groups onto the transmission system. It defines the performance required of the transmission system in terms of Quality and Security of Supply for secured events. This means that at all times:

- *Electricity system frequency should be maintained within statutory limits;*
- *No part of the National Electricity Transmission System (NETS) should be overloaded beyond its capability;*
- *Voltage performance should be within acceptable statutory limits; and*
- *The system should remain electrically stable.*

NESO is the code administrator of the SQSS and there is a panel made up of industry experts that are responsible for ensuring that the SQSS is up to date and manages any changes. Any changes to the SQSS are overseen by Ofgem.

3.2.7 Where capacity and capability of the transmission system are not sufficient, either from a generation group or across a boundary, we are required to reinforce the network. We do this by either modifying the existing network (if possible) and / or constructing additional transmission infrastructure to resolve the shortfall.

3.3 Our statutory duties

3.3.1 This section details the statutory duties most relevant to the development of new infrastructure. These duties are considered in NGET's approach to identifying options and the selection process. This is shown in NGET's review of potential strategic options and the application of the appraisal factors, as reported in Chapter 5 of this report.

Electricity Act 1989

3.3.2 When developing new infrastructure, NGET is required to comply with the following duties.

3.3.3 Section 9(2) of the Electricity Act (General duties of licence holders) states:

"*it shall be the duty of the holder of a licence authorising him to participate in the transmission of electricity: (a) to develop and maintain an efficient, co-ordinated and economical system of electricity transmission…;"*

3.3.4 Section 38 and Schedule 9 of the Electricity Act state that:

"(1) In formulating any relevant proposals, a licence holder…

- (a) shall have regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and

- (b) shall do what he reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects."

National Parks and Access to the Countryside Act 1949

3.3.5 Section 11A (1A) of the National Parks and Access to the Countryside Act 1949 imposes a duty on certain bodies and persons in respect of National Parks. National Grid, for the purpose of this provision, is a 'relevant authority' by virtue of being a 'statutory undertaker' such that the duty applies to it. The duty provides as follows:

3.3.6 *"(1A) In exercising or performing any functions in relation to, or so as to affect, land in any National Park in England, a relevant authority other than a devolved Welsh authority must seek to further the purposes specified in section 5(1) and if it appears that there is a conflict between those purposes, must attach greater weight to the purpose of conserving and enhancing the natural beauty, wildlife and cultural heritage of the area comprised in the National Park."* Section 5 sets out the statutory purposes of the National Park, as follows:

"(1) The provisions of this Part of this Act shall have effect for the purpose—

(a) of conserving and enhancing the natural beauty, wildlife and cultural heritage of the areas specified in the next following subsection; a*nd*

(b) of promoting opportunities for the understanding and enjoyment of the special qualities of those areas by the public."

Countryside and Rights of Way Act 2000

3.3.7 Section 85 of the Countryside and Rights of Way Act 2000 imposes a duty on public bodies in respect of areas of outstanding natural beauty. National Grid, for the purpose of this provision, is a 'relevant authority' by virtue of being a 'statutory undertaker', such that the duty applies to it. The duty provides as follows:

"(A1) In exercising or performing any functions in relation to, or so as to affect, land in an area of outstanding natural beauty in England, a relevant authority other than a devolved Welsh authority must seek to further the purpose of conserving and enhancing the natural beauty of the area of outstanding natural beauty."

Natural Environment and Rural Communities Act 2006

3.3.8 Section 40 of the Natural Environment and Rural Communities Act 2006 imposes a duty to conserve and enhance biodiversity. National Grid, for the purposes of this provision, is a 'public authority' by virtue of being a 'statutory undertaker' such that this duty applies to it. The duty provides as follows:

"(A1) For the purposes of this section "the general biodiversity objective" is the conservation and enhancement of biodiversity in England through the exercise of functions in relation to England.

(1) A public authority which has any functions exercisable in relation to England must from time to time consider what action the authority can properly take, consistently with the proper exercise of its functions, to further the general biodiversity objective."

Wildlife and Countryside Act 1981

3.3.9 Section 28G of the Wildlife and Countryside Act 1981 imposes a duty on 'statutory undertakers' in respect of sites of special scientific interest. The duty provides as follows:

"(1) An authority to which this section applies (referred to in this section and in sections

28H and 28I as “a section 28G authority”) shall have the duty set out in subsection (2) in exercising its functions so far as their exercise is likely to affect the flora, fauna or geological or physiographical features by reason of which a site of special scientific interest is of special interest.

(2) The duty is to take reasonable steps, consistent with the proper exercise of the authority’s functions, to further the conservation and enhancement of the flora, fauna or geological or physiographical features by reason of which the site is of special scientific interest.”

3.4 Government energy policy

3.4.1 In 2019, the UK Government committed to achieving net zero greenhouse gas emissions by 2050. In July 2024 a General Election was held, which led to a change in UK Government, although the 2050 target for net zero greenhouse emissions remains in place. In addition, the UK Government has committed to achieving a net zero electricity system by 2030.

3.4.2 These commitments require the UK to move away from fossil fuels and to adopt alternative sources of energy to power our homes, transport and businesses. The Government has set out how it plans to deliver on these commitments within multiple plans including:

- December 2020: Prime Minister’s Ten Point Plan for a Green Industrial Revolution.
- December 2020: Energy White Paper: Powering our Net Zero Future.
- October 2021: Net Zero Strategy: Build Back Greener.
- April 2022: British Energy Security Strategy (BESS). This document is built on the Net Zero Strategy and was published in response to the Russian invasion of Ukraine and the 2022 energy price crisis.
- March 2023: Powering Up Britain and Powering Up Britain: Energy Security Plan. This document provides an update of the strategy for secure, clean and affordable British energy for the long-term future.
- December 2024: Clean Power 2030 Action Plan: A new era of clean electricity. This document provides the strategic initiative aimed at transitioning to cleaner energy sources and reducing carbon emissions.

3.4.3 Key ambitions made within these plans to achieve net zero include:

- Up to 50 GW of offshore wind connected by 2030 including 5 GW of which will be offshore floating wind.
- Up to 8 reactors of nuclear energy being progressed reaching up to 24 GW to be achieved by 2050.
- Up to 10 GW of low carbon hydrogen production capacity by 2030, doubling the previous ambition.
- 600,000 heat pump installations a year by 2028 and improving housing stock insulation.

3.4.4 Key commitments that were made by the UK Government in the Powering Up Britain Strategy with regards to electricity network development include those listed below.

- For the appointed Electricity Networks Commissioner to provide recommendations to Government in June 2023 on how grid delivery can be accelerated.
- To work with industry and Ofgem to reform the grid connections process, including publishing a connections action plan in 2023.
- Undertake a Review of the Electricity Market Arrangements (REMA) and consult in Autumn 2023 on the reforms required to bring forward low carbon generation.
- To publish five revised energy National Policy Statements (NPS) covering Renewables, Oil and Gas Pipelines, Electricity Networks and Gas Generation, and an overarching Energy Statement for consultation. The transmission infrastructure that falls within EN-5 is considered “critical national infrastructure”. The updated NPSs came into force on 17 January 2024 so will therefore apply to the Project. Further details regarding the relevant NPSs for the Project are provided in the sections below.

3.5 Consenting regimes, national and marine planning policy

3.5.1 This project does not automatically qualify as a Nationally Significant Infrastructure Project (NSIP) under s14 of the Planning Act 2008 (“the 2008 Act”). However, the project will request a direction pursuant to s35 of the 2008 Act from the Secretary of State (SoS) for Energy Security and Net Zero (DESNZ) during Spring 2025, to bring the project into the Development Consent Order (DCO) regime. It is intended that a DCO application for the project would include all English onshore elements of the Project, as well as the offshore elements in English waters by inclusion of a deemed marine licence within the DCO. Should a direction pursuant to s35 of the 2008 Act be issued by the SoS, the project would be directed in to the 2008 Act and therefore a DCO application would be prepared and submitted to the Planning Inspectorate who acts on behalf of the SoS for the relevant department. This section therefore assumes that this Project will be a DCO application including a Deemed Marine Licence and therefore details the relevant planning policy.

3.5.2 Five NPS for energy infrastructure were designated by the Secretary of State for Energy and Climate Change in November 2023 and confirmed by Parliament in January 2024. The relevant NPS for electricity transmission infrastructure developments are the Overarching National Policy Statement for Energy (EN-1), National Planning Policy Statement for Renewable Energy Infrastructure (EN-3) and the National Policy Statement for Electricity Networks Infrastructure (EN-5), both EN-3 and EN-5 are read in conjunction with EN-1. This Project would be supported as a ‘Critical National Priority’ by the NPSs.

3.5.3 Section 104(3) of the Planning Act 2008 states that the decision maker must determine an application for a DCO in accordance with any relevant NPS, except in certain specified circumstances (such as where the adverse impact of the proposed development would outweigh its benefits). The energy NPS therefore provide the primary policy basis for decisions on DCO applications for electricity transmission projects. The NPS may also be a material consideration for decisions on other types of development consent in England and Wales (including offshore wind generation projects) and for planning applications under the Town and Country Planning Act 1990, for which the National Planning Policy Framework 2024 (NPPF) would be the relevant national planning policy document. The NPPF sets out the government’s planning policies for England and how these are expected to be applied. Section 104 (2) (aa) of the Planning Act 2008 requires the Secretary of State to have regard to any appropriate marine policy documents when making a decision on an application for a DCO where an NPS has effect

Summary of the relevant National and Marine Policy Statements

3.5.4 A summary of the relevant National Policy Statements is set out below. After a short summary of each relevant document, the report will consider key issues around need and assessment principles as outlined in these documents.

Overarching National Policy Statement for Energy (EN-1)

3.5.5 Section 1.3.10 of EN-1, states that in conjunction with any relevant technology specific NPS, EN-1 will be the primary policy for Secretary of State decision making on projects in the field of energy including those for which a direction has been given under s35 of the Planning Act 2008.

3.5.6 Section 3.3 of EN-1 sets out the need for new nationally significant electricity infrastructure and section 4.5.10 identifies the need to have regard to any appropriate marine policy documents, including Marine Plans, in decision making for DCOs.

3.5.7 Section 4.2 of EN-1 applies a policy presumption that, subject to any legal requirements (including under section 104 of the Planning Act 2008), the urgent need for Critical National Priority (CNP) Infrastructure to achieve energy objectives, together with the national security, economic, commercial, and net zero benefits, will in general outweigh any other residual impacts not capable of being addressed by application of the mitigation hierarchy.

National Planning Policy Statement for Renewable Energy Infrastructure (EN-3)

3.5.8 This NPS also has relevance to the Project, in the view of the need for the Project to reinforce boundary flows and facilitate future connections from offshore wind.

3.5.9 Section 1.6.3 confirms that EN-3 will apply to offshore transmission infrastructure projects in English waters which are directed into the NSIP regime under s35 of the Planning Act 2008.

National Planning Policy Statement for Electricity Networks Infrastructure (EN-5)

3.5.10 Paragraph 1.6.4 confirms that it also applies to developments that require development consent pursuant to s35 of the Planning Act 2008. EN-5 has relevance to the project as its scope includes electricity grid infrastructure, including network reinforcement and upgrade works and associated infrastructure such as substations

Marine Policy Statement (MPS) and Marine Plan

3.5.11 The Marine Policy Statement was adopted in 2011 and provides the policy framework for the preparation of Marine Plans and establishes how decisions affecting the marine area should be made. It has been implemented to contribute to the achievement of sustainable development in the United Kingdom marine area and has been prepared and adopted for the purposes of Section 44 of the Marine and Coastal Access Act 2009.

3.5.12 The Marine Policy Statement will be considered in the development of this Project in particular within the chapters relating to the Offshore Scheme.

3.5.13 The following Marine Plans will be considered in the preparation of assessments relating to this Project: East Inshore Marine Plan and East Offshore Marine Plan, April 2014.

Demonstrating the need for a project

3.5.14 Part 3 of EN-1 sets out Government policy on the need for new nationally significant energy infrastructure projects. Paragraphs 3.2.1 and 3.2.2 confirm that the UK needs a range of the types of energy infrastructure covered by the NPS to ensure the supply of energy always remains secure, reliable, affordable, and consistent with achieving net zero emissions in 2050 for a wide range of future scenarios. Paragraph 3.2.7 states that "substantial weight" should be given to the urgent need for the types of infrastructure covered by the NPS when considering applications for DCOs.

3.5.15 Description of the need for:

- new electricity transmission infrastructure is set out in EN-1 and EN-5
- new offshore/onshore wind generation is set out in EN-1 and EN-3, and
- new nuclear generation is set out in EN-1 and EN-6.

3.5.16 The need for new transmission infrastructure for this Project is described in Chapter 4 of the SOR.

Assessment principles applied by decision maker

3.5.17 Part 4 of EN-1 sets out the general policies that are applied in determining DCO applications relating to new energy infrastructure. Part 2 of EN-5 sets out the assessment principles in the specific context of electricity networks infrastructure.

3.5.18 There are a number of key principles of particular importance for transmission infrastructure projects.

Presumption in favour of development

3.5.19 Section 4.1 of EN-1 confirms that the Secretary of State will start with a presumption in favour of granting consent for energy NSIPs. This presumption applies unless any more specific and relevant policies set out in the relevant NPS clearly indicate that consent should be refused. The presumption is also subject to the exceptions set out in Section 104(2) of the Planning Act 2008. In assessing any application, the Secretary of State should take account of potential:

- benefits (e.g. the contribution to meeting the need for energy infrastructure, job creation, reduction of geographical disparities, environmental enhancements, and long term or wider benefits), and
- adverse impacts (including on the environment, and including any long-term and cumulative adverse impacts, as well as any measures to avoid, reduce, mitigate or compensate for any adverse impacts, following the mitigation hierarchy).

The critical national priority for low carbon infrastructure

3.5.20 Section 4.2 of EN-1 states that there is a CNP for the provision of nationally significant low carbon infrastructure. EN-1 confirms that the CNP extends to all power lines in scope of EN-5 (including network reinforcement and upgrade works, and associated infrastructure such as substations), CNP is not limited to infrastructure associated specifically with a particular generation technology.

3.5.21 Paragraph 4.2.7 explains that the CNP policy is relevant during Secretary of State decision making in reference to any residual impacts. Where the required assessment has been provided by an applicant, the CNP policy applies a starting assumption that CNP Infrastructure will meet tests such as:

- Where development within a Green Belt requires very special circumstances to justify development,
- where development within or outside a SSSI requires the benefits (including need) of the development in the location proposed to clearly outweigh both the likely impact on features of the site that make it a SSSI, and any broader impacts on the national network of SSSIs,
- where development in nationally designated landscapes requires exceptional circumstances to be demonstrated, and
- where substantial harm to or loss of significance to heritage assets should be exceptional or wholly exceptional.

3.5.22 The Secretary of State is required by the Habitats Regulations to consider whether a plan or project has the potential to have an adverse effect on the integrity and features of a site which is part of the National Site Network or a European Site. 'European Sites' include Special Protection Areas (SPA) and Special Areas of Conservation (SAC). The Habitats Regulations require an Appropriate Assessment if a project is likely to have a significant effect on a National Site Network site or a designated European site.

3.5.23 NGET, under Section 126 (6) of the Marine and Coastal Access Act must also satisfy the MMO that the project will not hinder the achievement of the Conservation Objectives stated for any Marine Conservation Zone (MCZ) the project might have the potential to impact upon.

3.5.24 There are three stages to the MCZ assessment process including:

- Screening (the process of identifying whether S.126 should apply to the proposed development and whether the activity is capable of affecting (other than insignificantly) either the protected features of the MCZ or the ecological or geomorphological processes on which the protected features are dependent;
- Stage 1 assessment, which considers whether there is a significant risk of the activity hindering the achievement of the Conservation Objectives stated for the MCZ;
- Stage 2 assessment, which considers whether there are benefits to the public of proceeding with the project that clearly outweigh the damage to the environment and what measures the applicant will take to provide equivalent environmental benefit to compensate for the damage which the project will have on the MCZ.

3.5.25 Paragraphs 4.2.18 to 4.2.22 set out the approach to be taken to CNP Infrastructure in the context of a Habitats Regulations Assessment (HRA) or a Marine Conservation Zone Assessment (MCZA):

- Any HRA or MCZA residual impacts will continue to be considered under existing frameworks.

- Where, following Appropriate Assessment or MCZA, CNP Infrastructure has residual adverse impacts on the integrity of sites forming part of the UK national site network, either alone or in combination with other plans or projects, or which significantly risk hindering the achievement of the stated conservation objectives for the MCZ (as relevant) the Secretary of State will consider making a derogation.
- In that consideration, the Secretary of State will start from the position that energy security and decarbonising the power sector to combat climate change:
  - requires a significant number of deliverable locations for CNP Infrastructure and for each location to maximise its capacity, with the fact that there are other potential plans or projects deliverable in different locations to meet the need for CNP Infrastructure being unlikely to be treated as an alternative solution and the existence of another way of developing the proposed plan or project which results in a significantly lower generation capacity being unlikely to meet the objectives and therefore be treated as an alternative solution, and
  - are capable of amounting to Imperative Reasons of Overriding Public Interest (IROPI) for HRAs, and, for MCZ assessments, the benefit to the public is capable of outweighing the risk of environmental damage, for CNP Infrastructure.
  - For HRAs, where an applicant has shown there are no deliverable alternative solutions, and that there are IROPI, compensatory measures must be secured as part of a derogation.
  - For MCZs, where an applicant has shown there are no other means of proceeding which would create a substantially lower risk, and the benefit to the public outweighs the risk of damage to the environment, the Secretary of State must be satisfied that Measures of Equivalent Environmental Benefit (MEEB) will be undertaken.

Consideration of Alternatives

3.5.26 Section 4.3 of EN-1 states that, from a planning policy perspective alone, there is no general requirement to consider alternatives or to establish whether the proposed project represents the best option. However, in relation to electricity transmission projects, paragraph 2.9.14 of EN-5 states:

"Where the nature or proposed route of an overhead line will likely result in particularly significant landscape and visual impacts, as would be assessed through landscape, seascape and visual impact assessment, the applicant should demonstrate that they have given due consideration to the costs and benefits of feasible alternatives to the overhead line. This could include – where appropriate – re-routing, underground or subsea cables and the feasibility e.g. in cost, engineering or environmental terms of these."

3.5.27 Section 4.3 of EN-1 also makes clear that there will be circumstances where an applicant is specifically required to include information in their application about the main alternatives that were considered. These circumstances may include requirements in relation to compulsory acquisition and habitats sites.

Good design

3.5.28 Section 4.7 of EN-1 stresses the importance of 'good design' for energy infrastructure, explaining that this goes beyond aesthetic considerations as fitness for purpose and sustainability are equally important. It is acknowledged in EN-1 that the nature of much energy infrastructure development will often limit the extent to which it can contribute to the enhancement of the quality of the area.

3.5.29 Section 2.4 of EN-5 highlights that the Secretary of State should bear in mind that electricity networks infrastructure must in the first instance be safe and secure, and that the functional design constraints of safety and security may limit an applicant's ability to influence the aesthetic appearance of that infrastructure.

Climate change adaptation and resilience

3.5.30 Section 4.10 of EN-1 explains how climate change adaptation and resilience should be taken into account, requiring the assessment of the impacts on and from the proposed energy project across a range of climate change scenarios. Section 2.3 of EN-5 expands on this in the specific context of electricity networks infrastructure. This states that DCO applications are required to set out the vulnerabilities / resilience of the proposals to flooding, effects of wind and storms on overhead lines, higher average temperatures leading to increased transmission losses, earth movement or subsidence caused by flooding or drought (for underground cables) and coastal erosion (for the landfall of offshore transmission cables and their associated substations in the inshore and coastal locations respectively).

Networks DCO applications submitted in isolation

3.5.31 Section 2.7 of EN-5 confirms that it can be appropriate for DCO applications for new transmission infrastructure to be submitted separately from applications for the generation that this infrastructure will serve. Section 2.8 of EN-5 explains that, where an application is a reinforcement project in its own right and does not accompany an application for a generating station, or is not underpinned by a "contractually-supported agreement" to provide an as-yet-unconsented generating station with a connection, the Secretary of State should have regard to the need case for new electricity networks infrastructure set out in Section 3.3 of EN-1.

Electricity Act duties

3.5.32 Paragraphs 2.8.4 and 2.8.5 of EN-5 recognise developers' duties pursuant to section 9 of the Electricity Act to bring forward efficient and economical proposals in terms of network design, as well as the duty to facilitate competition and so provide a connection whenever and wherever one is required.

Adverse impacts and potential benefits

3.5.33 Part 5 of EN-1 covers the impacts that are common across all energy NSIPs and sections 2.9-2.15 of EN-5 consider impact in the specific context of electricity networks infrastructure.

3.5.34 Those impacts identified in EN-1 include air quality and emissions, greenhouse gas emissions, biodiversity and geological conservation, civil and military aviation and defence interests, coastal change (to the extent in or proximate to a coastal area), dust, odour, artificial light, smoke, steam and insect infestation, flood risk, historic environment, landscape and visual, land use, noise and vibration, socio-economic impacts, traffic and transport, resource and waste management and water quality and resources. The extent to which these impacts are relevant to a particular stage of a project or are a relevant differentiator at a particular stage of the options appraisal process, will vary. In particular, some of these impacts are scoped out of this stage of the options appraisal process for this project.

3.5.35 EN-5 considers specific potential impacts associated with electricity networks, including the following topics: biodiversity and geological conservation, landscape and visual, noise and vibration, electric and magnetic fields and sulphur hexafluoride.

3.5.36 Landscape and Visual impacts are of particular relevance for electricity transmission infrastructure projects. Paragraph 2.9.7 of EN-5 states that the Government does not believe that development of overhead lines is incompatible in principle with the statutory duty under section 9 of the Electricity Act 1989 to have regard to visual and landscape amenity and to reasonably mitigate impacts. While paragraph 2.9.20 of EN-5 states that use of overhead lines as transmission technology should be the strong starting presumption for electricity networks developments, EN-5 recognises that in practice overhead lines can give rise to adverse landscape and visual impacts, dependent upon their type, scale, siting, degree of screening and the nature of the landscape and local environment through which they are routed. It also confirms that the presumption is reversed when crossing part of a nationally designated landscape.

3.5.37 In relation to alternative technologies for electricity transmission projects, paragraph 2.9.22 of EN-5 states in relation to developments crossing a nationally designated landscape that:

"undergrounding will not be required where it is infeasible in engineering terms, or where the harm that it causes (see section 2.11.4) is not outweighed by its corresponding landscape, visual amenity and natural beauty benefits."

3.5.38 Similarly, paragraph 2.9.24 of EN-5 states in relation to developments that do not cross a nationally designated landscape that:

“taking account of the fact that the government has not laid down any further rule on the circumstances requiring use of underground or subsea cables, the Secretary of State must weigh the feasibility, cost, and any harm of the undergrounding or subsea option against: the adverse implications of the overhead line proposal; the cost and feasibility of re-routing overhead lines or mitigation proposals for the relevant line section; and the cost and feasibility of the reconfiguration, rationalisation, and/or use of underground or subsea cabling of proximate existing or proposed electricity networks infrastructure.”

3.5.39 This SOR (Strategic Options Report) also includes an onshore OHL option alternative, more details can be found in Appendix G and Paragraph 2.9.16 of EN-5 confirms that the Holford Rules, which are a set of "common sense" guidelines for routeing new overhead lines should be embodied in applicants’ proposals. The Horlock Rules deal in a similar fashion with the siting of new substations and similar infrastructure. Paragraph 2.11.2 goes on to state that the Secretary of State should be satisfied that the development, so far as is reasonably possible, complies with the Holford Rules and Horlock Rules.

3.6 Consenting risk

3.6.1 Consenting risk is not considered as a differentiating factor at strategic optioneering stage to the extent that it is material to the identification of the preferred connection option. Whilst a longer onshore cable route could be considered to produce a greater consenting risk in relation to an assumed larger number of constraints and stakeholders, other connection options may be subject to potential cumulative impacts from multiple developer connections including in and around the identified landfall options.

3.6.2 On balance, whilst there are consenting risks and opportunities associated with each option, none have been considered as material to the identification of a preferred connection option. As above, the intention is to request a direction pursuant to s35, to consent the Project as a NSIP under the Planning Act 2008 including a Deemed Marine Licence which is considered the primary means of managing any consenting risks associated with the identification of the preferred connection option, on the basis that it allows for greater coordination with other developments and ensures a more streamlined approach to consenting the various elements of the Project.

3.7 Security and Quality of Supply Standard

3.7.1 NGET must comply with section 9 of the Electricity Act and Standard Condition D3 (Transmission system security standard and quality of service) of NGET's Transmission Licence. This means that where the boundary capacity of the Main Interconnected Transmission System (MITS) is exceeded against the standards, NGET must resolve the capacity shortfall under the terms of its Transmission Licence. The standards against which NGET assesses these shortfalls are set out in the "Design of the Main Interconnected Transmission System" section of the NETS SQSS[5].

3.7.2 The NETS SQSS also sets out in "Generation Connection Criteria applicable to the onshore transmission system" that connections to the transmission system must be secured to meet the identified requirements. Where the Generation Connection Criteria of the SQSS applies, the generator(s) are considered part of a "generation group" for assessment against these criteria.

What is a generation group

A generation group consists of a number of existing generating stations and / or proposed generating stations connecting in a particular geographical area of the transmission system.

3.7.3 Generators apply to NESO for connections to the NETS in Great Britain. If the application is for an onshore generation connection, the applicant will indicate the specific location of the generating station, which will indicate the likely geographical connection to the transmission system. If an application is made for a generation connection or impacts multiple TOs, NESO will co-ordinate a process involving the relevant stakeholders to determine the preferred connection option.

3.7.4 NESO ensures the relevant onshore or offshore transmission owner undertakes generation connection process studies via the relevant process and makes a connection offer to the customer for a connection point and identifies the relevant infrastructure work needed to make the connection. Once this offer is signed the connection is recorded on the TEC Register and forms a contractually binding connection location and timescale with which the TO, such as NGET, is required to connect the generation customer or undertake the works to facilitate their connection.

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[5] National Electricity Transmission System Security and Quality of Supply Standard, NESO https://www.neso.energy/industry-information/codes/security-and-quality-supply-standard-sqss

3.7.5 A connection offer will normally be given in respect of a particular geographical area. Sometimes this leads to a presumption as to the connection point located on the existing transmission network. In other circumstances where there is no or little existing transmission infrastructure, this will require the provision of new transmission infrastructure to facilitate the connection. The post connection offer assessment process enables further evaluation of the preferred connection option and refinement of the preferred overall transmission solution. This process continues, informed by evolving circumstances and consultation, until an application is submitted for development consent in relation to a transmission project.

3.7.6 NGET assess the adequacy of the Project's transmission system in accordance with the method defined in the SQSS. We are required to assess power flows between regions of the transmission system (Planned Transfers). The Planned Transfer from the region is calculated by taking the Average Cold Spell (ACS) Peak Demand in the region and generation following the modelling set out in the SQSS. The Planned Transfer is therefore the amount of power which will flow out of the region at ACS peak. Planned Transfer calculations will always consider the power flows for ACS peak demand conditions, as less generation will be entering the market when demand is lower.

3.7.7 Any transmission system is susceptible to faults that interfere with the ability of transmission circuits to carry power. Most faults are temporary, many are related to weather conditions such as lightning or severe weather, and many circuits can be restored to operation automatically in minutes after a fault. Other faults may be of longer duration and would require repair or replacement of failed electrical equipment.

3.7.8 Whilst some of these faults may be more likely than others, faults may occur at any time, and it would not be acceptable to have a significant interruption to supplies as a result of specified fault conditions, including combinations of faults. The principle underlying the SQSS is that the NETS should have sufficient spare capability or "redundancy" such that fault conditions do not result in widespread supply interruptions. The level of security of supply has been determined to ensure that the risk of supply interruptions is managed to a level that maintains a minimum standard of transmission system performance. The faults we need to design the system to be compliant with are called "Secured Events".

4. The need case for reinforcement to the transmission system

4.1 Background

4.1.1 The electricity industry in Great Britain is undergoing unprecedented change. Closure of fossil fuel burning generation and end of life nuclear power stations means significant additional investment in new sustainable generation and interconnection capacity will be needed to ensure existing minimum standards of security and supply are maintained.

4.1.2 Growth in onshore green technologies, offshore wind generation and interconnectors with Europe has seen a significant number of connections planned in Scotland, England and, significantly, in areas of the East Coast of England.

4.1.3 The Climate Change Act 2008 (as amended) now commits the UK Government by law to reducing greenhouse gas emissions by at least 100% from the 1990 baseline by 2050, strengthening the likelihood that increasing numbers of these connections will progress to delivery. This 2050 target is commonly known as ‘Net Zero’.

4.1.4 To achieve Net Zero, there will need to be a substantial shift away from the use of fossil fuel burning generation. This has led to investment in onshore green technologies and offshore wind generation, which will increase further in the future.

4.1.5 Historically, the transmission system was powered by coal powered generating stations. The increasing importance of low carbon generation has driven the closure of these generating stations, with more expected to close in the future. This generating capacity is being replaced by low carbon generation which is mostly geographically located away from the coal powered generating stations. The transmission system must be updated to reflect the location of the new generation capacity.

4.1.6 Electricity demand is especially concentrated in large urban areas across Great Britain, including urban areas in the M8 corridor, the M62 corridor, the M18 corridor, the Midlands, the M4 corridor and the Southeast. The transmission system carries bulk energy from the generators to points on the network where that power is taken onto the distribution networks for onward transmission to homes and businesses across England and Wales. As the country decarbonises and fossil fuel usage declines, demand for electrical energy will increase.

4.2 National Electricity Transmission System Security and Quality of Supply Standard

4.2.1 NGET must comply with section 9 of the Electricity Act and Standard Condition D3 (Transmission System Security Standard and Quality of Service) of its Transmission Licence. This means that where the boundary capacity of the Main Interconnected Transmission System (MITS) is exceeded against the standards, NGET must resolve the capacity shortfall under the terms of its Transmission Licence. The standards against which NGET assesses these shortfalls are set out in the “*Design of the Main Interconnected Transmission System*” section of the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

4.2.2 The NETS SQSS also sets out in "*Generation Connection Criteria applicable to the onshore transmission system*" that connections to the transmission system must be secured to meet the identified requirements set out in the NETS SQSS. Where the NETS SQSS applies, the generator(s) are considered part of a "generation group" for assessment against these criteria.

4.2.3 Any transmission system is susceptible to faults that interfere with the ability of transmission circuits to carry power. Most faults are temporary, many are related to weather conditions such as lightning or severe weather, and many circuits can be restored to operation automatically in minutes after a fault. Other faults may be of longer duration and would require repair or replacement of failed electrical equipment.

4.2.4 Whilst some of these faults may be more likely than others, faults may occur at any time, and it would not be acceptable to have a significant interruption to supplies as a result of specified fault conditions, including combinations of faults. The principle underlying the NETS SQSS is that the NETS should have sufficient spare capability or "redundancy" such that defined fault conditions do not result in widespread supply interruptions. The level of security of supply has been determined to ensure that the risk of supply interruptions is managed to a level that maintains a minimum standard of transmission system performance. The faults we need to design the system to be compliant with are called "Secured Events"

4.2.5 The NETS SQSS defines the performance required of the NETS in terms of Quality and Security of Supply for secured events that at all times:

- electricity system frequency should be maintained within statutory limits;
- no part of the NETS should be overloaded beyond its capability;
- voltage performance should be within acceptable statutory limits; and
- the system should remain electrically stable.

4.3 National Energy System Operator (NESO) Beyond 2030 Report

4.3.1 As previously outlined in Section 2.6, in March 2024, the ESO (as it then was), published the Beyond 2030 report as a stepping stone before developing the fully Centralised Strategic Network Plan (CSNP). Subsequently on 1 October 2024 the ESO became the National Energy System Operator (NESO) which is a public independent body with strategic oversight of both the electricity and gas systems.

4.3.2 The Beyond 2030 report was developed through a structured planning process that included the following steps:

- Evaluation of industry scenarios;
- Identification of requirements across the electricity system;
- TOs proposing various solution options to meet these requirements;
- Assessment of the proposed solution options;
- Development of high-level recommendations based on the assessment;
- Forwarding these recommendations for detailed design.

4.3.3 More information on Beyond 2030 is included in Appendix F.

4.3.4 The ESO recommended multiple East Coast onshore and offshore reinforcement developments as part of the Beyond 2030 report, including SW_E1A_3 also known as AC4, which originally coordinated offshore windfarm connection in Scotland with a HVDC link between Scotland and England. This project has now been refined to a link between Scotland and England known as EGL 5.

4.4 The existing transmission network

4.4.1 The transmission network in the vicinity of the project was primarily constructed in the 1960s, at the same time as much of the rest of the transmission system. It was designed to connect the in-land large coal fired power stations both in Scotland and Northern England, with changes occurring in the later parts of the century connecting gas fired power stations in the Humber region in particular. Little or no transmission infrastructure was constructed in some areas, so there is currently limited ability to support new connections on the coast.

4.4.2 National Grid is currently consulting on a connection between North Humber to High Marnham and Grimsby to Walpole along with connections of two HVDC links known as EGL 3 and EGL 4 into a new substation in the Walpole area.

4.4.3 The existing transmission system between Scotland and the Midlands of England is shown in Figure 4.1. The geography for the connection of the EGL 5 is shown in Figure 4.2, along with the existing projects currently undergoing consultation.

Figure 4.1 – The National Electricity Transmission System in the North and Midlands

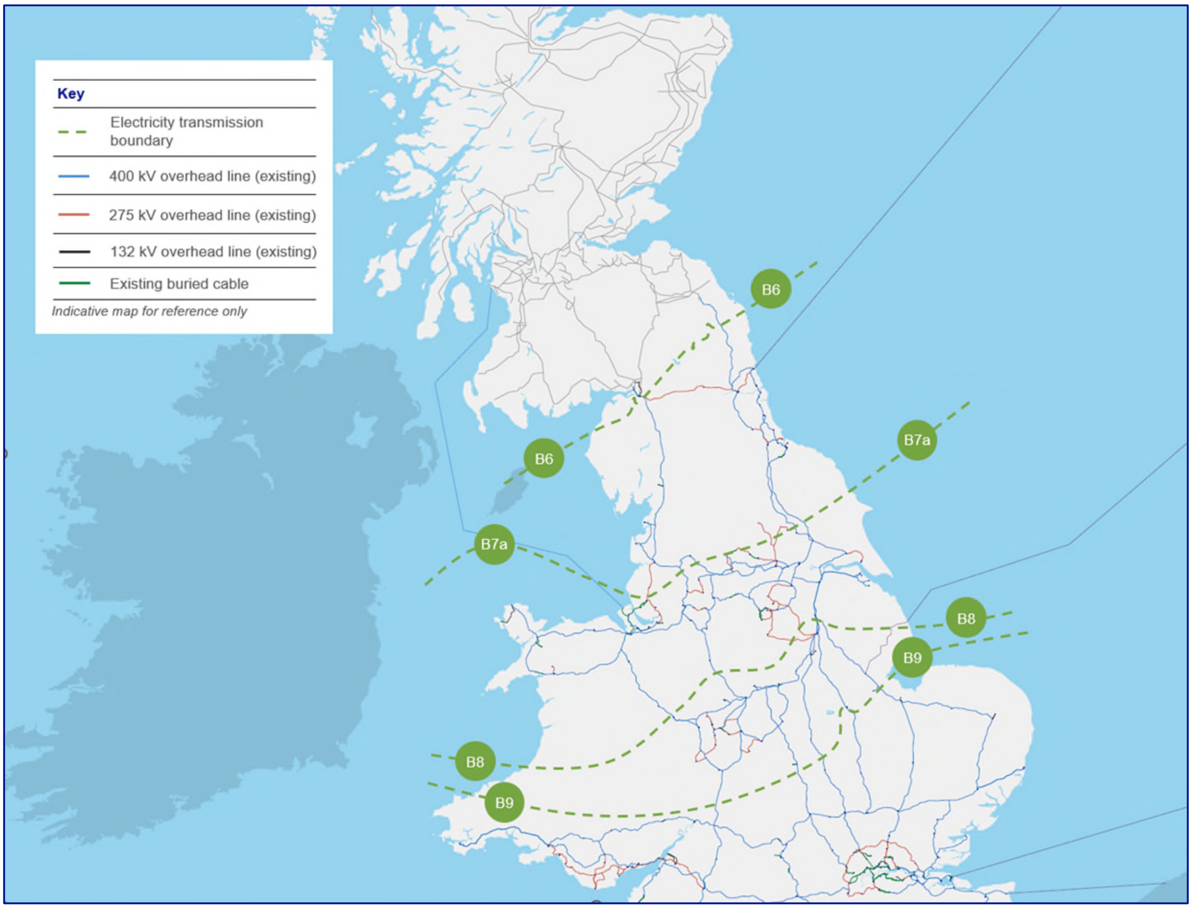
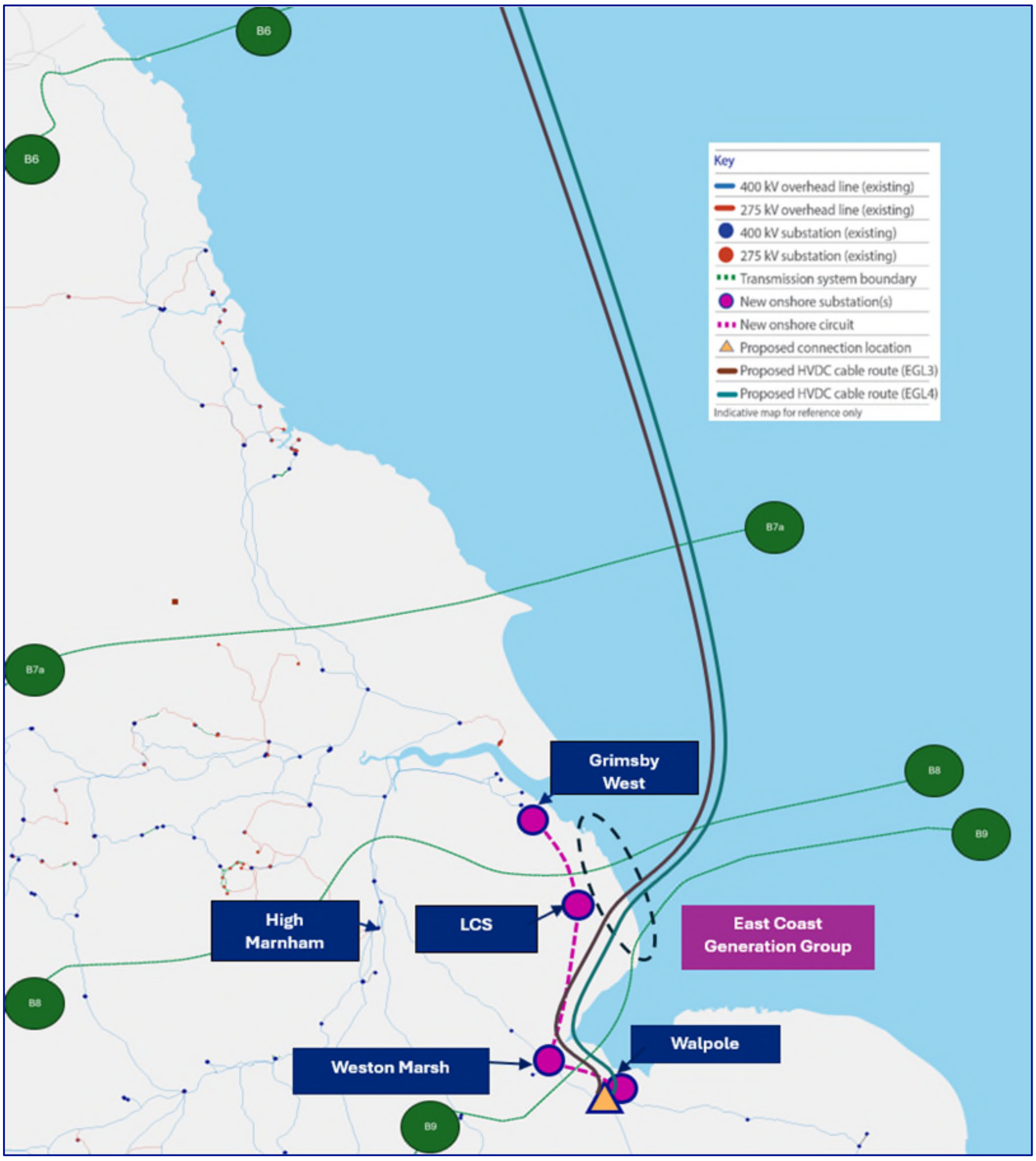


Figure 4.2 – The East Coast Lincolnshire region transmission system including Grimsby to Walpole, EGL 3 and EGL 4 connections currently under consultation



4.5 Generation groups

4.5.1 Figure 4.2 identifies the East Coast generation group area (being made from South of the Humber Estuary to North of The Wash).

4.5.2 The East Coast Connections generation group consists of proposed generation contracted to connect in an area south of the Humber Estuary and north of The Wash. This is currently a combination of offshore wind, interconnectors, energy storage / solar (PV array) and Combined Cycle Gas Turbine (CCGT).

4.5.3 The generation contracted to connect to the generation group, is shown in Table 4.1. These tables indicate the contracted generation within each generation group. This is the latest position as of February 2025. Because the generation projects contracted to connect may change from time to time, in any year (or at any time in a year) the TEC register is therefore updated as and when these changes occur. Accordingly, the TEC register may, when reviewed at any time in any given year, have different listed projects (or different capacities listed for projects).

East Coast Connections between South Humber to North Wash (From TEC Registers Apr 2025)

Project Name	Type	Capacity (MW)	Connection Year
*GT R4 Windfarm (Outer Dowsing)	Offshore Wind	1500.0 MW	2030
SENECA	Interconnector	1200.0 MW	2031
Mablethorpe Storage	Storage/CCGT	1500.0 MW	2031
Eco Grimsby West	Energy Storage & PV Array	249.0 MW	2031
*Meridien Solar Farn	Energy Storage & PV Array	750.0 MW	2033
*Spalding PV and BESS	Energy Storage & PV Array	480.0 MW	2033
Mablethorpe Green Energy Centre	Energy Storage & PV Array	1025.0 MW	2033
Eco Mablethorpe	Energy Storage & PV Array	249.0 MW	2034
Carbon Free 2030	Energy Storage/Solar	500.0 MW	2034
Stallingborough PV & BESS	Energy Storage/Solar	500.0 MW	2034
East Lincolnshire Solar	Energy Storage/Solar	800.0 MW	2035
Bute Hydrogen Project 3	CCGT & Energy Storage	3600.0MW	2035
Grimsby BESS	Energy Storage	500.0 MW	2035
West Grimsby Farm	PV Array	150.0 MW	2035
Butt Lane	Energy Storage	240.0 MW	2035
Stallingborough Carbon Capture	CCGT	906.0 MW	2035
Total		14,149.0 MW	

- *Note - *2,730MW of generation is connecting to Weston Marsh substation with >4 transmission circuits connecting to this location.

4.5.4 The East Coast Connection generation group has a significant amount of customer generation contracted to connect. Applying the requirements of the NETS SQSS generation criteria, these connection contracts provide the starting locations for reinforcements. To comply with the NETS SQSS, sufficient transmission capacity must be provided to allow the full contracted generation to connect in each generation group. This is then assumed to be dispatched in typical power station operation regime as set out in the NETS SQSS. The amount of energy provided by generation is often lower than its installed capacity due to lower input energy, capacity held in reserve and some generation pulled back if an excess of supply is occurring at that time. This means experiencing total output is unlikely so the system is designed to meet the typical expected generation outputs and therefore will be less than the total installed capacity in the group. Additional generation connected in each area will also impact the B8 and B9 system boundaries along with generation from the North and Scotland flowing to large demand centres across the boundaries.

4.5.5 As EGL 5 is a transmission circuit that can be reduced to no flow, 0 MW, during local faults, EGL 5 will not impact the generation group capability. The effect on the group is seen as neutral.

4.6 Boundaries

4.6.1 The transmission system shown in Figure 4.1 shows system boundaries B6, B7a, B8 and B9 and Figure 4.2 also shows the system boundaries, B6, B7a, B8 and B9.

4.6.2 A boundary splits the system into two parts, crossing critical circuit paths that carry power between areas and where power flow limitations may be encountered. Boundaries help identify regions where reinforcement is most needed by enabling analysis of power transfers between separated areas. They can be local boundaries, which are small areas of the Transmission System with a high concentration of generation, or wider boundaries, which are large areas containing significant amounts of both generation and demand. Boundary definitions have evolved over many years of planning and operating the transmission system.

4.6.3 Future boundary requirements are assessed using the FES 2024 to identify expected future power flows across the boundaries FES 2024 is the current version as of March 2025. Power system studies are conducted by NESO and NGET to determine the boundary capability, which is the maximum power flow that can be transferred across a boundary while maintaining compliance with technical standards. Limiting factors on transmission capacity include thermal circuit rating, voltage constraints, and dynamic stability.

4.7 Boundaries B6, B7a, B8 and B9

4.7.1 Boundaries B6, B7a, B8 and B9 are wider system boundaries containing areas with significant volumes of both generation and demand. Power system studies have been undertaken jointly by NGET and NESO to assess the impact of changes in demand and generation on power flows across the boundary and to determine if these impacts require reinforcement to the transmission system.

4.7.2 The boundaries B6, B7a, B8 and B9 as described above have been evaluated using the Economy Planned Transfer assessment, which takes prescribed generation contributions from above and below the boundary, alongside demand in each area to determine the expected flow across the boundary. In this case, the Economy Planned Transfer condition represents the most onerous boundary condition which must be secured by NGET to the requirements set out in the NETS SQSS.

4.7.3 Each of the circuits which cross the B6, B7a, B8 and B9 boundaries has a capacity during the winter ACS period. The summation of the capacity for all of these circuits provides the pre fault capacity. The post fault capacity is defined by the remaining capacity across a boundary following the worst fault "Secured Event" as described above.

4.7.4 Each boundary then will see flows across it based upon the circuit parameters and system conditions, when the natural flow of energy on every circuit will be maximised. This is known as the circuit boundary capability, which is based upon the capability seen following the worst fault "Secured Event".

4.7.5 The following capacities and capabilities are applicable to the boundaries by 2035 should no reinforcement occur. Reinforcements across the boundary would seek to deliver enhanced boundary capacity between 2030 and 2035, delivering sufficient capacity to meet the 2035 capacity requirements set out below. If all reinforcements were not delivered ahead of 2035 for each generation group and boundaries, significant generation projects would be impacted and system constraints would be incurred for energy seeking to meet the government 2030 goals and beyond. This means any delays would have a significant impact on government ambitions and consumers need for sustainable and affordable energy.

4.7.6 Table 4.2 shows the capacities and capabilities applicable to system boundaries B6, B7a, B8 and B9 by 2035, based upon the ETYS 2024 boundary assessment, including the following projects applied to the existing transmission system capacity:

- EGL 3 – 2 GW HVDC connection Scotland to England (connection to Walpole area)
- EGL 4 – 2 GW HVDC connection Scotland to England (connection to Walpole area)
- Grimsby to Walpole – circa 6 GW AC transmission connection
- North Humber to High Marnham – 6 GW AC transmission connection
- Brinsworth to Chesterfield to High Marnham – 400 kV uprating
- Chesterfield to Willington – 6 GW AC transmission connection

Table 4.2 – Transmission system capacities and system capabilities before 2035

System Boundary	Pre-Fault Capacity (MW)	Post Fault Capacity (MW)	Post Fault Capability (MW)
B6	22,665	16,013	15,783
B7a	30,457	23,805	19,700
B8	51,759	44,829	23,400
B9	35,341	28,411	19,300

Table 4.3 shows how the existing generation groups and boundaries perform in 2035 for the expected planned transfer flows.

Table 4.3 – Existing boundary performance by 2035 and generation group capacity to last contract date, currently 2035 in the TEC register, which will be facilitated by proposed need

System Boundary Export or Generation Group		2035 Post Fault Capability	2035 Post Fault Capacity	Capability Deficit (-) / Surplus (+)	Capacity Deficit (-) / Surplus (+)	Secured Event Fault
*East Coast contracts to 2035 (Generation)	14,149.0 MW	0 MW	0 MW	-14,149.0 MW	-14,149.0 MW	N/A
B6 – 2035 (boundary)	28,564.2 MW	15,783 MW	16,013 MW	-12,781.2 MW	-12,551.2 MW	Stella West – Eccles 400 kV double circuit
B7a – 2035 (boundary)	25,203.2 MW	19,700 MW	23,805 MW	-5,503.2 MW	-1,398.2 MW	Norton – Osbaldwick 400 kV double circuit
B8 – 2035 (boundary)	28,700.2 MW	23,400 MW	44,829 MW	-5,300.2 MW	+16,129 MW	North Humber to High Marnham 400 kV double circuit
B9 – 2035 (boundary)	25,093 MW	19,300 MW	28,411 MW	-5,793 MW	+3,318MW	Lincolnshire – Walpole 400 kV double circuit

- *Note - *2,730MW of generation is connecting to Weston Marsh substation with >4 transmission circuits connecting to this location.

4.7.7 Table 4.3 shows 14 GW of generation connections in the East Coast generation connection group. Also, this would reduce to a potential shortfall of circa 7GW following the completion of the Grimsby to Walpole circuit which shall provide transmission capacity to the area. In normal circumstances the transmission requirement should be less than the 7 GW shortfall. This is due to the generation connection criteria in the SQSS requiring the network to be designed based upon typical power station operating regimes within a generating group. This level changes depending on which individual power station is the subject of the assessment. So, for simplicity, the transmission entry capacity for each generator is shown in Table 4.2 and Table 4.3. The expected operation of generation in the East Coast group is currently indicating that the Grimsby to Walpole circuit will provide sufficient capacity to the group for expected operation.

4.7.8 Table 4.3 also shows additional transmission capacity across B6, B7a, is clearly needed, and that the boundaries B8 and B9 can benefit from options that cross them, but currently do not require options to cross them.

4.7.9 The boundary assessments completed on the Economy Planned Transfer, as defined in the NETS SQS, already accounts for generation contribution. To ensure that an appropriate measure of need using current assessments of capacity at the date of this report, we have taken the Holistic Transition, Electric Engagement, Hydrogen Evolution, CP30 – Further Flex and Renewables and CP30 – New Dispatch boundary requirement scenarios from the ETYS 2024 based upon FES 2024 backgrounds, as of February 2025. An average of all five scenarios has been applied, which aligns with NESO's use of three (plus two CP30) background scenarios up to 2035, to identify expected future boundary flows.

4.7.10 As described in the "Communicating our thermal needs" section set out in the NESO ETYS 24 documentation, the FES boundary graphs for each area display two sets of shaded areas. The 50th Percentile of power flows lies in the 25% and 75% range of the graph. The 90th percentile of power flows lies in the 5% to 95% range of the ETYS graphs. It states that where the capability of the boundary is between these two regions, 75% and 95%, over 20 years, then there may be a need for reinforcement.

4.7.11 NGET uses the average of the 95% percentile number across the five scenarios for boundary analysis. This ensures that for all five scenarios, our need case capacity and capability requirement would lie between the 75% and 95% ranges of annual power flows for all five scenarios and demonstrating the need for reinforcement regardless of which scenario occurs. Against this assessment in all five FES 24 and CP2030 scenarios should there is clearly a shortfall against boundary capability and capacity for the B6, B7a, whilst there is a potential capability shortfall B8 and B9 boundaries that by 2035 will require reinforcement.

4.7.12 In all cases, it is clear even if flows could be maximised across the system boundary for fault secured events, the boundary capabilities would be exceeded at all boundaries shown in Table 4.2. Boundary capacity is the physical maximum power that can be transferred across the existing physical boundary (i.e. without carrying out reinforcement work to increase capacity). Large boundary capacity and capability deficits were identified for the B6 and B7a system boundaries, smaller capability deficits were identified for the B8 and B9 system boundaries, which have a capacity surplus.

4.7.13 From 2035, further increases in system boundary requirements are expected and this is reflected in NGET's existing contractual commitments. To address these needs, additional reinforcements to these boundaries are expected in Central England and Wales which will supplement these system boundaries in the future. This will facilitate connections beyond 2035 when further increases in generation are expected in all regions, which will be subject to their own detailed need case and options assessment. Any future requirements would be informed by further need case assessments and option appraisals. These emerging requirements do not affect the need case set out within this report.

4.8 Need case conclusion

4.8.1 As described above, there are three distinct issues that need to be considered by system reinforcements that EGL 5 seeks to enhance:

- Provision of capacity and capability from Scotland across the B6 and B7a system boundaries.
- Consider provision of beneficial capability across B8 and/or B9 system boundaries.
- Neutral connection impact upon the East Coast Generation Group.

4.8.2 The remainder of this report considers strategic options that resolve the need set out above.

5. Options identification and selection process

5.1 Introduction

5.1.1 When a need to reinforce the NETS is established, we bring together a multidisciplinary Project Team to evaluate a wide range of options. This team produces a list of potential strategic options which can be further refined through evaluation processes, and which are described within this report.

5.1.2 The Project Team keeps the options under review, for example, as changes to the drivers emerge as a consequence of interactions with other projects. Throughout this review, potential strategic options can be modified or deselected, and new options can be included.

5.2 Identifying the technically feasible options

5.2.1 Once the need case has been established, there is a requirement to consider the many ways in which the need could be met. Before we undertook any detailed optioneering work, a technical compliance filter was applied to make sure that all of the potential strategic options being considered would work on the network, rejecting any that would not meet technical standards or would not work in practice. There are potentially many ways in which the identified need could be met, so further network modelling was carried out to understand the issues better. This initial identification is based on the network planning information which was available from ESO at the time of appraisal.

5.3 Review of recommended technology option

5.3.1 Following ESO recommendations for the connection of a new HVDC link in the Humber area, we considered currently available alternative technology options which could be used to address the identified need for additional transmission system capacity. As part of this review, we considered whether an AC based onshore option using an OHL technology solution to meet the identified requirement should be further investigated.

5.3.2 The largest capacity AC technology option that can be used on our transmission system consists of two 3,465 MW transmission circuits that are supported on a single set of towers (6,930 MW double circuit capacity). The largest HVDC capacity systems that can currently be accommodated on our transmission system are 2,000 MW HVDC cables.

5.3.3 Power flows on AC transmission system circuits cannot be controlled to the same extent as can be achieved using HVDC connections. This lower level of controllability can result in higher power flows particularly during transmission system fault conditions. Taking account of the potential for higher power flows that could be expected, therefore, to provide the potential equivalent capacity, the AC option would need to consist of a high capacity (6,930 MW) double circuit route to meet any high loading during fault conditions.

5.3.4 The required capacity HVDC link over the proposed distance has comparable capital costs, but much lower lifetime costs than the alternative onshore AC option in this case. The use of overhead lines is not considered to be feasible because they cannot be delivered by the required 2035 timescale. Overall, this AC based onshore option is expected to result in a greater level of environmental and socio-economic impact compared to the primarily subsea HVDC options and provides limited benefit over those options. Therefore it is considered a less preferable option which does not meet the requirements to progress beyond technical and benefit filter stage.

5.3.5 Further details of our initial evaluation of this onshore alternative option are provided in Appendix G.

5.4 Potential strategic options

5.4.1 We began by identifying technically feasible options that meet the need case outlined in Chapter 4 of this SOR. These options aim to enhance capacity and capability from Scotland across the B6 and B7a boundaries, consider beneficial capability across B8 and/or B9 boundaries, and ensure a neutral connection impact on the East Coast Generation Group. Notably, all substations above B7a do not meet the long list criteria. These options cover a wide geographical area and are detailed in this document.

5.4.2 A “benefit filter” was then applied to the technically feasible options, which allowed focus on those that best meet our obligations to the environment and consumers. It also ensures that any option presented has a comparable benefit over an alternative. The criteria for any potential strategic option to be considered further and not discontinued are one or more of the following:

- An environmental benefit;
- A technical system benefit;
- A capital and lifetime cost benefit, which includes the consideration of initial capital costs and long-term maintenance and operating costs; or
- A socio-economic benefit.

5.4.3 Where the benefits of multiple options are very similar to each other, all options are captured and included for appraisal. This ensures that all possible solutions are appraised regardless of having similar capability.

5.4.4 Table 5.1 lists the potential strategic options and is followed by a summary of the benefit filter application for potential options for the Project.

5.4.5 A number of options were taken forward for detailed appraisal.

Table 5.1 – Potential strategic options

Potential strategic option (Substation Connection Option)	Substation Voltage	Outcome
Connection to Osbaldwick	400 kV	Discounted – technical filter – requires new transmission circuit
Connection to Thornton	400 kV	Discounted – technical filter – requires new transmission circuit
Connection to Creyke Beck/Birkhill Wood	400 kV	Discounted – technical filter – proposed generation at capacity would require new circuits
Connection to Thorpe Marsh	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to Eggborough	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to Drax	400 kV	Discounted – technical filter – substation space constraints
Connection to Saltend South	275 kV	Discounted – technical filter – 275 kV would require upgrade and new circuits
Connection to Saltend North	275 kV	Discounted – technical filter – 275 kV would require upgrade and new circuits
Connection to Hedon	275 kV	Discounted – technical filter – 275 kV would require upgrade and new circuits
Connection to Keadby	400 kV	Discounted – technical filter – generation connections at capacity
Connection to Killingholme	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to Humber Refinery	400 kV	Discounted – cost and environmental filter – higher onshore cable distance

Potential strategic option (Substation Connection Option)	Substation Voltage	Outcome
		requirements and environmental impact
Connection to South Humber Bank	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to Grimsby West	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to New Grimsby West	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to West Burton	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to Cottam	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to High Marnham	400 kV	Discounted – cost and environmental filter – higher onshore cable distance requirements and environmental impact
Connection to Bicker Fen	400 kV	**Taken forward for detailed appraisal**
Connection to New Spalding North	400 kV	**Taken forward for detailed appraisal**
Connection to New Weston Marsh	400 kV	**Taken forward for detailed appraisal**
Connection to New Lincolnshire Connection Substation(s)	400 kV	**Taken forward for detailed appraisal**
Connection to Walpole	400 kV	Discounted – technical filter – substation space constraints

Potential strategic option (Substation Connection Option)	Substation Voltage	Outcome
Connection to New Walpole	400 kV	**Taken forward for detailed appraisal**
Connection to Ryhall	400 kV	Discounted – technical filter – substation space constraints and substation design limitations
Connection to New Ryhall	400 kV	**Taken forward for detailed appraisal**
Connection to Sutton Bridge	400 kV	Discounted – technical filter – substation space constraints and substation design limitations

Application of Benefit Filter

5.4.6 Any connection point at an existing 275 kV substation requires extensive upgrades to the existing transmission system to ensure that NETS SQSS compliance is maintained. Considering the additional works that are required to upgrade an existing 275 kV substation to 400 kV, none of these connection options provide substantive benefits compared to other identified connection options and were discounted at this stage.

5.4.7 A number of connection options included within the table above trigger wider transmission reinforcement or further works to ensure that NETS SQSS compliance is maintained. Considering the additional works that are required to ensure that NETS SQSS compliance is maintained, none of these options provide substantive benefits compared to any other of the identified connection point options and therefore were discounted.

5.4.8 Additionally, a number of connection options have technical constraints in place such as high fault levels, existing large generation connections, thermal capability or general space constraints for accommodating new connections. Furthermore, due to cost considerations and environmental filters, some options were discounted because they required higher onshore cable distances and had a greater environmental impact. Taking these constraints into account upon assessment of the associated options, none of these options provide substantive benefits compared to other of the identified connection point options and therefore were discounted. This applies to the remaining long list options which were not discounted for the previous two reasons.

5.4.9 The appraisal of all potential strategic options led to six options being selected to take forward for detailed appraisal, the details of which are contained within the proceeding sections. These are indicated within the Table 5.1 outcome column and Table 5.2 in the following section.

5.5 Proposed strategic options

5.5.1 Six strategic options that potentially achieve the need case and present a socio-economic benefit, an environmental benefit, a technical system benefit or a cost benefit were proposed for detailed appraisal and are outlined in Table 5.2. Each proposed strategic option has been checked for compliance with SQSS standard.

5.5.2 Undertaking this appraisal ensures stakeholders can see how we have made judgements and balanced the relevant factors in accordance with our legal duties.

Table 5.2 – Proposed strategic options for appraisal

Proposed strategic option title	Option description[6]
Option 1 – Connection to New Lincolnshire Connection Substation(s) (LCS)	546 km new offshore subsea transmission connection
Option 2 – Connection to Bicker Fen	594 km new offshore subsea transmission connection
Option 3 – Connection to New Ryhall	636 km new offshore subsea transmission connection
Option 4 – Connection to New Weston Marsh	600 km new offshore subsea transmission connection
Option 5 – Connection to New Walpole	624 km new offshore subsea transmission connection
Option 6 – Connection to New Spalding North	606 km new offshore subsea transmission connection

5.6 Our approach to appraising the proposed strategic options

5.6.1 At this stage of the optioneering process, the approach is based on the identification of "differentiators". This is where one option provides a clear benefit over another, for example in the form of a lesser environmental impact. At this stage, it is often not possible to identify differences against all appraisal factors due to the limited design detail and broad geographical area being considered.

5.6.2 The appraisal process considers the following areas:

- Environmental appraisal topics which consider whether there are environmental constraints or issues of sufficient importance to influence decision making at a strategic level, having particular regard for internationally or nationally important receptors;
- Socio-economic topics which consider whether there are socio-economic constraints or issues of sufficient importance to influence decision making at a strategic level, having particular regard for internationally or nationally important receptors; and

[6] The methodology for calculating the option length is set out in the appraisal assumptions below

- Consideration of technical benefits includes whether the option is providing the required capacity to meet the need case; whether the option has particular system benefits over alternatives; whether the option introduces any system complexity that causes system operability issues.

5.6.3 Consideration of capital and lifetime costs includes a range of factors:

- Capital cost of the substation and wider works;
- Capital cost of the circuit costs for each technology appraised; and
- Circuit lifetime costs, including circuit capital cost, cost of losses over 40 years and cost of operation over 40 years.

Appraisal assumptions

5.6.4 When considering each strategic option, we provided circuit cost information for the following technology options for all offshore based options:

- 400 kV AC Offshore cable
- 525 kV HVDC Offshore cable and converter stations

5.6.5 An AC offshore cable route over the intended distances is possible, but it only has benefits over HVDC subsea up to 50 km, after which has greater loss. To prevent this power loss, it requires regular onshore looping for reactive compensation, increasing costs and potentially triggering more consenting works.

5.6.6 A full evaluation and costs used in our appraisals can be found in Appendix D. In this appraisal, all options are considered using information appropriate to this stage of their development on the assumption that they are deliverable in a reasonable timescale. Timescales and deliverability are only be considered further in the appraisal process should they become differentiating factors in the selection of the option that best meets our environmental and legal obligations. If these issues of delivery timescales and risk do become differentiating factors in selection of an option, the issue is set out clearly in the options conclusion. If these factors are not differentiating, they are not considered further for this appraisal.

5.6.7 At the initial appraisal stage, we prepared indicative estimates of the capital costs. These indicative estimates are based on the high-level scope of works defined for each strategic option in respect of each technology option that is considered to be feasible. As these estimates are prepared before detailed design work has been carried out, we make equivalent assumptions for each option. Final costs for any solution taken forward following detailed design, consenting and mitigation will be in excess of any high-level appraisal cost. However, all options incur these increases proportional to initial estimate in the development of a detailed solution. This methodology ensures that all options for appraisal proposes are compared on a like-for-like basis.

5.6.8 Strategic options are identified at a very high level as being electrical solutions between geographic points. Therefore, the potential circuit lengths are derived by taking a straight-line distance between the points and adding 20% to accommodate potential route deviations that might be required if the route proceeds forward to more detailed routeing and siting. Where a clear obstacle exists, such as an estuary, water course or geographical feature, an alternative route length will be derived and explained in the option. Where an offshore alternative is presented, straight lines will be used to a midpoint offshore and 20% added to provide variation in route length.

5.6.9 These initial option lengths do not define route corridors, and environmental appraisal is provided over a wide study area between points of connection. Any routes for circuit technologies to take are subject to detailed routeing and siting for any strategic option taken forward as a preferred option(s).

5.6.10 The Project is being undertaken jointly by NGET and SSEN. We are responsible for all onshore infrastructure in England including substations, converter stations, OHLs and underground cables, and offshore infrastructure in English waters. SSEN are responsible for the onshore infrastructure in Scotland and offshore infrastructure in Scottish waters. The strategic options presented in this report solely cover the NGET component of the Project; therefore, all cost appraisals are only for infrastructure onshore in England or offshore in English waters. The costs associated with Scottish infrastructure are the responsibility of SSEN.

5.6.11 The options in the following sections of this report have been taken forward in this document as they meet the need case and have been selected using the methodology set out above.

5.7 Summary points

5.7.1 Six strategic options that potentially achieve the need case for reinforcement in the Humber and East Coast Region have been proposed for detailed appraisal. These options present an environmental benefit, a technical system benefit, a capital and lifetime cost benefit (which includes consideration of initial capital costs and long-term maintenance and operating costs), or a socio-economic benefit.

5.7.2 The details and results of this detailed appraisal follow in Chapter 6 onwards.

6. The results of our appraisal of strategic options

6.1 Introduction

6.1.1 This section presents a summary of the findings of the appraisal process undertaken for each of the six strategic options identified for the Project. This section discusses each of the options, looking at each option from a technical, environmental, socio-economic, and cost perspective. This section concludes with a tabulated summary of the appraisal to provide a visual indication of the benefits and disadvantages of each option comparatively.

6.1.2 In this appraisal, all options are considered using information appropriate to this stage of their development on the assumption that they are deliverable in a reasonable timescale.

6.1.3 Strategic options are identified at a very high level as being electrical solutions between geographic points. Therefore, the potential circuit lengths are derived by taking a straight-line distance between the points and adding 20% to accommodate potential route deviations that might be required if the route proceeds forward to more detailed routeing and siting.

All the options are appraised for the purposes of identifying an initial preferred option:

- for NGET's transmission system development proposals; and
- to provide relevant information as inputs needed for the NESO's CBA process.

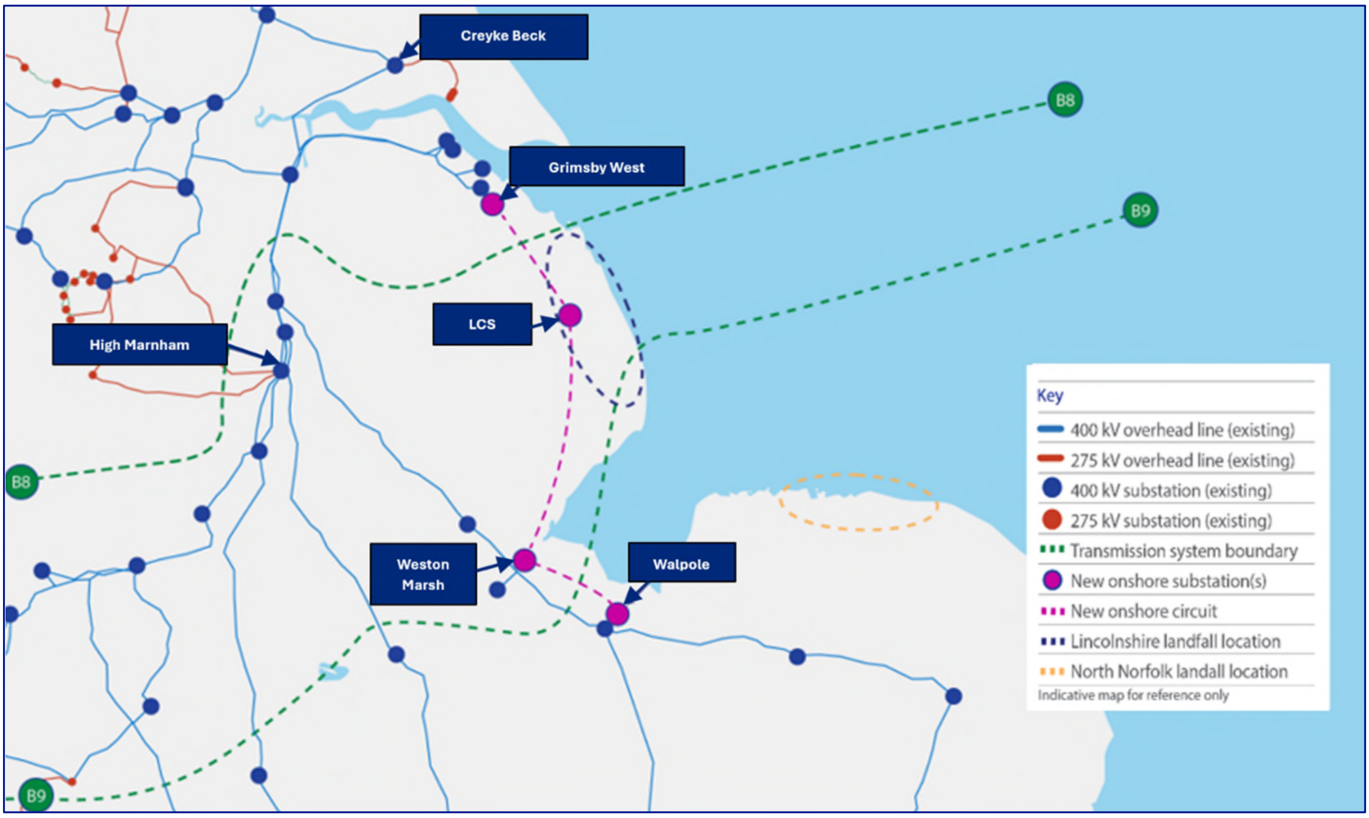
6.1.4 Constraint cost evaluation is carried out by the NESO and is captured in their independent CBA process and is regularly evaluated and reported in NOA publications.

6.1.5 At this development stage, two potential landfall areas on two coastlines for the new HVDC circuits are appraised to confirm that feasible connection opportunities exist. Each potential strategic option detailed in this report has a defined potential landfall and connection point.

6.1.6 The two coastlines in closest proximity to the proposed strategic options which feature in the forthcoming options appraisal are summarised in Figure 6.1 and as follows:

- For landfall options on the Lincolnshire coastline, the majority of the new circuits are to be routed within the North Sea making landfall between the Humber and The Wash.
- For landfall options on the North Norfolk coastline, the majority of the new circuits are to be routed within the North Sea making landfall between Kelling and Sheringham.

Figure 6.1 – Indicative landfall locations



6.1.7 For the purposes of this appraisal, any substation designated as "New" has been assigned, for identification purposes, based on the optimal closest existing substation. These substations will be subject to a detailed siting assessment should an option be selected. "New" substations do not currently exist on the network; they will be delivered either as part of the scope of another NGET project or within the scope of this Project. The option descriptions define which projects will be constructing the "New" substations.

6.2 Appraisal of Option 1 – Connection to New Lincolnshire Substation(s)

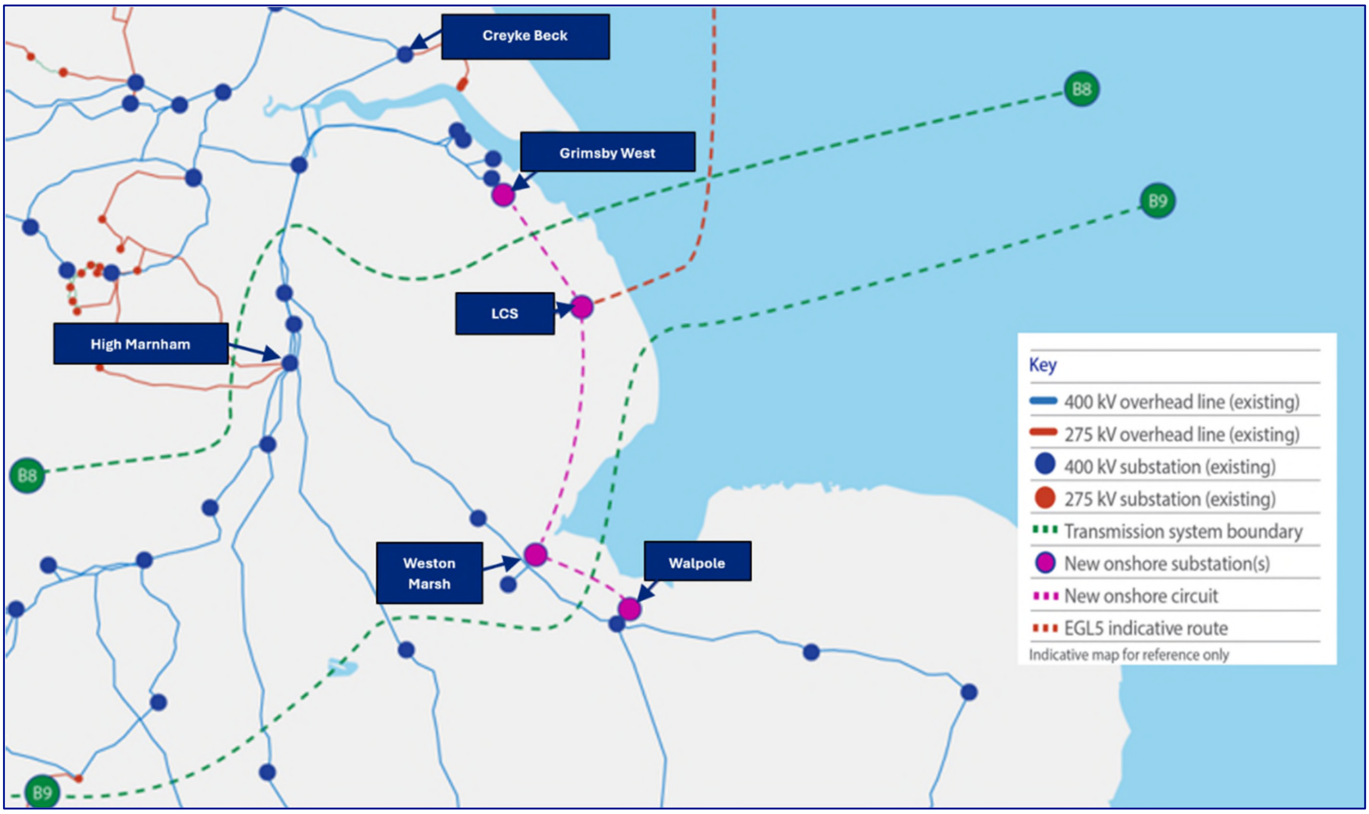
Description of strategic option 1

6.2.1 Option 1 involves the development of a new transmission circuit from Scotland connecting to one of the New Lincolnshire Connection Substation(s) (LCS). The majority of the new circuit is routed within the North Sea making landfall on the Lincolnshire coastline. The marine element of Option 1 is common to all strategic options until the point at which the marine route splits for landfall (to Lincolnshire or North Norfolk coastlines) (i.e. how far south the submarine cables are routed).

6.2.2 The New LCS are proposed as part of Grimsby to Walpole and therefore subject to an application for development consent in the future. As Grimsby to Walpole is a separate project, the application for development consent for LCS is a separate application to the consenting for the EGL 5 Project. Grimsby to Walpole specific information can be found in Chapter 8.

6.2.3 A diagram of Option 1 is shown in Figure 6.2.

Figure 6.2 – Indicative location of Option 1 – connection to New Lincolnshire Substation



6.2.4 The circuit distance for this connection is presented below. This is based on a subsea cable route distance from a preliminary cable routing study and a straight-line distance from a landfall on the Lincolnshire coastline to the New LCS.

- 445 km Offshore Distance
- 10 km Onshore Distance
- 455 km Total Straight-Line Distance
- 546 km Total Distance (including 20% tolerance)

6.2.5 This option is formed of a HVDC link which requires a pair of HVDC cables. Two converter stations are required, one in Scotland and one in the vicinity of the New LCS. The converter stations each have an approximate footprint of 6 ha (see C for further information).

6.2.6 Onshore underground HVDC cables are required from the Lincolnshire Landfall to the converter station in the vicinity of the New LCS. At New LCS, two bays are required to accommodate the connection of the Project.

Summary of the environmental and socio-economic appraisal

6.2.7 An environmental and socio-economic appraisal has been undertaken of a new transmission circuit making landfall on the Lincolnshire coast and connecting to one of the two New LCS, proposed as part of the Grimsby to Walpole Project, near Alford in East Lindsey.

6.2.8 For the purposes of the appraisal, a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Lincolnshire coastline (between south of Saltfleet and north of Ingoldmells) inland to the point of connection at New LCS.

6.2.9 The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations. The study area for the appraisal of marine factors extended from either landfall to the border for Scottish waters, a distance of approximately 400 km (from North Norfolk). The marine study area is split, east of Hull to provide the two different options for landfall, for Lincolnshire (where the study area extended from north of Theddlethorpe to north of Chapel St Leonards) and North Norfolk (where the study area extended from west of Morston to Cromer).

6.2.10 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to subsea cable routeing and landfall siting on the Lincolnshire coast. These include the Southern North Sea Special Area of Conservation (SAC), Greater Wash Special Protection Area (SPA), Holderness Inshore Marine Conservation Zone (MCZ), Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Between the strategic options making landfall on the Lincolnshire coast, these sites are common to any subsea cable route and therefore are not a significant differentiator between the strategic options being appraised.

6.2.11 With regard to socio-economic considerations in the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the landfall study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. Additionally, there are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.

6.2.12 The Lincolnshire coastline is also subject to a number of statutory ecological designations. From north to south this includes the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary Important Bird Area (IBA), Lincolnshire Coronation Coast National Nature Reserve (NNR), and Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are potentially avoidable through landfall selection. Where landfalls, such as Theddlethorpe, are located within coastal ecological designations, impacts may be avoided through a choice of cable installation methods (for example trenchless methods such as Horizontal Directional Drilling (HDD)). Coastal ecological designations may present a consenting constraint on some specific landfall sites within this option, potentially requiring significant mitigation measures.

6.2.13 Underground cable routeing towards the LCS has opportunities for shorter, more direct routes and as such the potential to avoid more constrained areas compared to other strategic options. Subject to the specific location within the Lincolnshire landfall area, the underground cable route is required to cross a minimum of one main river, as well as routeing through flood zones 2 and 3. There are fewer statutory ecological or historic environment designations in the area, however those which are present can be avoided with careful route and site selection.

6.2.14 Flood zones 2 and 3 are present in the vicinity of the proposed converter station, however, can be avoided with careful siting. Subject to site selection, the siting of a converter station in the rural/coastal area increases the potential for long-term effects on the setting of Scheduled Monuments including Markby Priory as well as the potential for long-term effects on views from within the Lincolnshire Wolds National Landscape. There is the potential to result in long term landscape and visual effects due to the introduction of new infrastructure in a landscape which currently has little major development. This includes the potential for cumulative effects in combination with the LCS. However, there may be opportunities to mitigate this through specific site selection within the area and design.

6.2.15 Small sized settlements are present throughout the study area, mostly along the coast. These are connected to the main transport network via routes including the A1104, A1111 and A52, some of which are likely to be required to be crossed. Careful routeing should be undertaken to avoid unnecessary crossings and reduce travel disruptions. Much of the land within the study area comprises agricultural land with an Agricultural Land Classification of grade 2 or 3a, the best and most versatile agricultural land. This does not prevent cable routeing through these areas but highlights the need for effective soil management and reinstatement for underground cable routes. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole (however, these constraints are common to all Lincolnshire landfall Options, particularly in the vicinity of the coastline).

6.2.16 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 1.

Summary of the technical appraisal

6.2.17 A technical appraisal has established that a new transmission circuit from Scotland connecting to New LCS satisfies the NETS SQSS requirement.

6.2.18 Technical appraisal of this option includes consideration of the following:

- The proposed transmission connection is made to the new Grimsby West to Walpole line away from any demand centres.
- Option 1 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary.
- There is neutral impact to the East Coast Generation Group.
- The proposed transmission connection is currently limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of LCS.
- As LCS is under the Grimsby to Walpole scope, Option 1 being feasible for the Project is contingent on Grimsby to Walpole progressing and being completed on schedule. For more info on Grimsby to Walpole please refer to Chapter 8 of this report.

Summary of the cost appraisal

6.2.19 As set out in Chapter 5, we undertook a cost evaluation of the following two technologies for subsea options evaluation.

- 400 kV AC subsea cable;
  - AC subsea connections circuit options use medium capacity double circuits (two 400kV AC circuits) with a total capacity of up to 6,380 Mega Volt Amperes (MVA);
- 525 kV HVDC subsea cable and converter stations;
  - HVDC subsea connection options use 525 kV voltage source links of 2 GW, which require a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at the New LCS.
  - Connections between the new converter station and New LCS are also required

6.2.20 Either of these options also entail the following works:

- NGET Substation Works
- Two bays at New LCS

6.2.21 Table 6.1 sets out the capital costs for Option 1 considering substation works and each technology option. See Appendix D for the full detailed breakdown of what this cost includes.

Table 6.1 – Option 1: capital cost for each technology option

Item	Capital Cost	
Substation and Wider Works	£16.0m	
New Circuits (546 km)	**AC Subsea Cable**	**HVDC Subsea Cable**
New Circuit	£16,698.4m	£2,221.5m
Total Capital Cost	**£16,714.4m**	**£2,237.5m**

6.2.22 Table 6.2 sets out the lifetime cost for the new circuit technology options. The lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in “Strategic options technical appendix 2020/2021 price base”, found in Appendix D.

Table 6.2 – Option 1: lifetime cost for each technology option

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
Capital Cost of New Circuits	**£16,698.4m**	**£2,221.5m**
NPV of Cost of Losses over 40 years	£548.9m	£157.1m

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
NPV of Operation & Maintenance costs over 40 years	£98.1m	£58.7m
Lifetime Cost of New Circuits	**£17,345m**	**£2,437m**

6.2.23 The table above presents figures and numbers for the following cost terms, with definitions provided in the bullet points below:

- Capital Cost of New Circuits is a term utilised to demonstrate the initial capital expenditure associated with the implementation of a new circuit;
- Net Present Value (NPV) of Cost of Losses is a term utilised to demonstrate the present-day monetary value of cost of losses while factoring in initial capital investment required for the Project;
- NPV of Operation and Maintenance Costs is a term utilised to demonstrate the present-day monetary value of operation and maintenance costs while factoring in initial capital investment required for the Project;
- Lifetime Cost of New Circuits is a term utilised to demonstrate the total capital expenditure associated with the implementation of a new circuit and is calculated by summing the above three cost terms.

6.2.24 Based on the data in the above tables, the following conclusions can be drawn:

- HVDC has the lowest capital cost of new circuits;
- HVDC has the lowest NPV of Cost of Losses over a forty-year projection;
- HVDC has the lowest NPV of Operation and Maintenance Costs over a forty-year projection;
- HVDC has the lowest lifetime cost of new circuits.

6.2.25 In light of this cost appraisal, our starting presumption for further development of this option, should it be selected, is for a majority HVDC connection.

Summary of strategic option 1

6.2.26 Option 1 proposes a new transmission connection from Scotland to New LCS with a landfall on the Lincolnshire coastline.

6.2.27 The total straight-line distance for this strategic option is 455 km, consisting of 445 km offshore HVDC cable and 10 km of onshore underground cable, with a total distance of 546 km including 20% tolerance. The HVDC connection and short distance from the landfall to the LCS is beneficial for this strategic option in terms of cost, as it results in lifetime costs totalling £2,437m.

6.2.28 Option 1 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary, there is also neutral impact to the East Coast Generation Group, thus Option 1 meets the need case. This strategic option has advantage by utilising underground routeing from Lincolnshire landfall to LCS to avoid more constrained and designated areas. Overall, with appropriate mitigation strategies undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 1. However, the reliance on Grimsby to Walpole progressing and being completed on schedule presents risk.

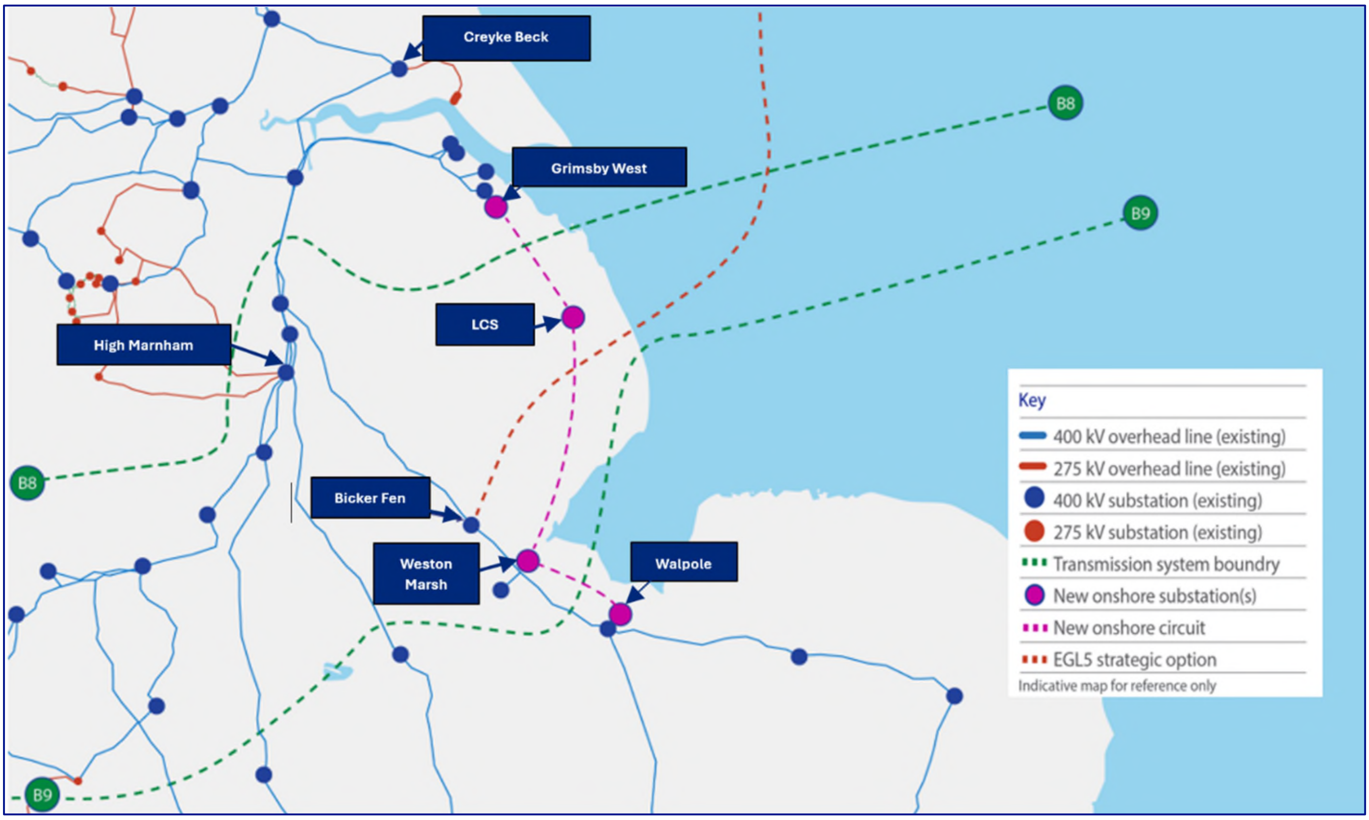
6.3 Appraisal of Option 2 – Connection to Bicker Fen

Description of strategic option 2

6.3.1 Option 2 involves the development of a new transmission circuit from Scotland connecting to the existing Bicker Fen substation. The majority of the new circuit is routed within the North Sea making landfall on the Lincolnshire coastline. The marine element of Option 2 is common to all strategic options until the point at which the marine option splits for landfall (to Lincolnshire or North Norfolk coastlines) (i.e. how far south the submarine cables are routed).

6.3.2 A diagram of the location of Strategic Option 2 is shown in Figure 6.3.

Figure 6.3 – Indicative location of Option 2 – Connection to Bicker Fen Substation



6.3.3 The circuit distance for this connection is presented below. This is based on a subsea cable route distance from a preliminary cable routing study and a straight-line distance from a landfall on the Lincolnshire coastline to the existing Bicker Fen substation.

- 445 km Offshore Distance
- 50 km Onshore Distance
- 495 km Total Straight-Line Distance
- 594 km Total Distance (including 20% tolerance)

6.3.4 This option is formed of a HVDC link which requires a pair of HVDC cables. Two converter stations are required, one in Scotland and one in the vicinity of Bicker Fen Substation. The converter stations each have an approximate footprint of 6 ha (see Appendix C for further information).

6.3.5 Onshore underground HVDC cables are required from the Lincolnshire Landfall to the converter station at Bicker Fen Substation. Two bays are required at Bicker Fen Substation to accommodate the connection of the Project. These two bays fall under the consenting process for the Project as set out in Section 3.5. For the purposes of the appraisal of Option 2, consideration has been given to the additional costs or impacts of adding two bays the existing Bicker Fen Substation.

Summary of the environmental and socio-economic appraisal

6.3.6 An environmental and socio-economic appraisal has been undertaken of the new transmission circuit making landfall on the Lincolnshire coast and connecting to the existing Bicker Fen Substation in Boston.

6.3.7 For the purposes of the appraisal a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Lincolnshire coastline (between south of Saltfleet and north of Ingoldmells) inland to the point of connection at Bicker Fen Substation.

6.3.8 The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations. The study area for the appraisal of marine factors extended from either landfall to the border for Scottish waters, a distance of approximately 400 km (from North Norfolk). The marine study area is split, east of Hull to provide the two different options for landfall, for Lincolnshire (where the study area extended from north of Theddlethorpe to north of Chapel St Leonards) and North Norfolk (where the study area extended from west of Morston to Cromer).

6.3.9 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to subsea cable routeing and landfall siting on the Lincolnshire coast. These include the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Between the strategic options making landfall on the Lincolnshire coast, these sites are common to any subsea cable route and therefore are not a significant differentiator between the strategic options being appraised.

6.3.10 With regard to socio-economic considerations in the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the landfall study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. Additionally, there are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.

6.3.11 The Lincolnshire coastline is also subject to a number of statutory ecological designations. From north to south this includes the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-

Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are potentially avoidable through landfall selection. Where landfalls, such as Theddlethorpe, are located within coastal ecological designations, impacts may be avoided through a choice of cable installation methods (for example trenchless methods such as HDD). Coastal ecological designations present a consenting constraint some specific landfall sites within on this option, requiring significant mitigation measures.

6.3.12 While onshore underground cable routes to Bicker Fen Substation are longer than other routes, the terrestrial study area is not considered to be highly constrained in terms of environmental designations. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable, with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Additionally, the underground cable route will likely be required to cross a minimum of four main rivers, as well as routeing through flood zones 2 and 3. There are 11 SSSIs present within the study area, as well as designated heritage assets such as Scheduled Monuments. These designations occupy small areas and can be avoided with careful routeing.

6.3.13 Small and moderately sized settlements are present throughout the study area often coalescing along main transport routes including the A16, A17, A52 and the Grantham to Skegness railway line. Careful routeing should be undertaken to avoid unnecessary crossings and reduce travel disruptions. Much of the land within the study area comprises agricultural land with an Agricultural Land Classification of grade 2 or 3, the best and most versatile agricultural land. This does not prevent cable routeing through these areas but highlights the need for effective soil management and reinstatement for underground cable routes to a converter station in the Bicker Fen area.

6.3.14 There are no statutory landscape, ecological and historic environment designations within 2 km of Bicker Fen Substation which influence site selection. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole (however, these constraints are common to all Lincolnshire landfall Options, particularly in the vicinity of the coastline). Other key other factors which could influence site selection relate to other energy projects close to and/or connecting to Bicker Fen including Triton Knoll Offshore Wind Farm, Viking Link Interconnector and Heckington Fen Solar Park. The boundary for Manby Anaerobic Digester also falls on the edge of the study area and Heckington Fen Solar Farm fall within it. Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 2.

Summary of the technical appraisal

6.3.15 A technical appraisal has established that a new transmission circuit from Scotland connecting to new Bicker Fen Substation satisfies the NETS SQSS requirement.

6.3.16 Technical appraisal of this option includes consideration of the following:

- The proposed transmission connection to the existing network is made away from major demand centres;
- Option 2 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary.
- There is neutral impact to the East Coast Generation Group.
- The proposed transmission connection is currently limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of Bicker Fen.

Summary of the cost appraisal

6.3.17 As set out in Chapter 5, we undertook a cost evaluation of the following two technologies for subsea options evaluation.

- 400 kV AC subsea cable.
  - AC subsea connections circuit options use medium capacity double circuits (two 400kV AC circuits) with a total capacity of up to 6,380 MVA
- 525 kV HVDC subsea cable and converter stations
  - HVDC subsea connection options use 525 kV voltage source links of 2 GW, which requires a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at Bicker Fen Substation.
  - Connections between the new converter station and Bicker Fen Substation are also required

6.3.18 Either of these options entail the following works:

- NGET Substation Works
  - Two bays at Bicker Fen Substation.

6.3.19 Table 6.3 sets out the capital costs for Option 2 considering substation works and each technology option. See Appendix D for the full detailed breakdown of what this cost includes.

Table 6.3 – Option 2: capital cost for each technology option

Item	Capital Cost	
Substation and Wider Works	£16.0m	
New Circuits (594 km)	**AC Subsea Cable**	**HVDC Subsea Cable**
New Circuit	£18,181.6m	£2,369.8m
Total Capital Cost	**£18,197.6m**	**£2,385.8m**

6.3.20 Table 6.4 sets out the lifetime cost for the new circuit technology options. The lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in “Strategic options technical appendix 2020/2021 price base”, found in Appendix D.

Table 6.4 – Option 2: lifetime cost for each technology option

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
Capital Cost of New Circuits	**£18,181.6m**	**£2,369.8m**
NPV of Cost of Losses over 40 years	£600.3m	£157.1m
NPV of Operation & Maintenance costs over 40 years	£107.3m	£58.8m
Lifetime Cost of New Circuits	**£18,889m**	**£2,586m**

6.3.21 Based on the data in the above tables, the following conclusions can be drawn:

- HVDC has the lowest capital cost of new circuits.
- HVDC has the lowest NPV of Cost of Losses over a forty-year projection.
- HVDC has the lowest NPV of Operation and Maintenance Costs over a forty-year projection.
- HVDC has the lowest lifetime cost of new circuits.

6.3.22 In light of this cost appraisal, our starting presumption for further development of this option, should it be selected, is for a majority HVDC connection.

Summary of strategic option 2

6.3.23 Option 2 proposes a new transmission connection from Scotland to the existing Bicker Fen Substation with a landfall on the Lincolnshire coastline.

6.3.24 The total straight-line distance for this strategic option is 495 km, consisting of 445 km offshore HVDC cable and 50 km of onshore underground cable, with a total distance of 594 km including 20% tolerance. The lifetime costs for this option are £2,586m.

6.3.25 Option 2 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary, there is also neutral impact to the East Coast Generation Group, thus Option 2 meets the need case. While cable routes to Bicker Fen Substation would be longer than other routes, the study area is not considered to be highly constrained in terms of environmental designations. With appropriate mitigation undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 2.

6.4 Appraisal of Option 3 – Connection to New Ryhall

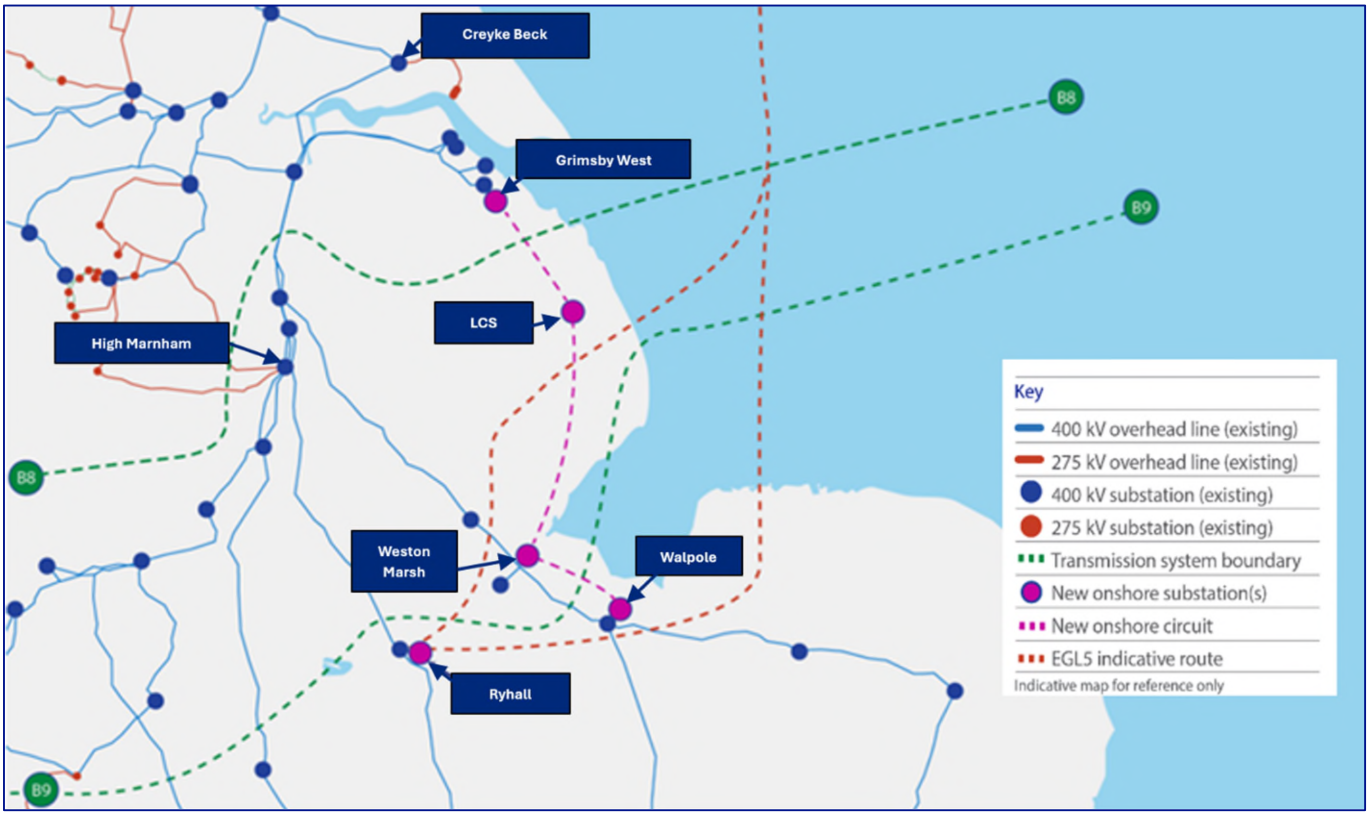
Description of strategic option 3

6.4.1 Option 3 involves the development of a new transmission circuit from Scotland connecting to new Ryhall Substation. The majority of the new circuit is routed within the North Sea, making landfall on either the Lincolnshire coastline or North Norfolk coastline. The marine element of Option 3 is generally comparable to all strategic options until the point at which the marine option splits for landfall (to Lincolnshire or North Norfolk coastlines) (i.e. how far south the submarine cables are routed).

6.4.2 The new Ryhall Substation is proposed as part of a new circuit between South Lincolnshire and East Leicestershire as part of the Weston Marsh to East Leicestershire project, and therefore subject to an application for development consent in the future. As Weston Marsh to East Leicestershire is a separate project, the application for development consent for the new Ryhall Substation is separate to consenting for the EGL 5 Project. Weston Marsh to East Leicestershire specific information can be found in Chapter 8.

6.4.3 A diagram of Strategic Option 3 is shown in Figure 6.4.

Figure 6.4 – Indicative location of Option 3 – Connection to New Ryhall Substation



6.4.4 The circuit distance for this connection is presented below. This is based on a subsea cable route distance from a preliminary cable routing study and a straight-line distance from a landfall on the Lincolnshire (Option 3a) or Norfolk (Option 3b) coastline to the new Ryhall Substation.

- 445 km Offshore Distance
- 85 km Onshore Distance
- 530 km Total Straight-Line Distance
- 636 km Total Distance (including 20% tolerance)

6.4.5 This option is formed of a HVDC link which requires a pair of HVDC cables. Two converter stations are required, one in Scotland and one in the vicinity of the new Ryhall Substation. The converter stations each have an approximate footprint of 6 ha (see Appendix C for further information).

6.4.6 Onshore underground HVDC cables are required from the landfall point to the converter station at new Ryhall Substation. Two bays are required at the new Ryhall Substation to accommodate the connection of the Project.

6.4.7 The distances for the Lincolnshire landfall point are used as the overall distance for this option, as it is the longer straight-line distance. However, the distances for a landfall on the Norfolk coastline are still within the 20% tolerance applied for potential route deviations as mentioned in paragraph 5.6.8 above. As such, a separate cost appraisal of the Norfolk distance is not considered necessary.

Summary of the environmental and socio-economic appraisal

6.4.8 An environmental and socio-economic appraisal has been undertaken of two new transmission circuits making landfall on the Lincolnshire or Norfolk coastlines and connecting to the new Ryhall Substation in South Kesteven.

Landfall option 3a: Lincolnshire coastline

6.4.9 For the purposes of the appraisal a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Lincolnshire coastline (between south of Saltfleet and north of Ingoldmells) inland to the point of connection at new Ryhall Substation.

6.4.10 The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations. The study area for the appraisal of marine factors extended from either landfall to the border for Scottish waters, a distance of approximately 400 km (from North Norfolk). The marine study area is split, east of Hull to provide the two different options for landfall, for Lincolnshire (where the study area extended from north of Theddlethorpe to north of Chapel St Leonards) and North Norfolk (where the study area extended from west of Morston to Cromer).

6.4.11 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to subsea cable routeing and landfall siting on the Lincolnshire coast. These include the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Between the strategic options making landfall on the Lincolnshire coast, these sites are common to any subsea cable route and therefore are not a significant differentiator between the strategic options being appraised.

6.4.12 With regard to socio-economic considerations in the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the landfall study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. Additionally, there are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.The Lincolnshire coastline is also subject to a number of statutory ecological designations. From north to south this includes the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-Theddlethorpe Dunes and

Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are potentially avoidable through landfall selection. Where landfalls, such as Theddlethorpe, are located within coastal ecological designations, impacts may be avoided through a choice of cable installation methods (for example trenchless methods such as HDD). Coastal ecological designations present a consenting constraint for some specific landfall sites within this option, requiring significant mitigation measures.

6.4.13 Environmental and socio-economic constraints influencing underground cable routes to new Ryhall Substation are similar to those for Option 2 (Bicker Fen); the study area is not considered to be highly constrained in terms environmental designations. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable, with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. There are 35 SSSIs present within the study area, as well as designated heritage assets such as Scheduled Monuments. These designations occupy small areas and can be avoided with careful routeing. The underground cable route will likely be required to cross a minimum of seven main rivers, as well as routeing through flood zones 2 and 3, with the converter station likely to sit within flood zone 2.

6.4.14 Small and moderately sized settlements are present throughout the study area often coalescing along main transport routes including the A15, A16, A17, A52, East Coast Main Line, Peterborough to Lincoln line, and the Grantham to Skegness railway line. Careful routeing should be undertaken to avoid unnecessary crossings and reduce travel disruptions. Much of the land within the study area comprises agricultural land with an Agricultural Land Classification of grade 2 or 3, the best and most versatile agricultural land. This does not prevent cable routeing through these areas but highlights the need for effective soil management and reinstatement for underground cable routes to a converter station in the vicinity of new Ryhall Substation.

6.4.15 Subject to site selection, the siting of converter station in the rural area increases the potential for long-term effects on the setting of Scheduled Monuments including Castle Bytham Castle. There is the potential to result in long term landscape and visual effects due to the introduction of new infrastructure in a landscape which currently has little major development. However, there may be opportunities to mitigate this through site selection within the study area and design.

6.4.16 Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole (however, these constraints are common to all Lincolnshire landfall Options, particularly in the vicinity of the coastline). The boundary for Manby Anaerobic Digester also falls on the edge of the study area and Heckington Fen Solar Farm falls within.

6.4.17 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 3a.

Landfall option 3b: Norfolk coastline

6.4.18 For the purposes of the appraisal a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Norfolk coastline (between Kelling and Sheringham) inland to the point of connection at the new Ryhall Substation. The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations.

6.4.19 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to route and landfall selection. These include some statutory designated sites which are also impacted by strategic options making landfall in Lincolnshire (the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC), but also includes additional sites which are impacted by making landfall in Norfolk. These include The Wash and North Norfolk Coast SAC, North Norfolk Coast SAC, SPA and Ramsar site, and Cromer Shoal Chalk Beds MCZ. One or more of these sites require to be crossed in order to make landfall on the Norfolk coast. While it requires confirmation through detailed survey and assessments, the qualifying features for the sites comprise habitat features or interests which could be affected by a subsea cable route and/or associated rock protection resulting in permanent habitat loss. These coastal ecological designations present a consenting constraint across the extent of the landfall for this option, requiring significant mitigation measures, particularly where more than one designation is crossed, increasing the likelihood of impact.

6.4.20 With regard to socio-economic considerations within the marine environment, the Norfolk landfall study area includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignment, Viking Link, North Sea Link and Hornsea 1, 2 and 3 export connection cables. Additionally, Sheringham Shoal and Dudgeon Extensions with consent authorised Project status, appear to have export connection cables reach landfall within the small section that is not designated as a SSSI. Additionally, there are four designated bathing waters within the Norfolk landfall study area which are classified as having excellent bathing water status in 2024.

6.4.21 Underground cable routeing from the Norfolk coast to the new Ryhall area is more constrained compared to other options due to the presence of statutory landscape, ecological and historic environment designations (as listed above). The Norfolk Coast National Landscape extends across the coastline and study area and cannot be avoided. While long term impacts on the National Landscape should be limited as result of the use of underground cables, alternative options which can avoid it and which also reflect the planning policy requirements are preferable.

6.4.22 There are a range of other constraints present in the study area including SACs, Ramsar sites, SSSIs, Scheduled Monuments and Registered Parks and Gardens. While the majority of these designations (particularly heritage designations) are relatively small and avoidable with careful routeing, their distribution affects the directness of potential underground cable routes and increase overall route lengths. In some locations, trenchless solutions may be able to be used to avoid impact on these receptors and minimise the need for an increase in route length.

6.4.23 There are a number of settlements present within the study area ranging from small villages to market towns; larger settlements include Fakenham, King's Lynn, Wisbech and Spalding. In combination with designated sites, the latter is likely to significantly influence route options requiring longer routes to the south of King's Lynn and the A149/A17 in order to avoid potential impacts. At least one crossing of both the Fen Line railway line and the Peterborough to Lincoln Line railway line is likely.

6.4.24 As with other strategic options routeing in high quality agricultural land is feasible, however, this assumes mitigation including effective soil management and reinstatement.

6.4.25 Subject to site selection, the siting of converter stations in the rural area increases the potential for long-term effects on the setting of Scheduled Monuments including Castle Bytham Castle. There is the potential to result in long term landscape and visual effects due to the introduction of new infrastructure in a landscape which currently has little major development. However, there may be opportunities to mitigate this through site selection and design.

6.4.26 Other planned or in development project constraints in the area include Hornsea 3 Offshore Wind Farm NSIP, Sheringham and Dudgeon Extension Projects NSIP and Palm Paper 3 CCGT Power station Kings Lynn.

6.4.27 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routeing and siting, the majority of environmental and socio-economic factors (both terrestrial and marine) are not considered to significantly constrain Option 3b. However, due to the potential for Option 3b to impact on a number of statutory designated sites in the marine and terrestrial environments at the landfall location, where existing and proposed development is also a constraint, compared to Option 3a, Option 3b is considered to be less preferable.

Summary of the technical appraisal

6.4.28 A technical appraisal has established that a new transmission circuit from Scotland connecting to new Ryhall Substation satisfies the NETS SQSS requirement.

6.4.29 Technical appraisal of this option includes consideration of the following:

- The proposed transmission connection to the existing network is made away from major demand centres.
- Option 3 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries.
- There is neutral impact to the East Coast Generation Group.
- The new Ryhall Substation benefits from four additional double circuits connected which provide additional resilience under fault conditions, since there are multiple pathways for current to flow.
- The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire. For more info on Weston Marsh to East Leicestershire please refer to Chapter 8 of this report.

Summary of the cost appraisal

6.4.30 As set out in Chapter 5, we undertook a cost evaluation of the following two technologies for subsea options evaluation.

- 400 kV AC subsea cable.
  - AC subsea connections circuit options use medium capacity double circuits (two 400 kV AC circuits) with a total capacity of up to 6,380 MVA
- 525 kV HVDC subsea cable and converter stations
  - HVDC subsea connection options use 525 kV voltage source links of 2 GW, which requires a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at the new Ryhall Substation.
  - Connections between the new converter station and new Ryhall Substation are also required

6.4.31 Either of these options entail the following works:

- NGET Substation Works
  - Two bays at new Ryhall Substation.

6.4.32 Table 6.5 sets out the capital costs for Option 3 considering substation works and each technology option. These costs are identical for Option 3a and Option 3b. This can be assumed given the difference in distance between the two landfall locations falls within the 20% tolerance applied for potential route deviations. Work required at the substation is identical for either option. See Appendix D for the full detailed breakdown of what this cost includes.

Table 6.5 – Option 3: capital cost for each technology option

Item	Capital Cost	
Substation and Wider Works	£16.0m	
New Circuits (636 km)	**AC Subsea Cable**	**HVDC Subsea Cable**
New Circuit	£19,459.1m	£2,499.6m
Total Capital Cost	**£19,475.1m**	**£2,515.6m**

6.4.33 Table 6.7 sets out the lifetime cost for the new circuit technology options. The lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in "Strategic options technical appendix 2020/2021 price base", found in Appendix D.

Table 6.7 – Option 3: lifetime cost for each technology option

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
Capital Cost of New Circuits	**£19,459.1m**	**£2,499.6m**

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
NPV of Cost of Losses over 40 years	£641.8m	£157.1m
NPV of Operation & Maintenance costs over 40 years	£114.5m	£58.9m
Lifetime Cost of New Circuits	**£20,216m**	**£2,716m**

6.4.34 Based on the data in the above tables, the following conclusions can be drawn:

- HVDC has the lowest capital cost of new circuits.
- HVDC has the lowest NPV of Cost of Losses over a forty-year projection.
- HVDC has the lowest NPV of Operation and Maintenance Costs over a forty-year projection.
- HVDC has the lowest lifetime cost of new circuits.

6.4.35 In light of this cost appraisal, our starting presumption for further development of this option, should it be selected, is for a majority HVDC connection.

Summary of strategic option 3

6.4.36 Option 3 proposes a new transmission connection from Scotland to new Ryhall Substation. The marine element of Option 3 is common to all strategic options until the point at which the marine option splits for landfall on the Lincolnshire (Option 3a) or Norfolk (Option 3b) coastline to the new Ryhall Substation.

6.4.37 The total straight-line distance for this strategic option is 530 km, consisting of 445 km offshore HVDC cable and 85 km of onshore underground cable, with a total distance of 636 km including 20% tolerance. The distance for the Lincolnshire landfall point is used in this summary as the distance via a Norfolk coastline landfall point to the substation is still within the 20% tolerance. Option 3 presents the longest distance, which results in higher lifetime costs of the Project at £2,716m.

6.4.38 Option 3 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries, there is also neutral impact to the East Coast Generation Group, thus Option 3 meets the need case. Environmental and socio-economic constraints for Option 3a influencing Underground cable routes to the new Ryhall Substation are not considered to be highly constrained by the environmental and socio-economic factors. However, for Option 3b the Norfolk coast to the new Ryhall area is more constrained compared to other options due to the presence of statutory landscape, ecological and historic environment designations, which is less preferred. Option 3 is also contingent on Weston Marsh to East Leicestershire progressing, which proposes a new circuit between South Lincolnshire and East Leicestershire.

6.5 Appraisal of Option 4 – Connection to New Weston Marsh

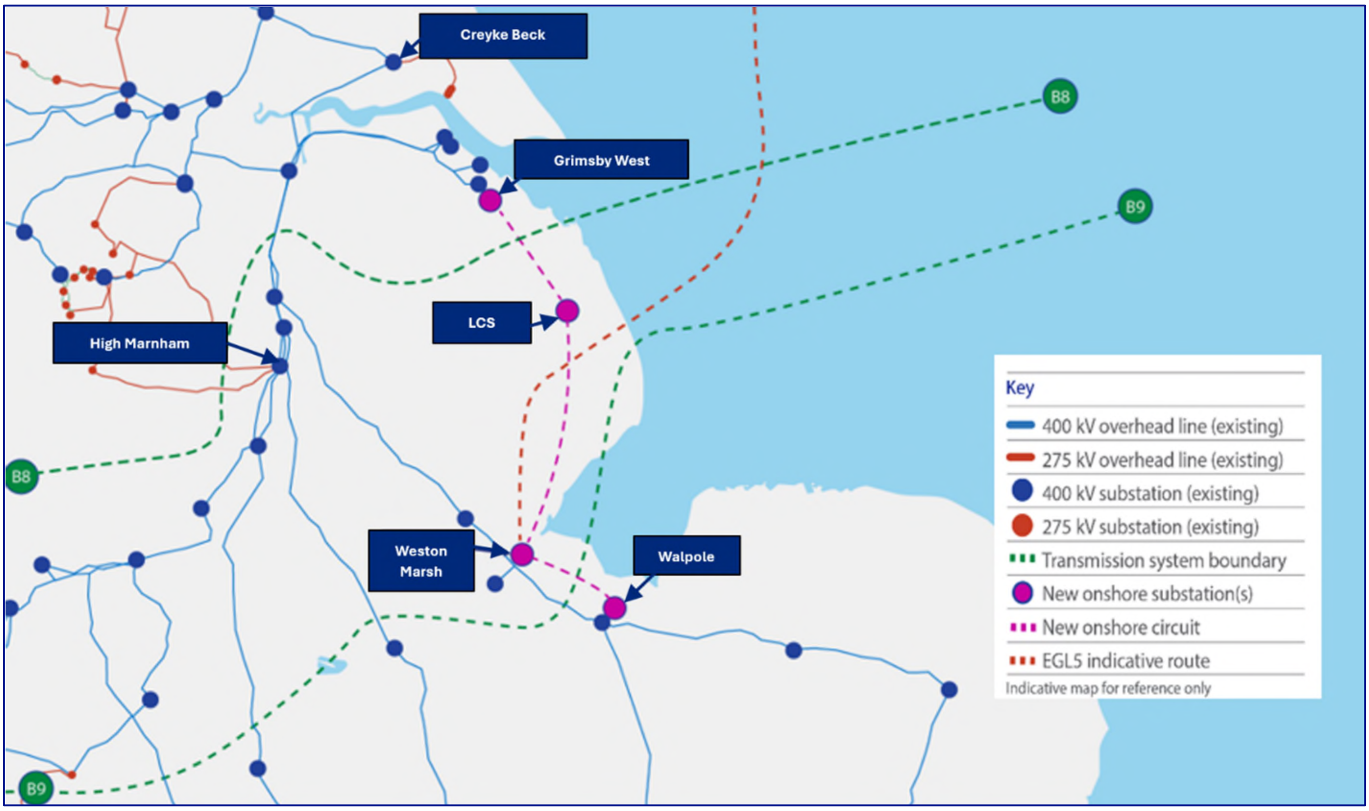
Description of strategic option 4

6.5.1 Option 4 involves the development of a new transmission circuit from Scotland connecting to new Weston Marsh Substation. The majority of the new circuit is routed within the North Sea making landfall on the Lincolnshire coastline. The marine element of Option 4 is common to all strategic options until the point at which the marine option splits for landfall (to Lincolnshire or North Norfolk coastlines) (i.e. how far south the submarine cables are routed)

6.5.2 The new Weston Marsh Substation is proposed as part of Grimsby to Walpole and therefore subject to an application for development consent in the future. Grimsby to Walpole is a separate NGET project and so the application for development consent for the new Weston Marsh Substation is a separate process to the consenting approach for the EGL 5 Project. Grimsby to Walpole specific information can be found in Chapter 8.

6.5.3 A diagram of Strategic Option 4 is shown in Figure 6.5.

Figure 6.5 – Indicative location of Option 4 – Connection to New Weston Marsh Substation



6.5.4 The circuit distance for this connection is presented below. This is based on a subsea cable route distance from a preliminary cable routing study and a straight-line distance from a landfall on the coastline to the point of connection to the 400 kV network at New Weston Marsh Substation.

- 445 km Offshore Distance
- 55 km Onshore Distance

- 500 km Total Straight-Line Distance
- 600 km Total Distance (including 20% tolerance)

6.5.5 This option is formed of a HVDC link which requires a pair of HVDC cables. Two converter stations are required, one in Scotland and one in the vicinity of the new Weston Marsh Substation. The converter stations each have an approximate footprint of 6 ha (see Appendix C for further information).

6.5.6 Onshore underground HVDC cables are required from the Lincolnshire Landfall to the converter station at new Weston Marsh Substation. Two bays are required at the new Weston Marsh Substation to accommodate the connection of the Project. As new Weston Marsh is part of Grimsby to Walpole, the consenting process for these bays is separate to the EGL 5 Project consenting approach set out in Section 3.5.

Summary of the environmental and socio-economic appraisal

6.5.7 An environmental and socio-economic appraisal has been undertaken of Option 4 making landfall on the Lincolnshire coast and connecting to the new Weston Marsh Substation in South Holland Borough.

6.5.8 For the purposes of the appraisal, a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Lincolnshire coastline (between south of Saltfleet and north of Ingoldmells) inland to the point of connection at New Weston Marsh Substation.

6.5.9 The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations. The study area for the appraisal of marine factors extended from either landfall to the border for Scottish waters, a distance of approximately 400 km (from North Norfolk). The marine study area is split, east of Hull to provide the two different options for landfall, for Lincolnshire (where the study area extended from north of Theddlethorpe to north of Chapel St Leonards) and North Norfolk (where the study area extended from west of Morston to Cromer).

6.5.10 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to subsea cable routeing and landfall siting on the Lincolnshire coast. These include the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Between the strategic options making landfall on the Lincolnshire coast, these sites are common to any subsea cable route and therefore are not a significant differentiator between the strategic options being appraised.

6.5.11 With regard to socio-economic considerations in the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the landfall study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. Additionally, there are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.

6.5.12 The Lincolnshire coastline is also subject to a number of statutory ecological designations. From north to south this includes the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are potentially avoidable through landfall selection. Where landfalls, such as Theddlethorpe, are located within coastal ecological designations, impacts may be avoided through a choice of cable installation methods (for example trenchless methods such as HDD). Coastal ecological designations present a consenting constraint some specific landfall sites within on this option, requiring significant mitigation measures.

6.5.13 Environmental and socio-economic constraints influencing terrestrial underground cable routes to Weston Marsh Substation are similar to those for Spalding North Substation (via Lincolnshire); the study area is not considered to be highly constrained in terms of environmental designations. Part of the Lincolnshire Wolds National Landscape extends into the north of the study area while The Wash SAC, SPA, Ramsar site and NNR lie to the south, however, these sites can be avoided with careful routeing. Subject to detailed routeing there may be some potential for disturbance and/or displacement impacts where qualifying bird species of The Wash SPA and Ramsar site utilise adjacent agricultural land, however, this should be temporary for the duration of cable installation only. There are 16 SSSIs present within the study area, as well as designated heritage assets such as Scheduled Monuments. These designations occupy small areas and can be avoided with careful routeing therefore are not considered to materially influence this option. The underground cable route will likely be required to cross a minimum of three main rivers, as well as routeing through flood zones 2 and 3.

6.5.14 Small and moderately sized settlements are present throughout the study area often coalescing along main transport routes including the A16, A52 and the Grantham to Skegness railway line. Boston is a key constraint and will influence the underground cable routeing and cable distances e.g. either north and west or south and east of the settlement.

6.5.15 The majority of land within the study area comprises agricultural land with an Agricultural Land Classification of grade 1 or 2, the best and most versatile agricultural land. This does not prevent cable routeing through these areas but highlights the need for effective soil management and reinstatement for underground cable routes to a converter station in the vicinity of Weston Marsh Substation.

6.5.16 A converter station in the Weston Marsh area has the potential to result in long term landscape and visual effects due to the introduction of new infrastructure in a landscape which currently has little major development. This includes the potential for cumulative effects in combination with the new Weston Marsh Substation (proposed as part of the Grimsby to Walpole Project), however, there may be some opportunities to mitigate this through site selection and design.

6.5.17 Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole (however, these constraints are common to all Lincolnshire landfall Options, particularly in the vicinity of the coastline). Boston Alternative Energy Facility also falls within the study area.

6.5.18 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 4.

Summary of the technical appraisal

6.5.19 A technical appraisal has established that a new transmission circuit from Scotland connecting to new Weston Marsh Substation satisfies the NETS SQSS requirement.

6.5.20 Technical appraisal of this option includes consideration of the following:

- The proposed transmission connection to the existing network is made away from major demand centres.
- Option 4 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary.
- There is neutral impact to the East Coast Generation Group.
- New Weston Marsh Substation benefits from four additional double circuits connected which provides additional resilience under fault conditions, since there are multiple pathways for current to flow.
- The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire. For more info on Weston Marsh to East Leicestershire please refer to Chapter 8 of this report.

Summary of the cost appraisal

6.5.21 As set out in Chapter 5, we undertook a cost evaluation of the following two technologies for subsea options evaluation.

- 400 kV AC subsea cable.
  - AC subsea connections circuit options use medium capacity double circuits (two 400 kV AC circuits) with a total capacity of up to 6,380 MVA
- 525 kV HVDC subsea cable and converter stations
  - HVDC subsea connection options use 525 kV voltage source links of 2 GW, which requires a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at new Weston Marsh Substation.
  - Connections between the new converter station and new Weston Marsh Substation are also required

6.5.22 Either of these options entail the following works:

- NGET Substation Works
  - Two bays at new Weston Marsh Substation.

6.5.23 Table 6.7 sets out the capital costs for Option 4 considering substation works and each technology option. See Appendix D for the full detailed breakdown of what this cost includes.

Table 6.7 – Option 4: capital cost for each technology option

Item	Capital Cost	
Substation and Wider Works	£16.0m	
New Circuits (600 km)	**AC Subsea Cable**	**HVDC Subsea Cable**
New Circuit	£18,351.6m	£2,388.4m
Total Capital Cost	**£18,367.6m**	**£2,404.4m**

6.5.24 Table 6.8 sets out the lifetime cost for the new circuit technology options. The lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in "Strategic options technical appendix 2020/2021 price base", found in Appendix D.

Table 6.8 – Option 4: lifetime cost for each technology option

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
Capital Cost of New Circuits	**£18,351.6m**	**£2,388.4m**
NPV of Cost of Losses over 40 years	£601.0m	£157.1m
NPV of Operation & Maintenance costs over 40 years	£108.0m	£58.8m
Lifetime Cost of New Circuits	**£19,061m**	**£2,604m**

6.5.25 Based on the data in the above tables, the following conclusions can be drawn:

- HVDC has the lowest capital cost of new circuits.
- HVDC has the lowest NPV of Cost of Losses over a forty-year projection.
- HVDC has the lowest NPV of Operation and Maintenance Costs over a forty-year projection.
- HVDC has the lowest lifetime cost of new circuits.

6.5.26 In light of this cost appraisal, our starting presumption for further development of this option, should it be selected, is for a majority HVDC connection.

Summary of strategic option 4

6.5.27 Option 4 proposes a new transmission connection from Scotland to new Weston Marsh Substation with a landfall on the Lincolnshire coastline.

6.5.28 The total straight-line distance for this strategic option is 500 km, consisting of 445 km offshore HVDC cable and 55 km of onshore underground cable, with a total distance of 600 km including 20% tolerance. This strategic option has lifetime costs of £2,604m.

6.5.29 Option 4 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary there is also neutral impact to the East Coast Generation Group, thus Option 4 meets the need case. The option is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire. Overall, with appropriate mitigation strategies undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 4.

6.6 Appraisal of Option 5 – Connection to New Walpole

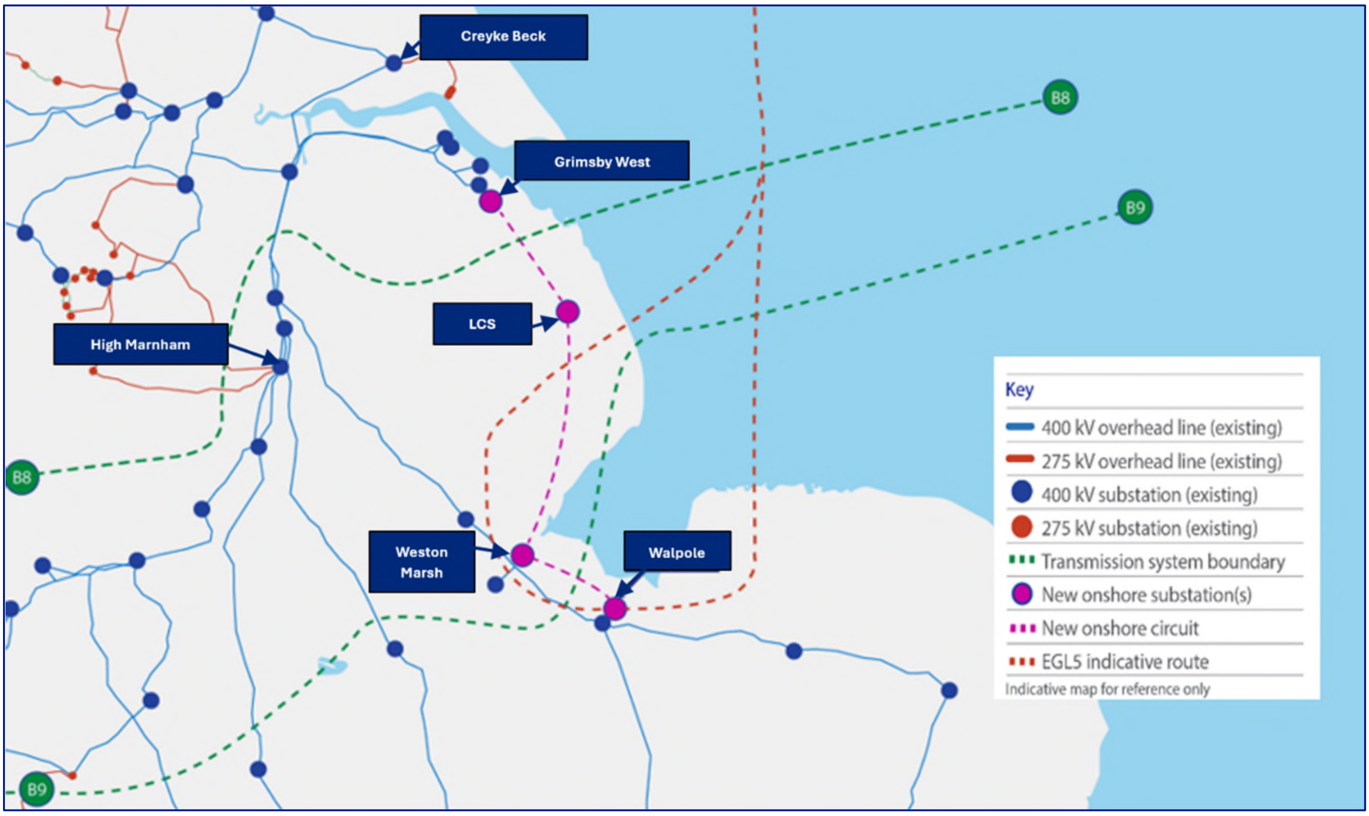
Description of strategic option 5

6.6.1 Option 5 involves the development of a new transmission circuit from Scotland connecting to new Walpole Substation. The majority of the new circuit is routed within the North Sea, making landfall on either the Lincolnshire coastline or North Norfolk coastline. The marine element of Option 5 is generally comparable to all strategic options until the point at which the marine option splits for landfall (to Lincolnshire or North Norfolk coastlines) (i.e. how far south the submarine cables are routed).

6.6.2 The new Walpole substation is proposed as part of Grimsby to Walpole and therefore subject to an application for development consent in the future. As Grimsby to Walpole is a separate NGET project, it has a separate application for development consent to the Project. Grimsby to Walpole specific information can be found in Chapter 8.

6.6.3 A diagram of Strategic Option 5 is shown in Figure 6.6.

Figure 6.6 – Indicative location of Option 5 – Connection to New Walpole Substation



6.6.4 The circuit distance for this connection is presented below. This is based on a subsea cable route distance from a preliminary cable routing study and a straight-line distance from a landfall on the Lincolnshire coastline to new Walpole.

- 445 km Offshore Distance

- 75 km Onshore Distance
- 520 km Total Straight-Line Distance
- 624 km Total Distance (including 20% tolerance)

6.6.5 This option is formed of a HVDC link which requires a pair of HVDC cables. Two converter stations are required, one in Scotland and one in the vicinity of the new Walpole Substation. The converter stations each have an approximate footprint of 6 ha (see Appendix C for further information).

6.6.6 Onshore underground HVDC cables are required from the landfall point to the converter station at new Walpole Substation. Two bays at the new Walpole Substation are required to accommodate the connection of the Project. New Walpole Substation falls under the Grimsby to Walpole scope and so consent for these two bays is to be obtained as part of the Grimsby to Walpole consenting process.

6.6.7 The distances for the Lincolnshire landfall point are used as the overall distance for this option, as it is the longer straight-line distance. However, the distances for a landfall on the Norfolk coastline are still within the 20% tolerance applied for potential route deviations as mentioned in Section 5.6 above. As such, a separate cost appraisal of the Norfolk distance is not considered necessary.

Summary of the environmental and socio-economic appraisal

6.6.8 An environmental and socio-economic appraisal has been undertaken of two new transmission circuits making landfall on the Lincolnshire or Norfolk coastlines and connecting to the new Walpole Substation in King's Lynn and West Norfolk, proposed as part of the Grimsby to Walpole Project and a key connection point for EGL 3 and EGL 4 Projects.

Landfall option 5a: Lincolnshire coastline

6.6.9 An environmental and socio-economic appraisal has been undertaken of a new transmission circuit making landfall on the Lincolnshire coast and connecting to the new Walpole Substation in King's Lynn and West Norfolk.

6.6.10 For the purposes of the appraisal, a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Lincolnshire coastline (between south of Saltfleet and north of Ingoldmells) inland to the point of connection at the new Walpole Substation.

6.6.11 The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations. The study area for the appraisal of marine factors extended from either landfall to the border for Scottish waters, a distance of approximately 400 km (from North Norfolk). The marine study area is split, east of Hull to provide the two different options for landfall, for Lincolnshire (where the study area extended from north of Theddlethorpe to north of Chapel St Leonards) and North Norfolk (where the study area extended from west of Morston to Cromer).

6.6.12 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to subsea cable routeing and landfall siting on the Lincolnshire coast. These include the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Between the strategic options making landfall on the Lincolnshire coast, these sites are common to any subsea cable route and therefore are not a significant differentiator between the strategic options being appraised.

6.6.13 With regard to socio-economic considerations in the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the landfall study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. Additionally, there are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.

6.6.14 The Lincolnshire coastline is also subject to a number of statutory ecological designations. From north to south this includes the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are potentially avoidable through landfall selection within the Lincolnshire landfall area. Where landfalls, such as Theddlethorpe, are located within coastal ecological designations, impacts may be avoided through a choice of cable installation methods (for example trenchless methods such as HDD) or seasonal construction restrictions. Coastal ecological designations present a consenting constraint some specific landfall sites within on this option, requiring significant mitigation measures.

6.6.15 Environmental and socio-economic constraints influencing underground cable routes to the Walpole area are similar to those for Weston Marsh and Spalding North substations; the study area is not considered to be highly constrained in terms environmental designations. Part of the Lincolnshire Wolds National Landscape extends into the north of the study area close to the coast while The Wash SAC, SPA, Ramsar site and NNR lie to the south, however, these sites can be avoided with careful routeing. Subject to detailed routeing there may be some potential for disturbance and/or displacement impacts where qualifying bird species of The Wash SPA and Ramsar site utilise adjacent agricultural land, however, this is likely be temporary for the duration of cable installation only.

6.6.16 There are a number of SSSIs (12) and Scheduled Monuments (47) present within the area between the Lincolnshire coastline and the Walpole area, but these designations occupy small areas and can be avoided with careful routeing therefore are not considered to materially influence this option.

6.6.17 The underground cable route will likely be required to cross a minimum of five main rivers, as well as routeing through flood zones 2 and 3, with the converter station unlikely to avoid flood zone 3.

6.6.18 Small and moderately sized settlements are present throughout the study area often coalescing along main transport routes including the A16, A17, A47, A52 and the Grantham to Skegness railway line. Boston is a key constraint and will influence the underground cable routeing and cable distances e.g. either north and west or south and east of the settlement. Similar constraints apply to settlements along the A17, including Holbeach and Long Sutton which will influence the directness of routes to the Walpole area.

6.6.19 The majority of land within the study area comprises agricultural land with an Agricultural Land Classification of grade 1 or 3. This does not prevent cable routeing through these areas but highlights the need for effective soil management and reinstatement for underground cable routes to a converter station in the vicinity of the new Walpole Substation.

6.6.20 There are a small number of statutory historic environment designations comprising Grade I, II and II* Listed Buildings in the Walpole area which could experience setting impacts subject to converter station siting including in combination with the new Walpole Substation proposed as part of the Grimsby to Walpole Project, however, existing electricity infrastructure is widely present in the area. The distribution of small settlements including Walpole St Andrew, Walpole St Peter, West Walton and Walton Highway as well as Wisbech may result in amenity related impacts, for example noise or visual impacts. Careful site selection and design including appropriate mitigation is required in order to avoid or reduce potential impacts on settlements.

6.6.21 Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole (however, these constraints are common to all Lincolnshire landfall Options, particularly in the vicinity of the coastline). Boston Alternative Energy Facility also falls within the study area.

6.6.22 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routeing and siting, environmental and socio-economic factors are not considered to significantly constrain this Option 5a.

Landfall option 5b: Norfolk coastline

6.6.23 For the purposes of the appraisal a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Norfolk coastline (between Kelling and Sheringham) inland to the point of connection at the new Walpole Substation. The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations.

6.6.24 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to route and landfall selection. These include some sites which are also be impacted by strategic options making landfall in Lincolnshire (the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC), but also includes additional sites which are impacted by making landfall in Norfolk. These include The Wash and North Norfolk Coast SAC, North Norfolk Coast SAC, SPA and Ramsar site, and Cromer Shoal Chalk Beds MCZ. One or more of these sites require to be crossed in order to make landfall on the Norfolk coast. While it requires confirmation through detailed survey and assessments, the qualifying features for the sites comprise habitat features or interests which could be affected by a subsea cable route and/or associated rock protection resulting in permanent habitat loss. These coastal ecological designations present a consenting constraint across the extent of the landfall for this option, requiring significant mitigation measures, particularly where more than one designation is crossed, increasing the likelihood of impact.

6.6.25 With regard to socio-economic considerations within the marine environment, the Norfolk landfall study area includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignment, Viking Link, North Sea Link and Hornsea 1, 2 and 3 export connection cables. Additionally, Sheringham Shoal and Dudgeon Extensions with consent authorised Project status, appears to have export connection cables reach landfall within the small section that is not designated as a SSSI. Additionally, there are four designated bathing waters within the Norfolk landfall study area which are classified as having excellent bathing water status in 2024.

6.6.26 Underground cable routeing from the Norfolk coast to the Walpole area is more constrained compared to other options due to the presence of a range of statutory landscape, ecological and historic environment designations, similar to those for Option 3b (New Ryhall via a landfall on North Norfolk coast). The Norfolk Coast National Landscape extends across the coastline and study area and cannot be avoided. While long term impacts on the National Landscape should be limited as result of the use of underground cables, alternative options which can avoid it and which also reflect the planning policy requirements are preferable.

6.6.27 There are a range of other constraints present in the study area including SACs, Ramsar sites, SSSIs, Scheduled Monuments and Registered Parks and Gardens. While the majority of these designations are relatively small and avoidable with careful routeing, their distribution affects the directness of potential underground cable routes and increase overall route lengths. There are a number of statutory historic environment designations comprising Grade I, II and II* Listed Buildings in the Walpole area which could experience setting impacts subject to converter station siting including in combination with the new Walpole Substation proposed as part of the Grimsby to Walpole Project, however, existing electricity infrastructure is widely present in the area. The distribution of small settlements including Walpole St Andrew, Walpole St Peter, West Walton and Walton Highway as well as Wisbech may result in amenity related impacts, for example noise or visual impacts. Careful site selection and design including appropriate mitigation are required in order to avoid or reduce potential impacts on settlements.

6.6.28 There are a number of settlements present within the study area ranging from small villages to market towns; larger settlements include Fakenham and King’s Lynn. In combination with designated sites, the latter is likely to significantly influence route options requiring longer routes to the south of King’s Lynn and the A149/A17 in order to avoid potential impacts. At least one crossing of the Fen Line is likely.

6.6.29 A large proportion of the study area comprises agricultural land with an Agricultural Land Capability classification of grade 3, however, west of King’s Lynn towards the Walpole area this increases to grade 1 and 2. As with other strategic options routeing in high quality agricultural land is feasible, however, this assumes mitigation including effective soil management and reinstatement.

6.6.30 The underground cable route will likely be required to cross a minimum of one main river, as well as routeing through flood zones 2 towards the end of the route. Areas of flood zone 3 are present but could likely be avoided with careful routing and siting.

6.6.31 Other planned or in development project constraints in the area include Hornsea 3 Offshore Wind Farm NSIP, Sheringham and Dudgeon Extension Projects NSIP, Palm Paper 3 CCGT Power station Kings Lynn.

6.6.32 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routeing and siting, the majority of environmental and socio-economic factors (both terrestrial and marine) are not considered to significantly constrain Option 5b. However, due to the potential for Option 5b to impact on a number of statutory designated sites in the marine and terrestrial environments at the landfall location, where existing and proposed development is also a constraint, compared to Option 5a, Option 5b is considered to be less preferable.

Summary of the technical appraisal

6.6.33 A technical appraisal has established that a new transmission circuit from Scotland connecting to new Walpole Substation satisfies the NETS SQSS requirement.

6.6.34 Technical appraisal of this option includes consideration of the following:

- The proposed transmission connection to the existing network is made away from major demand centres.
- Option 5 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries.
- There is neutral impact to the East Coast Generation Group.
- The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire which proposes a new circuit between South Lincolnshire and East Leicestershire.
- The proposed transmission connection connects into the same substation as EGL 3 and EGL 4, which presents additional system complexity. For more info on interaction with other projects please refer to Chapter 8.

Summary of the cost appraisal

6.6.35 As set out in Chapter 5, we undertook a cost evaluation of the following two technologies for subsea options evaluation.

- 400 kV AC subsea cable.
  - AC subsea connections circuit options use medium capacity double circuits (two 400 kV AC circuits) with a total capacity of up to 6,380 MVA
- 525 kV HVDC subsea cable and converter stations
  - HVDC subsea connection options use 525 kV 2 GW voltage source links, which requires a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at new Walpole Substation.
  - Connections between the new converter station and new Walpole Substation are also required

6.6.36 Either of these options entail the following works:

- NGET Substation Works
  - Two bays at new Walpole Substation.

6.6.37 Table 6.9 sets out the capital costs for Option 5 considering substation works and each technology option. These costs are identical for Option 5a and Option 5b. This can be assumed given the difference in distance between the two landfall locations falls within the 20% tolerance applied for potential route deviations. Work required at the substation is identical for either option. See Appendix D for the full detailed breakdown of what this cost includes.

Table 6.9 – Option 5: capital cost for each technology option[7]

Item	Capital Cost	
Substation and Wider Works	£16.0m	
New Circuits (624 km)	**AC Subsea Cable**	**HVDC Subsea Cable**
New Circuit	£19,101.9m	£2,462.5m
Total Capital Cost	**£19,117.9m**	**£2,478.5m**

6.6.38 Table 6.10 sets out the lifetime cost for the new circuit technology options. The lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in "Strategic options technical appendix 2020/2021 price base", found in Appendix D, where further cost breakdowns can also be found.

Table 6.10 – Option 5: lifetime cost for each technology option

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
Capital Cost of New Circuits	**£19,101.9m**	**£2,462.5m**
NPV of Cost of Losses over 40 years	£631.3m	£157.1m
NPV of Operation & Maintenance costs over 40 years	£112.8m	£58.9m
Lifetime Cost of New Circuits	**£19,846m**	**£2,679m**

6.6.39 Based on the data in the above tables, the following conclusions can be drawn:

- HVDC has the lowest capital cost of new circuits.
- HVDC has the lowest NPV of Cost of Losses over a forty-year projection.
- HVDC has the lowest NPV of Operation and Maintenance Costs over a forty-year projection.

[7] As with Option 3, due to the tolerance applied to the route length the costs are the same for Options 5a and 5b.

- HVDC has the lowest lifetime cost of new circuits.

6.6.40 In light of this cost appraisal, our starting presumption for further development of this option, should it be selected, is for a majority HVDC connection.

Summary of strategic option 5

6.6.41 Option 5 proposes a new transmission connection from Scotland to new Walpole Substation. The marine element of Option 5 is common to all strategic options until the point at which the marine option splits for landfall on the Lincolnshire (Option 5a) or Norfolk (Option 5b) coastline to the new Walpole Substation.

6.6.42 The total straight-line distance for this strategic option is 520 km consisting of 445km offshore HVDC cable and 75 km of onshore underground cable, with a total distance of 624 km including 20% tolerance. The distance for the Lincolnshire landfall point is used in this summary as the distance via a Norfolk coastline landfall point to the substation is still within the 20% tolerance. Option 5 presents relatively high lifetime costs of £2,679m, which is not preferred.

6.6.43 Option 5 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries, there is also neutral impact to the East Coast Generation Group, thus Option 5 meets the need case. The proposed transmission connection is into the same substation as EGL 3 and EGL 4 as well as being contingent on Grimsby to Walpole and Weston Marsh to East Leicestershire, which presents additional system complexity. Overall, environmental and socio-economic factors are not considered to significantly constrain Option 5a. However, due to the potential for Option 5b to impact on a number of statutory designated sites in the marine and terrestrial environments, Option 5b is considered to be less preferable.

6.7 Appraisal of Option 6 – Connection to New Spalding North

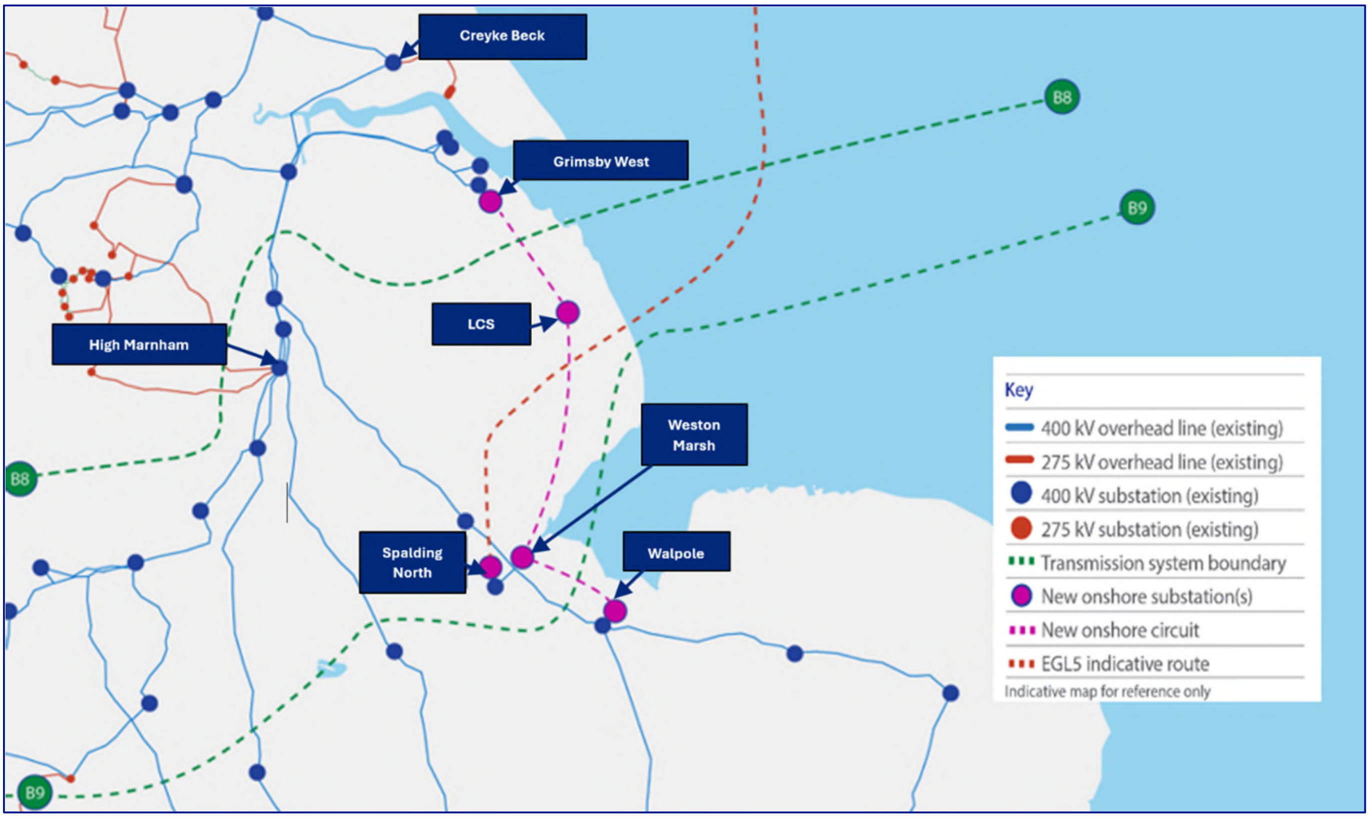
Description of strategic option 6

6.7.1 Option 6 involves the development of a new transmission circuit from Scotland connecting to a new Spalding North Substation. The majority of the new circuit is routed within the North Sea, making landfall on the Lincolnshire coastline. The marine element of Option 6 is common to all strategic options until the point at which the marine option splits for landfall (to Lincolnshire or North Norfolk coastlines) (i.e. how far south the submarine cables are routed).

6.7.2 The new Spalding North Substation is proposed as part of this option. This is subject to the project requesting a direction pursuant to s35 of the 2008 Act from the Secretary of State (SoS) for Energy Security and Net Zero (DESNZ) during Spring 2025, to bring the project into the Development Consent Order (DCO) regime. More details on this can be found in Section 3.5 on the consents approach. For the purposes of the appraisal of Option 6, consideration has been given to the costs and impacts of constructing a new Spalding North Substation to connect Option 6. However, for this strategic option to be viable, Weston Marsh to East Leicestershire would be required to connect to Spalding North substation. Weston Marsh to East Leicestershire specific information can be found in Chapter 8.

6.7.3 A diagram of Strategic Option 6 is shown in Figure 6.7.

Figure 6.7 – Indicative location of Option 6 – Connection to New Spalding North



6.7.4 The circuit distance for this connection is presented below. This is based on a subsea cable route distance from a preliminary cable routing study and a straight-line distance from a landfall on the Lincolnshire coastline to new Spalding North.

- 445 km Offshore Distance
- 60 km Onshore Distance
- 505 km Total Straight-Line Distance
- 606 km Total Distance (including 20% tolerance)

6.7.5 This option is formed of a HVDC link which requires a pair of HVDC cables. Two converter stations are required, one in Scotland and one in the vicinity of the new Spalding North Substation. The converter stations each have an approximate footprint of 6 ha (see Appendix C for further information).

Summary of the environmental and socio-economic appraisal

6.7.6 An environmental and socio-economic appraisal has been undertaken of a new transmission circuit making landfall on the Lincolnshire coast and connecting to the new Spalding North Substation in South Holland Borough.

6.7.7 For the purposes of the appraisal a study area was established in which the terrestrial elements of the Project (comprising underground cables and converter stations) could reasonably be expected to be developed. This extended from the Lincolnshire coastline (between south of Saltfleet and north of Ingoldmells) inland to the point of connection at Spalding North Substation.

6.7.8 The appraisal has also considered marine environmental and socio-economic factors in so far as they may be a differentiator between options, for example increased subsea cable route length in the marine environment and/or potentially impacting different or additional marine environmental or socio-economic considerations. The study area for the appraisal of marine factors extended from either landfall to the border for Scottish waters, a distance of approximately 400 km (from North Norfolk). The marine study area is split, east of Hull to provide the two different options for landfall, for Lincolnshire (where the study area extended from north of Theddlethorpe to north of Chapel St Leonards) and North Norfolk (where the study area extended from west of Morston to Cromer).

6.7.9 There are a number of statutory ecological designations present within the marine environment which could potentially be impacted subject to subsea cable routeing and landfall siting on the Lincolnshire coast. These include the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Between the strategic options making landfall on the Lincolnshire coast, these sites are common to any subsea cable route and therefore are not a significant differentiator between the strategic options being appraised.

6.7.10 With regard to socio-economic considerations in the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the landfall study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. Additionally, there are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.

6.7.11 The Lincolnshire coastline is also subject to a number of statutory ecological designations. From north to south this includes the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are potentially avoidable through landfall selection. Where landfalls, such as Theddlethorpe, are located within coastal ecological designations, impacts may be avoided through a choice of cable installation methods (for example trenchless methods such as HDD) or seasonal construction restrictions. Coastal ecological designations present a consenting constraint some specific landfall sites within this option, requiring significant mitigation measures.

6.7.12 Environmental and socio-economic constraints influencing underground cable routes to Spalding North are similar to those for Weston Marsh (Option 4, via Lincolnshire); the study area is not considered to be highly constrained in terms environmental designations. Part of the Lincolnshire Wolds National Landscape extends into the north of the study area while The Wash SAC, SPA, Ramsar site and NNR lie to the south, however, these sites can be avoided with careful routeing. Subject to detailed routeing there may be some potential for disturbance and/or displacement impacts where qualifying bird species of The Wash SPA and Ramsar site utilise adjacent agricultural land, however, this should be temporary for the duration of cable installation only. There are 17 SSSIs present within the study area, as well as designated heritage assets such as Scheduled Monuments. These designations occupy small areas and can be avoided with careful routeing therefore are not considered to materially influence this option.

6.7.13 The underground cable route will likely be required to cross a minimum of four main rivers, as well as routeing through flood zones 2 and 3, with the new substation unlikely to avoid flood zone 3.

6.7.14 Small and moderately sized settlements are present throughout the study area often coalescing along main transport routes including the A16, A52 and the Grantham to Skegness railway line. Boston is a key constraint and will influence the underground cable routeing and cable distances e.g. either north and west or south and east of the settlement.

6.7.15 The majority of land within the study area comprises agricultural land with an Agricultural Land Classification of grade 1, 2 and 3, the best and most versatile agricultural land. This does not prevent cable routeing through these areas but highlights the need for effective soil management and reinstatement for underground cable routes to a converter station in the vicinity of Spalding North.

6.7.16 A converter station in the Spalding North area has the potential to result in long term landscape and visual effects due to the introduction of new infrastructure in an area which currently has little major development. This includes the potential for cumulative effects in combination with the new Spalding North Substation however, there may be some opportunities to mitigate this through site selection and design.

6.7.17 Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole (however, these constraints are common to all Lincolnshire landfall Options, particularly in the vicinity of the coastline). Boston Alternative Energy Facility also falls within the study area.

6.7.18 Overall, on the basis of the information currently available and assuming that appropriate mitigation is undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 6.

Summary of the technical appraisal

6.7.19 A technical appraisal has established that a new transmission circuit from Scotland connecting to new Spalding North Substation satisfies the NETS SQSS requirement.

6.7.20 Technical appraisal of this option includes consideration of the following:

- The proposed transmission connection requires a new substation to be built in close proximity to the new Spalding North Substation site to facilitate connections above 1,800 MW.
- Option 6 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary.
- There is neutral impact to the East Coast Generation Group.
- The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between the South Lincolnshire and East Leicestershire. For this strategic option to be viable, Weston Marsh to East Leicestershire would be required to connect to Spalding North substation. As

Weston Marsh to East Leicestershire is a separate NGET project, any works undertaken through this scope are subject to a separate application for development consent, to the consent approach for the EGL 5 Project. For more info on Weston Marsh to East Leicestershire please refer to Chapter 8 of this report.

- The proposed transmission connection is limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of new Spalding North Substation; assuming two double circuits are connected to New Spalding North Substation.

Summary of the cost appraisal

6.7.21 As set out in Chapter 5, we undertook a cost evaluation of the following two technologies for subsea options evaluation.

- 400 kV Alternating Current (AC) subsea cable.
  - AC subsea connections circuit options use medium capacity double circuits (two 400 kV AC circuits) with a total capacity of up to 6,380 Mega Volt Amperes (MVA)
- 525 kV HVDC subsea cable and converter stations
  - HVDC subsea connection options use 525 kV 2 GW voltage source links, which requires a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at a new Spalding North Substation.
  - Connections between the new converter station and new Spalding North Substation are also required

6.7.22 Either of these options entail the following works:

- NGET Substation Works
  - Construction of a new Spalding North Substation consisting of 12 bays
  - Connection of new Spalding North Substation to existing NETS

6.7.23 This enables future proofing of the surrounding grid, allowing connections of future key projects. The EGL 5 Project connection requires two of these bays.

6.7.24 Table 6.11 sets out the capital costs for Option 6 considering substation works and each technology option. See Appendix D for the full detailed breakdown of what this cost includes.

Table 6.11 – Option 6: capital cost for each technology option

Item	Capital Cost	
Substation and Wider Works	£156.0m	
New Circuits (606 km)	**AC Subsea Cable**	**HVDC Subsea Cable**
New Circuit	£18,538.9m	£2,406.9m
Total Capital Cost	**£18,694.9m**	**£2,562.9m**

6.7.25 Table 6.12 sets out the lifetime cost for the new circuit technology options. The lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in "Strategic options technical appendix 2020/2021 price base", found in Appendix D.

Table 6.12 – Option 6: lifetime cost for each technology option

Subsea Based Option	AC Subsea Cable	HVDC Subsea Cable
Capital Cost of New Circuits	**£18,538.9m**	**£2,406.9m**
NPV of Cost of Losses over 40 years	£610.9m	£157.1m
NPV of Operation & Maintenance costs over 40 years	£109.1m	£58.9m
Lifetime Cost of New Circuits	**£19,259m**	**£2,623m**

6.7.26 Based on the data in the above tables, the following conclusions can be drawn:

- HVDC has the lowest capital cost of new circuits.
- HVDC has the lowest NPV of Cost of Losses over a forty-year projection.
- HVDC has the lowest NPV of Operation and Maintenance Costs over a forty-year projection.
- HVDC has the lowest lifetime cost of new circuits.

6.7.27 In light of this cost appraisal, our starting presumption for further development of this option, should it be selected, is for a majority HVDC connection.

Summary of strategic option 6

6.7.28 Option 6 proposes a new transmission circuit from Scotland to new Spalding North Substation with a landfall on the Lincolnshire coastline.

6.7.29 The total straight-line distance for this strategic option is 505 km, consisting of 445 km offshore HVDC cable and 60 km of onshore underground cable, with a total distance of 606 km including 20% tolerance. This strategic option has lifetime costs of £2,623m.

6.7.30 Option 6 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary, there is also neutral impact to the East Coast Generation Group, thus Option 6 meets the need case. As this option is dependent on Weston Marsh to East Leicestershire, for this strategic option to be viable, Weston Marsh to East Leicestershire would be required to connect to Spalding North substation. Overall, with appropriate mitigation strategies undertaken, together with sensitive routing and siting, environmental and socio-economic factors are not considered to significantly constrain Option 6.

7. Comparison of the appraisal of the strategic options

7.1 Overview

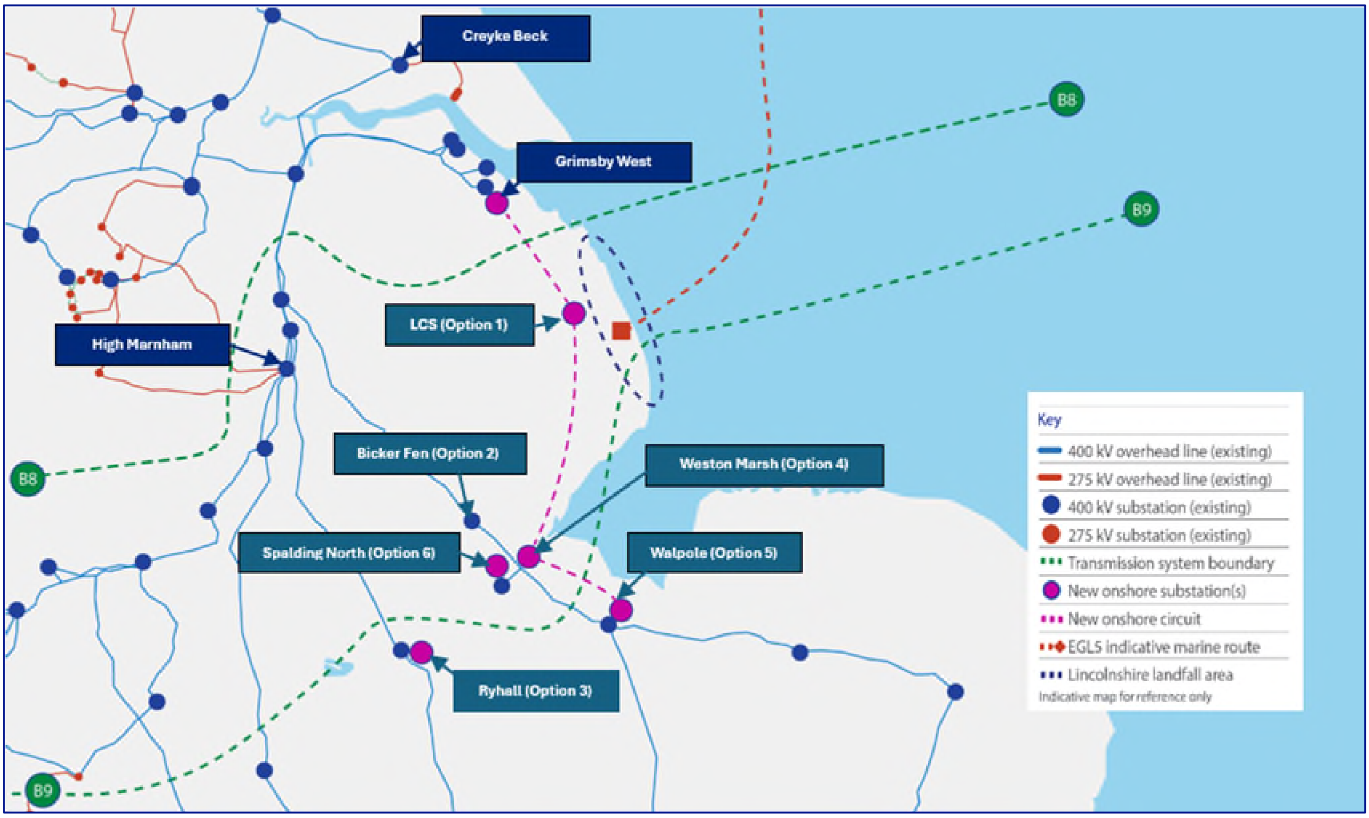
7.1.1 For the strategic options appraised in Chapter 6, this subsequent review considers the following comparative points:

- Environmental and Socio-Economic constraints
- Technical benefit and associated technical considerations
- Capital and lifetime costs of options

7.1.2 This section summarises and compares the above considerations across all six strategic options to facilitate the identification of a preferred strategic option.

7.1.3 Figure 7.1 shows the indicative location overview of all strategic options, the B8 and B9 boundaries and the approximate location of the Lincolnshire landfall area.

Figure 7.1 – Indicative overview of all strategic options



7.2 Environmental and socio-economic considerations

7.2.1 One of the key conclusions of the environmental and socio-economic appraisals of the potential strategic options (Option 1 to Option 6) was that all the strategic options have the potential for environmental and socio-economic effects. Some of the effects identified are largely common to all the potential strategic options, particularly in respect of the marine and coastal environment where subsea cables are routed and come ashore.

7.2.2 Each of the potential strategic options considered (Option 1 to Option 6) could make landfall on the Lincolnshire coastline. Subject to site selection for any of the potential strategic options, making landfall on the Lincolnshire coast could impact on the same coastal ecological designations. These include the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. These sites are all potentially avoidable, subject to landfall selection and cable installation methods (for example HDD or adherence to seasonal working restrictions), so are not considered to constrain or differentiate between options.

7.2.3 As part of this appraisal, a landfall on the North Norfolk coastline for two strategic options was also appraised: Option 3 (New Ryhall) and Option 5 (New Walpole). Subsea cable routes are broadly north to south meaning that an option to the Norfolk coastline crosses or potentially impacts on the same marine ecological designations as options to the Lincolnshire coastline. However, landfall on the Norfolk coastline also has the potential to impact on additional sites including the Wash and North Norfolk Coast SAC, North Norfolk Coast SAC, SPA and Ramsar site, Cromer Shoal Chalk Beds MCZ and the Norfolk Coast National Landscape.

7.2.4 The additional sites which could be impacted by Option 3b (New Ryhall) or Option 5b (New Walpole) with landfall via the Norfolk coastline include sites designated for habitat which may be permanently impacted by a subsea cable route and/or associated rock protection resulting in permanent habitat loss, for which we have assumed there is no means of mitigating fully in terms of compensatory like for like habitat. For this reason, an option to either the new Ryhall Substation or new Walpole Substation via the north Norfolk coastline is considered to pose greater environmental and consenting risk than alternative options via the Lincolnshire coast. Therefore, potential strategic Option 3b (New Ryhall) and potential strategic Option 5b (New Walpole) both with landfall via the Norfolk coastline are less preferred for environmental reasons.

7.2.5 Our appraisal of each potential strategic option also considered potential effects in the area between an assumed landfall location and the relevant substation (existing or planned). One of the key differentiators between the potential strategic options, relates to overall route length and risks from above ground permanent infrastructure which can impact the extent of environmental and socio-economic effects.

7.2.6 Option 1 (LCS) is the closest option to the Lincolnshire coastline and is expected to have lower environmental and socio-economic effects than other options due to shorter, more direct underground cable routes, which as a result of the shortest distance presents the lowest cost. However, its proximity to the Lincolnshire Wolds National Landscape and the low-lying coastal hinterland means that a converter station in this area has the potential for long term effects on views from within the National Landscape as well as on landscape and visual more generally. This includes the potential for cumulative impacts on the National Landscape and landscape and visual interests in combination with the New Lincolnshire Connection Substation(s). Subject to site selection there is also the potential for setting impacts on statutory historic environment designations including Scheduled Monuments and Listed Buildings. There are some opportunities to mitigate effects on the National Landscape and setting of historic environment constraints through detailed siting and provision of landscape mitigation, for example to screen views from the National Landscape.

7.2.7 Option 2 (Bicker Fen), Option 3a (New Ryhall via a landfall on Lincolnshire coastline), Option 4 (Weston Marsh), Option 5a (New Walpole via a landfall on Lincolnshire coastline), and Option 6 (New Spalding North) are broadly comparable requiring long-distance underground cable routes through predominantly agricultural land. These options avoid or provide opportunities to mitigate impacts on internationally and nationally designated landscapes, ecological sites and historic environment features through careful route selection. Impacts on terrestrial designated sites (landscape, ecology and historic environment) are avoidable with careful routeing.

7.2.8 Each of these options require converter station sites in predominantly rural areas with the potential for landscape and visual effects. Option 6 (New Spalding North) requires a new substation to be built as part of the scheme. There are small villages in the vicinity of Bicker Fen and Walpole substations, and new Spalding North Substation would be immediately adjacent to the town of Spalding, albeit set in an industrial area.

7.2.9 There are designated historic environment assets within the vicinity of some of the sites; at both Lincolnshire Connection Substation(s) and New Ryhall there is one Scheduled Monument, while at Walpole there are a small number of Listed Buildings. Subject to converter station siting there is the potential for setting impacts to occur for each option. Within the Walpole area the key constraints influencing converter station siting are setting impacts on designated historic environment assets and potential impacts on nearby settlements. At a strategic level, other than the requirement for a new substation for Option 6, there are no significant environmental or socio-economic differentiators between the remaining options.

7.2.10 Each of the options appraised have their relative advantages and disadvantages. A comparison of the key findings of the environmental and socio-economic appraisal is provided in Table 7.4 below.

7.3 Technical considerations

7.3.1 From the six potential options considered, all options satisfy the critical requirement for meeting needs case. The majority of the new circuits for each of the strategic options are to be routed in the North Sea, with the key differentiator being where the landfall is located. All options are formed of a HVDC link which requires a pair of HVDC cables. Moreover, two converter stations are required, one in Scotland and one in the vicinity of each proposed substation location. The converter stations have an approximate footprint of 6 ha (see Appendix C). All options connect to the existing network away from major demand centres.

7.3.2 Onshore underground HVDC cables are required from the landfall point to the converter station at each proposed substation option. As per Table 7.1, Option 2 (Bicker Fen) is the only option that connects to an existing substation; however, it requires two bays to facilitate the Project. The other options all propose utilising two bays at substations which do not currently exist, some of these substations are proposed as part of other projects. Option 1 requires a connection into LCS, which has already been scoped and sized to allow the Project to connect. This is however contingent on Grimsby to Walpole progressing and completing on schedule.

Table 7.1 – Substation dependencies

Option	Substation exists	Project obtaining consent for the connection substation
Option 1 (LCS)	No	Grimsby to Walpole
Option 2 (Bicker Fen)	Yes	N/A
Option 3 (New Ryhall)	No	Weston Marsh to East Leicestershire
Option 4 (New Weston Marsh)	No	Grimsby to Walpole
Option 5 (New Walpole)	No	Grimsby to Walpole
Option 6 (New Spalding North)	No	EGL 5 Project

7.3.3 Apart from Option 2 (Bicker Fen), all connections proposed in the Strategic Options are to substations that do not presently exist. Option 6 (New Spalding North) would be constructed specifically as part of the consenting process for this project. All other substations are being constructed as part of separate projects. Chapter 8 provides further information on these interacting projects.

7.3.4 Option 3 (New Ryhall) is proposed as part of the Weston Marsh to East Leicestershire project, which is a new circuit between South Lincolnshire and East Leicestershire.

7.3.5 Construction of Options 1, 4 and 5 (LCS, New Weston Marsh and New Walpole substations) are all proposed as part of Grimsby to Walpole. All these options are subject to an application for development consent in the future.

7.3.6 Option 6 (New Spalding North) requires the most substation works as part of the Project, including 12 new bays. All other Strategic Options require two bays at their respective substations. Increased infrastructure works lead to higher capital costs and increased constructability risks for the Project.

7.3.7 Each option has been appraised as to whether it can meet the identified boundary reinforcement requirement and what impact it causes to other customer connections projects in the East Coast Generation Group. The need case in Chapter 4 states the requirement for provision of capacity and capability across the B6 and B7a and beneficial capability across B8 and/or B9 system boundaries with neutral connection impact upon the East Coast Generation Group.

7.3.8 All options cross boundaries B6, B7a and B8 and whilst not all options cross boundary B9, they will provide some benefit to it. All options also have neutral connection impact upon the East Coast Generation Group thus all meet the need case.

7.3.9 In terms of power flow, Options 1, 2 and 6 (LCS, Bicker Fen and New Spalding North) are limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of each of these substations. Option 3 (New Ryhall) and Option 4 (Weston Marsh) have four additional double circuits to those connected by the Project. This provides additional resilience under fault conditions, since there are multiple pathways for current to flow. Option 3 (New Ryhall) and Option 4 (Weston Marsh) therefore are the most beneficial options in terms of power flow flexibility. However, whilst these options provide some benefit to the transmission system, both these options' ability to provide maximum benefit are dependent on the completion of the Weston Marsh to East Leicestershire project. Option 5 (New Walpole) connects into the same substation as EGL 3 and EGL 4, which presents cumulative issues. It also relies on the completion of Weston Marsh to East Leicestershire to provide maximum benefit to the transmission system.

Table 7.2 – Straight-line option length summary

Option	Offshore	Onshore	Total Straight-Line Distance	Total including 20% Tolerance
Option 1 (LCS)	445 km	10 km	455 km	546 km
Option 2 (Bicker Fen)	445 km	50 km	495 km	594 km
Option 3 (New Ryhall)	445 km	85 km	530 km	636 km
Option 4 (New Weston Marsh)	445 km	55 km	500 km	600 km
Option 5 (New Walpole)	445 km	75 km	520 km	624 km
Option 6 (New Spalding North)	445 km	60 km	505 km	606 km

7.3.10 With reference to Table 7.2, considering existing and proposed new infrastructure that is required for these options, Option 3 (New Ryhall) is characterised by the longest and Option 1 (LCS) is the shortest onshore cable route. However, all options require at least 445 km of subsea cable plus onshore cable between the landfall and the converter station and between the converter station and respective substation.

7.3.11 To summarise the technical comparison of the options, the technologies implemented are all adequately established and do not add any uncertainty or risk when implementing them onto the Project. Considering substation and circuit works, all options with the exception of Option 2 (Bicker Fen) are to substations that do not presently exist. Option 6 (New Spalding North) would be constructed specifically as part of the consenting process for this project. All other substations are being constructed as part of separate projects. Cost Considerations

7.3.12 Table 7.3 sets out an overview of the capital and lifetime costs associated with each strategic option. Total Capital Cost incorporates the initial cost of circuits as well as any substation works, whilst the Lifetime Cost pertains only to new circuits. This table provides a comparison of strategic options based on the most economical technology choice for each option, namely HVDC.

Table 7.3 – Capital and Lifetime Cost Comparison of Strategic Options

	1. Connection to Lincolnshire Connection Substation(s)	2. Connection to Bicker Fen	3. Connection to New Ryhall	4. Connection to New Weston Marsh	5. Connection to New Walpole	6. Connection to New Spalding North
Technology	HVDC Subsea 2,000 MW 546 km	HVDC Subsea 2,000 MW 594 km	HVDC Subsea 2,000 MW 636 km	HVDC Subsea 2,000 MW 600 km	HVDC Subsea 2,000 MW 624 km	HVDC Subsea 2,000 MW 606 km
Total Capital Cost	£2,237.5m	£2,385.8 m	£2,515.6 m	£2,404.4 m	£2,478.5 m	£2,562.9 m
Lifetime Cost of new circuits	**£2,437m**	**£2,586 m**	**£2,716 m**	**£2,604 m**	**£2,679 m**	**£2,623 m**

7.3.13 All options presented in Table 7.3 comply with the NETS SQSS and meet the technical requirement to satisfy the Project need case.

7.3.14 Option 1 (LCS) presents the lowest capital and lifetime costs due to the shortest route with LCS being closest to the landfall on the Lincolnshire coastline. Option 2 has the second lowest cost.

7.3.15 Option 4 (Weston Marsh) has median capital and lifetime costs respective to the other strategic options. Therefore, in costs terms, this option performs well.

7.3.16 Option 5 (New Walpole) incurs relatively high capital and lifetime cost relative to the other strategic options. The high capital and lifetime costs associated with Option 5 (New Walpole) are not justified by any significant benefits. Therefore, potential selection of this option from a cost perspective is not preferred.

7.3.17 Option 6 (New Spalding North) presents a comparatively high capital cost, due to the necessity to build a new substation as part of this connection option. The estimated lifetime cost is not significantly above the median. Overall, potential selection of this option from a cost perspective is not preferred.

7.3.18 Option 3 (New Ryhall) has a relatively high capital and lifetime cost when compared to the other strategic options due to this option having the longest route length among all of the options being appraised.

7.4 Summary of strategic options appraisals

Table 7.4 – Overview of strategic options appraisal

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
1 Connection to Lincolnshire Connection Substation(s)	There are a number of small settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Urban areas within the study area of the proposed converter station could be a constraint and potential risk to siting. Underground cable routes will require multiple road crossings. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 3. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024.	The route length for Option 1 is 546 km, of which 10 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** technology has an associated capital cost of £16,698.4m. The NPV of the cost of losses is £548.9m whilst the NPV of operation and maintenance costs over a 40-year period is £98.1m. This leads to a lifetime cost of £17,345m for the AC subsea option. The **HVDC subsea** technology has an associated capital cost of £2,221.5m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.7m. This leads to a lifetime cost of £2,437m for the HVDC subsea option. The most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at New LCS, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection there is the potential for effects on the Humber Estuary SAC, SPA and Ramsar site, Humber Estuary IBA, Lincolnshire Coronation Coast NNR, and Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, SPA and Ramsar site, as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. Subject to landfall location, underground cable routes will be required to cross a minimum of one main river, as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. While the Lincolnshire Wolds National Landscape can be avoided, there is the potential for impacts on its setting and from views within it as a result of the converter stations being located in a landscape in which there is little major development. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments including Markby Priory and Listed Buildings, subject to converter station siting.	The proposed transmission connection is made to the new Grimsby West to Walpole line away from any demand centres. Option 1 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary. There is also neutral impact to the East Coast Generation Group. The proposed transmission connection is currently limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of LCS. As the LCS are under the Grimsby to Walpole scope, Option 1 being feasible for the Project is contingent on Grimsby to Walpole progressing and being completed on schedule.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
2 Connection to Bicker Fen	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Underground cable routes will require multiple road crossings, and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 2 or 3, with areas of grade 1 in the vicinity of the proposed converter station. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. Key other factors which could influence site selection relate to other energy projects close to and/or connecting to Bicker Fen including Triton Knoll Offshore Wind Farm, Viking Link Interconnector and Heckington Fen Solar Park. The boundary for Manby Anaerobic Digester also falls on the edge of the	The route length for Option 2 is 594 km, of which 50 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £18,181.6m. The NPV of the cost of losses is £600.3m whilst the NPV of operation and maintenance costs over a 40-year period is £107.3m. This leads to a lifetime cost of £18,889m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,369.8m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.8m. This leads to a lifetime cost of £2,586m for the HVDC subsea option. The most cost-effective technology is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at Bicker Fen Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. There are 11 SSSI in the study area for Option 2. This option will require underground routes crossing a minimum of four main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable, with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments and Listed Buildings subject to converter station siting. Key factors which could influence site selection relate to other energy projects close to and/or connecting to Bicker Fen including Triton Knoll Offshore Wind Farm, Viking Link Interconnector and Heckington Fen Solar Park.	The proposed transmission connection to the existing network is made away from major demand centres. Option 2 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary. There is also neutral impact to the East Coast Generation Group. The proposed transmission connection is currently limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of Bicker Fen Substation.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
2 Connection to Bicker Fen	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Underground cable routes will require multiple road crossings, and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 2 or 3, with areas of grade 1 in the vicinity of the proposed converter station. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. Key other factors which could influence site selection relate to other energy projects close to and/or connecting to Bicker Fen including Triton Knoll Offshore Wind Farm, Viking Link Interconnector and Heckington Fen Solar Park. The boundary for Manby Anaerobic Digester also falls on the edge of the	The route length for Option 2 is 594 km, of which 50 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £18,181.6m. The NPV of the cost of losses is £600.3m whilst the NPV of operation and maintenance costs over a 40-year period is £107.3m. This leads to a lifetime cost of £18,889m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,369.8m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.8m. This leads to a lifetime cost of £2,586m for the HVDC subsea option. The most cost-effective technology is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at Bicker Fen Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. There are 11 SSSI in the study area for Option 2. This option will require underground routes crossing a minimum of four main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable, with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments and Listed Buildings subject to converter station siting. Key factors which could influence site selection relate to other energy projects close to and/or connecting to Bicker Fen including Triton Knoll Offshore Wind Farm, Viking Link Interconnector and Heckington Fen Solar Park.	The proposed transmission connection to the existing network is made away from major demand centres. Option 2 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary. There is also neutral impact to the East Coast Generation Group. The proposed transmission connection is currently limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of Bicker Fen Substation.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
	study area and Heckington Fen Solar Farm fall within it.			
3a Connection to New Ryhall (Lincolnshire)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Underground cable routes will require multiple road and rail crossings. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 2 or 3. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. The boundary for Manby Anaerobic Digester also falls on the edge of the study area and Heckington Fen Solar Farm fall within it.	The route length for Option 3 is 636 km, of which 85 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £19,459.1m. The NPV of the cost of losses is £641.8m whilst the NPV of operation and maintenance costs over a 40-year period is £114.5m. This leads to a lifetime cost of £20,216m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,499.6m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.9m. This leads to a lifetime cost of £2,716m for the HVDC subsea option. Therefore, the most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at new Ryhall Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. There are 35 SSSI in the study area for Option 3a. This option will require underground routes crossing multiple main rivers and maintained drains as well as routeing through flood zones 2 and 3, with the converter station likely to sit within flood zone 2. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable, with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments, including Castle Bytham Castle, and Listed Buildings subject to converter station siting.	The proposed transmission connection to the existing network is made away from major demand centres. Option 3 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries. There is also neutral impact to the East Coast Generation Group. New Ryhall Substation has four additional double circuits connected which provide additional resilience under fault conditions, since there are multiple pathways for current to flow. The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
	study area and Heckington Fen Solar Farm fall within it.			
3a Connection to New Ryhall (Lincolnshire)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Underground cable routes will require multiple road and rail crossings. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 2 or 3. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. The boundary for Manby Anaerobic Digester also falls on the edge of the study area and Heckington Fen Solar Farm fall within it.	The route length for Option 3 is 636 km, of which 85 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £19,459.1m. The NPV of the cost of losses is £641.8m whilst the NPV of operation and maintenance costs over a 40-year period is £114.5m. This leads to a lifetime cost of £20,216m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,499.6m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.9m. This leads to a lifetime cost of £2,716m for the HVDC subsea option. Therefore, the most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at new Ryhall Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. There are 35 SSSI in the study area for Option 3a. This option will require underground routes crossing multiple main rivers and maintained drains as well as routeing through flood zones 2 and 3, with the converter station likely to sit within flood zone 2. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable, with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments, including Castle Bytham Castle, and Listed Buildings subject to converter station siting.	The proposed transmission connection to the existing network is made away from major demand centres. Option 3 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries. There is also neutral impact to the East Coast Generation Group. New Ryhall Substation has four additional double circuits connected which provide additional resilience under fault conditions, since there are multiple pathways for current to flow. The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
3b Connection to New Ryhall (Norfolk)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as King's Lynn combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and at least two rail crossings. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 1 or 2, and the proposed converter station would be sited within grade 3. With regard to the marine environment, the Norfolk landfall study area includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignment, Viking Link, North Sea Link and Hornsea 1, 2 and 3 export connection cables. Additionally, Sheringham Shoal and Dudgeon Extensions with consent authorised Project status, appears to have export connection cables reach landfall within the small section that is not designated as a SSSI. There are four designated bathing waters within the Norfolk landfall study area which are classified as having excellent bathing water status in 2024. Other planned or in development project constraints in the area include Hornsea 3 Offshore Wind Farm NSIP, Sheringham and Dudgeon Extension Projects NSIP and Palm Paper 3 CCGT Power station Kings Lynn.	Same as 3a, see above.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ, the Inner Dowsing, Race Bank and North Ridge SAC, Wash and North Norfolk Coast SAC, North Norfolk Coast SPA, SAC and SSSI and Cromer Shoals Chalk Beds MCZ. Subject to landfall selection, there is the potential for effects on the Wash and North Norfolk Coast SAC, North Norfolk Coast SPA, SAC and SSSI and Cromer Shoals Chalk Beds MCZ. One or more of these sites require to be crossed in order to make landfall on the Norfolk coast. There are 45 SSSI in the study area for Option 3b. These coastal ecological designations present a consenting constraint across the extent of the landfall for this option, requiring significant mitigation measures, particularly where more than one designation is crossed, increasing the likelihood of impact. This option will require underground routes crossing multiple main rivers and maintained drains as well as routeing through flood zones 2 and 3, with the converter station likely to sit within flood zone 2. The option requires landfalls and onward underground cable routes within and crossing the Norfolk Coast National Landscape. While long term effects are unlikely to occur assuming careful routeing and reinstatement it is preferable to avoid the National Landscape where possible. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments, including Castle	Same as 3a, see above.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
			Bytham Castle, and Listed Buildings subject to converter station siting.	
4 Connection to New Weston Marsh	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as Boston combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and rail crossings. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 1 or 2, and the proposed converter station would be sited within grade 1. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections	The route length for Option 4 is 600 km, of which 55 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £18,351.6m. The NPV of the cost of losses is £601m whilst the NPV of operation and maintenance costs over a 40-year period is £108m. This leads to a lifetime cost of £19,061m for the AC subsea option. The **HVDC option** has an associated capital cost of £2,388.4m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.8m. This leads to a lifetime cost of £2,604m for the HVDC subsea option. Therefore, the most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at New Weston Marsh Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. The Wash SAC, SPA, Ramsar site and NNR is present in the study area for the underground cable and will require careful routeing. There are 16 SSSI in the study area for Option 4. This option will require underground routes crossing a minimum of three main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable (but to a lesser extent than for Options 2 and 3a), with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments and Listed	The proposed transmission connection to the existing network is made away from major demand centres. Option 4 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary. There is also neutral impact to the East Coast Generation Group. New Weston Marsh Substation has four additional double circuits connected which provide additional resilience under fault conditions, since there are multiple pathways for current to flow. The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire. Option 4 is also dependent upon Grimsby to Walpole however, it is not dependent upon the OHL construction and could be separated from

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
	and Grimsby to Walpole. Boston Alternative Energy Facility also falls within the study area.		Buildings subject to cable routeing and converter station siting.	the Grimsby to Walpole if required.
5a Connection to New Walpole (Lincolnshire)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as Boston combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 1 or 3. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. Boston Alternative Energy Facility also falls within the study area.	The route length for Option 5 is 624 km, of which 75 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £19,101.9m. The NPV of the cost of losses is £631.3m whilst the NPV of operation and maintenance costs over a 40-year period is £112.8m. This leads to a lifetime cost of £19,846m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,462.5m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.9m. This leads to a lifetime cost of £2,679m for the HVDC subsea option. Therefore, the most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at New Walpole Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. The Wash SAC, SPA, Ramsar site and NNR is present in the study area for the underground cable and will require careful routeing. There are 12 SSSI's in the study area for Option 5a. This option will require underground routes crossing of a minimum of five main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. While designated heritage assets are likely to be avoidable, there is the potential for impacts on the setting of Listed Buildings in the vicinity of Walpole subject to converter station siting. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable (but to a lesser extent than for Options 2, 3a and 4), with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, less direct routes may need to be developed to avoid this landscape designation.	The proposed transmission connection to the existing network is made away from major demand centres. Option 5 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries. There is also neutral impact to the East Coast Generation Group. The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire. This option is also dependent upon Grimsby to Walpole; however, it is not dependent upon the OHL construction and could be separated from Grimsby to Walpole if required. The proposed transmission connection is at the same substation as EGL 3 and EGL 4,

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
	and Grimsby to Walpole. Boston Alternative Energy Facility also falls within the study area.		Buildings subject to cable routeing and converter station siting.	the Grimsby to Walpole if required.
5a Connection to New Walpole (Lincolnshire)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as Boston combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 1 or 3. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections and Grimsby to Walpole. Boston Alternative Energy Facility also falls within the study area.	The route length for Option 5 is 624 km, of which 75 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £19,101.9m. The NPV of the cost of losses is £631.3m whilst the NPV of operation and maintenance costs over a 40-year period is £112.8m. This leads to a lifetime cost of £19,846m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,462.5m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.9m. This leads to a lifetime cost of £2,679m for the HVDC subsea option. Therefore, the most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, two bays are required at New Walpole Substation, adding a capital cost of £16m.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. The Wash SAC, SPA, Ramsar site and NNR is present in the study area for the underground cable and will require careful routeing. There are 12 SSSI's in the study area for Option 5a. This option will require underground routes crossing of a minimum of five main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. While designated heritage assets are likely to be avoidable, there is the potential for impacts on the setting of Listed Buildings in the vicinity of Walpole subject to converter station siting. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable (but to a lesser extent than for Options 2, 3a and 4), with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, less direct routes may need to be developed to avoid this landscape designation.	The proposed transmission connection to the existing network is made away from major demand centres. Option 5 provides transmission capacity uplift across the B6, B7a, B8 and B9 boundaries. There is also neutral impact to the East Coast Generation Group. The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which proposes a new circuit between South Lincolnshire and East Leicestershire. This option is also dependent upon Grimsby to Walpole; however, it is not dependent upon the OHL construction and could be separated from Grimsby to Walpole if required. The proposed transmission connection is at the same substation as EGL 3 and EGL 4,

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
				which presents additional system complexity.
5b Connection to New Walpole (Norfolk)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as King's Lynn combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 3, and the proposed converter station would be sited within grade 1. With regard to the marine environment, the Norfolk landfall study area includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignment, Viking Link, North Sea Link and Hornsea 1, 2 and 3 export connection cables. Additionally, Sheringham Shoal and Dudgeon Extensions with consent authorised Project status, appears to have export connection cables reach landfall within the small section that is not designated as a SSSI. There are four designated bathing waters within the Norfolk landfall study area which are classified as having excellent bathing water status in 2024. Other planned or in development project constraints in the area include Hornsea 3 Offshore Wind Farm NSIP, Sheringham and Dudgeon Extension Projects NSIP and Palm Paper 3 CCGT Power station Kings Lynn.	Same as 5a, see above.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ, the Inner Dowsing, Race Bank and North Ridge SAC, Wash and North Norfolk Coast SAC, North Norfolk Coast SPA, SAC and SSSI and Cromer Shoals Chalk Beds MCZ. Subject to landfall selection, there is the potential for effects on the Wash and North Norfolk Coast SAC, North Norfolk Coast SPA, SAC and SSSI and Cromer Shoals Chalk Beds MCZ. One or more of these sites require to be crossed in order to make landfall on the Norfolk coast. There are 32 SSSI in the study area for Option 5b. These coastal ecological designations present a consenting constraint across the extent of the landfall for this option , requiring significant mitigation measures, particularly where more than one designation is crossed, increasing the likelihood of impact. This option will require underground routes crossing multiple main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. The option requires landfalls and onward underground cable routes within and crossing the Norfolk Coast National Landscape. While long term effects are unlikely to occur assuming careful routeing and reinstatement it is preferable to avoid the National Landscape where possible. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets located throughout the Option are likely to be avoidable	Same as 5a, see above.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
				which presents additional system complexity.
5b Connection to New Walpole (Norfolk)	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as King's Lynn combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 3, and the proposed converter station would be sited within grade 1. With regard to the marine environment, the Norfolk landfall study area includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignment, Viking Link, North Sea Link and Hornsea 1, 2 and 3 export connection cables. Additionally, Sheringham Shoal and Dudgeon Extensions with consent authorised Project status, appears to have export connection cables reach landfall within the small section that is not designated as a SSSI. There are four designated bathing waters within the Norfolk landfall study area which are classified as having excellent bathing water status in 2024. Other planned or in development project constraints in the area include Hornsea 3 Offshore Wind Farm NSIP, Sheringham and Dudgeon Extension Projects NSIP and Palm Paper 3 CCGT Power station Kings Lynn.	Same as 5a, see above.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ, the Inner Dowsing, Race Bank and North Ridge SAC, Wash and North Norfolk Coast SAC, North Norfolk Coast SPA, SAC and SSSI and Cromer Shoals Chalk Beds MCZ. Subject to landfall selection, there is the potential for effects on the Wash and North Norfolk Coast SAC, North Norfolk Coast SPA, SAC and SSSI and Cromer Shoals Chalk Beds MCZ. One or more of these sites require to be crossed in order to make landfall on the Norfolk coast. There are 32 SSSI in the study area for Option 5b. These coastal ecological designations present a consenting constraint across the extent of the landfall for this option , requiring significant mitigation measures, particularly where more than one designation is crossed, increasing the likelihood of impact. This option will require underground routes crossing multiple main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. The option requires landfalls and onward underground cable routes within and crossing the Norfolk Coast National Landscape. While long term effects are unlikely to occur assuming careful routeing and reinstatement it is preferable to avoid the National Landscape where possible. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets located throughout the Option are likely to be avoidable	Same as 5a, see above.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
			there is the potential for impacts on the setting of Listed Buildings in the vicinity of Walpole subject to converter station siting.	
6 Connection to New Spalding North	There are numerous small and moderate sized settlements scattered throughout the study area, however, these are likely to be avoidable assuming careful routeing. Larger settlements such as Boston combine with other constraints to create pinch points which will influence route options. Underground cable routes will require multiple road crossings and at least one rail crossing. Much of the land to be crossed by underground cable routes comprises agricultural land with an Agricultural Land Classification of grade 1, 2 and 3, and the proposed converter station would be sited within urban classification. With regard to the marine environment, the Lincolnshire landfall study area at the north falls in close proximity with the outer extent of Humber Port Authority limit and includes areas of high vessel intensity. Most of the fishing activity within the study area is carried out by UK vessels, with comparatively few non-UK vessels recorded in the area. There are two operational interconnector cables in the study area and in the vicinity of the marine route alignments, Viking Link and North Sea Link. There are five designated bathing waters within the Lincolnshire landfall study area which are classified as having excellent bathing water status in 2024. Other constraints in the area include gas pipelines (if making landfall at Theddlethorpe), and a number of other projects under development or in planning, including the Viking CCS NSIP, Lincolnshire Offshore Gas Gathering System (LOGGS) pipelines, EGL 3 and EGL 4, Ossian Offshore Wind Farm export connections, Outer Dowsing Offshore Wind Farm export connections	The route length for Option 6 is 606 km, of which 60 km is onshore. Two technologies were appraised for this option: AC subsea cable and HVDC subsea cable. The **AC subsea** option has an associated capital cost of £18,538.9. The NPV of the cost of losses is £610.9m whilst the NPV of operation and maintenance costs over a 40-year period is £109.1m. This leads to a lifetime cost of £19,259m for the AC subsea option. The **HVDC subsea** option has an associated capital cost of £2,406.9m including converter stations at each end. The NPV of the cost of losses is £157.1m whilst the NPV of operation and maintenance costs over a 40-year period is £58.9m. This leads to a lifetime cost of £2,623m for the HVDC subsea option. Therefore, the most cost-effective option is HVDC, and this is considered the starting assumption for further exploration of this option. Additionally, regardless of subsea technology chosen, a New Spalding North Substation, consisting of 12 bays, is required, adding a capital cost of £156m. The Project will require two of these bays, with the other ten being future proofing for the surrounding grid.	Subject to subsea cable routeing and how far south the landfall is located, there is the potential for effects on the Southern North Sea SAC, Greater Wash SPA, Holderness Inshore MCZ, Holderness Offshore MCZ and subject to how far south the landfall is located potentially also the Inner Dowsing, Race Bank and North Ridge SAC. Subject to landfall selection, there is the potential for effects on the Humber Estuary SPA, SAC and SSSI, Saltfleetby-Theddlethorpe Dunes and Gibraltar Point SAC, Saltfleetby-Theddlethorpe Dunes SSSI and NNR and Donna Nook NNR as well as Sea Bank Clay Pits SSSI and Chapel Point to Wolla Bank SSSI. This option will require underground routes crossing multiple main rivers and maintained drains as well as routeing through flood zones 2 and 3. Flood zones 2 and 3 are likely to be unavoidable for converter station siting. Part of the Lincolnshire Wolds National Landscape extends into the study area for the underground cable (but to a lesser extent than for Options 2 and 3a), with the potential for local impacts to views and its setting. Subject to the specific landfall selection within the Lincolnshire landfall area, significantly longer, less direct routes may need to be developed to avoid this landscape designation. Potential effects on visual amenity on residents in settlements or in scattered properties in the vicinity of converter stations. While designated heritage assets are likely to be avoidable there is the potential for impacts on the setting of Scheduled Monuments and Listed Buildings subject to converter station siting.	The proposed transmission connection requires a new substation to be built in close proximity to the existing Spalding North Substation to facilitate connections above 1,800 MW. Option 6 provides transmission capacity uplift across the B6, B7a and B8 boundaries and some benefit to the B9 boundary. There is also neutral impact to the East Coast Generation Group. The proposed transmission connection is limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of new Spalding North; assuming two double circuits are connected to New Spalding North Substation. The proposed transmission connection's ability to provide maximum benefit to the transmission system is dependent on the completion of Weston Marsh to East Leicestershire, which

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
	and Grimsby to Walpole. Boston Alternative Energy Facility also falls within the study area.			proposes a new circuit between South Lincolnshire and East Leicestershire, whilst also requiring the Weston Marsh to East Leicestershire route to connect to new Spalding North Substation.

Option	Appraisal Factors			
	Socio-economic	Cost	Environment	Technical
	and Grimsby to Walpole. Boston Alternative Energy Facility also falls within the study area.			proposes a new circuit between South Lincolnshire and East Leicestershire, whilst also requiring the Weston Marsh to East Leicestershire route to connect to new Spalding North Substation.

8. Interaction with other projects

8.1 Introduction

8.1.1 Within the Lincolnshire Region, there are several projects that interact with the Project. The following section provides an overview of these projects and how they interact with the Project.

8.2 Overview of interacting projects

8.2.1 An interacting project, is a project that meets the following guidelines:

- other National Grid projects within the region;
- is a committed development because it has planning permission (which has not expired) or is a spatial planning policy designation; or
- it is at a progressed stage in the pre-application consultation process, following a consultation process which identifies the proposed site; and
- is a dependency for a strategic option to be viable; or
- the Project is closely related to the strategic option as it involves the same area of land identified, it abuts the land identified or would be within proximity to the strategic option to the extent where there is a likelihood of cumulative environmental and/or community impacts. Note that interfacing projects, where strategic options need to consider are discussed in Chapter 6.

8.2.2 Table 8.1 provides an outline of the projects that interact with the Project.

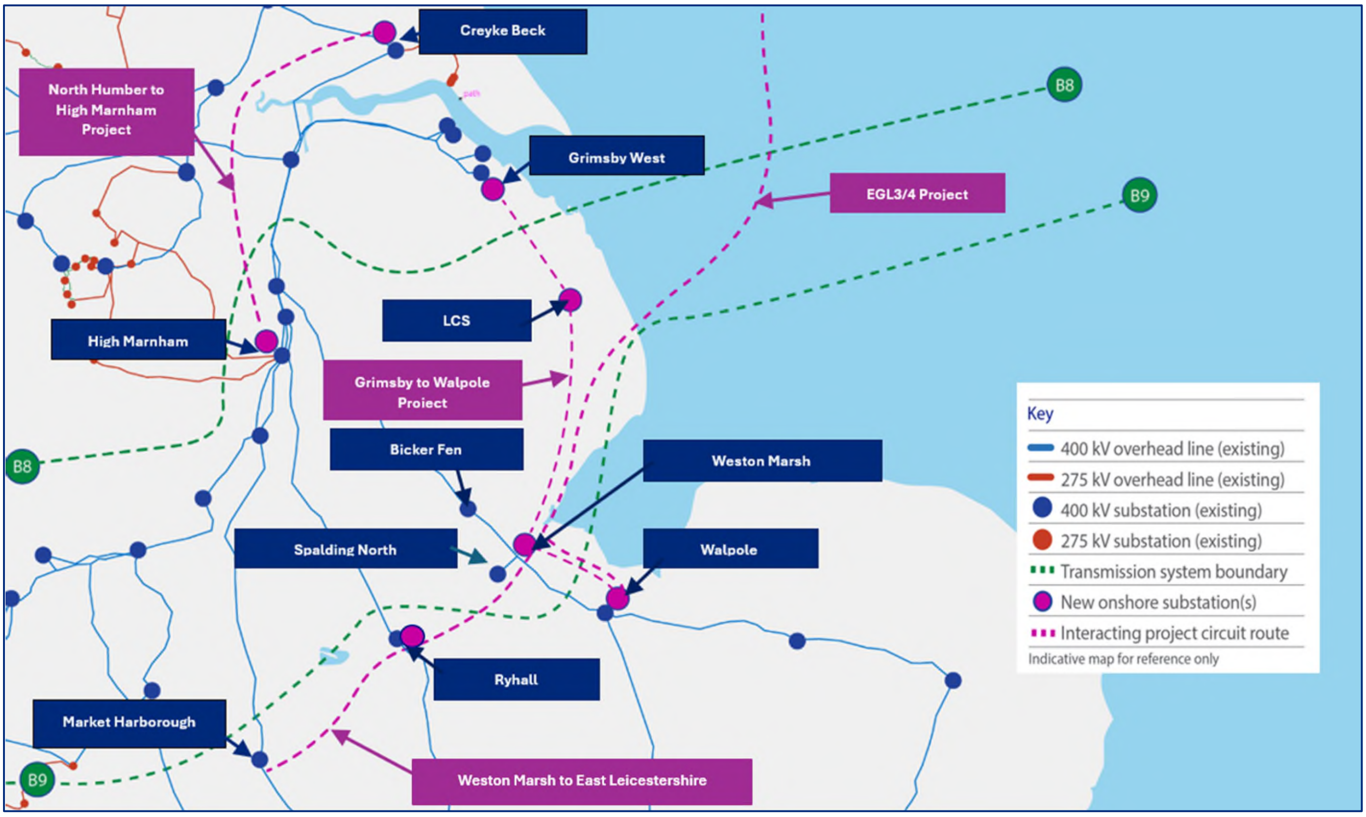
Table 8.1 – Interacting projects

Project name	Project website	Project description
Grimsby to Walpole	Grimsby to Walpole	A new high-voltage electricity transmission line and associated works between a new substation at Grimsby West in North East Lincolnshire and a new substation in the Walpole area, in Norfolk.
North Humber to High Marnham	North Humber to High Marnham	A new primarily overhead line connection from a new Creyke Beck substation to a new High Marnham substation.

Project name	Project website	Project description
Eastern Green Link 3 and 4 (EGL 3 and EGL 4)	Eastern Green Link 3 and 4	Two new, primarily offshore, high voltage electricity links and associated onshore infrastructure between Scotland and England.
Weston Marsh to East Leicestershire	TBC	A new circuit between South Lincolnshire and Leicestershire.

8.2.3 Figure 8.1 shows the proposed projects which interact with EGL 5.

Figure 8.1 – Interacting projects



8.2.4 As per Chapter 6 above, Option 1 (LCS) is dependent upon Grimsby to Walpole. Lincolnshire Connection Substation(s) are proposed as part of Grimsby to Walpole and therefore subject to an application for development consent in the future. This will enable Grimsby to Walpole to progress in advance of the EGL 5 Project. Option 4 (New Weston Marsh) and Option 5 (New Walpole) are also dependent upon Grimsby to Walpole; however, they are not dependent upon the OHL construction and could be separated from Grimsby to Walpole should it be required.

8.2.5 Option 3 (New Ryhall) and Option 6 (New Spalding North) are dependent upon Weston Marsh to East Leicestershire being taken forward. For Option 6 (New Spalding North) to be viable, Weston Marsh to East Leicestershire would be required to connect to Spalding North substation. Option 5 (New Walpole) is also dependent upon Weston

Marsh to East Leicestershire in order to achieve maximum benefit to the transmission system.

8.2.6 For options with a Lincolnshire Landfall due to similar geographic locations, there is potential for interaction with EGL 3 and EGL 4 dependent upon the exact routes that are chosen.

8.2.7 These interactions have been considered throughout the options appraisal process and feed into the conclusions and next steps in the following chapter.

9. Conclusions and next steps

9.1 Overview of identifying the strategic options

9.1.1 This SOR presents the findings of our options appraisal process for the EGL 5 Project and is intended to provide a clear justification and evidence for our decision making of a preferred strategic option. This report demonstrates that we have used the need case to consider the ways in which the project could be delivered by generating a number of potential strategic options. Technical feasibility considerations have been applied to make sure that all of the potential strategic options considered would work on the network, rejecting any that would not meet technical standards or would not work in practice. The number of options was then reduced to the proposed strategic options list by applying the benefits filter to make sure that the proposed strategic options taken forward for detailed appraisal have some benefit over other similar options. The report concludes with the identification of a preferred strategic option, which will be taken forward for consideration of an emerging preferred corridor and the selection of a preliminary route.

9.1.2 This SOR will be available for the purpose of consultation, drawn upon when engaging with stakeholders and submitted as part of the consents application approach set out in Section 3.5.

9.1.3 We have a key role in providing a transmission system which benefits all consumers in England and Wales. Where new network infrastructure is needed, NGET must work within the regulatory, legislative and policy framework that is set by the government on behalf of consumers and society in developing proposals. That means considering the various benefits and impacts that potential works could have, including environmental, socio-economic, technical, and cost factors.

9.1.4 This SOR has considered options to meet the need case set out in Chapter 4. A requirement has been identified for transmission circuit reinforcements that contribute to NETS SQSS compliance.

9.1.5 We have considered the information which is available at this stage of the process and have outlined how data has been gathered and evaluated for each option. In addition, NGET have also considered their duties under the Electricity Act 1989 to develop efficient, co-ordinated and economical solutions, their duty to have regard to the environment in Schedule 9 of the 1989 Act, and the policy, advice and guidance provided by Government through the adopted and emerging National Policy Statements.

9.1.6 Other ongoing NGET projects within the area of Humber and East Coast Regions have also been considered as part of the Project need case. Moreover, there are several projects that interact with this Project namely:

- Weston Marsh to East Leicestershire
- EGL 3
- EGL 4
- Grimsby to Walpole

9.1.7 EGL 3, EGL 4, Grimsby to Walpole, and Weston Marsh to East Leicestershire are anticipated to interact with the EGL 5 Project due to their geographic locations regardless of the preferred strategic option. As outlined in Chapter 7 and Chapter 8.

9.1.8 The Project should coordinate wherever possible with the aforementioned projects, as part of the need case presented in Chapter 4 and the interaction with other projects set out in Chapter 8. Some of the options, are dependent upon the other interacting projects gaining the relevant consent and proceeding through to completion. One such example is Option 1 (LCS) which is dependent upon Grimsby to Walpole in order to be viable. All the above interacting projects, apart from Weston Marsh to East Leicestershire due to awaiting publication, have information published on their respective project websites for which URLs are provided in Chapter 8.

9.1.9 The generation background within the East Coast Generation Group and ensuring neutral impact to those listed in Table 4.1, have also been considered throughout the strategic optioneering process.

9.2 The case for the selection of the strategic option

9.2.1 Taking all of this into account, to meet the need for provision of capacity and capability across the B6 and B7a and beneficial capability across B8 and/or B9 system boundaries with neutral connection impact upon the East Coast Generation Group, our proposal at the current stage is to take forward Option 1 (LCS) which involves the development of a new transmission circuit from Scotland connecting to New LCS. The majority of the new circuit would be routed within the North Sea making landfall on the Lincolnshire coastline. The proposed route for this option spans approximately 546 km, which is based on a straight-line distance calculation as laid out in Section 5.6.

Environmental and socio-economic factors

1.1.1 For Option 3b (New Ryhall via a landfall on the Norfolk coastline) and Option 5b (New Walpole Substation via landfall on the Norfolk coastline) additional statutory designations were identified which could be impacted on (combinations of MCZ, SAC, SSI, SPA depending on location) and require underground cables crossing the Norfolk Coast National Landscape. It is preferable to avoid the National Landscape wherever possible but long-term effects are unlikely to occur assuming careful routeing and reinstatement. Potential strategic Option 3b (New Ryhall via a landfall on the Norfolk coastline) and Option 5b (New Walpole Substation via landfall on the Norfolk coastline) are therefore less preferable for environmental reasons.

1.1.2 The routes for further inland options from the Lincolnshire coast (Options 2 – 6) have a high likelihood of being routed through flood zones 2 and 3, with most requiring numerous main river crossings. Option 1 (LCS) is routed through flood zone 2, but at a reduced length than the other routes. Option 5 (New Walpole) from the Norfolk coast landfall is likely to have the least impact on flood zones and main rivers.

1.1.3 In environmental terms, the other potential strategic options are broadly comparable (except with regard to length of cable route required) the potential impact on statutory designations is mainly limited to the marine route/landfall and therefore common to all options. Agricultural land across the routes is largely best and most versatile at grades 3a and 2, and not a differentiating factor at this scale. However, we note that Option 6 (New Spalding North) will require the construction of a new substation, which may lead to further environmental considerations.

1.1.4 One of the key differentiators between options relates to overall route length which can impact the extent of environmental and socio-economic effects. Reflecting the location of each substation (existing or planned), the total route length for each of the Project potential strategic option ranged between 546 km (10 km of which is onshore) for Option 1 (LCS) and 636 km (85 km of which is onshore) for Option 3 (New Ryhall).

1.1.5 Option 1 (LCS) requires the shortest cable route length, both onshore and overall, and therefore likely to have the least overall impact on environmental and socio-economic factors. Option 3 (New Ryhall) requires long distance routes either crossing the National Landscape or requiring even longer routes to avoid it regardless of the chosen landfall. While impacts on the National Landscape from laying the cable are temporary, alternative options which can avoid it are preferable, including in order to address planning policy requirements.

1.1.6 Each of Option 5 (New Walpole) and Option 6 (New Spalding North) are comparable in terms of requiring long distance cable routes, 624 km and 606 km respectively. Option 2 (Bicker Fen) and Option 4 (Weston Marsh) require routes of similar distance, 594 km and 600 km respectively. Although Option 4 (Weston Marsh) is not the longest route, it has a slightly longer route than most strategic options, and therefore more impacts are expected. However, due to the nature of the constraints which are/are not present, the impacts associated with Option 4 (Weston Marsh) are not considered to be materially different to or greater than, the impacts of going to Bicker Fen Substation (Option 2).

Technical factors

9.2.2 To summarise, from a technical standpoint, Option 1 (LCS) resolves the technical need case increasing capacity across the B6, B7a and B8 boundaries. Whilst it does not cross boundary B9 it does provide benefit to it. It also has neutral impact to the East Coast Generation Group.

9.2.3 However, Option 1 (LCS) does not perform as well as some of the other options it is limited by a single 6.9 GW double circuit connection in the event of a fault of the other double circuit out of each of these substations.

9.2.4 Option 1 (LCS) is also contingent on Grimsby to Walpole obtaining consent, progressing and being completed on schedule. This is due to LCS being part of the Grimsby to Walpole scope.

Cost factors

9.2.5 The overview of the capital and lifetime cost impacts of Option 1 (LCS), with HVDC as the recommended technology, as set out in Section 6.2, is summarised below:

- Total Capital cost of £2,237.5m;
- Lifetime cost of new circuits of £2,437m

9.2.6 Overall, Option 1 (LCS) presents the lowest capital and lifetime cost among all options taken forward for appraisal. From a cost perspective, these considerations add significant weight to the preference of this option.

9.2.7 HVDC technology is well established and does not add uncertainty or constructability risk to the Project.

9.3 Next steps

9.3.1 The Project will now be taken forward to the next stage of development. This involves preliminary routing and siting work, identification of a preliminary preferred route corridor and siting choice for the converter station and preparation of a graduated swathe, which indicates a more likely location for the development. This will be consulted on at consultation to seek feedback from consultees and help shape the further development of the Project.

Appendices

Appendix A Glossary

Acronym / Term	Definition
AC	Alternating Current
AC Cable	AC Underground Cable
ACS	Average Cold Spell
AONB	Area of Outstanding Natural Beauty
ASTI	Accelerated Strategic Transmission Investment
Availability Factor	The time a generator is able to produce electricity over a period of time divided by that period of time
BESS	British Energy Security Strategy
CBA	Cost Benefit Analysis
CCC	Committee on Climate Change
CCGT	Combined Cycle Gas Turbine
CION	Connection and Infrastructure Options Note
CNP	Critical National Priority
Conductor	Used to transport power
Constraint costs	payments made to constrain generation, to manage power flows where forecast power flows would exceed to capability of the electricity transmission system
CSC	Current Source Converter
CSNP	Centralised Strategic Network Plan
DC	Direct Current
DCO	Development Consent Order issued under the Planning Act 2008
DESNZ	Department for Energy Security and Net Zero, the ministerial department with primary responsibility for energy.
Double circuit	Two transmission circuits each consisting of three conductors (one for each phase of the three phase circuits) carried on two sides of a single pylon
Economy Planned Transfer Assessment	Modelling approach for the Economy Planned Transfer Assessment is set out in NETS SQSS Appendix E
Electricity Act	The Electricity Act 1989
EN-1	Overarching National Policy Statement for Energy

Acronym / Term	Definition
EN-3	National Policy Statement for Renewable Energy Infrastructure
EN-5	National Policy Statement for Electricity Network Infrastructure
EN-6	National Policy Statement for Nuclear Power Generation
ESO	Electricity System Operator (the former operator of the National Electricity Transmission System)
ETYS	Electricity Ten Year Statement sets out the Electricity System Operator’s view of future transmission requirements and where the capability of the transmission network might need to be addressed over the next decade.
EV	Electric Vehicle
FES	Future Energy Scenarios represent different credible scenarios for the transition to a cleaner greener energy future by 2050.
GHG	Greenhouse gases
GIL	Gas Insulated Lines
GW	Gigawatt
HRA	Habitats Regulations Assessment
HND	Holistic Network Design, a publication by ESO issued in July 2022 setting out a single integrated transmission network design that supports the large-scale delivery of electricity generated from offshore wind by 2030
HND FUE	Holistic Network Design Follow Up Exercise, an updated publication of the HND.
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IBA	Important Bird Area
ICE	Internal Combustion Engine
IET, PB/CCI Report	An independent report endorsed by the Institution of Engineering and Technology by Parsons Brinckerhoff in association with Cable Consulting International
Insulators	Used to safely connect conductors to pylons
IROPI	Imperative Reasons of Overriding Public Interest
kV	Kilovolt
LCS	Lincolnshire Connection Substation
MCAA	Marine and Coastal Access Act 2009

Acronym / Term	Definition
MCZ	Marine Conservation Zone
MCZA	MCZ Assessment
MEEB	Measures of Equivalent Environmental Benefit
MITS	Main Interconnected Transmission System
MVA	Mega Volt Amperes
NETS	National Electricity Transmission System.
NGET	National Grid Electricity Transmission plc
Net zero	UK Government's commitment to reduce greenhouse gas emissions to net zero by 2050 as per the Climate Change Act 2008 (2050 Target Amendment) Order 2019. Net zero means any emissions that cannot be avoided would be balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere.
NESO	Operator of National Electricity Transmission System, the National Energy System Operator
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standard
NNR	National Nature Reserve
NOA	Network Options Assessment
NPS	National Policy Statements
NPV	Net Present Value
NSIP	Nationally Significant Infrastructure Project
NZMR	Net Zero Market Reform
Ofgem	The Office of Gas and Electricity Markets
OHL	Overhead Line
OTNR	Offshore Transmission Network Review
Planned transfer	The amount of power which will flow out of a region at ACS peak. The Planned Transfers for a region of the NETS is calculated using the modelling approach set out in the NET SQSS.
(the) Policy	National Grid's Stakeholder, Community and Amenity Policy
Pylons	Used to support conductors
PV	Photovoltaic
REMA	Review of Electricity Market Arrangements

Acronym / Term	Definition
RESPs	Regional Energy Strategic Planners
RIBA	Royal Institute of British Architects
SAC	Special Areas for Conservation
SF_6	Sulphur Hexafluoride (gas used to provide electrical insulation)
SGT	Super-Grid Transformer
SOR	Strategic Options Report
Span length	Distance between adjacent pylons
SPA	Special Protection Areas
SP Energy Networks	SP Transmission plc is a wholly owned subsidiary of Scottish Power (SP) Energy Networks responsible for the transmission of electricity in central and southern Scotland.
SQSS	Security and Quality of Supply Standard. This sets out the criteria and methodology for planning and operating the transmission system.
SSEN	Scottish and Southern Electricity Networks (SSEN) Transmission is the trading name for Scottish Hydro Electric Transmission responsible for the electricity transmission network in the north of Scotland
SSEP	Strategic Spatial Energy Plan
SSSI	Sites of Special Scientific Interest
STC	System Operator – Transmission Owner Code
Strategic options appraisal	A robust and transparent process used to compare options and to assess the positive and negative effects they may have across a wide range of criteria including environmental, socioeconomic, technical and cost factors.
Study area	A defined geographic area used for the purpose of strategic option appraisal
Substation	Transmission substations are found where electricity enters the power grid to convert generator outputs to a level that suits its means of transmission
TAAP	Transmission Accelerated Action Plan
TEC	Transmission Entry Capacity
TO	Transmission Owner
T-pylon	Monopole pylon design developed by National Grid
Transmission Licence	Licence granted under Section 6(1)(b) of the Electricity Act

Acronym / Term	Definition
VSC	Voltage Source Converters
volt (V)	The electrical unit of potential difference 1 kilovolt (kV) = 1,000volts
watt (W)	The SI unit of power 1 kilowatt (kW) = 1,000 watts 1 megawatt (MW) = 1,000 kW 1 gigawatt (GW) = 1,000 MW
XLPE	Cross Linked Polyethylene (solid material used to provide electrical insulation)

Appendix B Summary of National Grid Electricity Transmission Legal Obligations

1.1 Electricity Transmission Licence

1.1.1 The Electricity Act 1989 (the ‘Electricity Act’) defines transmission of electricity within GB and its offshore waters, as a prohibited activity, which cannot be carried out without permission by a transmission licence granted under Section 6(1)(b) of the Electricity Act (a ‘Transmission Licence’).

1.1.2 National Grid Electricity Transmission (‘National Grid’) has been granted a Transmission Licence that permits transmission owner activities in respect of the electricity transmission system National Grid owns, develops and maintains in England and Wales.

1.1.3 Each Transmission Licence includes conditions which define the scope of the permission granted to carry out a prohibited activity in terms of duties, obligations, restrictions and rights. The generic conditions that apply to any holder of a Transmission Owner licence type are set out in sections A, B and D of the Standard Conditions of the Transmission Licence. Conditions that only apply to a specific licensee are set out as Special Conditions of that Transmission Licence.

1.1.4 National Grid is therefore bound by the legal obligations primarily set out in the Electricity Act and its Transmission Licence. The following list provides a summary overview of requirements that are considered when developing proposals to construct new transmission system infrastructure.

1.2 Electricity Act duties

1.2.1 In accordance with Section 9 of the Electricity Act, National Grid is required to develop and maintain an efficient, coordinated and economical system of electricity transmission.

1.2.2 Schedule 9 of the Electricity Act requires National Grid, when formulating proposals for new lines and other works, to:

"…have regard to the desirability of preserving natural beauty, of conserving flora, fauna, and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and to do what [it] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects".

1.2.3 National Grid's Stakeholder, Community and Amenity Policy (‘the Policy‘) sets out how the company will meet this Schedule 9 duty. The commitments within the Policy include:

- only seeking to build new lines and substations where the existing transmission infrastructure cannot be upgraded technically or economically to meet transmission security standards;

- where new infrastructure is required, seeking to avoid areas that are nationally or internationally designated for their landscape, wildlife or cultural significance; and
- minimising the effects of new infrastructure on other sites valued for their amenity.

1.2.4 The Policy also refers to the application of best practice methods to assess the environmental impacts of proposals and identify appropriate mitigation and/or offsetting measures. Effective consultation with stakeholders and the public is also promoted by the Policy.

1.3 National Grid's Transmission Licence requirements

1.3.1 Condition B12: System Operator – Transmission Owner Code

All Transmission Licensees are required to have the System Operator Transmission Owner Code ('STC') in place that defines the arrangements within the transmission sector and sets out how the transmission system operator can access and use transmission services provided by transmission owners.

The STC structure aligns with key activities within the transmission sector including:

- Planning Co-ordination (of transmission system development works and construction);
- Provision of transmission services within different operational timescales; and
- Payments from transmission system operator to providers of transmission services (after service has been delivered).

1.3.2 Condition B16: Electricity Network Innovation Strategy

All Transmission Licensees are required to have a joined-up approach to innovation and develop an Electricity Network Innovation Strategy that is reviewed every two years.

1.3.3 Condition D2: Obligation to provide transmission services

Each transmission owner is required to provide transmission services to the transmission system operator as defined in the STC. Transmission services provided to the transmission system operator include:

- enabling use to be made of existing transmission owner assets, and
- responding to requests for the construction of additional transmission system capacity (including system extension, disconnections and/or reinforcement).

1.3.4 Condition D3: Transmission system security standard and quality of service

Transmission owners are required to at all times plan, develop the transmission system in accordance with the National Electricity Transmission System Security and Quality of Supply Standard ('NETS SQSS').

A transmission owner with supporting evidence, may ask the Authority to grant derogation from the requirements set out in the NETS SQSS. Any decision in respect of NETS SQSS derogations are subject to the Authority's consideration of all relevant factors.

1.3.5 Condition D17: Whole Electricity System Obligations

Transmission owners are required to coordinate and cooperate with Transmission Licensees and electricity distributors in order to build common understanding of where actions taken by one could have cross-network impacts. A transmission owner should implement actions or processes that are identified that:

- will not have a negative impact on its network, and
- are in the interest of the efficient and economical operation of the total system.

Appendix C Technology overview

1.1 Introduction

1.1.1 This section provides an overview of the technologies available when the strategic options described in this Report were identified. It provides a high-level description of the relevant features of each technology. The cost methodology for each technology is presented in Appendix D.

1.1.2 The majority of electricity systems throughout the world are AC systems. Consumers have their electricity supplied at different voltages depending upon the amount of power they consume e.g. 230 V for domestic customers and 11 kV for large factories and hospitals. The voltage level is relatively easy to change when using AC electricity, which means a more economical electricity network can be developed for customer requirement. This has meant that the electrification of whole countries could be and was delivered quickly and efficiently using AC technology.

1.1.3 DC electricity did not develop as the means of transmitting large amounts of power from generating stations to customers because DC is difficult to transform to a higher voltage and bulk transmission by low voltage DC is only effective for transporting power over short distances. However, DC is appropriate in certain applications such as the extension of an existing AC system or when providing a connection to the transmission system.

1.1.4 In terms of voltage, the transmission system in England and Wales operates at both 275 kV and 400 kV. The majority of National Grid's transmission system is now constructed and operated at 400 kV, which facilitates higher power transfers and lower transmission losses.

1.1.5 There are a number of different technologies that can be used to provide transmission connections. These technologies have different features which affect how, when and where they can be used. The main technology options for electricity transmission are:

- OHLs
- Underground cables
- GILs, and
- High Voltage Direct Current (HVDC).

1.1.6 This appendix provides generic information about each of these four technologies. Further information, including a more detailed technical review is available in a series of factsheets that can be found at the Project website referenced at the beginning of this Report.

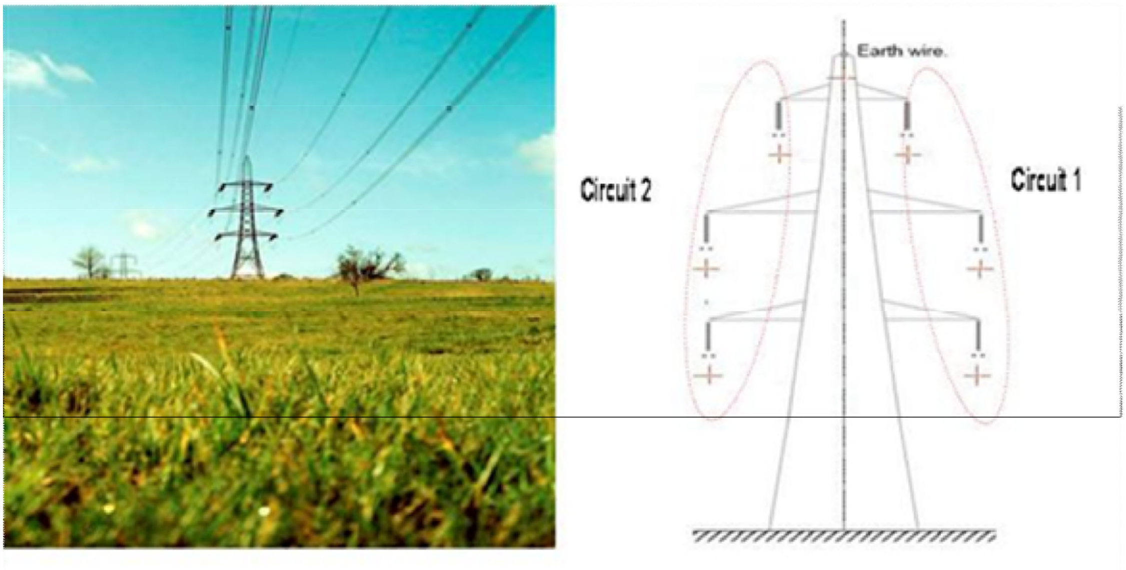
1.2 Overhead lines

1.2.1 OHLs form the majority of the existing transmission system circuits in Great Britain and in transmission systems across the world. As such there is established understanding of their construction and use.

1.2.2 OHLs are made up of three main component parts which are; conductors (used to transport the power), pylons (used to support the conductors) and insulators (used to safely connect the conductors to pylons).

1.2.3 Figure C.1 shows a typical pylon used to support two 275 kV or 400 kV OHL circuits. This type of pylon has six arms (three either side), each carrying a set (or bundle) of conductors.

Figure C.1 – Example of a 400 kV Double-circuit Tower



1.2.4 The number of conductors supported by each arm depends on the amount of power to be transmitted and will be either two, three or four conductors per arm. Technology developments have increased the capacity that can be carried by a single conductor and therefore, new OHLs tend to have two or three conductors per arm.

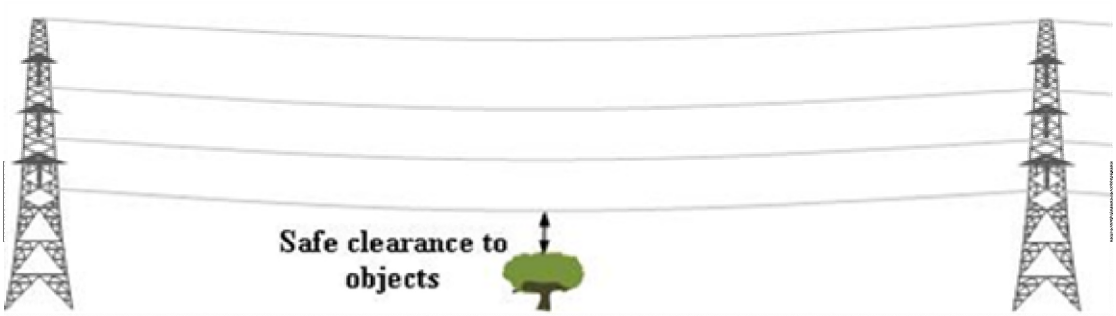
1.2.5 With the conclusion of the Royal Institute of British Architects (RIBA) pylon design competition[8] and other recent work with manufacturers to develop alternative pylon designs, National Grid is now able to consider a broader range of pylon types, including steel lattice and monopole designs. The height and width is different for each pylon type, which may help National Grid to manage the impact on landscape and visual amenity better. Figure C.2 shows an image on the monopole design called the T-pylon that was developed by National Grid.

[8] Pylon Design an RIBA competition, https://www.architecture.com/awards-and-competitions-landing-page/competitions-landing-page/pylon

Figure C.2 – The T-pylon

1.2.6 Pylons are designed with sufficient height to ensure that the clearances between each conductor and between the lowest conductor and the ground, buildings or structures are adequate to prevent electricity jumping across. The minimum clearance between the lowest conductor and the ground is normally at the mid-point between pylons. There must be sufficient clearance between objects and the lowest point of the conductor as shown in Figure C.3.

Figure C.3 – Safe height between lowest point of conductor and other obstacle (“Safe Clearance”)



1.2.7 The distance between adjacent pylons is termed the ‘span length’. The span length is governed by a number of factors, the principal ones being pylon height, number and size of conductors (i.e. weight), ground contours and changes in route direction. A balance must therefore be struck between the size and physical presence of each tower versus the number of towers; this is a decision based on both visual and economic aspects. The typical ‘standard’ span length used by National Grid is approximately 360 m.

1.2.8 Lower voltages need less clearance and therefore the pylons needed to support 132 kV lines are not as high as traditional 400 kV and 275 kV pylons. However, lower voltage circuits are unable to transport the same levels of power as higher voltage circuits.

1.2.9 National Grid has established operational processes and procedures for the design, construction, operation and maintenance of OHLs. Circuits must be taken out of service from time to time for repair and maintenance. However, shorter emergency restoration times are achievable on OHLs as compared, for example, to underground cables. This provides additional operational flexibility if circuits need to be rapidly returned to service to maintain a secure supply of electricity when, for example, another transmission circuit is taken out of service unexpectedly.

1.2.10 In addition, emergency pylons can be erected in relatively short timescales to bypass damaged sections and restore supplies. OHL maintenance and repair therefore does not significantly reduce security of supply risks to end consumers.

1.2.11 Each of the three main components that make up an OHL has a different design life, which are:

- Between 40 and 50 years for overhead line conductors
- 80 years for pylons
- Between 20 and 40 years for insulators.

1.2.12 National Grid expects an initial design life of around 40 years, based on the specified design life of the component parts. However, pylons can be easily refurbished and so substantial pylon replacement works are not normally required at the end of the 40-year design life.

1.3 Underground cables

1.3.1 Underground cables at 275 kV and 400 kV make up approximately 10% of the existing transmission system in England and Wales, which is typical of the proportion of underground to overhead equipment in transmission systems worldwide. Most of the underground cable is installed in urban areas where achieving an overhead route is not feasible. Examples of other situations where underground cables have been installed, in preference to OHLs, include crossing rivers, passing close to or through parts of nationally designated landscape areas and preserving important views.

1.3.2 Underground cable systems are made up of two main components – the cable and connectors. Connectors can be cable joints, which connect a cable to another cable, or OHLs connectors in a substation.

1.3.3 Cables consist of an electrical conductor in the centre, which is usually copper or aluminium, surrounded by insulating material and sheaths of protective metal and plastic. The insulating material ensures that although the conductor is operating at a high voltage, the outside of the cable is at zero volts (and therefore safe). Figure C.4 shows a cross section of a transmission cable and a joint that is used to connect two underground cables.

Figure C.4 – Cable cross-section and joint

1.3.4 Underground cables can be connected to above-ground electrical equipment at a substation, enclosed within a fenced compound. The connection point is referred to as a cable sealing end. Figure C.5 shows two examples of cable sealing end compounds.

Figure C.5 – Cable Sealing End Compounds

1.3.5 An electrical characteristic of a cable system is capacitance between the conductor and earth. Capacitance causes a continuous ‘charging current’ to flow, the magnitude of which is dependent on the length of the cable circuit (the longer the cable, the greater the charging current) and the operating voltage (the higher the voltage the greater the current). Charging currents have the effect of reducing the power transfer through the cable.

1.3.6 High cable capacitance also has the effect of increasing the voltage along the length of the circuit, reaching a peak at the remote end of the cable.

1.3.7 National Grid can reduce cable capacitance problems by connecting reactive compensation equipment to the cable, either at the ends of the cable, or, in the case of longer cables, at regular intervals along the route. Specific operational arrangements and switching facilities at points along the cable circuit may also be needed to manage charging currents.

1.3.8 Identifying faults in underground cable circuits often requires multiple excavations to locate the fault and some repairs require removal and installation of new cables, which can take a number of weeks to complete.

1.3.9 High voltage underground cables must be regularly taken out of service for maintenance and inspection and, should any faults be found and depending on whether cable excavation is required, emergency restoration for security of supply reasons typically takes a lot longer than for OHLs (days rather than hours).

1.3.10 The installation of underground cables requires significant civil engineering works. These make the construction times for cables longer than OHLs.

1.3.11 The construction swathe required for two AC circuits comprising two cables per phase will be between 35-50 m wide.

1.3.12 Each of the two main components that make up an underground cable system has a design life of between 40 and 50 years.

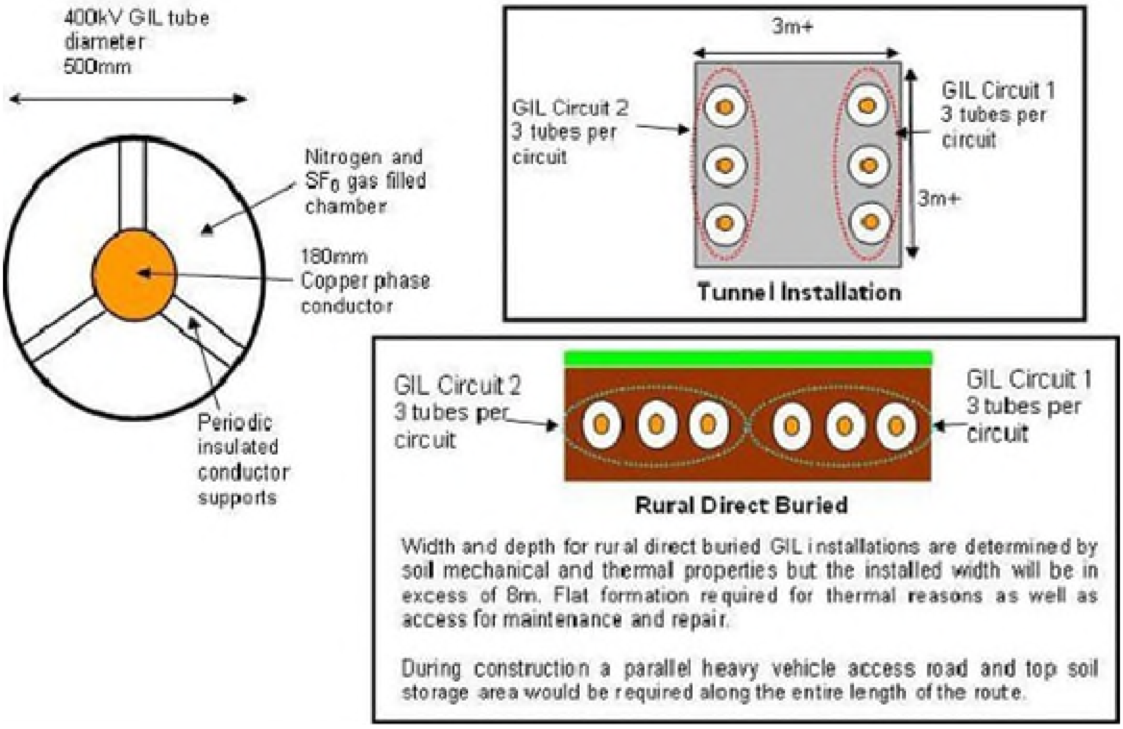
1.3.13 Asset replacement is generally expected at the end of design life. However, National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

1.4 Gas Insulated Lines ("GIL")

1.4.1 GIL is an alternative to underground cable for high voltage transmission. GIL has been developed from the well-established technology of gas-insulated switchgear, which has been installed on the transmission system since the 1960s.

1.4.2 GIL uses a mixture of nitrogen and sulphur hexafluoride (SF6) gas to provide the electrical insulation. GIL is constructed from welded or flanged metal tubes with an aluminium conductor in the centre. Three tubes are required per circuit, one tube for each phase. Six tubes are therefore required for two circuits, as illustrated in Figure C.6.

Figure C.6 – Key components of GIL



1.4.3 GIL tubes are brought to site in 10 – 20 m lengths and they are joined in situ. It is important that no impurities enter the tubes during construction as impurities can cause the gas insulation to fail. GIL installation methods are therefore more onerous than those used in, for example, natural gas pipeline installations.

1.4.4 A major advantage of GIL compared to underground cable is that it does not require reactive compensation.

1.4.5 The installation widths over the land can also be narrower than cable installations, especially where more than one cable per phase is required.

1.4.6 GIL can have a reliability advantage over cable in that it can be reenergised immediately after a fault (similar to OHLs) whereas a cable requires investigations prior to reenergisation. If the fault was a transient fault, it will remain energised and if the fault was permanent the circuit will automatically and safely deenergise again.

1.4.7 There are environmental concerns with GIL as the SF_6[9] gas used in the insulating gas mixture is a potent 'greenhouse gas'. Since SF6 is an essential part of the gas mixture GIL installations are designed to ensure that the risk of gas leakage is minimised.

1.4.8 There are a number of ways in which the risk of gas leakage from GIL can be managed, which include:

- use of high-integrity welded joints to connect sections of tube;
- designing the GIL tube to withstand an internal fault; and

[9] SF_6 is a greenhouse gas with a global warming potential, according to the Intergovernmental Panel on Climate Change, Working Group 1 (Climate Change 2007, Chapter 2.10.2), of 22,800 times that of CO2. www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

- splitting each GIL tube into a number of smaller, discrete gas zones that can be independently monitored and controlled.

1.4.9 At decommissioning the SF_6 can be separated out from the gas mixture and either recycled or disposed of without any environmental damage.

1.4.10 GIL is a relatively new technology and therefore has limited historical data, meaning that its operational performance has not been empirically proven. National Grid has two GIL installations on the transmission system which are 545 m and 150 m long[10]. These are both in electricity substations; one is above ground and the other is in a trough. The longest directly buried transmission voltage GIL in the world is approximately one kilometre long and was recently installed on the German transmission system around Frankfurt Airport.

1.4.11 In the absence of proven design life information, and to promote consistency with assessment of other technology options, National Grid assesses GIL over a design life of up to 40 years.

1.5 High Voltage Direct Current (“HVDC”)

1.5.1 HVDC technology can provide efficient solutions for the bulk transmission of electricity between AC electricity systems (or between points on an electricity system).

1.5.2 There are circumstances where HVDC has advantages over AC, generally where transmission takes place over very long distances or between different, electrically-separate systems, such as between Great Britain and countries in Europe such as France, Belgium, The Netherlands, Ireland etc.…

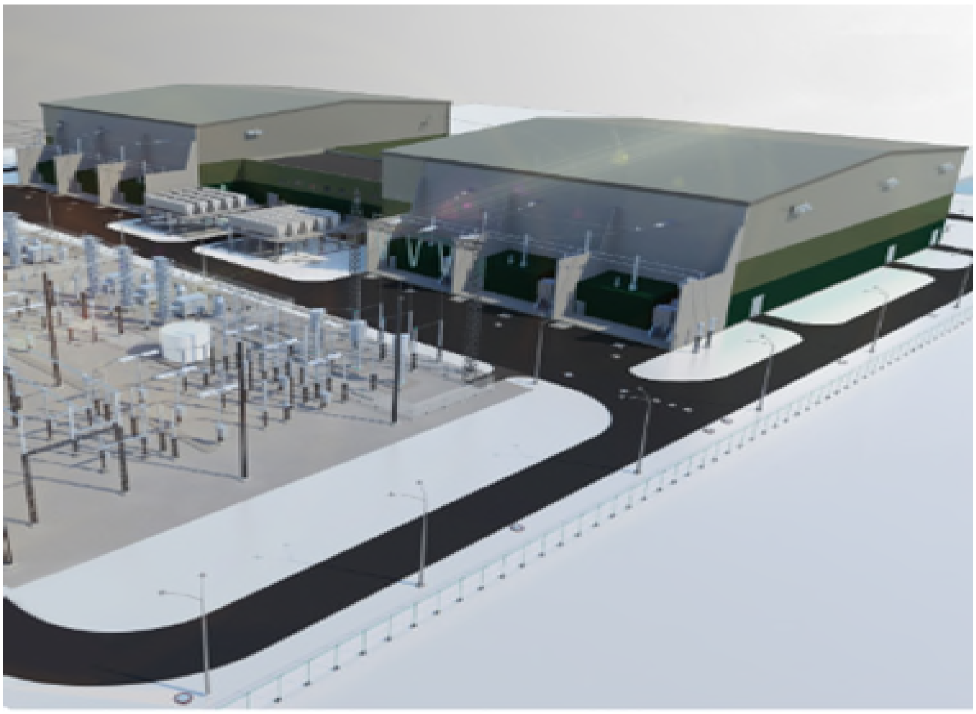
1.5.3 HVDC links may also be used to connect a generating station that is distant from the rest of the electricity system. For example, very remote hydroelectric schemes in China are connected by HVDC technology with OHLs.

1.5.4 Proposed offshore wind farms to be located over 60 km from the coast of Great Britain are likely to be connected using HVDC technology as an alternative to an AC subsea cable. This is because AC subsea cables over 60 km long have a number of technical limitations, such as high charging currents and the need for mid-point compensation equipment.

1.5.5 The connection point between AC and DC electrical systems has equipment that can convert AC to DC (and vice versa), known as a converter. The DC electricity is transmitted at high voltage between converter stations. Convertor stations can use two types of technology. “Classic” or Current Source Convertors (CSC) were the first type of HVDC technology developed and this design was used for National Grid’s Western Link. Voltage Source Convertors (VSC) are a newer design and offer advantages over the previous CSC convertors, as they can better support weaker systems and offer more flexibility in the way they operate, including direction of power flow.

[10] The distances are based on initial manufacturer estimates of tunnel and buried GIL dimensions which would be subject to full technical appraisal by National Grid and manufacturers to achieve required ratings which may increase the separation required. It should be noted that the diagram does not show the swathe of land required during construction. Any GIL tunnel installations would have to meet the detailed design requirements of National Grid for such installations.

Figure C.7 – VSC Converter Station



1.5.6 HVDC can offer advantages over AC underground cable, such as:

- a minimum of two cables per circuit is required for HVDC whereas a minimum of three cables per circuit is required for AC.
- reactive compensation mid-route is not required for HVDC.
- cables with smaller cross-sectional areas can be used (compared to equivalent AC system rating).
- This allows HVDC cables to be more easily installed for subsea applications than AC cables for a given capacity.

1.5.7 HVDC cables are generally based upon two technology types: Mass Impregnated and Extruded technologies. VSC technology may utilise either technology type, whereas CSC technology tends to be limited to Mass Impregnated cables due to the way poles are reversed for change of power flow direction.

Figure C.8 – HVDC Cable Laying Barge at transition between shore and sea cables

1.5.8 HVDC systems have a design life of about 40 years. This design life period is on the basis that large parts of the converter stations (valves and control systems) would be replaced after 20 years.

Appendix D Economic Appraisal

1.1 Introduction

1.1.1 As part of the economic appraisal of Strategic Options, NGET makes comparative assessments of the lifetime costs associated with each technology option that is considered to be feasible.

1.1.2 This section provides an overview of the methods that NGET uses to estimate lifetime costs as part the economic appraisal of a Strategic Option. It also provides a summary of generic capital cost information for transmission system circuits for each technology option included in Appendix C and an overview of the method that NGET uses to assess the Net Present Value ("NPV") of costs that are expected to be incurred during the lifetime of new transmission assets.

1.1.3 The IET, PB/CCI Report[11] presents cost information in size of transmission circuit capacity categories for each circuit design that was considered as part of the independent study. To aid comparison between the cost data presented in the IET PB/CCI Report and that used by National Grid for appraisal of Strategic Options, this appendix includes cost estimates using National Grid cost data for circuit designs that are equivalent to those considered as part of the independent study. Examples in this appendix are presented using the category size labels of "Lo", "Med" and "Hi" used in the IET PB/CCI Report.

1.2 Lifetime Costs for Transmission

1.2.1 For each technology option appraised within a Strategic Option, National Grid estimates total lifetime costs for the new transmission assets. The total lifetime cost estimate consists of the sum of the estimates of the:

- initial capital cost of developing, procuring, installing and commissioning the new transmission assets, and
- net present value ("NPV") of costs that are expected to be incurred during the lifetime of these new transmission assets

1.3 Capital Cost Estimates

1.3.1 At the initial appraisal stage, National Grid prepares indicative estimates of the capital costs. These indicative estimates are based on the high-level scope of works defined for each Strategic Option in respect of each technology option that is considered to be feasible. As these estimates are prepared before detailed design work has been carried out, National Grid takes account of equivalent assumptions for each option. Final project costs for any solution taken forward following detailed design and risk mitigation will be in excess of any high-level appraisal cost. However, all options would incur these increases in the development of a detailed solution.

[11] "Electricity Transmission Costing Study – An Independent Report Endorsed by the Institution of Engineering & Technology" by Parsons Brinckerhoff in association with Cable Consulting International. Page 10 refers to Double circuit capacities. http://www.theiet.org/factfiles/transmission-report.cfm

1.3.2 This section considers the capital costs in two parts, firstly the AC technology costs are discussed, followed by HVDC technologies. Each of these technologies is described in Appendix C in more detail.

1.4 AC Technology Capital Cost Estimates

1.4.1 Table D.1 shows the category sizes that are relevant for AC technology circuit designs:

Table D.1 – AC Technology Circuit Designs

Category	Design	Rating
Lo	Two AC circuits of 1,595 MVA	3,190 MVA
Med	Two AC circuits of 3,190 MVA	6,380 MVA
Hi	Two AC circuits of 3,465 MVA	6,930 MVA

1.4.2 Table D.2 provides a summary of technology configuration and capital cost information (in financial year 2020/21 prices) for each of the AC technology options that National Grid considers as part of an appraisal of Strategic Options.

Table D.2 – AC Technology Configuration and National Grid Capital Costs by Rating

IET, PB/CCI Report short-form label	Circuit Ratings by Voltage		Technology Configuration			Capital Costs		
	275 kV AC Technologies	400 kV AC Technologies	Overhead Line (OHL)	AC Underground Cable (AC Cable)	Gas Insulated Line (GIL)	Overhead Line (OHL)	AC Underground Cable (AC Cable)	Gas Insulated Line (GIL)
	Total rating for two Circuits (2 x rating of each circuit)	Total rating for two Circuits (2 x rating of each circuit)	No. of Conductors Sets "bundles" on each arm/circuit of a pylon	No. of Cables per phase	No of direct buried GIL tubes per phase	Cost for a "double" two circuit pylon route (Cost per circuit, of a double circuit pylon route)	Cost for a two circuit AC cable route (Cost per circuit, of a two circuit AC cable route)	Cost for a two circuit GIL route (Cost per circuit, of a two circuit GIL route)
Lo	3,190 MVA (2 x 1,595 MVA) [2,000 MVA 2 x 1,000 MVA for AC Cable only]	3,190 MVA (2 x 1,595 MVA)	2 conductor sets per circuit (6 conductors per circuit)	1 Cable per Phase (3 cables per circuit)	1 tube per phase (3 standard GIL tubes per circuit)	£3.31m/km (£1.66m/km)	£16.35m/km (£8.17m/km)	£26.81m/km (£13.411m/km)
Med	N/A [3,190 MVA 2 x 1,595 MVA for AC Cable only]	6,380 MVA (2 x 3,190 MVA)	2 conductor sets per circuit (6 conductors per circuit)	2 Cables per Phase (6 cables per circuit)	1 tube per phase (3 "developing" new large GIL tubes per circuit)	£3.64m/km (£1.82m/km)	£28.32m/km (£14.16m/km)	£31.13m/km (£15.56m/km)
Hi	N/A	6,930 MVA (2 x 3,465 MVA)	3 conductor sets per circuit (9 conductors per circuit)	3 Cables per Phase (9 cables per circuit)	2 tubes per phase (6 standard GIL tubes per circuit)	£3.98m/km (£1.99m/km)	£39.89m/km (£19.95m/km)	£43.25m/km (£21.63m/km)

Notes: -

1. Capital Costs for all technologies are based upon rural/arable land installation with no major obstacles (examples of major obstacles would be Roads, Rivers, Railways etc…)
2. All underground AC Cable and GIL technology costs are for direct buried installations only. AC cable and GIL Tunnel installations would have a higher capital installation cost than direct buried rural installations. However, AC cable or GIL replacement costs following the end of conductor life would benefit from re-use of the tunnel infrastructure.
3. AC cable installation costs exclude the cost of reactors and mid-point switching stations, which are described later in this appendix.
4. 275kV circuits will often require Super-Grid Transformers (SGT) to allow connection into the 400kV system, SGT capital costs are not included above but described later in this appendix.
5. 275kV AC cable installations above 1000MVA, as indicated in the table above, would require 2 cables per phase to be installed to achieve ratings of 1595MVA per circuit at 275kV.

1.4.3 Table D.2 provides a summary of the capital costs associated with the key[12] components of transmission circuits for each technology option. Additional equipment is required for technology configurations that include new:

- AC underground cable circuits
- Connections between 400 kV and 275 kV parts of the National Grid's transmission system.

1.4.4 The following sections provide an overview of the additional requirements associated with each of these technology options and indicative capital costs of additional equipment.

1.5 AC Underground Cable additional equipment

1.5.1 Appendix C of this Report provides a summary of the electrical characteristics of AC underground cable systems and explains that reactive gain occurs on AC underground cables.

1.5.2 Table D.3 provides a summary of the typical reactive gain within AC underground cable circuits forming part of the National Grid's transmission system.

Table D.3 – Reactive Gain Within AC underground cable circuits

Category	Voltage	Design	Reactive Gain per circuit
Lo	275 kV	One 2,500 mm^2 cable per phase	5 Mvar/km
Med	275 kV	Two 2,500 mm^2 cable per phase	10 Mvar/km
Lo	400 kV	One 2,500 mm^2 cable per phase	10 Mvar/km
Med	400 kV	Two 2,500 mm^2 cable per phase	20 Mvar/km
Hi	400 kV	Three 2,500 mm^2 cable per phase	30 Mvar/km

1.5.3 National Grid is required to ensure that reactive gain on any circuit that forms part of its transmission system does not exceed 225 Mvar. Above this limit, reactive gain would lead to unacceptable voltages (voltage requirements as defined in the NETS SQSS). In order to manage reactive gain and therefore voltages, reactors are installed on AC underground cable circuits to ensure that reactive gain in total is less than 225 Mvar.

1.5.4 For example, a 50 km "Med" double circuit would have an overall reactive gain of 1,000 Mvar per circuit (2,000 Mvar in total for two circuits). The standard shunt reactor size installed at 400 kV on the National Grid transmission system is 200 Mvar. Therefore four 200 Mvar reactors (800 Mvar) need to be installed on each circuit or eight 200 Mvar

[12] Components that are not required for all technology options are presented separately in this Appendix.

reactors (1,600 Mvar) reactors for the two circuits. Each of these reactors cost £8.7m adding £69.6m to an overall cable cost for the example double circuit above.

1.5.5 Mid-point switching stations may be required as part of a design to meet the reactive compensation requirements for AC underground cable circuit. The need for switching stations is dependent upon cable design, location and requirements which cannot be fully defined without detailed design.

1.5.6 For the purposes of economic appraisal of Strategic Options, National Grid includes a cost allowance that reflects typical requirements for switching stations. These allowances shown in Table D.4 are:

Table D.4 – Reactive Gain Within AC underground cable circuits

Category	Switching Station Requirement
Lo	Reactive Switching Station every 60 km between substations
Med	Reactive Switching Station every 30 km between substations
Hi	Reactive Switching Station every 20 km between substations

1.5.7 It is noted that more detailed design of AC underground cable systems may require a switching station after a shorter or longer distance than the typical values used by National Grid at the initial appraisal stage.

1.5.8 Table D.5 shows the capital cost associated with AC underground cable additional equipment.

Table D.5 – Additional costs associated with AC underground cables

Category	Cost per mid-point switching station	Cost per 200 Mvar reactor
Lo	£15.09m	£8.7m per reactor
Med	£18.44m	
Hi	£18.44m	

1.6 Connections between AC 275 kV and 400 kV circuits additional equipment

1.6.1 Equipment that transform voltages between 275 kV and 400 kV (a 400/275 kV supergrid transformer or "SGT") is required for any new 275 kV circuit that connects to a 400 kV part of the National Grid's transmission system (and vice versa). The number of supergrid transformers needed is dependent on the capacity of the new circuit. National Grid can estimate the number of SGTs required as part of an indicative scope of works that is used for the initial appraisal of Strategic Options.

1.6.2 Table D.6 shows the capital cost associated with the SGT requirements.

Table D.6 – Additional costs associated with 275 kV circuits requiring connection to the 400 kV system

275kV Equipment	Capital Cost (SGT - including civil engineering work)
400/275kV SGT 1,100 MVA (excluding switchgear)	£7.75m per SGT

1.7 High Voltage Direct Current ("HVDC") Capital Cost Estimates

1.7.1 Conventional HVDC technology sizes are not easily translated into the "Lo", "Med" and "Hi" ratings suggested in the IET, PB/CCI report. Whilst National Grid information for HVDC is presented for each of these categories, there are differences in the circuit capacity levels. As part of an initial appraisal, National Grid's assessment is based on a standard 2 GW converter size. Higher ratings are achievable using multiple circuits.

1.7.2 The capital costs of HVDC installations can be much higher than for equivalent AC OHL transmission routes. Each individual HVDC link, between each converter station, requires its own dedicated set of HVDC cables. HVDC may be more economic than equivalent AC OHLs where the route length is many hundreds of kilometres.

1.7.3 Table D.7 provides a summary of technology configuration and capital cost information (in financial year 2020/21 prices) for each of the HVDC technology options that National Grid considers as part of an appraisal of Strategic Options.

Table D.7 – HVDC Technology Capital Costs for 2 GW installations

HVDC Converter Type	2 GW Total HVDC Link Converter Costs (Converter Cost at Each End)	2 GW DC Cable Pair Cost
Current Source Technology or "Classic" HVDC	£475m HVDC link cost (£237.5m at each end)	£3.09m/km VDC
Voltage Source Technology HVDC	£534.38m HVDC link cost (£267.19m at each end)	£3.09m/km

Notes:

- Sometimes a different HVDC capacity (different from the required AC capacity) can be utilised for a project due to the different way HVDC technology can control power flow. The capacity requirements for HVDC circuits will be specified in any option considering HVDC. The cost shall be based upon Table D.4.
- Where a single HVDC Link is proposed as an option, to maintain compliance with the NETS SQSS, there may be a requirement to install an additional "Earth Return" DC cable. For example, a 2 GW Link must be capable of operating at ½ its capacity i.e. 1GW during maintenance or following a cable fault. To allow this operation the additional cable known as an "Earth Return" must be installed, this increases cable costs by a further 50% to £4.6m/km.

- Capital Costs for HVDC cable installations are based upon subsea or rural/arable land installation with no major obstacles (examples of major obstacles would be Subsea Pipelines, Roads, Rivers, Railways etc…)

1.7.4 Costs can be adjusted from this table to achieve equivalent circuit ratings where required. For example, a “Lo” rating 3,190 MW would require two HVDC links of (1.6 GW capacity each), while “Med” and “Hi” rating 6,380 MW-6,930 MW would require three links with technology stretch of (2.1-2.3 GW each).

1.7.5 Converter costs at each end can also be adjusted, by Linear scaling, from the cost information in Table D.7, to reflect the size of the HVDC link being appraised. HVDC Cable costs are normally left unaltered, as operating at the higher load does not have a large impact the cable costs per km.

1.7.6 The capacity of HVDC circuits assessed for this Report is not always exactly equivalent to capacity of AC circuits assessed. However, Table D.8 illustrates how comparisons may be drawn using scaling methodology outlined above.

Table D.8 – Illustrative example using scaled 2 GW HVDC costs to match equivalent AC ratings (only required where HVDC requirements match AC technology circuit capacity requirements)

IET, PB/CCI Report short-form label	Converter Requirements (Circuit Rating)	Total Cable Costs/km (Cable Cost per link)	CSC “Classic” HVDC Total Converter Capital Cost (Total Converter cost per end)	VSC HVDC Total Converter Capital Cost (Total Converter cost per end)
Lo	2 x 1.6 GW HVDC Links (3190MW)	£5.82m/km (2 x £2.91/km)	£704m (4 x £176m [4 converters 2 each end])	(4 x £736m (4 x £184m [4 converters 2 each end])
Med	3 x 2.1* GW HVDC Links (6380MW)	£9.27m/km (3 x £3.09/km)	£1,422m (6 x £237m [6 converters 3 each end])	£1602m (6 x £267m [6 converters 3 each end])
Hi	3 x 2.3* GW HVDC Links (6930MW)	£10.32m/km (3 x £3.44/km)	£1,818m (6 x £303m [6 converters 3 each end])	£1,890m (6 x £315m [6 converter 3 each end])

Notes:

- Costs based on 2 GW costs shown in Table D.4 and table shows how HVDC costs are estimated based upon HVDC capacity required for each option.
- Scaling can be used to estimate costs for any size of HVDC link required.
- *Current subsea cable technology for VSC design restricted to 2 GW, so above examples illustrative if technology should become available.

1.8 Indication of technology end of design life replacement impact

1.8.1 It is unusual for a part of National Grid’s transmission system to be decommissioned and the site reinstated. In general, assets will be replaced towards the end of the assets design life. Typically, transmission assets will be decommissioned and removed only as part of an upgrade or replacement by different assets.

1.8.2 National Grid does not take account of replacement costs in the lifetime cost assessment.

1.8.3 National Grid’s asset replacement decisions take account of actual asset condition. This may lead to actual life of any technology being longer or shorter than the design life, depending on the environment it is installed in, lifetime loading, equipment family failures among other factors for example.

1.8.4 The following provides a high-level summary of common replacement requirements applicable to specific technology options:

- OHL - Based on the design life of component parts, National Grid assumes an initial design life of around 40 years for OHL circuits. After the initial 40-year life of an OHL circuit, substantial pylon replacement works would not normally be required. The cost of Pylons is reflected in the initial indicative capital costs, but the cost of replacement at 40 years would not include the pylon cost. As pylons have an 80-year life and can be reused to carry new replacement conductors. The replacement costs for OHL circuits at the end of their initial design life are assessed by National Grid as being around 50% of the initial capital cost, through the reuse of pylons.
- AC underground Cable - At the end of their initial design life, circa 40 years, replacement costs for underground cables are estimated to be equal or potentially slightly greater than the initial capital cost. This is because of works being required to excavate and remove old cables prior to installing new cables in their place in some instances.
- GIL - At the end of the initial design life, circa 40 years, estimated replacement costs for underground GIL would be equal to or potentially greater than the initial capital cost. This is because of works being required to excavate and remove GIL prior to installing new GIL in their place in some instances.
- HVDC - It should be noted at the end of the initial design life, circa 40 years, replacement costs for HVDC are significant. This due to the large capital costs for the replacement of converter stations and the cost of replacing underground or subsea DC cables when required.

1.9 Net Present Value Cost Estimates

1.9.1 At the initial appraisal stage, National Grid prepares estimates of the costs that are expected to be incurred during the design lifetime of the new assets. National Grid considers costs associated with:

- Operation and maintenance
- Electrical losses

1.9.2 For both categories, Net Present Value (“NPV”) calculations are carried out using annual cost estimates and a generic percentage discount rate over the design life period associated with the technology option being considered.

1.9.3 The design life for all technology equipment is outlined in the technology description in Appendix C. The majority of expected design lives are of the order of 40 years, which is used to assess the following NPV cost estimates below.

1.9.4 In general discount rates used in NPV calculations would be expected to reflect the normal rate of return for the investor. National Grid’s current rate of return is 6.25%. However, the Treasury Green Book recommends a rate of 3.5% for the reasons set out below[13]

“The discount rate is used to convert all costs and benefits to ‘present values’, so that they can be compared. The recommended discount rate is 3.5%. Calculating the present value of the differences between the streams of costs and benefits provides the net present value (NPV) of an option. The NPV is the primary criterion for deciding whether government action can be justified.”

1.9.5 National Grid considered the impact of using the lower Rate of Return (used by UK Government) on lifetime cost of losses assessments for transmission system investment proposals. Using the rate of 3.5% will discount loss costs, at a lower rate than that of 6.25%. This has the overall effect of increasing the 40-year cost of losses giving a more onerous cost of losses for higher loss technologies.

1.9.6 For the appraisal of Strategic Options, National Grid recognises the value of closer alignment of its NPV calculations with the approach set out by government for critical infrastructure projects.

1.10 Annual Operations and Maintenance Cost

1.10.1 The maintenance costs associated with each technology vary significantly depending upon type. Some electrical equipment is maintained regularly to ensure system performance is maintained. More complex equipment like HVDC converters have a significantly higher cost associated with them, due to their high maintenance requirements for replacement parts. Table D.9 shows the cost of maintenance for each technology, which unlike capital and losses is not dependent on capacity.

[13] http://www.hm-treasury.gov.uk/d/green_book_complete.pdf Paragraph 5.49 on Page 26 recommends a discount rate of 3.5% calculation for NPV is also shown in the foot note of this page.

NPV calculations are carried out using the following equation over the period of consideration.

Dn =1/(1 + r)n

Where Dn = Annual Loss Cost, r = 3.5% and n = 40 years

Table D.9 – Annual maintenance costs by technology

	Overhead Line (OHL)	AC Underground Cable (AC Cable)	Gas Insulated Line (GIL)	High Voltage Direct Current (HVDC)
Circuit Annual maintenance cost per two circuit km (AC) (Annual cost per circuit Km [AC])	£2,660/km (£1,330/km)	£5,644.45/km (£2,822.22/km)	£2,687.83/km (£1,343.92/km)	£134/km Subsea Cables
Associated equipment Annual Maintenance cost per item	N/A	£6,719.58 per reactor £41,661 per switching station	N/A	£1,300,911 per converter station
Additional costs for 275 kV circuits requiring connection to the 400 kV system				
275/400 kV SGT 1100 MVA Annual maintenance cost per SGT	£6,719.58 per SGT	£6,719.58 per SGT	£6.719.58 per SGT	N/A

1.11 Annual Electrical Losses and Cost

1.11.1 At a system level annual losses on the National Grid electricity system equate to less the 2% of energy transported. This means that over 98% of the energy entering the transmission system from generators/interconnectors reaches the bulk demand substations where the energy transitions to the distribution system. Electricity transmission voltages are used to reduce losses, as more power can be transported with lower currents at transmission level, giving rise to the very efficient loss level achieved of less than 2%. The calculations below are used to show how this translates to a transmission route.

1.11.2 Transmission losses occur in all electrical equipment and are related to the operation and design of the equipment. The main losses within a transmission system come from heating losses associated with the resistance of the electrical circuits, often referred to as I2R losses (the electrical current flowing through the circuit, squared, multiplied by the resistance). As the load (the amount of power each circuit is carrying) increases, the current in the circuit is larger.

1.11.3 The average load of a transmission circuit which is incorporated into the transmission system is estimated to be 34% (known as a circuit average utilisation). This figure is calculated from the analysis of the load on each circuit forming part of National Grid's transmission system over the course of a year. This takes account of varying generation and demand conditions and is an appropriate assumption for the majority of Strategic Options.

1.11.4 This level of circuit utilisation is required because if a fault occurs there needs to be an alternative route to carry power to prevent wide scale loss of electricity for homes, business, towns and cities. Such events would represent a very small part of a circuit's 40-year life, but this availability of alternative routes is an essential requirement at all times to provide secure electricity supplies to the nation.

1.11.5 In all AC technologies the power losses are calculated directly from the electrical resistance and impedance properties of each technology and associated equipment. Table D.10 provides a summary of circuit resistance data for each AC technology and capacity options considered in this Report.

Table D.10 – AC circuit technologies and associated resistance per circuit

IET, PB/CCI Report short-form label	AC Overhead Line Conductor Type (complete single circuit resistance for conductor set)	AC Underground Cable Type (complete single circuit resistance for conductor set)	AC Gas Insulated Line (GIL) Type (complete single circuit resistance for conductor set)
Lo	2 x 570 mm^2 (0.025 Ω/km)	1 x 2,500 mm^2 (0.013 Ω/km*)	Single Tube per phase (0.0086 Ω/km)
Med	2 x 850 mm^2 (0.0184 Ω/km)	2 x 2500 mm^2 (0.0065 Ω/km*)	Single Tube per phase (0.0086 Ω/km)
Hi	3 x 700 mm^2 (0.014 Ω/km)	3 x 2,500 mm^2 (0.0043 Ω/km*)	Two tubes per phase (0.0065 Ω/km)
Losses per 200 Mvar Reactor required for AC underground cables			
Reactor Losses	N/A	0.4 MW per reactor	N/A
Additional losses for 275kV circuits requiring connection to the 400 kV system			
275 kV options only 275/400 kV SGT losses	0.2576 Ω (plus 83 kW of iron losses) per SGT	0.2576 Ω (plus 83 kW of iron losses) per SGT	0.2576 Ω (plus 83 kW of iron losses) per SGT

1.11.6 The process of converting AC power to DC is not 100% efficient. Power losses occur in all elements of the converter station: the valves, transformers, reactive compensation/filtering and auxiliary plant. Manufacturers typically represent these losses in the form of an overall percentage. Table D.11 below shows the typical percentage losses encountered in the conversion process, ignoring losses in the DC cable circuits themselves.

Table D.11 – HVDC circuit technologies and associated resistance per circuit

HVDC Converter Type	2 GW Converter Station losses	2 GW DC Cable Pair Losses	2 GW Total Link loss
Current Source (CSC) Technology or "Classic" HVDC	0.5% per converter	Ignored	1% per HVDC Link
Voltage Source (VSC) Technology HVDC	1.0% per converter	Ignored	2% per HVDC Link

1.11.7 The example calculation explained in detail below is for "Med" category circuits and has been selected to demonstrate the principles of the mathematics set out in this section. This example does not describe specific options set out within this report. A detailed example explanation of the calculations used to calculate AC losses is included in Appendix E.

1.11.8 The circuit category, for options contained within this report, is set out within each option. The example below demonstrates the mathematics and principles, which is equally applicable to "Lo", "Med" and "Hi" category circuits, over any distance.

1.11.9 The example calculations (using calculation methodology described in Appendix E) of instantaneous losses for each technology option for an example circuit of 40 km "Med" capacity 6,380 MVA (two x 3,190 MVA).

- OHLs = (2 x 3) x 1,565.5 A2 x (40 x 0.0184 Ω/km) = 10.8 MW

a) Underground Cable = (2 x 3) x1,565.5 A^2 x (40 x 0.0065 Ω/km) + (6 x 0.4 MW) = 6.2 MW

b) Gas Insulated Lines = (2 x 3) x 1,565.5 A2 x (40 x 0.0086 Ω/km) = 5.1 MW

c) CSC HVDC = 34% x 6,380 MW x 1% = 21.7 MW

d) VSC HVDC = 34% x 6380 MW x 2% = 43.4 MW

1.11.10 An annual loss figure can be calculated from the instantaneous loss. National Grid multiplies the instantaneous loss figure by the number of hours in a year and also by the cost of energy. National Grid uses £60/MWhr.

1.11.11 The following is a summary of National Grid's example calculations of Annual Losses and Maintenance costs for each technology option for an example circuit of 40 km "Med" capacity 6,380 MVA (two x 3,190 MVA).

- OHL annual loss = 10.8 MW x 24 x 365 x £60/MWhr = £5.7m.

e) U-ground Cable annual loss = 6.2 MW x 24 x 365 x £60/MWhr = £3.3m.

f) Gas Insulated lines annual loss = 5.1 MW x 24 x 365 x £60/MWhr = £2.7m

g) CSC HVDC annual loss = 21.7 MW x 24 x 365 x £60/MWhr = £11.4m

h) VSC HVDC annual loss = 43.4 MW x 24 x 365 x £60/MWhr = £22.8m

1.12 Example Lifetime costs and NPV Cost Estimate

1.12.1 The annual Operation, Maintenance and loss information is assessed against the NPV model at 3.5% over 40 years and added to the capital costs to provide a lifetime cost for each technology.

1.12.2 Table D.12 shows an example for a "Med" capacity route 6380 MVA (2 x 3,190 MVA) 400 kV, 40 km in length over 40 years.

Table D.12 – Example Lifetime Cost table (rounded to the nearest £m)

Example 400 kV "Med" Capacity over 40km	Overhead Line (OHL)	AC Underground Cable (AC Cable)	Gas Insulated Line (GIL)	CSC High Voltage Direct Current (HVDC)	VSC High Voltage Direct Current (HVDC)
Capital Cost	£145.6m	£1,167.6m	£1,244.8m	£1,795.8m	£1,973.9m
NPV Loss Cost over 40 years at 3.5% discount rate	£125m	£62.6m	£58.4m	£235.6m	£471.2m
NPV Maintenance Cost over 40 years at 3.5% discount rate	£2.33m	£5.5m	£2.4m	£171.7m	£171.7m
Lifetime Cost	£273m	£1,236m	£1,306m	£2,203m	£2,617m

Appendix E Mathematical Principles used for AC Loss Calculation

1.13 Introduction

1.13.1 This Appendix provides a detailed description of the mathematical formulae and principles that National Grid applies when calculating transmission system losses. The calculations use recognised mathematical equations which can be found in power system analysis text books.

1.13.2 The example calculation explained in detail below is for “Med” category circuits and has been selected to demonstrate the principles of the mathematics set out in this section. This example does not describe specific options set out within this report.

1.13.3 The circuit category, for options contained within this report, is set out within each option. The example below demonstrates the mathematics and principles, which is equally applicable to “Lo”, “Med” and “Hi” category circuits, over any distance.

1.14 Example Loss Calculation (1) – 40 km 400 kV “Med” Category Circuits

1.14.1 The following is an example loss calculation for a 40 km 400 kV “Med” category (capacity of 6,380 MVA made up of two 3,190 MVA circuits).

1.14.2 Firstly, the current flowing in each of the two circuits is calculated from the three-phase power equation of $P= \sqrt{3}V_{LL}I_{LL} \cos\theta$. Assuming a unity power factor ($\cos\theta= 1$), the current in each circuit can be calculated using a rearranged form of the three-phase power equation of:

(In a star (Y) configuration electrical system $I = I_{LL} = I_{LN}$)

$I = P/\sqrt{3}V_{LL}$

Where, P is the circuit utilisation power, which is 34% of circuit rating as set out in Appendix D, which for the each of the two circuits in the “Med” category example is calculated as:

P = 34% x 3,190 MVA = 1,084.6 MVA

and V_{LL} is the line to line voltage which for this example is 400 kV.

For this example, the average current flowing in each of the two circuits is:

$I = 1{,}084.6 \times 106/(\sqrt{3} \times 400 \times 103\ ) = 1{,}565.5$ Amps

1.14.3 The current calculated above will flow in each of the phases of the three-phase circuit. Therefore, from this value it is possible to calculate the instantaneous loss which occurs at the 34% utilisation loading factor against circuit rating for any AC technology.

1.14.4 For this “Med” category example, the total resistance for each technology option is calculated (from information in Appendix D, Table D.10) as follows:

OHL = 0.0184Ω/km x 40 km = 0.736 Ω

Cable Circuit[14] = 0.0065Ω/km x 40 km = 0.26 Ω

Gas Insulated Line = 0.0086Ω/km x 40 km = 0.344 Ω

These circuit resistance values are the total resistance seen in each phase of that particular technology taking account the number of conductors needed for each technology option.

1.14.5 The following is a total instantaneous loss calculation for the underground cable technology option for the "Med" category example:

Losses per phase are calculated using $P=I^2R$

1,565.52 x 0.26 = 0.64 MW

Losses per circuit are calculated using $P=3I^2R$

3 x 1,565.52 x 0.26 = 1.91 MW

Losses for "Med" category are calculated by multiplying losses per circuit by number of circuits in the category.

2 x 1.91 MW = 3.8 MW

1.14.6 For underground cable circuits, three reactors per circuit are required (six in total for the two circuits in the "Med" category). Each of these reactors has a loss of 0.4 MW. The total instantaneous losses for this "Med" category example with the underground cable technology option are assessed as:

3.8 + (6 x 0.4) = 6.2 MW

1.14.7 The same methodology is applied for the other AC technology option types for the "Med" category example considered in this Appendix. The following is a summary of the instantaneous total losses that were assessed for each technology option:

OHLs = (2 x 3) x 1,565.52 x 0.736 = 10.8 MW

Cables = (2 x 3) x 1,565.52 x 0.26 + (6 x 0.4) = 6.2 MW

Gas Insulated Lines = (2 x 3) x 1,565.52 x 0.344 = 5.1 MW

1.15 Example Loss Calculation (2) – 40 km 275 kV "Lo" Category Circuits Connecting to a 400 kV part of the National Grid's transmission system

1.15.1 The following is an example loss calculation for a 40 km 275 kV "Lo" category (capacity of 3,190 MVA made up of two 1,595 MVA circuits) and includes details of how losses of the supergrid transformer ("SGT") connections to 400 kV circuits are assessed. This example assesses the losses associated with the GIL technology option up to a connection point to the 400 kV system.

1.15.2 The circuit utilisation power (P) which for the each of the two circuits in the "Lo" category example is calculated as:

[14] A 40 km three phase underground cable circuit will also require three reactors to ensure that reactive gain is managed within required limits.

$P = 34\% \times 1{,}595 = 542.3$ MVA

For this example, the average current flowing in each of the two circuits is:

$I = 542.3\text{x}10^6/(\sqrt{3} \times 275\text{x}10^3) = 1{,}138.5$ Amps

1.15.3 For this "Lo" category example, the total resistance for the GIL technology option is calculated (from information in Appendix D, Table D.10) as follows:

$0.0086\Omega/\text{km} \times 40 \text{ km} = 0.344\ \Omega$

1.15.4 The following is a total instantaneous loss calculation for the GIL technology option for this "Lo" category example:

Losses per circuit are calculated using $P=3I^2R$

3 x 1138.5 x 0.344 = 1.35 MW

Losses for "Lo" category 275 kV circuits are calculated by multiplying losses per circuit by number of circuits in the category

2 x 1.35 MW = 2.7 MW

1.15.5 SGT losses also need to be included as part of the assessment for this "Lo" category example which includes connection to 400 kV circuits. SGT resistance[15] is calculated (from information in Appendix D, Table D.10) as 0.2576 Ω.

1.15.6 The following is a total instantaneous loss calculation for the SGT connection part of this "Lo" category example:

The average current flowing in each of the two SGT 400 kV winding are calculated as:

$I_{HV} = 542.3 \times 10^6/(\sqrt{3} \times 400\text{x}10^3) = 782.7$ Amps

Losses per SGT are calculated using $P=3I^2R$

SGT Loss = 3 x 782.7 x 0.2576 = 0.475 MW

Iron Losses in each SGT = 84kW

Total SGT instantaneous loss (one SGT per GIL circuit) = (2 x 0.475) + (2 x 0.084) = 1.1 MW.

1.15.7 For this example, the total "Lo" category loss is the sum of the calculated GIL and SGT total loss figures:

"Lo" category loss = 2.7 + 1.1 = 3.8 MW

[15] Resistance value referred to the 400 kV side of the transformer.

Appendix F Beyond 2030 Publication

1.1 Pathway to 2030 – HND

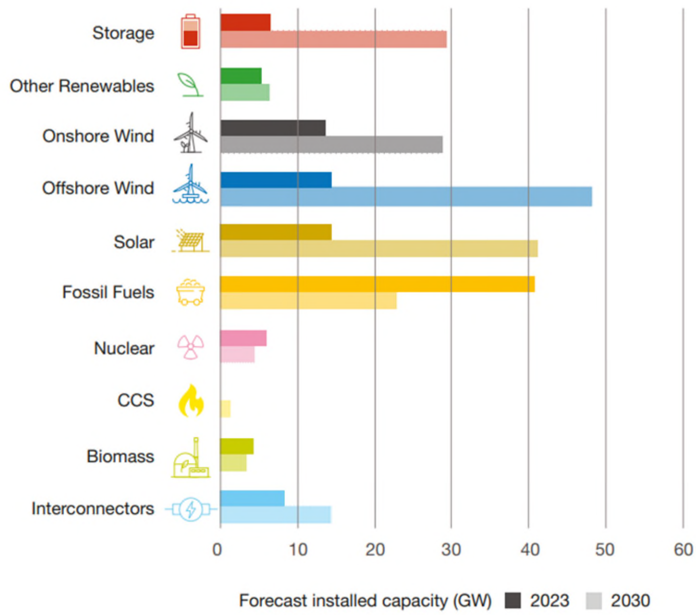
1.1.1 In 2023, 51% of the electricity in GB used was generated by zero-carbon sources. It is expected that by 2030, the electricity system will more commonly run on 100% renewable energy sources for measurable time frames, which will be vital to meet the UK Government’s ambition of having an electricity mix consisting of 95% low-carbon power.

1.1.2 Adjacent to the changes in the electricity network, gas consumption has also been projected to fall by 40% by 2030, which will be realised through the potential to replace natural gas with hydrogen where possible, and the potential to create opportunities to make use of economically efficient and reliable electricity for heating and transport.

1.1.3 This transition can be facilitated through the development of large-scale offshore wind generation, a sector that has seen Great Britain arise as a world leader. Within offshore wind, refinement of the approach used can help reduce the effects of increased infrastructure needs to effectively transfer power across the transmission system. The UK government has, hence, established the Offshore Transmission Network Review (OTNR) with the goal of developing a holistic network design that will ensure the delivery of 50 GW of offshore wind by 2030 remains viable.

1.1.4 The bar chart below from the Beyond 2030 report shows the generation mix in 2023 in comparison to the forecasted mix in 2030.

Figure F.1 – Generation mix comparison (2023 and 2030) [source: Beyond 2030, ESO, March 2024]

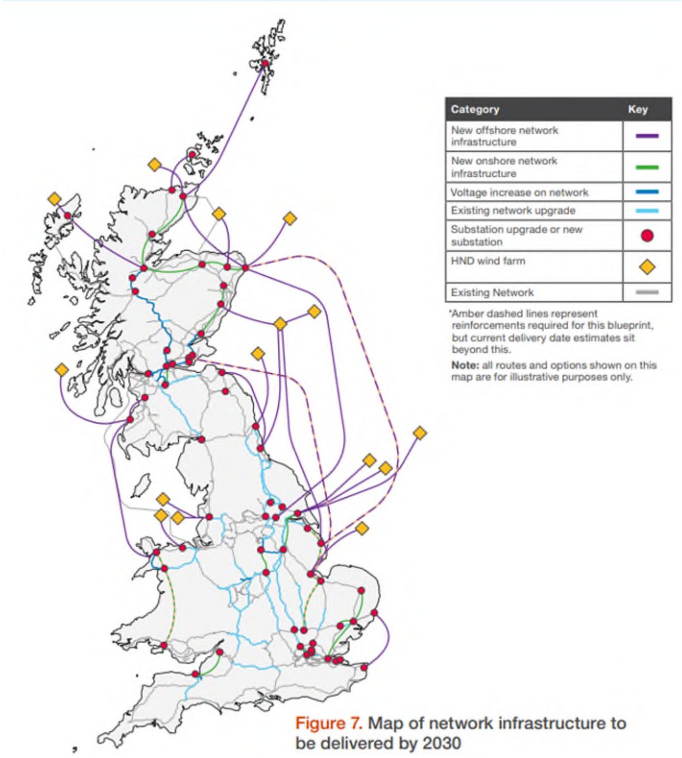


1.1.5 ESO’s Pathway to 2030 Holistic Network Design (HND) 2022 plan to connect 23 GW of offshore wind in the transmission system seeks to reduce reliance on imports of gas and reduce CO_2 emissions by up to two million tonnes between 2030 and 2032. To facilitate this growth in the offshore sector, a recommendation of over £60 billion of investment into the transmission system has been made. This investment will comprise of offshore network design and 91 reinforcements to the transmission system, resulting in a holistic approach to network planning.

1.1.6 To enable this plan, engagement with the GB energy regulator, Ofgem, was required. It was concluded that a customer benefit of up to £2.1 billion would be expedited through avoidance of network congestion costs, which led Ofgem to agree on the regulatory acceleration of 26 projects in 2022.

1.1.7 The essential transmission opportunities to enable delivery of the plan in 2030 are presented in the following figure.

Figure F.2 – Network infrastructure to be delivered by 2030 [source: Beyond 2030, ESO, March 2024]



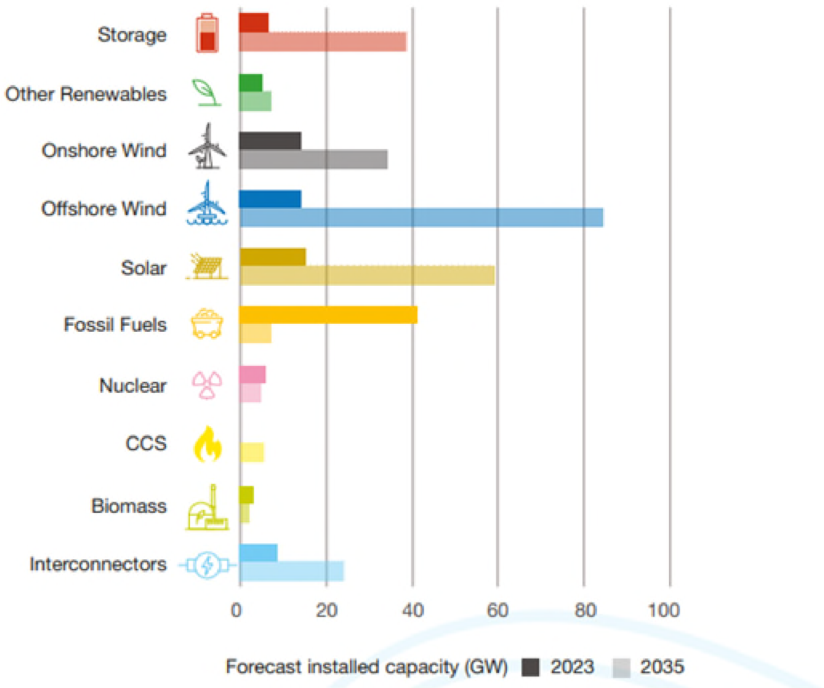
1.2 Beyond 2030 – HND FUE

1.2.1 Scoping beyond 2030, by 2035, several processes will be fully electrified and will be realised even in everyday life activities. New internal combustion engine (ICE) cars will not be sold, with only Electric Vehicles (EVs) and other zero-carbon transport options being newly available for purchase. In addition, domestic gas boilers will not be installed in new homes from 2025. The above will result in an uptake of up to approximately 30 million EVs present and up to 13 million heat pumps installed domestically and within businesses, with overall electricity demand expected to rise by 64%, in comparison to 2023.

1.2.2 The potential realised through innovation in technology development will enable further increase in the renewable energy capacity within power industries. As an example, clean hydrogen is forecasted to have a production capacity of up to 22 GW by 2035.

1.2.3 The bar chart below from the Beyond 2030 report shows the generation mix in 2023 in comparison to the forecasted mix in 2035.

Figure F.3 – Generation mix comparison (2023 and 2035) [source: Beyond 2030, ESO, March 2024]



1.2.4 As it stands, the HND scheme is not sufficient by itself to reinforce the transmission system within the Pathway to 2030, as more electricity will be generated than the network can efficiently support and transport. Therefore, the UK Government requested ESO to further develop the HND and enable a set of recommendations for a greater amount of offshore wind generation to connect to the network.

1.2.5 ESO have undertaken a network assessment of options to facilitate an efficient high-level network design, in cooperation with GB's Transmission Owners (TOs). This design implements a further 21 GW of offshore wind generation which will establish Great Britain as the owner of the largest offshore fleet in Europe. The design will be a set of holistic recommendations of measurable scale with over three times as much undersea cabling (compared to current infrastructure) needed by 2035. With this in place, power flows can be further balanced across the transmission system, enhancing energy security and reliability of supply.

1.2.6 Development of network infrastructure is required through this network design and will need to consider minimising impacts on the environment and communities. These impacts can be reduced via optimisation of network designs, early community engagement, innovative solutions and sufficient financial incentives and community packages.

1.2.7 The map below depicts the network infrastructure to be delivered beyond 2030 within the transmission system.

Figure F.4 – Network infrastructure to be delivered beyond 2030 [source: Beyond 2030, ESO, March 2024]

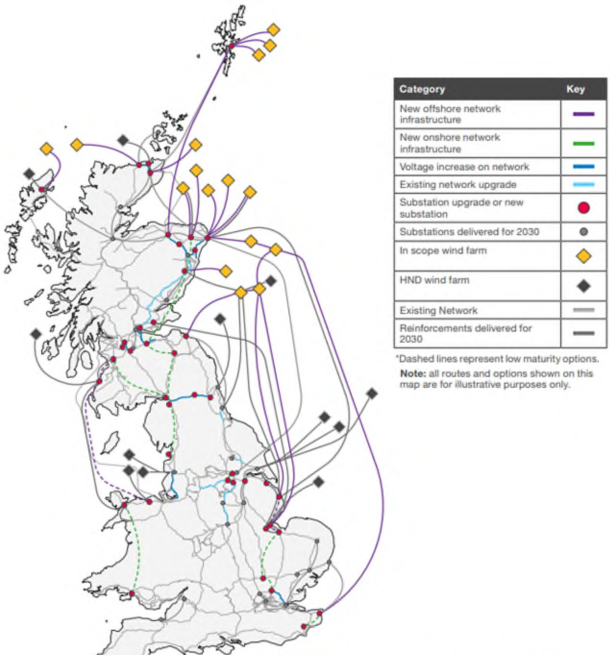


Figure 10. Map of network infrastructure to be delivered beyond 2030

1.3 Way forward

1.3.1 The Beyond 2030 report builds on the 2022 Holistic Network Design (HND) and is a key step towards the effort to upgrade Great Britain's electricity transmission infrastructure. Both publications support the ambition of connecting a total of 86 GW of offshore wind as well as an array of other low-carbon technologies, potentially adding up to £15 billion to the economy. The plan also aims to produce significant supply chain benefits, create jobs, and facilitate greater energy security.

1.3.2 Central to achieving these goals is the UK Government's Transmission Acceleration Action Plan (TAAP) from November 2023, which outlines a series of activities to reduce network delivery times and gain societal consent for the transformational infrastructure changes.

1.3.3 The Beyond 2030 report also sets out the key role of strategic demand - utilising efficient placement of generation to potentially reduce future infrastructure needs. The Transmission Owners (TOs) will commence the Detailed Network Design (DND) phase to optimise the Beyond 2030 report's proposed designs. Continued coordination among project developers is crucial to minimise environmental and community impacts. Continued alignment with broader industry and policy changes to facilitate the decarbonisation of Great Britain's electricity system is crucial and will facilitate the necessary transition to whole energy system planning to meet rising energy needs.

1.3.4 The Beyond 2030 report has set out information on key policies and proposals, listed below, that are either under consideration or will be taken forward. These policies and proposals should not be viewed in isolation but as holistic changes to the design and operation of the energy system:

- Energy Act and creation of the National Energy System Operator (NESO) – NESO is built upon the principles and structure of NESO and will cover Great Britain, spanning electricity and gas, giving an independent view of the whole energy system.
- Strategic Spatial Energy Plan (SSEP) – The SSEP will see UK Government targets across the whole energy system mapped spatially across Great Britain over a period of several years and define the optimal mix and location of clean generation and storage to meet forecast demand, net-zero targets and security of supply for all consumers.
- Centralised Strategic Network Plan (CSNP) – NESO will take on the role of central whole-system planner for the energy system, at both national and regional levels, and be responsible for a new CSNP.
- Regional Energy Strategic Planners (RESP) - As part of the new approach to energy planning, RESPs will support net-zero ambitions through the creation of strategic energy plans at a regional and national level, providing critical planning assumptions to inform system and network needs.
- Connections Reform – NESO will lead the development of several tactical and strategic reforms that have the potential to result in radical changes to both the size of the connections queue and how long it takes for projects which are 'ready to connect' to connect to the network.
- Network Competition - In November 2023, the TAAP outlined the Government's commitment to introduce competition for onshore transmission projects as soon as reasonably possible.
- Net Zero Market Reform (NZMR) - The objective of the NZMR programme is to outline holistic market design and complementary investment policy for net zero and contribute to the Review of Electricity Market (REMA) debate from the perspective of Great Britain's electricity system operator.

Appendix G Onshore alternative option

1.1 Option overview

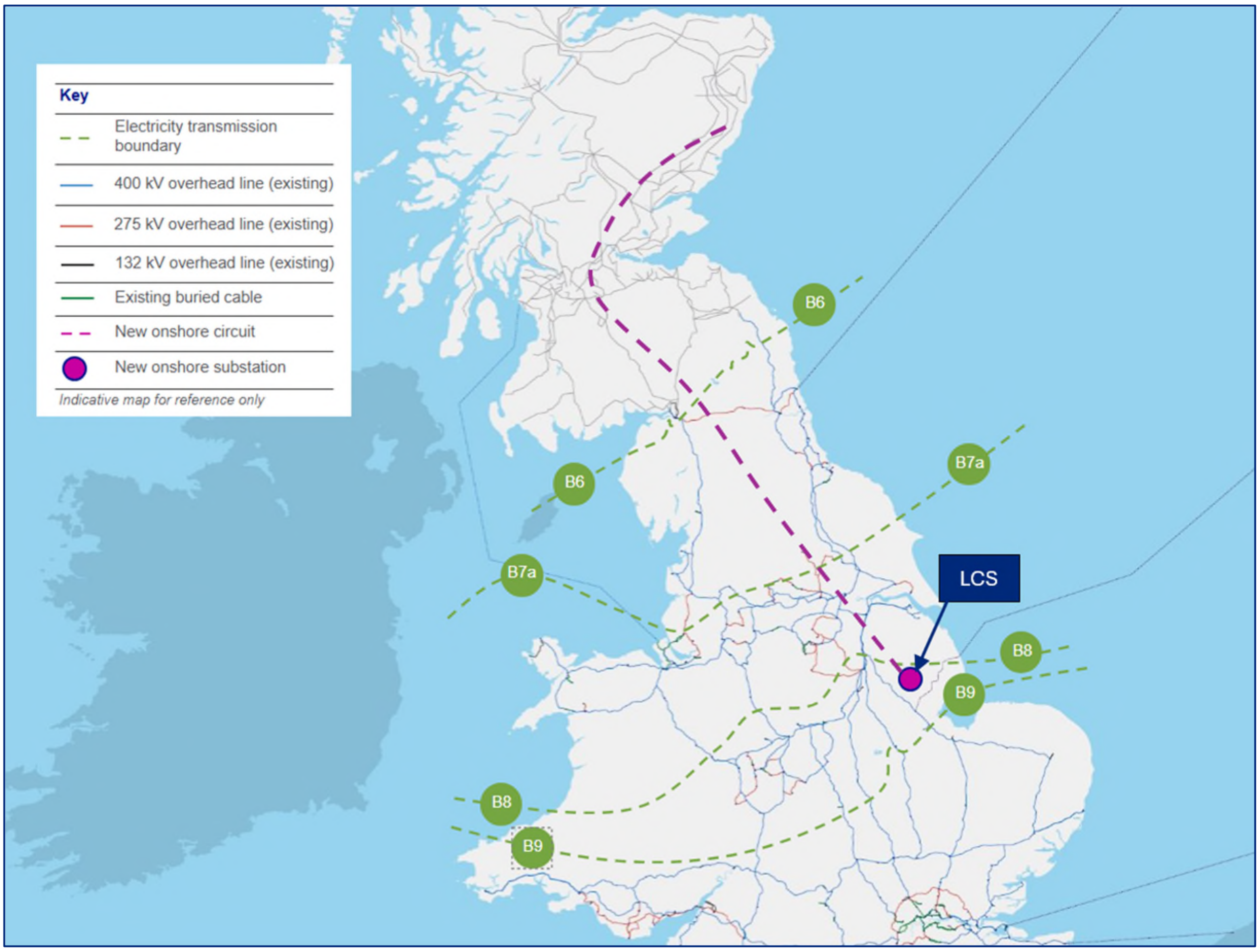
1.1.1 As set out in Chapter 5, this appendix will provide an overview of the key factors NGET considered with regards to appraising a land based option as part of the strategic options process and the reasons why this option was not progressed to a full appraisal as a potential strategic option.

1.1.2 An onshore reinforcement option was identified that is broadly equivalent to the preferred strategic option identified in this report, Option 1 – Connection to New Lincolnshire Connection Substation(s) (LCS), which proposes the development of a new offshore transmission circuit from Scotland connecting to New Lincolnshire Connection Substation(s). A geographical depiction of this option is seen below through Figure F.1.

1.1.3 This option necessitates the construction of a new 648 km new AC 400 kV medium capacity 6,380 MW circuit or a new onshore HVDC 6,000 MW connection between Scotland and New LCS.

1.1.4 In accordance with the methodology set out in Chapter 5, the circuit distance considered for this option was derived by taking a straight-line distance between Scotland and New LCS and adding 20% to accommodate potential route deviations.

Figure G.1 – Connection to New LCS (Land)



1.1.5 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and coordinated development and therefore would meet NGET's obligations under section 9 of the Electricity Act. Therefore, prior to consultation on any required mitigation, the environmental and socio-economic appraisal, which takes into consideration NGET's duty to have regard to the environment in Schedule 9, has sought to establish the impacts of the proposal based upon an assumed use of OHL technology. This enables the appraisal to highlight areas of highest impact aiding discussions throughout the next stage of the project. The next stage is outlined in Section 9.3 of this report.

1.1.6 A new OHL route from the from Scotland connecting to New LCS encounters and potentially impacts on a number of environmental and socio-economic constraints including a range of statutory designated landscapes, National Parks and statutory ecological and historic environment designations as well as being routed close to or through urbanised areas impacting on settlements. While many environmental and socio-economic impacts could be mitigated through careful route selection and appropriate mitigation including undergrounding sections of the route, this option results in greater environmental and socio-economic impacts compared to alternative subsea HVDC options. The potential impacts of this option affect its deliverability, in particular whether such an OHL could be consented and constructed by 2030.

1.1.7 Overall, this option is expected to result in a greater level of environmental and socio-economic impact compared to the subsea HVDC options considered (Option 1 - Option 6) and provides limited benefit over those options. Therefore it is considered a less preferable option which does not meet the requirements to progress beyond technical and benefit filter stage.

1.1.8 We undertook a cost appraisal of the following two technologies considering a distance of 648 km:

- Land based 400kV AC connection
  - AC connections circuit options use medium capacity double circuits (two 400kV AC circuits) with a total capacity of up to 6,380 Mega Volt Amperes (MVA); or
- Land based 525 kV HVDC cable and converter stations
  - HVDC connection options use 525 kV voltage source links of 2 GW, which requires a new converter station at each end of each circuit, similar in size to a large warehouse. In this case a 2 GW connection requires two converter stations in total, with one of the converters located at LCS.
  - Connections between the new converter station and New LCS are also required

1.1.9 Either of these options entail the following works:

- NGET Substation Works
  - Two bays at New LCS.

1.1.10 Technical appraisal of this option includes the following:

- A land-based circuit constructed for this option covers a significant length of the country due to the length being greater than 600 km. An AC option is likely to see a lower load limit than the given circuit rating due to the high impedance observed in AC circuits greater than 500 km in length.

- It is likely that an AC OHL option of such length requires some sections of mitigation to limit impact on designations or due to natural features and this is likely to increase the cost of this option.
- The option will significantly increase the loading on the existing circuits flowing south from the connection substation in comparison to a HVDC solution where power flows over a long distance are controlled.

1.1.11 We undertook a cost evaluation of the following four technologies for onshore options evaluation:

- 400 kV AC OHL
- 400 kV AC underground cable
- 400 kV AC GIL
- 525 kV HVDC underground cable

1.1.12 Table G.1 sets out the capital costs for the onshore alternative option.

Table G.1 – Connection to New LCS (Land): capital cost for each technology option

Item	Capital Cost			
Substation and Wider Works	£16.0m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit	£2,358.7m	£19,834.8m	£20,165.8m	£2,536.7m
Total Capital Cost	**£2,374.7m**	**£19,850.8m**	**£20,181.8m**	**£2,552.7m**

1.1.13 Table G.2 sets out the lifetime cost for the new circuit technology options, the lifetime costs are different for each circuit technology and are included as a differentiator between technologies. These costs are calculated using the methodology described in "Strategic options technical appendix 2020/2021 price base", found in Appendix D.

Table G.2 – Connection to New LCS: lifetime cost for each technology option

Subsea Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	**£2,358.7m**	**£19,834.8m**	**£20,165.8m**	**£2,536.7m**
NPV of Cost of Losses over 40 years	£2,024.9m	£1,297.4m	£946.4m	£157.1m
NPV of Operation & Maintenance costs over 40 years	£37.9m	£117.2m	£38.2m	£59.0m
Lifetime Cost of New Circuits	**£4,421m**	**£21,249m**	**£21,150m**	**£2,753m**

1.1.14 Based on the findings from this indicative evaluation of this option, a 6,380 MVA AC connection between Scotland and England with a connection location for the new circuit at New LCS, was identified as the preferred land-based option. In light of this appraisal, our starting presumption for further development of this option should it be selected, is for a majority OHL connection.

1.1.15 Comparing the estimated capital cost of £2,374.7m for Option LCS (Land) to our preferred HVDC option which presents an estimated capital cost of £2,237.5m, the preferred HVDC option presents a considerable saving of over £100m to consumers.

1.1.16 Comparing the estimated lifetime cost of £4,421m for Option LCS (Land) to our preferred HVDC option which presents an estimated lifetime cost of £2,437m, the preferred HVDC option presents a significant saving of just under £2,000m to consumers.

1.1.17 It should be noted that over the proposed distance of 648 km, the need for mitigation of an OHL option is likely to be required, increasing the capital cost of the land-based option. If just 5% (32 km) of the OHL (with circuit length of 648 km) required some underground mitigation through sensitive areas, this increases the capital cost by over £1,200m.

1.1.18 For the reasons outlined in this Appendix, NGET decided not to progress the onshore alternative Option LCS (Land) for further development.

National Grid plc
National Grid House,
Warwick Technology Park,
Gallows Hill, Warwick.
CV34 6DA United Kingdom

Registered in England and Wales
No. 4031152
nationalgrid.com