The Great Grid Upgrade

Cross Border Connection
Carlisle to Newcastle

Strategic Options Report

October 2025

nationalgrid

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Cross Border Connection / Carlisle to Newcastle Document control

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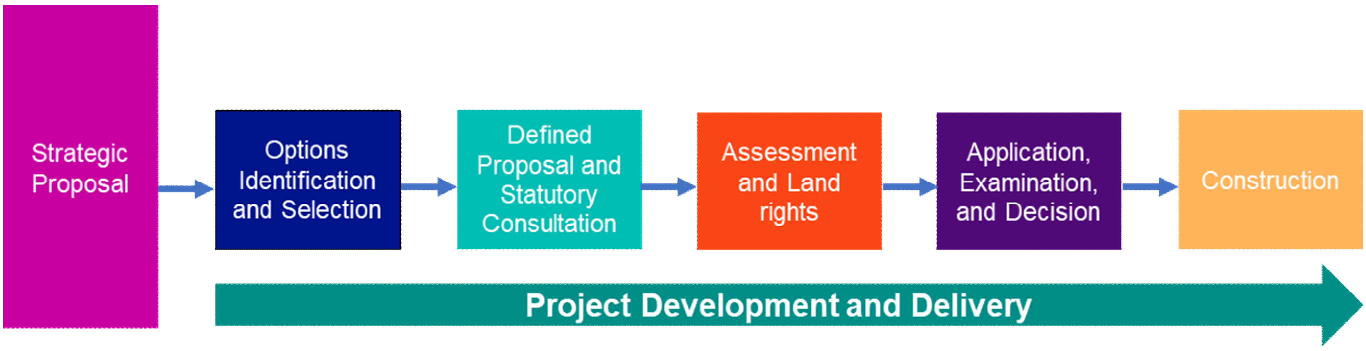
Executive summary

Purpose of the Strategic Options Report

This Strategic Options Report (SOR) provides an overview of the options that National Grid Electricity Transmission plc (NGET) identified and subsequently evaluated for the Cross Border Connection project. This SOR also provides an overview of the options that NGET have evaluated for the Carlisle to Newcastle project.

When the need for transmission system works is 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's approach to consenting process



This report forms part of the initial 'Strategic Proposal' stage specific/relevant to NGET's Projects.

How the electricity system is planned and operated

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 (SPEN), which is also known as Scottish Power Transmission (SPT), is the TO for Southern Scotland and Scottish and Southern Electricity Networks (SSEN) is the TO for Northern Scotland and Scottish Islands Groups. Each TO holds an electricity transmission licence permitting transmission ownership activities in their relevant regions.

NGET's transmission licence requires that NGET provide an efficient, economic, and co-ordinated transmission system in England and Wales. When planning changes to the transmission system, NGET must also have regard to the desirability of preserving amenity, in line with the duties under Sections 9 and 38 of the Electricity Act 1989 (the Electricity Act).

The duties under the Electricity Act on transmission licence holders also apply to SPT as well as NGET. However, as SPT's responsibility for the transmission network is limited to within Scotland, there are differences in relation to the other relevant statutory duties to which SPT is subject.

National Energy System Operator (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 makes investment recommendations to TOs, including NGET, through an annual network planning cycle and other periodic reviews, indicating which areas of the transmission system require reinforcement.

The legislation, policy and regulatory framework in England

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 addition, in 2024 the UK Government committed to achieving a clean 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);
- Powering Up Britain: Energy Security Plan (March 2023); and
- Clean Power 2030 Action Plan: A new era of clean electricity (December 2024)

Consenting regimes and national planning policy

Electricity network infrastructure developments

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

- planning permission under the Town and Country Planning Act 1990;
- a marine licence under the Marine and Coastal Access Act 2009;
- a Development Consent Order (DCO) under the Planning Act 2008; and/or
- a variety of consents under related legislation.

The Planning Act 2008 defines developments of new electricity overhead lines (OHLs) of 132 kV and above, over 2 km as Nationally Significant Infrastructure Projects (NSIPs) requiring a DCO, subject to relevant statutory thresholds. Such an order may also incorporate consent for other types of work that are associated with new OHL infrastructure development, and these may be incorporated as part of a DCO that is granted. DCO applications are determined in accordance with National Policy Statements (NPSs) which are designated by the UK Government.

Six NPSs for energy infrastructure were designated by the Secretary of State (SoS) in January 2024. The relevant NPSs for electricity transmission infrastructure developments are the Overarching National Policy Statement for Energy (EN-1), National 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.

Marine Policy Statement (MPS) and Marine Plan

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.

The Marine Policy Statement will be considered in the development of the Cross Border Connection project, within the chapters relating to the offshore strategic option.

Demonstrating the Need for a Project

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.

The need case for reinforcement to the transmission system

NGET and SPT must comply with Section 9 of the Electricity Act and Standard Condition D3 (Transmission System Security Standard and Quality of Service) of their Transmission Licences, which requires them to develop and maintain an efficient, coordinated and economical system of electricity transmission. The criteria that the transmission system must meet are set out in the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS)[1]. The NETS SQSS is administered by NESO and approved by the Office of Gas and Electricity Markets (Ofgem).

The need to reinforce the transmission system arises from changes to the generation and demand connected to it. When these changes result in required power flows that would exceed the capability of the transmission system, as set out in the NETS SQSS, NGET and SPT must resolve the shortfall under the terms of their Transmission Licences.

[1] Security and Quality of Supply Standard (SQSS)

https://www.nationalgrideso.com/industry-information/codes/security-and-qua36.52lity-supply-standard-sqss

The criteria of the NETS SQSS determine the minimum level of network capability required to ensure security of supply to demand customers. The NETS SQSS allows for development beyond the minimum requirements where this is economically beneficial for consumers.

When assessing the need for system reinforcement, NGET and SPT consider power flows in the vicinity of the expected generation / demand connections and on critical circuit paths (System Boundaries) on the transmission system. Computer based analysis is used to assess the impact of changes to connected customer requirements on power transfers within and between separate areas of the transmission system. The assessments consider the contracted generation position, NESO’s view of how that may change and how it may be dispatched to meet demand, and the Future Energy Scenarios (FES) developed by NESO and the wider industry, which provide insight into longer term generation and demand developments. The contracted generation, and NESO’s view on the likely dispatch, inform reinforcement needs within a region to comply with the NETS SQSS within that region, including the preferred connection point of any reinforcements to the existing network. The FES are used to identify system boundary reinforcements that are in consumers’ interests in the longer term and will contribute to wider system compliance with the NETS SQSS.

The analysis described in this document took account of changes to the contracted background and the user connections expected up to 2033. This assessment considers the connection of generation in southern Scotland, across the Teviot and Gala region, and the FES required boundary transfers for 2035. The system boundary considered as part of our assessment and referred to in this report is the B6 – SPT to NGET boundary (shared by SPT and NGET).

In the need case set out in the SOR, the requirement for reinforcement of the transmission system addresses drivers associated with new generation as well as B6 boundary capacity. The B6 boundary reinforcement driver is free-standing and not directly dependent upon particular generating projects, being consequent upon the volume of flows which need to be accommodated across the B6 boundary. Increased flows across the B6 boundary will result in increased flows on existing circuits in Northern England, resulting in a need to reinforce the network in Northern England. The project to address this need (FSU1) is located entirely in England and is being promoted by National Grid.

Figure B - NETS in Southern Scotland and the North of England

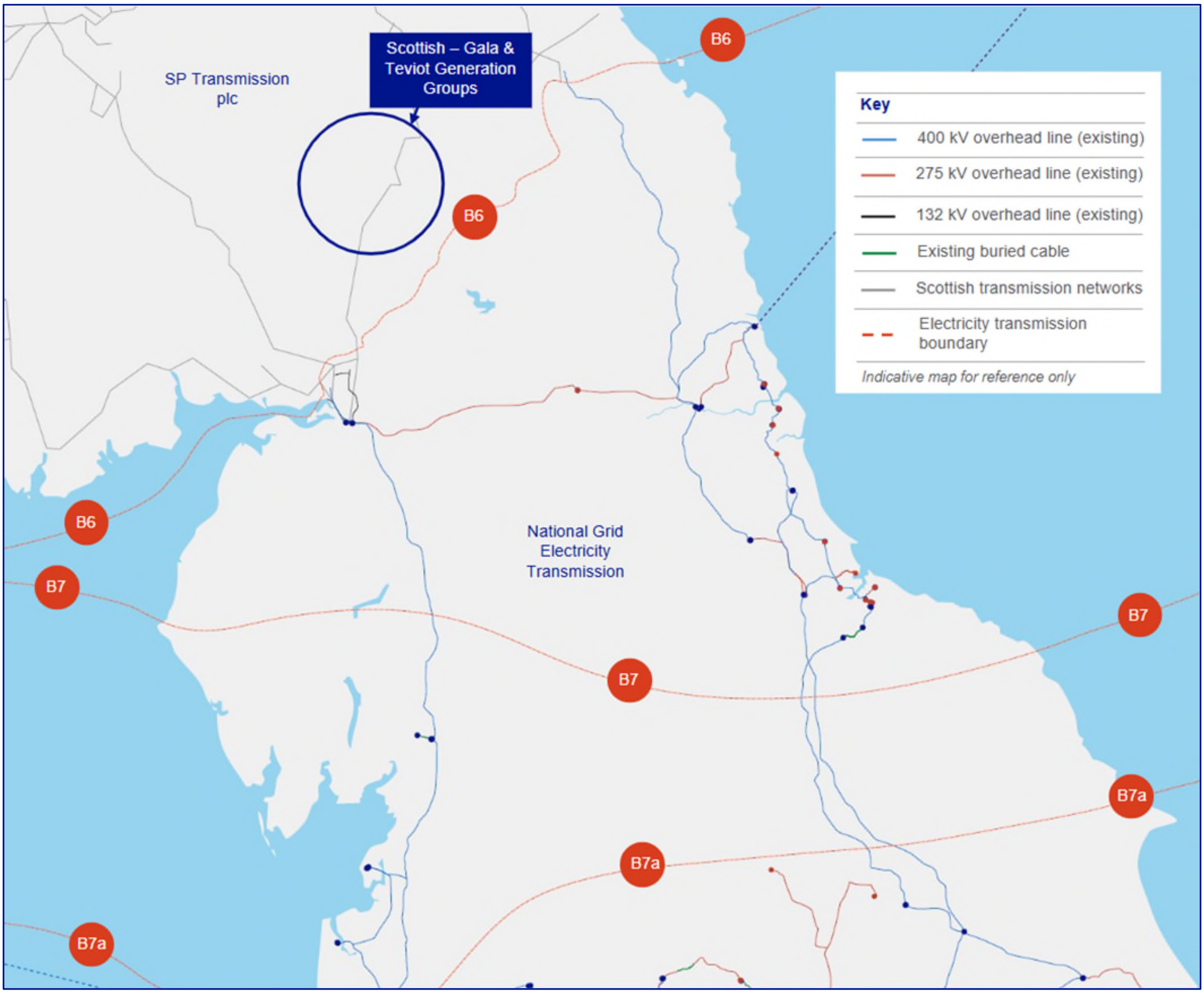


Figure B shows the existing transmission system including boundaries (B6, B7 and B7a) and both the Teviot and Gala generation groups. The Teviot, Gala Generation groups, and B6 boundary are the most relevant to the need case set out in this document and are described in detail within this document.

Scottish – Gala and Teviot Generation Groups

The Gala generation group is 748.28 MW of generation connecting to the Gala area, and the Teviot Generation group is 1,216.9 MW of generation to be connected in the Teviot area that forms part of the need case in this document. This group of generators are not able to connect solely to the existing system because there is insufficient capacity in the area for the system to remain compliant with the NETS SQSS. Additional transmission capacity is required in the Gala and Teviot areas to facilitate its connection.

NGET’s B6 analysis results

Taking account of the increases to B6 system boundary capability and capacity that would be provided by the reinforcement proposals that NGET and SPT are progressing prior to options set out in this report, along with generation and demand requirements forecast by Electricity Ten Year Statement (ETYS) 2024 B6 scenarios by 2035, Table 4.3 shows a:

- capability deficit of -11,605 MW and
- capacity deficit of -10,392 MW

In a scenario where the Gala or Teviot generation groups were not progressed, the B6 boundary deficit would remain as the defining need for the Cross Border Connection.

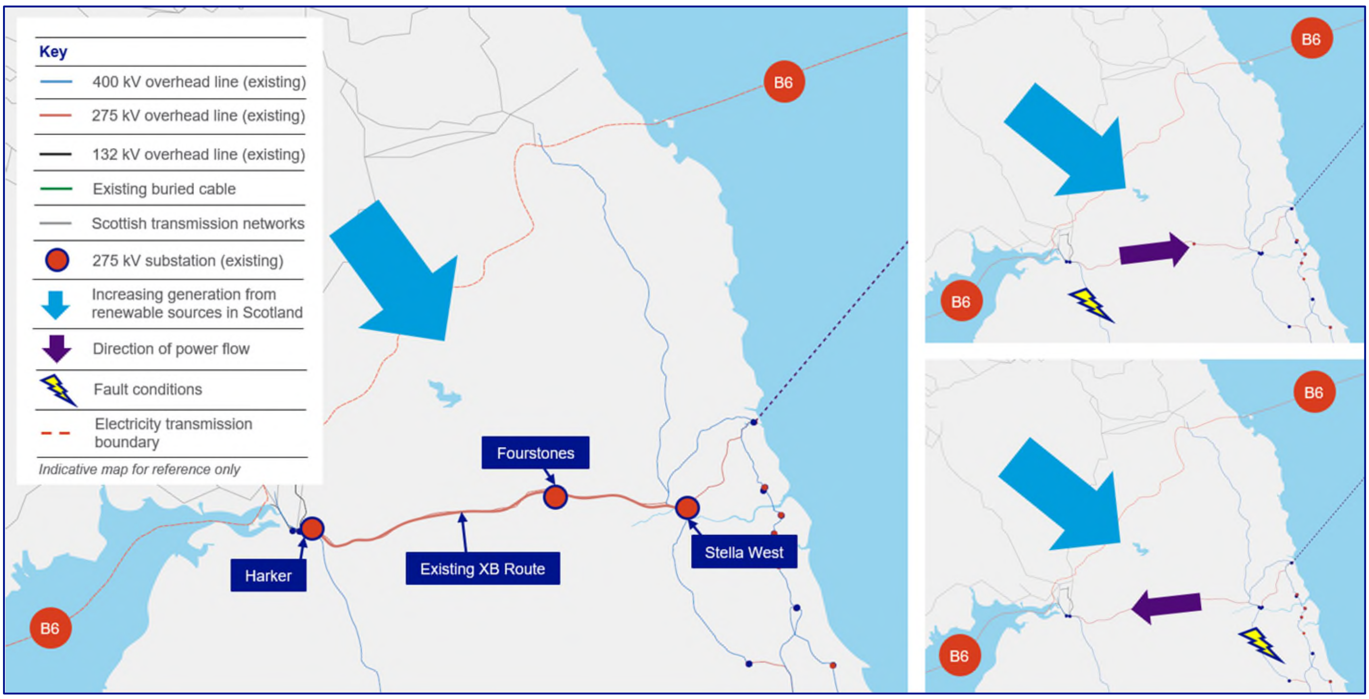
NGET East-West Transfer Analysis

The transmission system in the Northwest and Northeast of England are currently connected together by a single 275 kV connection between Harker and Stella West, known on the National Grid transmission system as the XB route.

The Harker to Stella West 275 kV circuit is the only East-West circuit between Central Scotland and Northern Yorkshire and Lancashire in England. This circuit is critical to rebalancing the network faults to the west or east in this region.

As energy transfers increase across the B6 boundary from Scotland, due to increasing generation connections in Scotland, transmission faults south of Harker and Stella West for example must be secured. The transfer flows, which occur for these faults south of Stella West or south of Harker, will significantly overload the capacity and capability of this existing XB route 275 kV Northeast-Northwest transfer circuit in the future. This is shown in Figure C below:

Figure C - Faults south of the existing XB route



As shown in Figure C, faults south of the Existing XB route 275 kV Harker to Stella west ensure power flows to the opposite coast for onward transmission south and will lead to overloads of the existing circuits, which have an existing maximum capacity of 1,628 MW.

The worst-case fault north of the XB route also causing East-West transfers, currently would be for the 400 kV circuits between Gretna (Scotland) and Harker (England). This would cause significant imports of Scottish generation to Stella West, where further generation is connecting in the northeast of England. Without the ability to Transfer upwards of 4,000 MW of power to the West Coast of England, the circuits south of Stella West would overload and the imbalance would cause further overloads across multiple circuits south of this region. Therefore, the East-West transfer of power is critical to progress compliance of the network with the NETS SQSS for both faults to the north and the south of the existing XB 275 kV circuit.

Scottish and English border strategy implications

The B6 boundary shown in Figure C is represented as a single line on the geographical map.

By 2035 we have a B6 capability deficit of -11,605 MW and capacity deficit of -10,392 MW. This will require circa 12,000 MW (or 12 GW) of additional capacity to be provided to satisfy this need. These figures also equate to the amount of additional energy that must cross the B6 boundary.

To resolve this need, a number of projects are proposed within the NESO Beyond 2030 document. This includes the projects considered within this report, which are: the Cross Border Connection project - NESO code (CMN3) and the Carlisle to Newcastle project - NESO code (FSU1). Additionally, there are two further projects: NESO code CLN2, which currently indicates a circuit in England from North West England to Lancashire; and WCN2, which is a connection from South West Scotland to North West England.

Both CLN2 and WCN2 require strategic optioneering to determine their requirements which will be documented in subsequent strategic option reports related to those projects. However, to ensure we meet the need case set out in this document by circa 2035, two transmission double circuits may be required to cross the B6 boundary to provide the capacity of circa 12 GW. The largest capacity a double circuit transmission route can carry is 6.9 GW, which means two double circuit 400 kV connections may be required to cross the B6 boundary if onshore options are determined to progress alongside other projects identified as being required to meet the overall regional need case.

Need case Conclusion

There are a number of issues that need to be resolved by system reinforcements to meet both our licence obligations and progress compliance with the NETS SQSS. The issues that need to be resolved are:

- Provision of 11,605 MW of boundary capability and 10,392 MW of boundary capacity to the B6 boundary to progress NETS SQSS compliance;
- The additional capacity required across the B6 boundary being circa 12 GW, requires 2 of the 4 proposed projects to cross B6 to achieve this;
- Provision of transmission capacity, as required by NGET's and SPT's transmission licences, to connect 748.28 MW of generation in the Gala area and 1,216.9 MW of generation in the Teviot area of Scotland; and
- Provision of a minimum of 4,000 MW of East-West transfer capacity in Northern England to progress NETS SQSS compliance.

The solutions to the issues identified above must be considered at the same time, but in series, because the solutions adopted for one set of issues may enable the delivery of alternative solutions to the other set. The options appraisal in this document takes that approach.

SPT's approach to the Scottish component of the Cross Border Connection project

In Scotland, decisions regarding the development and consenting of electricity networks are largely devolved to Scottish Ministers. While the UK Parliament retains the legislative framework for electricity, including transmission, the Scottish Government handles planning and consenting for electricity infrastructure within Scotland. Separate applications therefore require to be made for the Scottish and English components of the Cross Border Connection Project, which will be decided by different decision makers under different consenting regimes.

The Scottish Component of the Cross Border Connection Project comprises the following key elements:

- A new double circuit 400 kV OHL carried on steel lattice towers between the proposed Gala North Substation[2], and a new Teviot Substation;
- The new Teviot Substation which will also connect the contracted Teviot Generation group wind farm as outlined in Chapter 4; and
- A new double circuit 400 kV OHL carried on steel lattice towers from the new Teviot Substation to the Scotland-England border.

Need case for the Scottish component of the Cross Border Connection project

The part of the need case which relates to the Scottish Component of the Cross Border Connection project is addressing the needs of uplifting the B6 boundary capacity and supporting future network needs in the vicinity of Gala and Teviot (including facilitating SPT's connection agreements with the Gala and Teviot Generation groups). These aspects are only relevant to the North-South elements of the need case. They do not address the element of the need case which concerns East-West power flows in the north of England as those apply only in areas of NGET's licence area.

Connecting the northern end of the Cross Border Connection into the proposed new Gala North Substation enables the new circuit to integrate with both current and future network proposals in turn facilitating an increase to the B6 boundary capability. Connection into Gala North also provides the additional local reinforcement required at Gala North to achieve full SQSS Section 2 compliance.

There is currently no existing 400 kV transmission network in the vicinity of the contracted customers in the Teviot area. To meet the growing needs in these areas and enable the timely and efficient connection of contracted generation as well as future network needs (i.e. the expansion of the 400 kV system), the new 400 kV double circuit line will require to be routed from Gala North to a new collector substation at Teviot.

[2] SPT has proposed a new Gala North substation as part of RIIO-T3. Gala North will facilitate connection of contracted generation within the vicinity and has been designed to enable integration with key wider system reinforcement including the Cross Border Connection Project.

South of Teviot, the new 400 kV double circuit needs to be extended to the Scottish border in order to connect with the English Component of CMN3 and reinforce the B6 boundary transfer capability.

The Scottish Component of the Cross Border Connection project forms an essential part of SPT's strategy to reinforce and increase the capacity of the electricity system within its licence area. It is the result of SPT's licence obligations and is reflected in the agreements between NESO and the respective developers as necessary work. It is, accordingly, a scheme that SPT is bound to deliver in line with its: (i) statutory duties in terms of Section 9 of the Electricity Act 1989 (the Electricity Act); (ii) licence duties to Ofgem; and (iii) contractual duties to NESO.

SPT's approach to routeing and siting of the preferred strategic option

SPT's starting point is to identify and evaluate potential network solutions that meet the needs of the transmission system, balancing technical, economic and environmental considerations.

Once a preferred solution has been selected, it takes a two-stage approach to routeing and siting of its preferred solution:

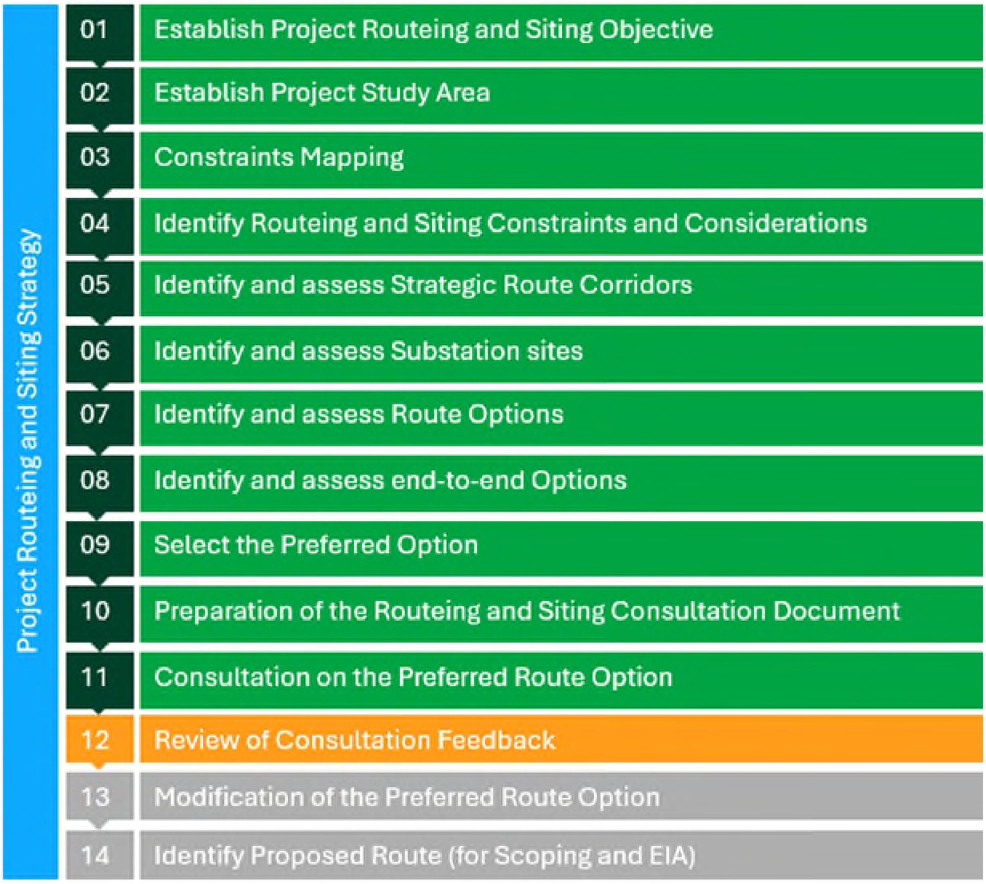
- Stage 1: Identification and appraisal of route options to select a preferred route, including consultation with stakeholders and the wider public to establish a proposed route. Whilst presented as a linear process, for simplicity, the approach is iterative and the steps may be re-visited several times. The outcome of each step is subject to a technical and, where relevant, consultation, 'check' with key stakeholders including the public, prior to commencing the next step; and
- Stage 2: Environmental Impact Assessment (EIA) of the proposed alignment and any associated infrastructure. This is an important stage as the EIA process is used to further refine the route alignment to avoid and reduce potential environmental effects, including land use impacts. This results in the alignment for the purposes of applications.

The Scottish Component of the Cross Border Connection project has progressed the routeing and siting process to Step 12 in Figure D below – consultation on its preferred route option.

Following the identification of the study area, SPT mapped constraints within the study area to enable them to identify and assess strategic route corridors and substation sites. This led SPT to the identification of a preferred route option from Gala North Substation to the border, and a preferred site for the Teviot Substation, on which consultation took place.

Notwithstanding the work undertaken by SPT on routing to date, as it has been made clear in public consultation, this is without prejudice to decisions taken by NGET on the route south of the border and the Scottish section of the project will be subject to alignment with the section in England before detailed design.

Figure D - SPT's approach to the Routeing and Siting Study



NGET's options identification and selection process

Once the need case had been established, there was a requirement to consider the many ways in which this need could be met. Before NGET 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, including ensuring compliance with NETS SQSS.

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

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

In relation to meeting the need case of the provision of 4,000 MW of East-West transfer capacity in Northern England, as part of this process, NGET is currently examining the condition of the existing infrastructure to ascertain whether it can be retrofitted, but it is considered more likely that the upgrade will need to be delivered through the construction of new infrastructure.

The appraisal of potential strategic options for the Carlisle to Newcastle and the Cross Border Connection projects led to four and five strategic options being selected respectively to be taken forward for detailed appraisal. These are indicated in Table A and Table B, as shown below.

For the East-West transfer capacity: four of the strategic options meet the need of the provision of East-West transfer capacity in Northern England, through either retrofitting of the existing 275 kV XB route from Harker to Stella West to a 400 kV line, or building a new 400 kV transmission line.

For the North-South transfer capacity: five of the strategic options provide the required transmission capacity to connect the generation in the Teviot and Gala area, and provide the required boundary capacity to the B6 boundary.

Table A - Proposed strategic options for Carlisle to Newcastle appraisal

Proposed strategic option title	Option description
East-West Strategic Option A: Carlisle Area to Stella West Area – Northern Zone	98 km new 400 kV transmission connection
East-West Strategic Option B: Carlisle Area to Stella West Area – Central Zone	92 km new 400 kV transmission connection
East-West Strategic Option C: Carlisle Area to Stella West Area – Southern Zone	98 km new 400 kV transmission connection
East-West Strategic Option D: Carlisle Area to Spennymoor Area	174 km new 400 kV transmission connection

Table B - Proposed strategic options for Cross Border Connection appraisal

Proposed strategic option title	Option description
North-South Strategic Option 1: Teviot to Carlisle Area	58 km new 400 kV transmission connection
North-South Strategic Option 2: Teviot to Haltwhistle Area	69 km new 400 kV transmission connection
North-South Strategic Option 3: Teviot to Fourstones Area	74 km new 400 kV transmission connection
North-South Strategic Option 4: Teviot to Stella West Area	104 km new 400 kV transmission connection
North-South Strategic Option 5: Teviot to Stella West Area (subsea HVDC)	146 km new 525 kV transmission connection

Collaboration and co-ordination between NGET and SPT

For the purpose of co-ordination and to fulfil their license obligations, NGET and SPT regularly engage with each other to ensure that they are informed about the emerging options for their respective projects. This enables both parties to have in mind the approaches adopted to meet the north-south need that is addressed in this document.

NGET and SPT have set up a joint steering committee for the Cross Border Connection project to aid co-ordination of joint approaches and activities.

At certain intervals, such as the conclusion of NGET's strategic options process, NGET and SPT undertake joint reviews to take outcomes into account and to assess potential impacts on their processes afterwards.

The results of NGET's strategic options assessment

For the purpose of this SOR, and the appraisal process that informed this SOR, the Carlisle to Newcastle strategic options were considered in the first instance. This was then followed by the Cross Border Connection appraisal.

This is because there are four strategic options to address East-West power flows. Of these, three are in alignment with NGET's existing XB line corridor, but one strategic option is located further to the south. If the options in the corridor of the XB line were to be preferred, then they would enable the possibility of connections to the Teviot substation area along that line in order to address the requirements of Scottish generation and the B6 boundary reinforcement – Options 2-5. The fourth option for East-West power flows would be likely to result in different strategic options being developed for the Scottish generation and B6 boundary reinforcement needs, although North-South Strategic Option 1 would remain a possibility, due to its endpoint in the Carlisle area. If East-West Option D is discounted, the five strategic options addressing the Scottish generation and B6 boundary reinforcement needs could be addressed.

For each of the proposed Carlisle to Newcastle strategic options, a new substation will be needed in the Carlisle area. This would be regardless of the preferred solution for the Cross Border Connection project. Therefore, to ensure that the cost appraisal leads to a fair comparison of all options, the costs and technical considerations associated with this new substation are considered within the Carlisle to Newcastle strategic options and are not duplicated elsewhere within the appraisal (i.e. within the Cross Border Connection costs).

If the Cross Border Connection project connects in the Carlisle area (North-South Strategic Option 1) then construction of this project would not require simultaneous delivery of the Carlisle to Newcastle project to accommodate East-West power flows as it would not connect at a point along the XB transmission line. Although the Carlisle to Newcastle project is still required in order to deliver East-West transfer capacity in Northern England, NGET are not obliged to deliver this project at the same time as the Cross Border Connection project, because Security and Quality of Supply Standard (SQSS) compliance allows NGET to connect and manage new connections.

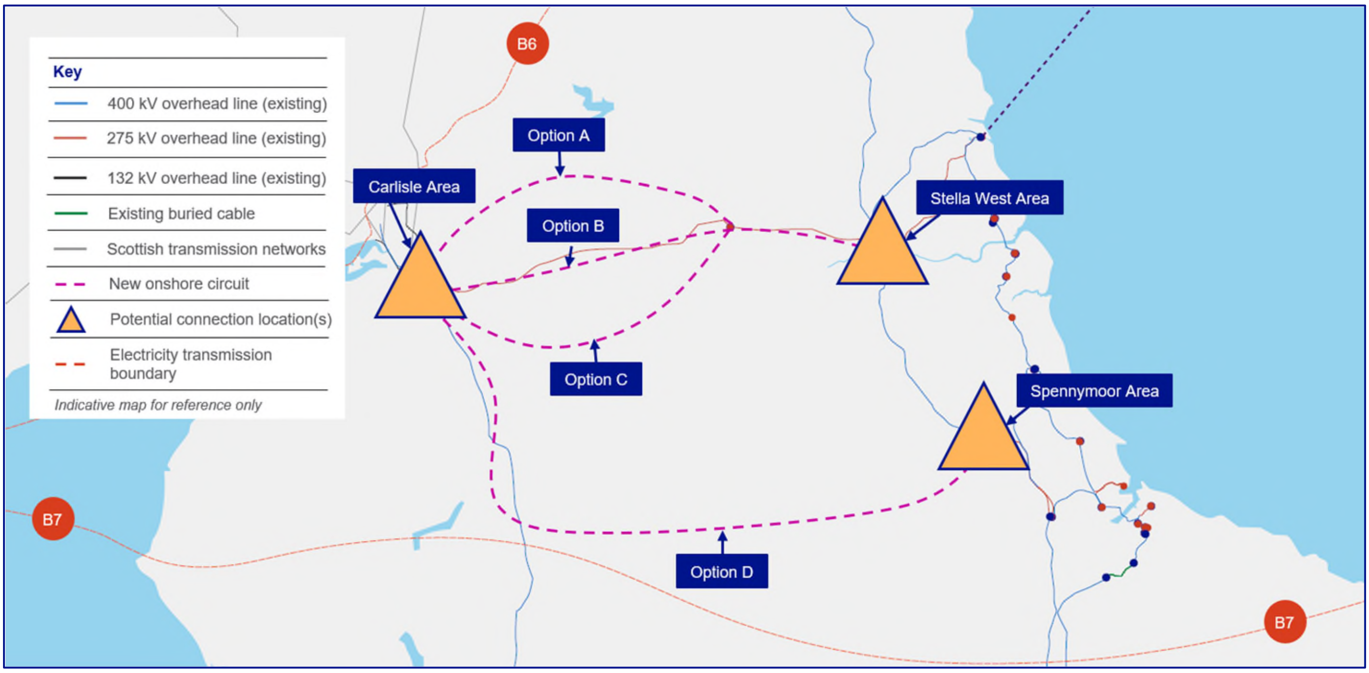
With a connection in the Carlisle area, the Cross Border Connection project is therefore not reliant on the Carlisle to Newcastle project at the date of connection as capacity can be managed in the short term.

This means that, where the Cross Border Connection project connects in the Carlisle area, it could then be constructed separately from, and ahead of, the Carlisle to Newcastle project (although East-West transfer capacity would still need to be delivered through the Carlisle to Newcastle project in the short to medium term).

Carlisle to Newcastle project:

The four East-West Strategic Options for the Carlisle to Newcastle project that have been subject to environmental, socio-economic, cost, and technical appraisal, and which provide the required East-West transfer capacity across Northern England are as follows:

Figure E - Map view of all Carlisle to Newcastle strategic options



East-West Strategic Options A-C:

This would either retrofit the existing 275 kV XB route to a 400 kV line or build a new 400 kV transmission line from a new 400 kV substation in the Carlisle area to the existing Stella West 400 kV substation, which will require an extension. There is an existing 275 kV substation on the XB route at Fourstones which provides a grid supply to the distribution network. Any of these three options would require a supply to be maintained. There are various options that facilitate this, which will be considered as the Carlisle to Newcastle project is further developed. For the purpose of strategic option assessment, a worst-case consistent assumption of a new 400 kV substation at Fourstones is used. These three options consider the zone to the north of the existing XB route (Option A, 98 km), the central zone along the route (Option B, 92 km) and the zone to the south of the existing XB route (Option C, 98 km).

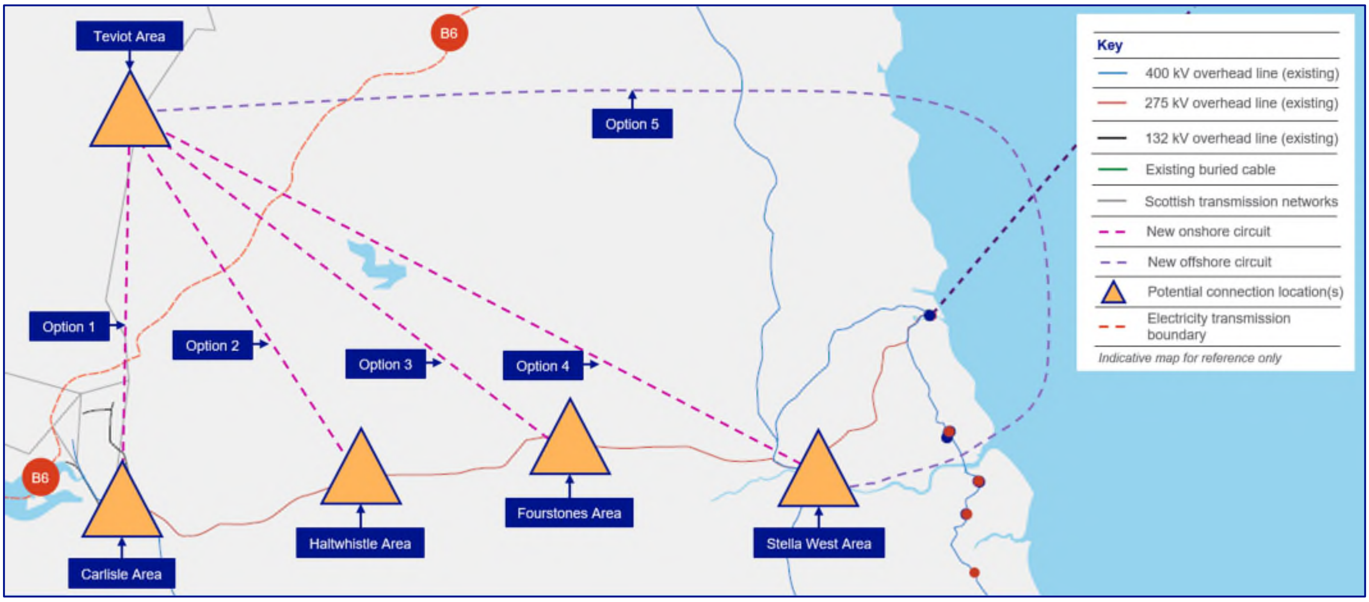
East-West Strategic Option D:

A new (174 km) 400 kV line from a new substation in the Carlisle area to the existing 400 kV substation in the Spennymoor area, which will require an extension. This option would not be proximate to Fourstones substation and therefore, in order to maintain supply to the Distribution Network Operator (DNO) connected at Fourstones, a separate connection to the substation would be required. The existing 275 kV XB route is unlikely to be removed, as a minimum the section between Stella West and Fourstones would be retained.

Cross Border Connection project:

The five North-South Strategic Options for the Cross Border Connection project, that have been subject to environmental, socio-economic, cost, and technical appraisal, and which provide the required transmission capacity to connect the generation in the Teviot and Gala area, and the required boundary capacity to the B6 boundary, are as follows:

Figure F - Map view of all Cross Border Connection strategic options



North-South Strategic Option 1:

North-South Strategic Option 1 is a 58 km connection between the Teviot area and the new 400 kV substation in the Carlisle area, as proposed by the East-West options.

North-South Strategic Option 2:

North-South Strategic Option 2 is a 69 km connection between the Teviot area and a new 400 kV substation in the Haltwhistle area, as proposed by East-West options A-C. If East-West Option D is taken forward, North-South Option 2 will not be available.

North-South Strategic Option 3:

North-South Strategic Option 3 is a 74 km connection between Teviot area and Fourstones area. This option would trigger a new 400 kV substation at Fourstones, as proposed by East-West options A-C. This new Fourstones area substation would require an extension to facilitate this connection. If East-West Option D is taken forward, North-South Option 3 will not be available.

North-South Strategic Option 4:

North-South Strategic Option 4 is a 104 km connection between the Teviot area and a new 400 kV substation in the Stella West area.

North-South Strategic Option 5:

North-South Strategic Option 5 is a 146 km subsea connection between the Teviot area and a new 400 kV substation in the Stella West area.

Conclusions and next steps

This SOR presents the findings of NGET's options appraisal process and is intended to provide a clear justification for NGET's selection of preferred strategic options to meet the identified need case.

For the purpose of this SOR, and the appraisal process that informed the SOR, the East-West Strategic Options were considered in the first instance. This was then followed by the North-South appraisal. For each of the proposed East-West Strategic Options, a new substation will be needed in the Carlisle area. This would be regardless of the preferred solution for the Cross Border Connection project. Therefore, to ensure that that the cost appraisal leads to a fair comparison of all options, the costs and technical considerations associated with this new substation are considered within the East-West Strategic Options and are not duplicated elsewhere within the appraisal (i.e. within the North-South costs).

To meet the need case to increase capability and post-fault capacity across the B6 boundary, to provide the required capacity for the Teviot and Gala generation group, and Northern England region, and to provide sufficient East-West transfer capacity in Northern England, NGET's proposal at the current stage is:

- For East-West: to amalgamate the three zones considered across East-West Strategic Options A, B and C into one study area.
  - In order to ensure that NGET proceeds with the most suitable solution that aligns with its statutory duties, this amalgamated study area will be taken forward into the next stage of the project development. This wider, defined study area will facilitate the required technical and environmental assessment, whilst allowing targeted stakeholder engagement. This assessment and engagement, undertaken across the amalgamated study area will inform the indicative routeing and siting that will be undertaken, ensuring that impacts on the significant landscape and heritage designations can be reduced.
  - East-West Strategic Option D is considered more technically complex and challenging when compared to East-West Strategic Options A, B, and C. It would require a significantly longer circuit route length compared to East-West Strategic Options A, B, and C. East-West Strategic Option D is also considered to be the most expensive of the four Carlisle to Newcastle strategic options. Whilst Option D would potentially result in significant environmental impacts, on balance it is considered to perform better in relation to potential impacts to the World Heritage Site (WHS) compared to the other East-West Strategic Options. Whilst impacts on the

WHS may be more benign, there is still a potential for impacts on other high value receptors where opportunities for mitigation are relatively challenging. It is considered the best performing East-West Option in respect of overall environmental and socio-economic factors, subject to availability of suitable mitigation options.

  - East West Strategic Option D is not the preferred strategic option at this stage. However, as the impacts and opportunities for mitigation presented by amalgamated Options A, B and C become better understood, its performance will be reviewed in order to establish that this preference remains.

- For North-South: Take forward North-South Strategic Option 1 – Teviot to Carlisle Area:
  - North-South Strategic Option 1 provides the shortest route length of the proposed strategic options, and alongside North-South Strategic Option 3, requires the least amount of substation works, with no new substation required (noting that the strategic option would connect into the new substation as proposed by the East-West options). North-South Strategic Option 1 is the lowest cost of the five Strategic options and is considered to be notably less constrained with regards to every aspect of the environmental appraisal when compared with the other four strategic options.

Based on the appraisal that has been undertaken to-date, which included the comparison of utilising different technologies for delivering each strategic option, NGET's starting presumption for further development of these options would be for a majority OHL connection. This would be confirmed at a later stage after further studies have been completed, and the designs have been developed. Having identified the preferred approach for advancing the development of the Carlisle to Newcastle project, as well as the preferred strategic option for the Cross Border Connection project, NGET undertook a further appraisal of the cumulative considerations that may materialise as a result of the delivery of both the Carlisle to Newcastle and the Cross Border Connection projects. This would identify any factors that may not impact either of the Carlisle to Newcastle or Cross Border Connection projects on an individual basis, but would materialise when the options are considered together.

This cumulative appraisal at this early stage did not identify any further significant considerations that had not previously been taken into consideration as part of the individual option appraisal and comparison that would change the preferred strategic solutions for the Carlisle to Newcastle and the Cross Border Connection projects, presented above, which remain as the preferred and most suitable route forward for these projects. We will continue to review and back check optioneering as projects mature. As part of each DCO application, National Grid will undertake a cumulative impact assessment which will be submitted as part of the application.

NGET will continue to review the work, including any notable changes in circumstances, and will have regard to consultation responses.

The Cross Border Connection project will now be taken forward to the next stage of development. This involves identification of a preliminary route corridor and graduated swathe, which indicates a more likely location for the development. This will be consulted on at non-statutory consultation to seek feedback from consultees and help shape the further development of the project.

For both the Carlisle to Newcastle and Cross Border Connection projects, the next steps of project development will focus on understanding the Hadrian's Wall component of the UNESCO:

Frontiers of the Roman Empire World Heritage Site (the WHS) as a key receptor in greater detail to identify and understand potential opportunities and risks at a regional level. Critically, this work will inform and guide work necessary to refine the study area, which alongside some targeted engineering work, will help to define project parameters and opportunities to support future routeing and siting work. This early work will be supported by engagement with key WHS stakeholders such as Historic England.

The Cross Border Connection project is likely to proceed ahead of the Carlisle to Newcastle project. This is due to the requirement to meet the connection dates of Scottish generation. As a result, the Cross Border Connection project will undertake the siting, consenting and construction of the Carlisle Area substation to achieve the required timescales.

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 assessment and decision-making process involved in promoting two new transmission projects. It presents the findings of our options appraisal process and is intended to provide a clear justification and evidence for our selection of preferred strategic options for the Cross Border Connection and the Carlisle to Newcastle projects. This report has been prepared in accordance with the Our Approach to Consenting[3] document.

1.1.2 Additionally, Scottish Power Transmission plc (SPT) has provided valuable information and insights as they are an integral partner in delivery of the Cross Border Connection project. For more information, please refer to Chapter 5.

1.1.3 The Government has committed to achieving fully decarbonised electricity 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. NGET needs 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.

1.1.4 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 consent's application approach set out in Section 3.5.

1.1.5 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.

1.1.6 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:

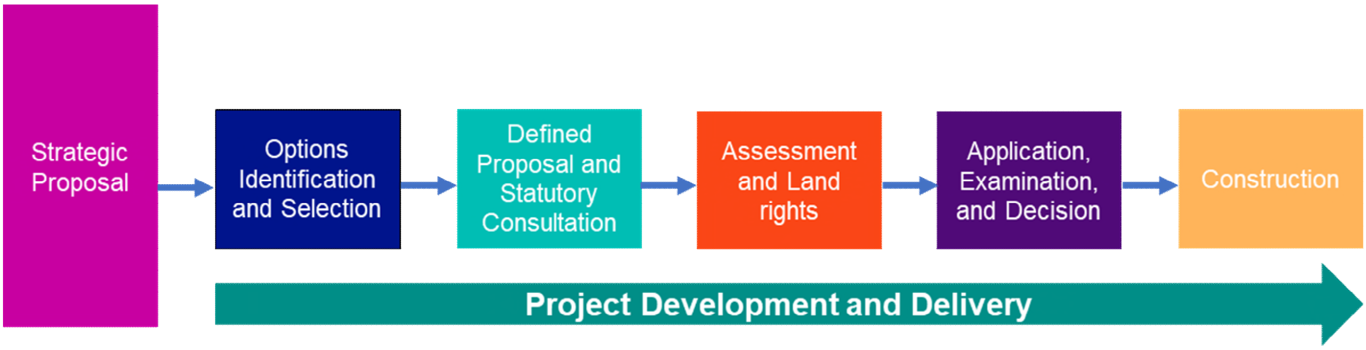
- Strategic Proposal;
- Options Identification and Selection;
- Defined Proposal and Statutory Consultation;
- Assessment and Land Rights;
- Application, Examination and Decision; and
- Construction.

[3]Our Approach to Consenting, National Grid, April 2022

www.nationalgrid.com/electricity-transmission/document/142336/download

1.1.7 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" stage and is at the very start of the process as shown in Figure 1.1.

Figure 1.1 – NGET's approach to the consenting process



1.1.8 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 non-statutory consultation.

1.2 Structure of this Report

- The report is structured as follows:
- Chapter 1: Introduction
- Chapter 2: How the electricity transmission system planned and operated
- Chapter 3: The legislative, policy and regulatory framework
- Chapter 4: The need case for reinforcement to the transmission system
- Chapter 5: SPT's approach to strategic options in Scotland
- Chapter 6: NGET's options identification and selection process
- Chapter 7: The results of NGET's appraisal of strategic options
- Chapter 8: Comparison of the appraisal of the strategic options
- Chapter 9: Conclusions and next steps

1.2.1 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: Summary of National Grid Electricity Transmission Legal Obligations
- Appendix B: Requirement for Development Consent Order
- Appendix C: Technology Overview
- Appendix D: Economic Appraisal
- Appendix E: Mathematical Principles used for AC Loss Calculation
- Appendix F: Beyond 2030 publication
- Appendix G: Glossary of Terms and Acronyms

2. How the electricity transmission system is planned and operated

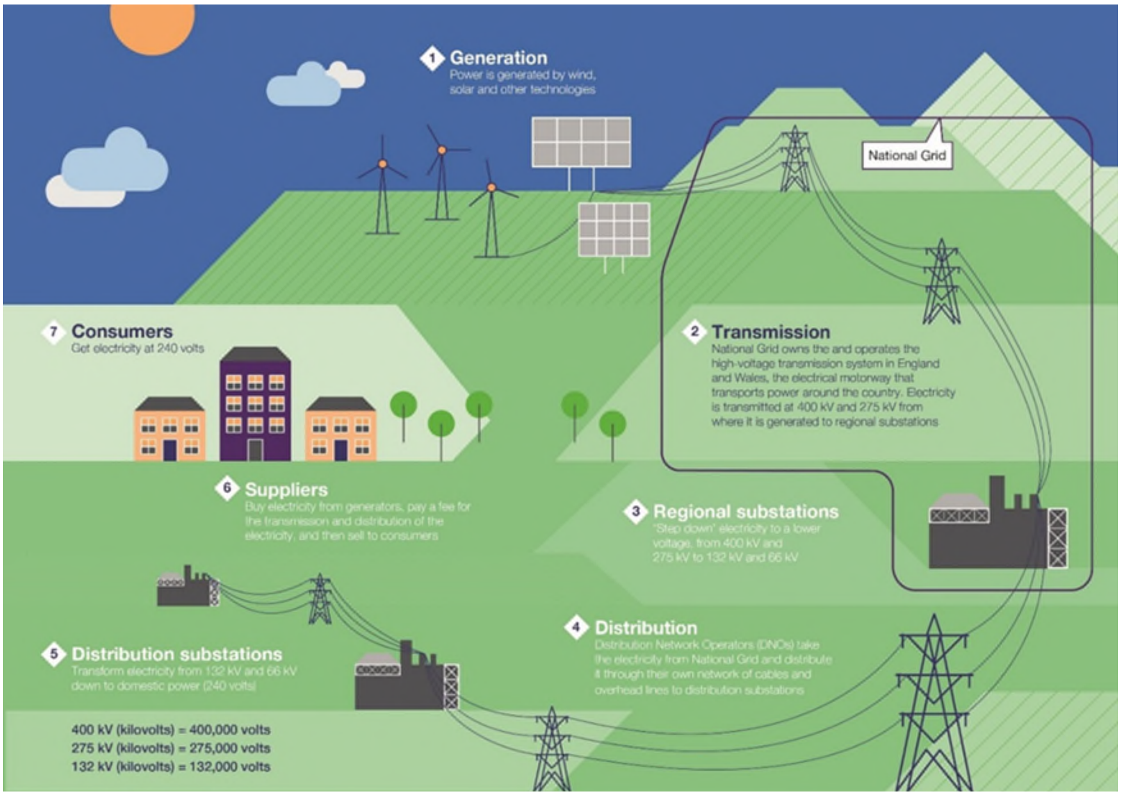
2.1 The transmission system

2.1.1 The electricity transmission system is a means of transmitting bulk electricity around the country from where it is generated to where it is needed. The existing transmission system in Great Britain operates at voltage levels of 400 kV and 275 kV and transports bulk supplies of electricity from large generating stations to demand centres. These systems are typically the responsibility of the Transmission Owners (TOs). 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. These systems are typically the responsibility of the Distribution Network Operator (DNO). The electricity system is illustrated in the below 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 TOs for the Great Britain network. NGET is the TO for the transmission network in England and Wales. SP Energy Networks (SPEN) 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: large 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 OHL 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.

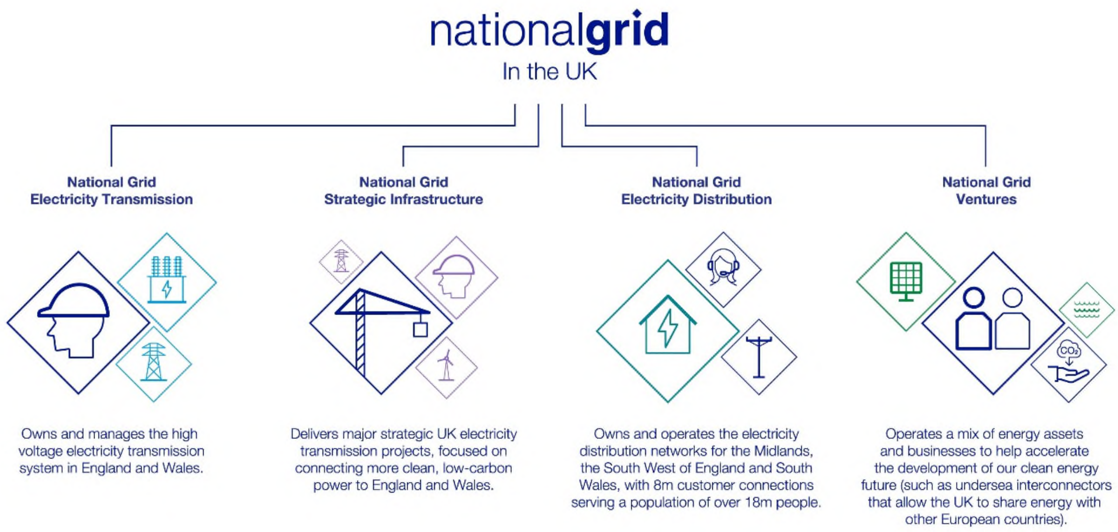
2.1.6 A single electricity market serves the whole of Great Britain. In this competitive wholesale market, generators and suppliers trade electricity on a half-hourly basis. Generators produce electricity and sell it in the wholesale market. Suppliers purchase electricity in the wholesale market and 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 Department for Energy Security and Net Zero (DESNZ), the Office of Gas and Electricity Markets (Ofgem), NGET and the National Energy System Operator (NESO).

Figure 2.2 – Roles and responsibilities within the energy sector



2.3 The role of National Grid Electricity Transmission

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

2.3.2 NGET's transmission system consists of approximately 7,200 km of OHL 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 NGET's legal obligations include duties under Section 9, Section 38 and Schedule 9 of the Electricity Act. In summary, these require NGET 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 OHL 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 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[4] (as amended).

2.4.3 Where necessary for the delivery of new projects applications for Development Consent Orders (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 (GHG) from the atmosphere

2.5 The role of the Office of Gas and Electricity Markets

2.5.1 Ofgem 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 In March 2024, the former Energy System Operator (ESO) published the "Beyond 2030" network plan, also known as the transitional Centralised Strategic Network Plan 2 (tCSNP2). Both the Scotland-North England Cross Border Connection and the Carlisle to Newcastle (East - West Link) were identified in this report as further network reinforcements needed beyond 2030 to support the transition to Net Zero. In December, Ofgem published its decision on the regulatory framework for tCSNP2 projects, which places these two projects in a "Development Track." As a result, these projects will be included in the NESO's tCSNP2 re-assessment, to be completed in early 2026.

[4] Planning Act 2008

https://www.legislation.gov.uk/ukpga/2008/29/contents

2.6 The role of the National Energy System Operator

2.6.1 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 1 October 2024, NESO became a public body owned by DESNZ. It was formerly part of National Grid PLC and called 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 and its predecessor ESO have been or – in the case of NESO – are responsible for multiple roles across the electricity system, including:

- 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.

What is constraining generation?

Generation is constrained when the electricity network cannot physically transfer power from one region to another. In these circumstances, NESO, in its system operator role, will ask generators to change their output to maintain system stability. Generators then receive constraint payments to compensate them for the reduction in their demand.

- Future Energy Scenarios (FES): NESO is responsible for an annual process to publish the FES[5] 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

[5] Future Energy Scenarios 2024: NESO Pathways to Net Zero
https://www.nationalgrideso.com/future-energy/future-energy-scenarios

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 considered the economic case for options to reinforce the transmission system and made economic recommendations. The NOA included a Cost Benefit Analysis (CBA) process to determine when it would be appropriate to take forward options proposed by TOs to increase network capacity. The CBA considered the capital costs of the proposal, delivery timescales and constraint costs (as explained in Chapter 6) avoided by delivering the proposal. The NOA was used to establish when a proposed reinforcement became the most economical way to deliver value to Great Britain's energy consumers.

- Network Planning Review (NPR): The Pathway to 2030 Holistic Network Design and the recommendations set out in the most recent 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[6] (CSNP). The CSNP will aim to foster the holistic development of the National Electricity Transmission System (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, the ESO published the Holistic Network Design (HND) setting out a single 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. The report is a pivotal document outlining the strategic direction for the UK's electricity transmission network as it transitions towards a decarbonised future. This report provides an overview of the network design that will act as the pathway to a clean, secure, and affordable energy network, aligning with the Climate Change Committee's (CCC's) Sixth Carbon Budget and Scotland's ScotWind leasing round to 2035. It is closely linked to the tCSNP2, which serves as a framework for the necessary investments and infrastructure developments required to meet the ambitious targets set for 2030 and beyond. The Scotland–North

[6] Decision on the initial findings of our Electricity Transmission Network Planning Review, Ofgem https://www.ofgem.gov.uk/publications/decision-initial-findings-our-electricity-transmission-network-planning-review

England Cross Border Connection project and the Carlisle to Newcastle (East–West Link) project will be included in the NESO's tCSNP2 refresh.

2.6.10 The tCSNP2 provides a comprehensive roadmap for the evolution of the UK's transmission network, ensuring that the infrastructure is not only capable of meeting current demands but also adaptable for future energy needs. More detail on the Beyond 2030 report can be found in Appendix F.

3. The legislative, policy and regulatory framework in England

3.1 Overview

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

3.2 Why is NGET required to reinforce the transmission system?

3.2.1 NGET's duties are determined by the Electricity Act and under the terms of NGET's 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 NGET's 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. NGET 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 TO 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), NGET 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 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, NGET are required to reinforce the network. NGET do this by either modifying the existing network (if possible) and / or constructing additional transmission infrastructure to resolve the shortfall.

3.3 NGET's 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 6 of this report.

Electricity Act 1989

3.3.2 In the instances when NGET are developing new infrastructure, NGET are 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 transmit 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:

"(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; and*
- *(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

3.3.6 Section 85(A1) 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

3.3.7 Section 40 of the Natural Environment and Rural Communities Act 2006 imposes a duty in respect of 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

3.3.8 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 addition, the UK Government has committed to achieving a clean 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:

- November 2020: Prime Minister's Ten Point Plan for a Green Industrial Revolution[7].
- December 2020: Energy White Paper: Powering our Net Zero Future[8].
- October 2021: Net Zero Strategy: Build Back Greener[9].
- April 2022: British Energy Security Strategy (BESS)[10]. 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[11] and Powering Up Britain: Energy Security Plan[12.] This document provides an update of the strategy for secure, clean and affordable British energy for the long-term future.

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[7] The Ten Point Plan for a Green Industrial Revolution, HM Government, November 2020
https://assets.publishing.service.gov.uk/media/5fb5513de90e0720978b1a6f/10_POINT_PLAN_BOOKLET.pdf

[8] Energy White Paper: Powering our Net Zero Future, HM Government, December 2020
https://assets.publishing.service.gov.uk/media/5fdc61e2d3bf7f3a3bdc8cbf/201216_BEIS_EWP_Command_Paper_Accessible.pdf

[9] Net Zero Strategy: Build Back Greener, HM Government, October 2021
https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf

[10] British Energy Security Strategy, HM Government, April 2022
https://assets.publishing.service.gov.uk/media/626112c0e90e07168e3fdba3/british-energy-security-strategy-web-accessible.pdf

[11] Powering up Britain, HM Government, March 2023
https://assets.publishing.service.gov.uk/media/642468ff2fa8480013ec0f39/powering-up-britain-joint-overview.pdf

[12] Powering up Britain: Energy Security Plan, HM Government, March 2023
https://assets.publishing.service.gov.uk/media/642708eafbe620000f17daa2/powering-up-britain-energy-security-plan.pdf

- December 2024: Clean Power 2030 Action Plan: A new era of clean electricity[13]. 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 nuclear reactors 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 (NPSs) covering Renewables, Oil and Gas Pipelines, Electricity Networks and Gas Generation, and an overarching Energy Statement for consultation. The revised NPSs will include a requirement for offshore wind to be considered as “critical national infrastructure”.

3.4.5 UK energy policy would apply to the whole of the Cross Border Connection project, including the Scottish element. However, there are differences in the planning policy which would apply to the English and Scottish elements. For the relevant planning policy in Scotland, please refer to Chapter 5.

3.5 Consenting regimes and national planning policy

Electricity network infrastructure developments

3.5.1 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 which may include:

- planning permission under the Town and Country Planning Act 1990;

[13] Clean Power 2030 Action Plan: A new era of clean electricity, UK Government, December 2024 https://assets.publishing.service.gov.uk/media/677bc80399c93b7286a396d6/clean-power-2030-action-plan-main-report.pdf

- a marine licence under the Marine and Coastal Access Act 2009;
- a DCO under the Planning Act 2008; and/or
- a variety of consents under related legislation.

3.5.2 For the purpose of the onshore options considered within this SOR, NGET follow the DCO process as outlined in the Planning Act 2008 to obtain statutory consent, in England. It is important to note that this DCO process is not applicable to SPT, in Scotland in relation to the electricity transmission Infrastructure. The approaches of SPT and NGET to options selection and routing reflect the different consenting regimes within which they operate. For more information on the consenting regime in Scotland, please refer to Chapter 5.

3.5.3 The Planning Act 2008 defines developments of new electricity OHL of 132 kV and above as Nationally Significant Infrastructure Projects (NSIPs) requiring a DCO subject to relevant statutory thresholds. Such an order may also incorporate consent for other types of work that are associated with new OHL infrastructure development, and these may be incorporated as part of a DCO that is granted. DCO applications are determined in accordance with NPSs which are designated by the UK Government.

3.5.4 Six NPSs for energy infrastructure were designated by the SoS in January 2024. The relevant NPSs for electricity transmission infrastructure developments are the Overarching National Policy Statement for Energy (EN-1), National 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.

3.5.5 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 provides 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.

3.5.6 The development of the Carlisle to Newcastle and the Cross Border Connection projects are aligned with the National Policy Statement for Electricity Networks Infrastructure (EN-5). As outlined in the project need case in chapter 4 of this document, and with reference to Figure 1.1 above, the project represents the development of new transmission infrastructure. Numerous factors are considered relating to the following non-exhaustive list:

- good site selection and design for energy infrastructure;
- climate change adaptation and resilience;
- environmental and biodiversity net gain;
- land rights and land interests;
- strategic and holistic network planning; and
- appropriate mitigation measures.

Marine Policy Statement (MPS) and Marine Plan

3.5.7 The MPS 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.

3.5.8 The MPS will be considered in the development of this Cross Border Connection project, within the chapters relating to the offshore strategic option.

Demonstrating the need for a project

3.5.9 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 NPSs when considering applications for DCOs.

- EN-1 and EN-5 describes the need for new electricity transmission infrastructure.
- EN-1 and EN-3 describes the need for new offshore/onshore wind generation.
- EN-1 and EN-6 describes the need for new nuclear generation.

Assessment principles applied by decision maker

3.5.10 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.

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

Presumption in favour of development

3.5.12 Section 4.1 of EN-1 confirms that the SoS 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 NPSs 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 SoS 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

3.5.13 Section 4.2 of EN-1 states that there is a Critical National Priority (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.

3.5.14 Paragraph 4.2.7 explains that the CNP policy is relevant during SoS 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 Site of Special Scientific Interest (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.

3.5.15 The SoS 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 (SPAs) and Special Areas of Conservation (SACs). 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.

3.5.16 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 Marine Conservation Zone (MCZ) (as relevant) the SoS will consider making a derogation.
- In that consideration, the SoS 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 MCZAs, 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 SoS must be satisfied that Measures of Equivalent Environmental Benefit (MEEB) will be undertaken.

Consideration of alternatives

3.5.17 Section 4.3 of EN-1 states that the NPS itself does not pose a general requirement to consider alternatives. The need to consider alternatives is, in the first instance, a matter of law. However, it makes clear that there are circumstances in which an applicant is specifically required to include information in their application about the main alternatives considered. This includes, for example, where a consideration of alternatives is required under the Habitats Regulations; in the context of compulsory purchase; or where the adverse environmental effects of a proposal are such that an alternative is a mandatory material consideration.

3.5.18 In relation to electricity transmission projects specifically, paragraph 2.9.14 of EN-5 provides as follows:

"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."

Good design

3.5.19 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.

3.5.20 Section 2.4 of EN-5 highlights that the SoS 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

3.5.21 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 OHL , 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

3.5.22 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 SoS should have regard to the need case for new electricity networks infrastructure set out in Section 3.3 of EN-1.

Electricity Act duties

3.5.23 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

3.5.24 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.

3.5.25 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 these projects.

3.5.26 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.

3.5.27 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 OHL is incompatible in principle with the statutory duty under Section 9 of the Electricity Act 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 OHL as transmission technology should be the strong starting presumption for electricity networks developments, EN-5 recognises that in practice OHL 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.

3.5.28 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."

3.5.29 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."

3.5.30 Paragraph 2.9.16 of EN-5 confirms that the Holford Rules, which are a set of "common sense" guidelines for routeing new OHL , 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 SoS should be satisfied that the development, so far as is reasonably possible, complies with the Holford Rules and Horlock Rules.

3.6 Security and Quality of Supply Standard

3.6.1 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. As set out in Section 2.5, the transmission system must at all times meet defined level of minimum levels of security and quality of supply. The National Electricity Transmission System Security and Quality of Supply Standard[14] (NETS SQSS) defines criteria relevant to:

- The Main Interconnected Transmission System (MITS)
- Generations connections; and
- Demand connections.

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

3.6.2 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.

3.6.3 NGET assesses the adequacy of its transmission system in accordance with the method defined in the NETS SQSS. NGET is required to assess power flows that transfer between regions of the transmission system. The Planned Transfer (the amount of power which will flow out of the region at Average Cold Spell (ACS) peak is calculated from the ACS peak demand and generation in that region, following the modelling approach set out in the NETS SQSS. 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.

3.6.4 Any transmission system is susceptible to faults that interfere with the ability of transmission circuits to carry power. Most faults are temporary, e.g. 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.

3.6.5 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 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".

3.6.6 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. The need case for reinforcement to the transmission system

4.1 Need for future reinforcement in the Southern Scotland and Northern England regions

4.1.1 As discussed in the previous Chapter, UK Government policy requires significant reinforcement of the transmission system to facilitate the connection of renewable energy sources and to transport electricity to where it is used. In particular, the BESS sets targets for the connection of up to 50 GW of offshore wind by 2030 as a key part of a strategy for secure, clean and affordable British energy for the long term.

4.1.2 As described in Section 2.6, NESO through its publications, develops a set of possible energy growth scenarios to 2050 and uses these to provide a 10-year view of the future transmission requirements and the capability of Great Britain's NETS. These scenarios mainly inform the requirement for transmission capability between regions of the system, for example between Scotland and Northern England.

4.1.3 The local need for system capability within a region is based on the generation and demand customers contracted to connect in the area and NESO's view of how those customers will produce or use energy.

4.1.4 National Grid and SPT are responsible for ensuring compliance with the NETS SQSS, which sets out the criteria and methodology for planning and operating the system, in their respective licenced regions.

4.1.5 Reinforcement of the southern Scotland and northern England regions is required due to the planned growth in generation within the region, most notably the development of onshore wind farms in southern Scotland. The regional need also reflects the requirement to reinforce transmission capacity across the B6 Boundary. These needs are addressed in further detail below.

4.1.6 The CMNC scheme was recommended to proceed by ESO as part of the NOA published in July 2022. This has subsequently been superseded by the CMN3 scheme replacing CMNC, albeit a variation upon the proposal.

4.1.7 The CMN3 scheme was recommended to proceed by ESO as part of its Beyond 2030 report, published in March 2024.

4.1.8 The FSU1 Northeast-Northwest England Transfer Connection was recommended to proceed by ESO as part of its Beyond 2030 report, published in March 2024. The FSU1 project is being promoted by National Grid in England to address constraints on East-West power flows in particular.

4.1.9 In the need case set out in this chapter of the SOR, the requirement for reinforcement of the transmission system addresses drivers associated with new generation as well as B6 boundary capacity. The B6 boundary reinforcement driver is free-standing and not directly dependent upon particular generating projects, being consequent upon the volume of flows which need to be accommodated across the B6 boundary. Increased flows across the B6 boundary will result in increased flows on existing circuits in Northern England, resulting in a need to reinforce the network in Northern England. The project to address this need (FSU1) is located entirely in England and is being promoted by National Grid.

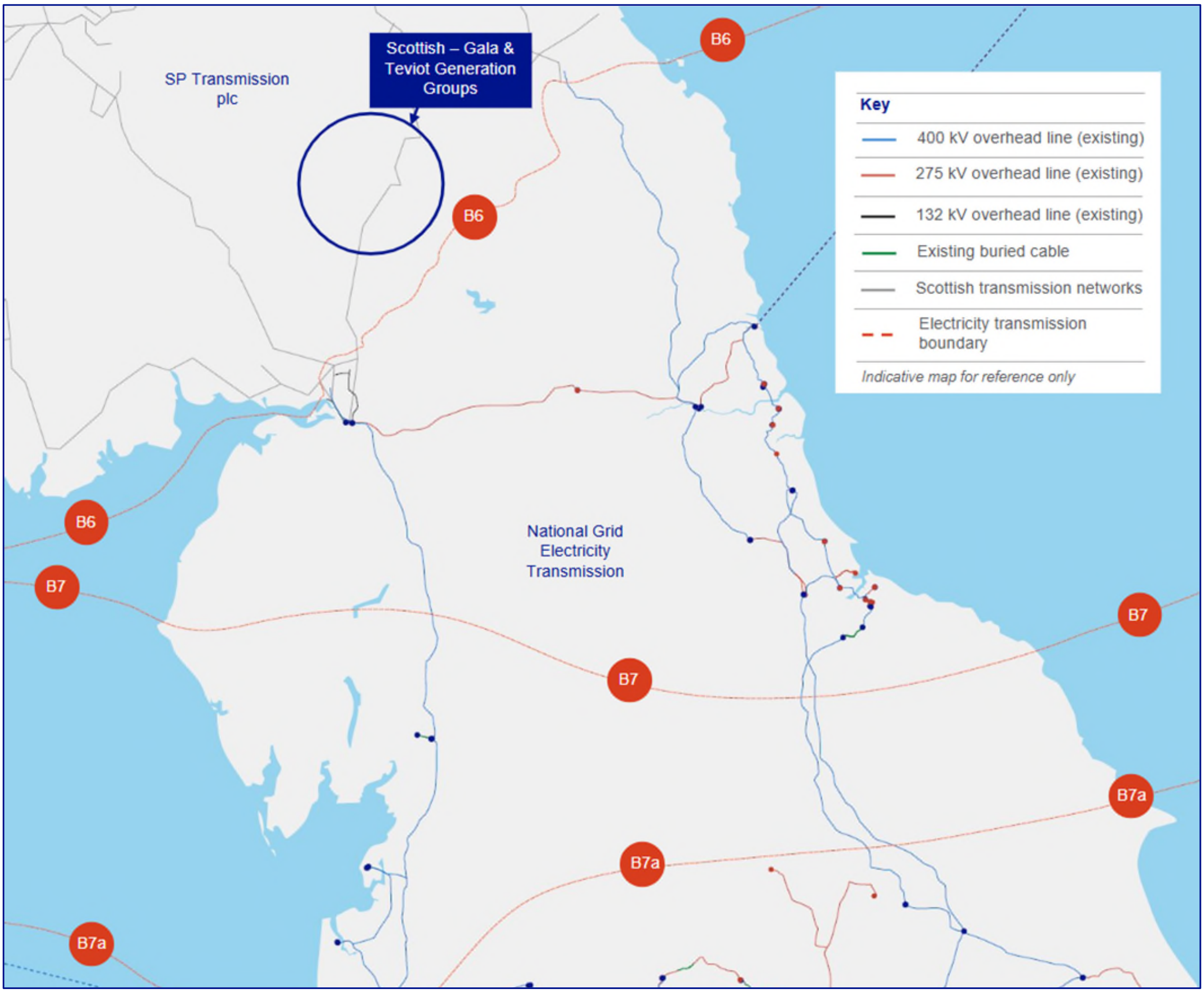
4.1.10 These points are elaborated upon further below.

4.2 The existing transmission network

4.2.1 The transmission system in the Scotland and the North of England region was primarily constructed in the 1960s, at the same time as much of the rest of the transmission system. It was designed to connect coastal, in land large coal fired power stations and nuclear power stations in Scotland and the North of England. The existing transmission system in Scotland, the North of England and the Midlands is shown in Figure 4.1.

4.2.2 Electricity demand is especially concentrated in large urban areas, including urban areas in 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 Great Britain. As the country decarbonises, the demand for energy from renewable sources will increase and replace fossil fuel usage.

Figure 4.1 - NETS in Scotland and the North of England



4.2.3 Figure 4.1 shows the existing transmission system and Teviot and Gala Generation Group, the B6, B7 and B7a boundary. The Teviot and Gala Generation group, and B6 boundary are the most relevant to the need case set out in this document and are described in detail below.

4.2.4 The following projects are already proposed to cross the B6 boundary and are expected to be complete around 2035. They are therefore included in the background of the assessment of need for the B6 boundary, to ensure there is a requirement for reinforcement over and above these proposed projects:

- EGL 1 – 2 GW High Voltage Direct Current (HVDC) Link Scotland to England;
- EGL 2 – 2 GW HVDC Link Scotland to England;
- EGL 3 – 2 GW HVDC Link Scotland to England;
- EGL 4 – 2 GW HVDC Link Scotland to England; and
- EGL 5 – 2 GW HVDC Link Scotland to England.

4.3 Generation groups

4.3.1 Figure 4.1 identifies two generation groups around the Gala and Teviot regions in Scotland. A generation group is a set of generators who have a connection agreement in place with NESO which requires the TO, in this case SPT, the Licensed TO in Southern Scotland, to provide a connection to the transmission system.

4.3.2 This connection agreement obligates SPT to connect the generation to the transmission network. SPT's transmission licence means that their network must be designed in accordance with the NETS SQSS. This includes meeting both the NETS SQSS Chapter 2 Generation Criteria and the Chapter 4 Wider Works Criteria. Due to the proximity of the generation, in particular the Teviot group, to the Scotland / England border, the connection of the generation impacts the NGET network. NGET is obligated to develop its network to meet the NETS SQSS as a result of connections anywhere on the network. Both NGET and SPT must ensure compliance with their transmission licences, including Condition D2 – Obligation to provide transmission services. Under Condition D2 our obligations include, responding to requests for the construction of additional transmission system capacity (including system extension, disconnections and/or reinforcement). This requirement includes providing the capacity required to the contracted dates as set out in the TEC register published by NESO. Therefore, NGET and SPT are both required by their licences to ensure the generation groups are connected and meet the requirements of the NETS SQSS.

4.3.3 In designing the network to connect this generation NGET and SPT have considered reinforcement options that provide economic and efficient solutions, both connecting the generation and supporting the boundary capacity increase across B6 described in detail later in this chapter.

4.4 Scottish – Gala and Teviot Generation groups

4.4.1 SPT has contracted with a number of generators within the Gala and Teviot areas, as set out in Table 4.1a and 4.1b below.

Table 4.1a - Contracted capacities in the Gala area

Site Name	Contacted Capacity	Energisation Date
	MW	
Galileo 16	125	2032
Lightsource Threepwood	150	2030
Longcroft Energy Park	156	2031
Peat Law Renewable Energy Park	253.28	2033
Scawd Law Wind Farn	64	2032
Total	**748.28 MW**	

Table 4.1b - Contracted capacities in the Teviot area

Site Name	Contracted Capacity	Energisation Date
	MW	
Teviot Wind Farm	522.9	2033
Borders Wind Farm	400	2033
Sundhope Wind Farm	180	2033
Brown Rig Wind Farm	114	2033
Total	**1,216.9 MW**	

4.4.2 The Gala generation group is 748.28 megawatt (MW) of generation connecting to the Gala area and the Teviot Generation group is 1,216.9 MW of generation to be connected in the Teviot area, which together form part of the need case in this document. This group of generators is not able to connect solely to the existing system because there is insufficient capacity in the area for the system to remain compliant with the NETS SQSS. Additional transmission capacity is required in the Gala and Teviot areas to facilitate its connection.

4.5 Boundaries

4.5.1 A boundary splits the transmission 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.

4.5.2 Major system reinforcements such as new circuits often have longer delivery times than generation projects. Waiting for certainty in the generation background before a reinforcement is undertaken can therefore lead to periods of time when connected generation is significantly constrained in its output, resulting in high costs to consumers. To mitigate this risk future boundary requirements are assessed using NESO FES to identify likely power flows across the boundaries ahead of certainty of the generation background. Power system analysis is conducted by NESO, NGET and SPT to determine the boundary capability with the existing network and currently planned developments, which is the maximum power flow that can be transferred across a boundary while maintaining compliance with technical standards. Limiting factors on transmission capacity or capability include thermal circuit rating, voltage constraints, and dynamic stability. This capability is compared with the FES boundary requirements to identify whether a capability shortfall is likely.

4.5.3 Boundary capability is calculated from the capacity of each circuit and the way in which power flow distributes across the circuits.

4.5.4 The circuit capacity during the winter ACS period of each of the circuits which cross a system boundary is known. The sum of the capacity for all of these circuits provides the pre fault capacity.

4.5.5 The post fault capacity is defined by the remaining capacity across a boundary following the worst-case fault condition (secured event) considered under the NETS SQSS. Following a secured event, the flows in each boundary circuit will be based upon the circuit parameters and system conditions. When one circuit reaches its maximum capacity no more power can be transferred across the boundary, even though other circuits may be below their capacity. This power flow defines the circuit boundary capability, which is based upon the capability seen following the secured event.

4.5.6 Where a shortfall is identified the TOs design options to resolve it. These are assessed by NESO to determine whether any of the options would provide consumer benefit if they were progressed. These assessments are based on an economic analysis of the year-round operation of the whole system. Whilst the assessment recommends progression of options that will provide benefit and contribute to NETS SQSS compliance, they do not ensure full compliance with the NETS SQSS. Additional developments may be needed to meet the NETS SQSS – these are identified by the TOs as the generation background becomes more certain.

4.5.7 Whilst the NESO assessment covers year-round operation of the system, its publications show a limited set of conditions as an indication of the likely requirement. For consistency with NESO publications, in this document, in describing the assessments undertaken, NGET and SPT have taken the average requirements to cover 95% of operating conditions.

4.5.8 The boundary assessments completed on the Economy Planned Transfer, as defined in the NETS SQSS, already accounts for generation contribution. To ensure that an appropriate measure of need using current assessments of capacity at the date of this report, NGET has taken the Holistic Transition, Electric Engagement, Hydrogen Evolution, CP30 – Further Flex & 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.

4.5.9 As described in the "Communicating our thermal needs" section set out in the ESO 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 capability of the boundary is lower than these two regions 75% and 95% over 20 years there may be a need for reinforcement.

4.5.10 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 scenarios there is clearly a shortfall against boundary capability and capacity for the B6, boundary that by 2035 will require reinforcement.

4.6 NGET's B6 analysis results

4.6.1 Table 4.2 shows the capacities and capabilities applicable to the B6 system boundary in 2035 including all HVDC links and the existing Alternating Current (AC) transmission system:

Table 4.2 - Existing transmission system capacities and capabilities by 2035

System Boundary	Pre Fault Capacity	Post Fault Capacity	Post Fault Capability
	MW	MW	MW
B6	24,665	18,013	16,800

4.6.2 Table 4.3 below shows how the boundaries perform in 2035 for the average 95th percentile FES planned transfer flows.

Table 4.3 - Proposed B6 boundary performance by 2035 including all HVDC connections

Generation Group or Boundary Export	Required transfer by 2035	Pre 2035 Post Fault Capability	Pre 2035 Post Fault Capacity	Capability Surplus (+) / Deficit (-)	Capacity Surplus (+) / Deficit (-)	Secured Event Fault
B6 – 2035 (Boundary)	28,405.2 MW	16,800 MW	18,013 MW	**-11,605 MW**	**-10,392 MW**	Stella West to Eccles double circuit

4.6.3 The analysis has taken account of the increases to B6 system boundary capability and capacity that would be provided by the reinforcement proposals that NGET and SPT are already progressing prior to options set out in this report. Along with generation and demand requirements forecast by ETYS 2024 B6 scenarios by 2035, Table 4.3 shows a:

- capability deficit of -11,605 MW and
- capacity deficit of -10,392 MW

4.6.4 In a scenario where the Gala or Teviot generation groups are not progressed, the B6 boundary deficit would remain as the defining need for the Cross Border project.

4.7 NGET East-West flow analysis

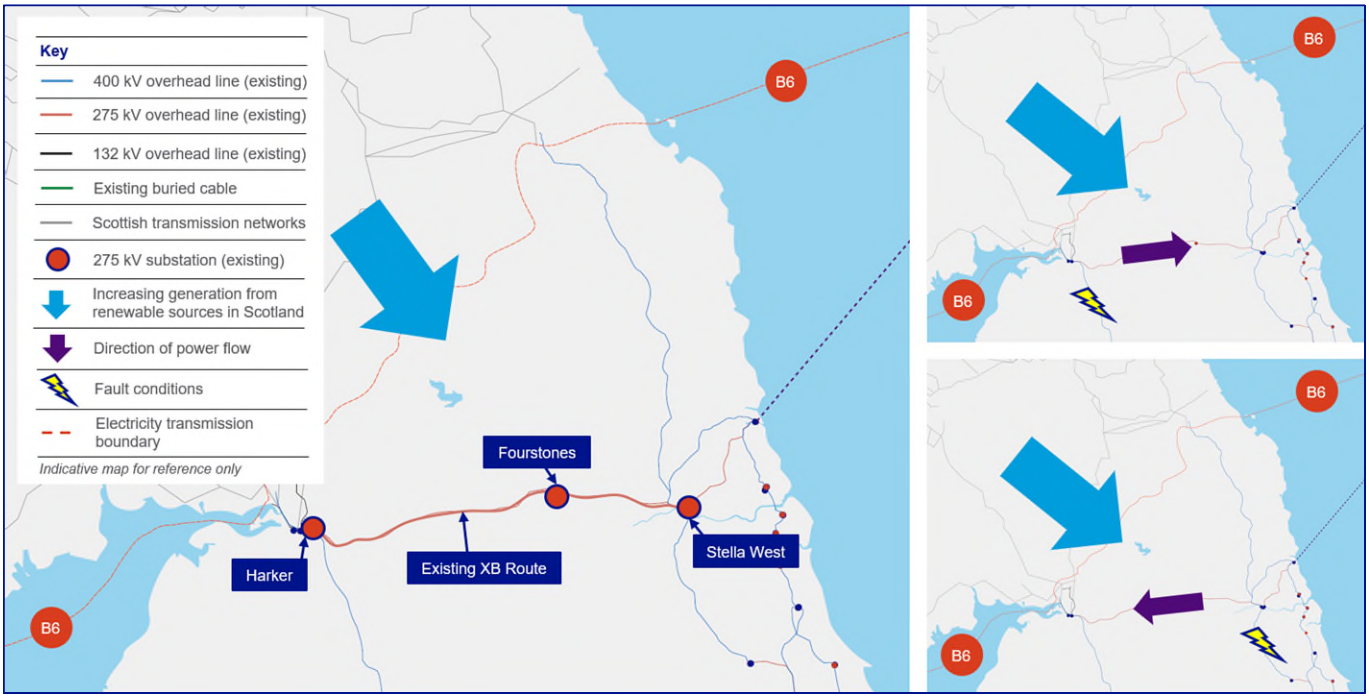
4.7.1 The transmission system in the Northwest and Northeast of England are currently connected together by a single 275 kV connection between Harker and Stella West known on the National Grid transmission system as the XB route.

Figure 4.2 - Harker to Stella West 275 kV

4.7.2 As shown in Figure 4.2, the Harker to Stella West 275 kV circuit is the only East-West circuit between Central Scotland and Northern Yorkshire and Lancashire in England. This circuit is critical to rebalancing the network faults to the west or east in this region.

4.7.3 As energy transfers increase across the B6 boundary from Scotland, due to increasing generation connections in Scotland, transmission faults south of Harker and Stella West for example must be secured. The transfer flows, which occur for these faults south of Stella West or south of Harker, will significantly overload the capacity and capability of the existing XB route 275 kV Northeast-Northwest transfer circuit in the future. This is shown in Figure 4.3 below.

Figure 4.3 – Faults South of Existing XB route



4.7.4 As shown in Figure 4.3, faults south of the Existing XB route 275 kV Harker to Stella west ensure power flows to the opposite coast for onward transmission south and will lead to overloads of the existing circuits which have an existing maximum capacity of 1,628 MW.

4.7.5 The worst-case fault north of the XB route also causing East-West transfers currently would be for the 400 kV circuits between Gretna (Scotland) and Harker (England). This would cause significant imports of Scottish generation to Stella West where further generation is connecting in the northeast of England. Without the ability to Transfer upwards of 4,000 MW of power to the West Coast of England the circuits south of Stella West would overload and the imbalance would cause further overloads across multiple circuits south of this region. Therefore, the East-West transfer of power is critical to progress compliance of the Network with the NETS SQSS for both faults to the north and the south of the Existing XB 275 kV circuit.

4.8 Scottish and English border strategy implications

4.8.1 The B6 boundary shown in figure 4.2 is represented as single line on the geographical map.

4.8.2 Table 4.3 shows that by 2035 we have a capability deficit of -11,605 MW and capacity deficit of -10,392 MW this will require circa 12,000 MW or 12 GW of additional capacity to be provided to satisfy this need. These figures also equate to the amount of energy that must cross the B6 boundary.

4.8.3 A number of projects are proposed to be delivered with the NESO Beyond 2030 document. This includes the projects considered for this report, which are: the Cross Border Connection project - NESO code (CMN3) and the Carlisle to Newcastle project - NESO code (FSU1). Additionally, there are two further projects: NESO code CLN2, which currently indicates a circuit in England from North West England to Lancashire, and WCN2, which is a connection from South West Scotland to North West England.

4.8.4 Both CLN2 and WCN2 require strategic optioneering to determine their requirements which will be documented in subsequent strategic option reports related to those projects. However, to ensure we meet the need case set out in this document by circa 2035, two transmission double circuits may be required to cross the B6 boundary to provide the capacity of circa 12 GW. The largest capacity a double circuit transmission route can carry is 6.9 GW, which means two double circuit 400 kV connections may be required to cross the B6 boundary if onshore options are determined to progress alongside other projects identified as being required to meet the overall regional need case.

4.9 Need Case conclusion

4.9.1 As described above there are a number of issues that need to be resolved by system reinforcements to meet both our licence obligations and progress compliance with the NETS SQSS. The issues that need to be resolved are:

- Provision of 11,605 MW of boundary capability and 10,392 MW of boundary capacity to the B6 boundary to progress NETS SQSS compliance.
- The additional capacity required across the B6 boundary being circa 12GW, requires 2 of the 4 proposed projects to cross B6 to achieve this.
- Provision of transmission capacity as required by NGET's and SPT's transmission licences to connect 748.28 MW of generation in the Gala area and 1,216.9 MW of generation in the Teviot area of Scotland.
- Provision of a minimum of 4,000 MW of East-West transfer capacity in Northern England to progress NETS SQSS compliance.

4.9.2 The solutions to the issues identified above must be considered at the same time, but in series, because the solutions adopted for one set of issues may enable the delivery of alternative solutions to the other set. The options appraisal in this document takes that approach.

4.9.3 The remainder of this report considers strategic options that resolve the need set out above. NGET and SPT must comply with Section 9 of the Electricity Act and Standard Condition D3 (Transmission system security standard and quality of service) of their Transmission Licences, failing to resolve the need set out above would breach this requirement.

5. SPT's approach to the Scottish component of the Cross Border Connection project

5.1 Background

5.1.1 In Scotland, decisions regarding the development and consenting of electricity networks are largely devolved to Scottish Ministers. While the UK Parliament retains the legislative framework for electricity, including transmission, the Scottish Government handles planning and consenting for electricity infrastructure within Scotland. Separate applications therefore require to be made for the Scottish and English components of the Cross Border Connection Project, which will be decided by different decision makers under different consenting regimes.

5.1.2 The purpose of this chapter is to provide a high-level summary of the work undertaken by SPT to date.

5.2 Overview of the Scottish component of the Cross Border Connection project

5.2.1 The Scottish Component of the Cross Border Connection Project comprises the following key elements:

- A new double circuit 400 kV OHL carried on steel lattice towers between the proposed Gala North Substation[15], and a new Teviot Substation;
- The new Teviot Substation which will also connect the contracted Teviot Generation group wind farm as outlined in Chapter 4; and
- A new double circuit 400 kV OHL carried on steel lattice towers from the new Teviot Substation to the Scotland-England border.

5.3 SPT's statutory and licence duties

5.3.1 Like NGET, SPT have a duty under the Electricity Act 1989 (the Electricity Act) to develop and maintain an efficient, co-ordinated and economical system of electricity transmission and is licenced under Section 6(1)(b) of the Electricity Act to transmit electricity. SPT's licence is granted subject to certain standard and special conditions. Under Section 9(2) of the Electricity Act, SPT is required to fulfil the following duty:

- To develop and maintain an efficient, co-ordinated and economical system of electricity transmission; and

[15] SPT has proposed a new Gala North substation as part of RIIO-T3. Gala North will facilitate connection of contracted generation within the vicinity and has been designed to enable integration with key wider system reinforcement including the Cross Border Connection Project.

- To facilitate competition in the supply and generation of electricity.

5.3.2 This statutory duty is reflected in SPT's transmission licence. In addition, SPT has the following obligations pursuant to its licence conditions (LCs):

- To at all times have in force a (STC) which, amongst other things, provides for the co-ordination of the planning of the transmission system (LC B12);
- To plan and develop its transmission system in accordance with the SQSS including Chapter 2 which facilitates the connection of generation and Chapter 3 which sets out the arrangement for demand (LC D3);
- To make its transmission system available for generators wishing to connect to it and ensure that the system is fit for purpose through appropriate reinforcements to accommodate the contracted capacity. SPT has an obligation to provide NESO with a Transmission Owner Construction Offer in response to NESO's receipt of an application for connection to the system or modification of an existing connection (LC D4A Obligations in relation to offers for connection etc.).

5.3.3 In response to statutory duties and licence obligations upon it, SPT therefore is required to ensure that the transmission system is developed and maintained in an economic, coordinated and efficient manner in the interests of existing and future electricity consumers

5.3.4 SPT must identify the system reinforcements that are necessary as a result of NESO making connection offers to generation developers wishing to connect to the transmission system. In identifying the reinforcement, SPT requires to have due regard to the statutory obligation to develop an efficient, coordinated and economical system for the transmission of electricity, and also the obligations on NESO to co-ordinate and direct the flow of electricity onto and over the GB transmission system. This is addressed in more detail below in reference to the role and responsibilities of Ofgem, the energy regulator for Great Britain.

5.3.5 Section 38 of, and Schedule 9 to, the Electricity Act impose the following duties on SPT when formulating any relevant proposals:

- 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 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.*"

5.3.6 SPT also has a duty to consider the possible environmental impacts of new electric lines and to do what can 'reasonably be done' to mitigate any adverse impacts. In terms of its statutory duties and licence obligations, SPT must therefore balance technical, cost (economical) and environmental factors.

5.3.7 It is against that background that the Scottish Component of the Cross Border Connection project has been identified and developed.

5.4 The roles of NESO and Ofgem

5.4.1 NESO facilitates several roles on behalf of the electricity industry, including making formal offers to applicants requesting connection to the NETS. NESO also undertakes an evaluation of the economic merit of wider system reinforcement proposals and provides investment recommendations for these proposals to transmission owners indicating which areas of the transmission system require reinforcement.

5.4.2 Section 3A of the Electricity Act imposes certain duties on the Scottish Ministers, SoS, and the Gas and Electricity Markets Authority, which operates through Ofgem. The principal objective in carrying out their respective functions is to protect the interests of consumers in relation to electricity conveyed by distribution systems or transmission systems.

5.4.3 The Scottish Ministers, SoS and Ofgem are required to carry out their functions in the manner they consider is best calculated to further the principal objective, wherever appropriate by promoting effective competition between persons engaged in, or in commercial activities connected with, the generation, transmission, distribution or supply of electricity or the provision or use of electricity interconnectors. In performing these duties, the Scottish Ministers, SoS and Ofgem shall have regard to:

- The need to secure that all reasonable demands for electricity are met;
- The need to ensure licence holders are able to finance the activities which are the subject of their obligations under Part 1 of the Electricity Act and the Utilities Act 2000 etc.; and
- The need to contribute to the achievement of sustainable development.

5.4.4 A key part of Ofgem’s role is to protect the interests of energy consumers, especially vulnerable people, by ensuring they are treated fairly and benefit from a cleaner, greener environment. Its policy and regulatory framework are designed to support this underlying objective.

5.5 The Scottish consenting regime

5.5.1 The DCO regime does not apply in Scotland. Instead, SPT requires to apply for consent from Scottish Ministers under Section 37 of the Electricity Act. Such applications are processed on behalf of the Scottish Ministers by the Energy Consents Unit (ECU) in Scotland. As part of that process, SPT will seek a direction that planning permission is deemed to be granted under Section 57(2) of the Town and Country Planning (Scotland) Act 1997 (1997 Act).

5.5.2 In determining the application, the Scottish Ministers must have regard to the desirability of preserving the natural beauty of the countryside, of conserving flora, fauna, and geological and physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest in accordance with Paragraph 3 of Schedule 9 to the Electricity Act, and any other material considerations. The Scottish Ministers will also consult with statutory stakeholders, relevant Local Planning Authorities and members of the public.

5.5.3 In support of its application, SPT must produce an EIA in accordance with the Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (2017 Regulations). Unlike the DCO regime there is currently no statutory requirement for preliminary environmental information or pre-application consultation.

5.5.4 Again, unlike DCOs, Section 37 consents do not include provision for compulsory acquisition. If SPT requires to compulsorily acquire land or rights to enable the Scottish Component of the Cross Border Connection project, separate applications will be made pursuant to its powers under the Electricity Act. The approaches of SPT and NGET reflect the different consenting regimes within which they operate.

The Scottish policy context

5.5.5 As explained in Chapter 3, the Cross Border Connection project as a whole is strongly supported by UK Energy Policy (which applies UK-wide) and its need case has been further strengthened by NESO's Beyond 2030 Report.

5.5.6 The Scottish Component of the Cross Border Connection project is also strongly supported by the Scottish policy framework, most notably Scotland's NPF4[16]. NPF4 was adopted in February 2023 and sets the approach to planning and development to help achieve a net zero, sustainable Scotland by 2045. It identifies eighteen 'national developments', which are developments the Scottish Ministers consider to be nationally important and necessary for the delivery of Scotland's National Spatial Strategy. Six national developments support the delivery of 'sustainable places', including 'National Development 3 - Strategic Renewable Electricity Generation and Transmission Infrastructure', which supports renewable electricity generation, repowering, and expansion of the electricity grid. Page 103 of NPF4 describes National Development 3 and it states:

> "*A large and rapid increase in electricity generation from renewable sources will be essential for Scotland to meet its net zero emissions targets. Certain types of renewable electricity generation will also be required, which will include energy storage technology and capacity, to provide the vital services, including flexible response, that a zero-carbon network will require. Generation is for domestic consumption as well as for export to the UK and beyond, with new capacity helping to decarbonise heat, transport and industrial energy demand. This has the potential to support jobs and business investment, with wider economic benefits.*
>
> *The electricity transmission grid will need substantial reinforcement including the addition of new infrastructure to connect and transmit the output from new on and offshore capacity to consumers in Scotland, the rest of the UK and*

[16] National Planning Framework 4

https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/02/national-planning-framework-4/documents/national-planning-framework-4-revised-draft/national-planning-framework-4-revised-draft/govscot%3Adocument/national-planning-framework-4.pdf *beyond. Delivery of this national development will be informed by market, policy and regulatory developments and decisions."*

5.5.7 The Need for National Development 3, also stated on page 103 of NPF4:

"Additional electricity generation from renewables and electricity transmission capacity of scale is fundamental to achieving a net zero economy and supports improved network resilience in rural and island areas."

5.5.8 As new onshore high-voltage electricity transmission infrastructure, the Scottish Component of the Cross Border Connection project holds national development status under the provisions of NPF4. As such, its need in policy terms is firmly established.

5.6 Need case for the Scottish component of the Cross Border Connection project.

5.6.1 Chapter 4 of this document summarises the need case for the English Component of the Cross Border Connection project.

5.6.2 The part of the need case which relates to the Scottish Component of the Cross Border Connection project is addressing the needs of uplifting the B6 boundary capacity and supporting future network needs in the vicinity of Gala and Teviot (including facilitating SPT's connection agreements with the Gala and Teviot Generation groups). These aspects are only relevant to the North-South elements of the need case set out in Chapter 4. They do not address that element of the need case set out in Chapter 4 which concerns East-West power flows in the north of England as those apply only in areas of NGET's licence area.

5.6.3 Against the contracted volumes of renewable generation across central and southern Scotland, providing SQSS compliant connections requires additional local capacity within the relevant areas of the system, with a resulting need for greater power transfer capability and associated upgrades across the wider network.

5.6.4 In line with SPT's overarching obligation to pursue economic, efficient and coordinated network reinforcement solutions, connecting the northern end of the Cross Border Connection into the proposed new Gala North Substation enables the new circuit to integrate with both current and future network proposals in turn facilitating an increase to the B6 boundary capability. Connection into Gala North also provides the additional local reinforcement required at Gala North to achieve full SQSS Section 2 compliance.

5.6.5 There is currently no existing 400 kV transmission network in the vicinity of the contracted customers in the Teviot area as detailed in Chapter 4. The only network which is currently available is the 132 kV system, in particular the V route between Hawick and Gretna/Harker. However, this is fully committed and cannot accommodate the current contracted volumes of new generation. To meet the growing needs in these areas and enable the timely and efficient connection of contracted generation (described in Chapter 4) as well as future network needs (i.e. the expansion of the 400 kV system), the new 400 kV double circuit line will require to be routed from Gala North to a new collector substation at Teviot.

5.6.6 South of Teviot, the new 400 kV double circuit needs to be extended to the Scottish border in order to connect with the English Component of CMN3 and reinforce the B6 boundary transfer capability.

5.6.7 Following the directions of NESO and Ofgem, SPT are developing the project on the basis that the southern connection to existing transmission infrastructure should be in the Carlisle area, subject to the outcome of NGET's optioneering work conducted by NGET and summarised in the rest of this Report.

5.6.8 In summary, the Scottish Component of the Cross Border Connection project forms an essential part of SPT's strategy to reinforce and increase the capacity of the electricity system within its licence area. It is the result of SPT's licence obligations and is reflected in the agreements between NESO and the respective developers as necessary work. It is, accordingly, a scheme that SPT is bound to deliver in line with its: (i) statutory duties in terms of Section 9 of the Electricity Act; (ii) licence duties to Ofgem; and (iii) contractual duties to NESO.

5.7 SPT's approach to routeing and siting of the preferred strategic option

5.7.1 SPT's approach to routeing, siting and consideration of alternatives in accordance with its statutory duties under the Electricity Act is explained in its document "Major Infrastructure Projects: Approach to Routeing and Environmental Impact Assessment"[17].

5.7.2 SPT's starting point is to identify and evaluate potential network solutions that meet the needs of the transmission system, balancing technical, economic and environmental considerations.

5.7.3 Once a preferred solution has been selected, it takes a two-stage approach to routeing and siting of its preferred solution:

- Stage 1: Identification and appraisal of route options to select a preferred route including consultation with stakeholders and the wider public to establish a proposed route, as set out in Figure 5.1 below. Whilst presented as a linear process for simplicity, the approach is iterative, and the steps may be re-visited several times. The outcome of each step is subject to a technical and, where relevant, consultation, 'check' with key stakeholders including the public, prior to commencing the next step.
- Stage 2: EIA of the proposed alignment and any associated infrastructure. This is an important stage as the EIA process is used to further refine the route alignment to avoid and reduce potential environmental effects, including land use impacts. This results in the alignment for the purposes of applications.

5.7.4 The Scottish Component of the Cross Border Connection project has progressed the routeing and siting process to Step 12 in Figure 5.1 below – consultation on its preferred route option.

5.7.5 In line with the established approach to routeing, SPT progressed development of the preferred solution with identification of a study area for the assessment of route options. The extent of the study area was informed by the location of the "start' and "end" points of the Cross Border Connection project in Scotland, as well as the requirement to connect proposed wind generation to the electricity network via a new substation in the south of Scotland. The northern extent of the Study Area has been defined by the proposed Gala North Substation and the southern extent by the Scotland-England border which coincides with the boundary between SPT and NGET's licence areas. The western and

[17] https://www.spenergynetworks.co.uk/userfiles/file/SPEN_Approach_to_Routeing_Document_2nd_version.pdf

eastern extents of the study area have largely been established taking account of SPT's statutory duties and in particular the directness of route options which they would enable.

5.7.6 The western extent of the study area has largely been defined by the Tweedsmuir Hills and Moffat Hills while the eastern extent of the study area has been defined by the Cheviot Hills and Kielder Forest. This established a large study area which enabled the identification and consideration of a range of route and site options while also seeking to balance potential adverse environmental effects with technical feasibility and economic viability.

5.7.7 Following the identification of the study area, SPT mapped constraints within the study area to enable them to identify and assess strategic route corridors and substation sites. This led SPT to the identification of a preferred route option from Gala North Substation to the border, and a preferred site for the Teviot Substation, on which consultation took place.

5.7.8 Full details of the preferred option consulted upon are set out in the Routeing and Siting Consultation Document published in September 2024[18]. A report detailing the outcome of the consultation is expected to be published in quarter 3 / quarter 4 of 2025.

5.7.9 Notwithstanding the work undertaken by SPT on routing to date, as it has been made clear in public consultation, this is without prejudice to decisions taken by NGET on the route south of the border and the Scottish section of the project will be subject to alignment with the section in England before detailed design. NGET's option selection process is described in Chapter 6 of this report.

Figure 5.1 – SPT's approach to the Routeing and Siting Study

[18] https://www.spenergynetworks.co.uk/userfiles/file/CBC-RCD-ALL-COMPILED-LO-RES_REV02.pdf

6. NGET's options identification and selection process

6.1 Identifying the technically feasible options

6.1.1 Once the need case has been established, there is a requirement to consider the many ways in which the project could be delivered. 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. The initial identification is based on the network planning information available from ESO at the time of appraisal.

6.1.2 This chapter provides the information on the potential strategic options that have been identified by NGET to satisfy the need case.

6.1.3 NGET began with the identification of technically feasible options which individually meet the need case as is set out in Chapter 4 of this SOR. These options cover a wide geographical area and a number of different technologies and are presented in this document.

6.1.4 A "benefits filter" was then applied to the technically feasible options, which allowed focus on those that best meet the 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 any of the following:

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

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

6.1.6 Table 6.1 and Table 6.2 list the potential strategic options and provide an outcome from the benefits filter appraisal for both the Carlisle to Newcastle and the Cross Border Connection projects.

6.1.7 The Carlisle to Newcastle project aims to ensure the provision of a minimum 4,000 MW of East-West transfer capacity in Northern England.

6.1.8 The Cross Border Connection project aims to ensure the provision of transmission capacity to connect 1,216.9 MW of generation in the Teviot area and 748.28 MW of generation in the Gala area of Scotland, to support the provision of 10,392 MW of B6 Boundary capacity by providing 6,930 MW of the total required capacity.

6.1.9 A number of longlisted options were taken forward and considered for detailed appraisal, as shown in Table 6.1 and Table 6.2 below.

Table 6.1: East-West potential strategic options

	Potential strategic option	Brief description	Outcome
1	East-West: use of 275 kV XB line	Circa 85 km existing 275 kV transmission connection	Further examination required
2	East-West: Retrofitting the existing XB line or building a new 400 kV line from North Carlisle/Harker	Circa 96 km new 400 kV transmission connection	Merged with 12th option and taken forward
3	East-West: Retrofitting the existing XB line or building a new 400 kV line from South Carlisle/Harker	Circa 85 km new 400 kV transmission connection	Merged with 11th option and taken forward
4	East-West: Taking connection from Harker – Hutton to Humber region	Circa 135 km new 400 kV transmission connection	Taken forward
5	East-West: Retrofitting the existing XB line or building a new 400 kV line, outside of World Heritage Site (South)	Circa 85 km new 400 kV transmission connection	Taken forward
6	East-West: Retrofitting the existing XB line or building a new 400 kV line, outside of World Heritage Site (North)	Circa 96 km new 400 kV transmission connection	Taken forward

Table 6.2: North-South potential strategic options

	Potential strategic option	Brief description	Outcome
7	North-South: Teviot to Harker	circa 51 km new 400 kV transmission connection	Merged with the 8th option and taken forward
8	North-South: Teviot to Carlisle	Circa 51 km new 400 kV transmission connection	Merged with the 7th option and taken forward
9	North-South: Teviot to Haltwhistle	Circa 45 km new 400 kV transmission connection	Merged with the 10th option and taken forward
10	North-South: Teviot to North of Haltwhistle	Circa 45 km new 400 kV transmission connection	Merged with the 9th option and taken forward
11	North-South: Teviot to Fourstones	Circa 51 km new 400 kV transmission connection	Taken forward
12	North-South: Teviot to Blyth	Circa 80 km new 400 kV transmission connection	Discounted
13	North-South: Teviot to Stella West	Circa 75 km new 400 kV transmission connection	Taken forward
14	North-South: Teviot to Carlisle – Subsea option – West	Circa 135 km new 400 kV transmission connection and 310 km new offshore subsea HVDC connection	Discounted
15	North-South: Teviot to Blyth – Subsea option – East	Circa 80 km new 400 kV transmission connection and 180 km new offshore subsea HVDC connection	Taken forward

6.1.10 From the set of strategic options presented in Table 6.1 and Table 6.2 above, several of them were modified to be taken forward onto the proposed strategic options stage, with some merging of options also taking place. The remaining options were discounted due to either non-compliance with standards or due to overall unfeasibility of the solutions.

6.1.11 With regards to the East-West options, a revision of the initial options led to the consideration of the study area spanning from the Carlisle area to Stella West, with each of the new East-West options (A, B, C) correlating with different zones of this area (northern, central and southern).

6.1.12 As set out in Chapter 4, the Harker to Stella West 275 kV XB circuit is the only East-West circuit between Central Scotland and Northern Yorkshire and Lancashire in England. This circuit is critical to rebalancing the network faults to the west or east in this region. As energy transfers increase across the B6 boundary and the need to transfer significant power following faults, the existing 275 kV capacity of 1,626 MW of these circuits and increased impedance at 275 kV compared to 400 kV prevents the required rebalancing of the network.

6.1.13 For the East-West options, NGET are currently examining the condition of the existing infrastructure to ascertain whether it can be retrofitted, but it is considered more likely that the upgrade will need to be delivered through the construction of new infrastructure.

6.1.14 The approach that has been followed within this SOR – considering a separate geographical zone as a study area for each of the strategic options – aims to ensure sufficient consideration is given to the significant constraints that are present across the project’s key regions. For example, the Frontiers of the Roman Empire (Hadrian's Wall) World Heritage Site (WHS) is a significant constraint that stretches East-West across Northern England, impacting on both the Carlisle to Newcastle and Cross Border Connection projects. Other significant constraints, such as Northumberland National Park and the North Pennines National Landscape, occupy substantial areas within the regions under consideration for these projects.

6.1.15 Therefore, by considering a wider geographical area for each end point of the strategic options (substation location), as opposed to a specific geographical point, additional consideration can be given to ways in which these strategic options could avoid impacts on the aforementioned constraints, or as a minimum, reduce the impact on the constraints.

6.1.16 In addition, through the consideration of study areas between each end of the strategic options, the appraisal is able to provide a more granular view on the required considerations in relation to key constraints, including identifying potential pinch points within the study areas, as well as possible solutions to minimise impacts on the constraints. For example, for the Carlisle to Newcastle project, three of the proposed strategic options shown within Table 6.1, comprise a study area between the Carlisle area in the West to the Stella West area in the East. However, these three East-West options consider three different zones – a northern zone, a central zone and a southern zone. This approach was required in order to ensure due consideration was given to the significance of the WHS, which stretches between the Carlisle area and the Stella West area. By considering these three zones, it became possible to consider the potential interactions on the WHS, whilst also comparing the different impacts that these three strategic options may have on the National Park, to the North, and the National Landscape to the South, as well as the WHS itself.

6.1.17 For the North-South options, Teviot to Harker and Teviot to Carlisle were merged into a wider study area and were taken forward as Teviot to Carlisle Area (North-South Option 1 from table below). In a similar manner, Teviot to Haltwhistle and Teviot to North of Haltwhistle were merged into Teviot to Haltwhistle Area (North-South Option 2).

6.1.18 Cross Border Connection: Teviot to Blyth was discounted because it was considered not viable from a technical perspective. In addition, no boundary uplift would be provided by this option, and therefore it would not meet the project need case.

6.1.19 The Cross Border Connection project includes the consideration of a subsea option to provide the required boundary capacity to the B6 boundary. A subsea option was not considered for the Carlisle to Newcastle project for the two key reasons outlined below:

- there are no feasible subsea routes between the West and East end points of the Northern England network. Any such route would need to connect the two end points by navigating either the entirety of the Scottish coastline or the West coast of England and Wales and the entirety of the South and East coast of England; and
- for a subsea option landing in the Newcastle region, there would be significant network constraints and significant onshore reinforcement works would be triggered, including new 400 kV double circuits.

6.1.20 The appraisal of all potential strategic options led to four East-West Strategic Options being selected for the Carlisle to Newcastle project, and five North-South Strategic Options being selected for the Cross Border Connection project to be taken forward for the detailed appraisal, after merging some of the strategic options, the details of which are contained within the proceeding sections. These are indicated on Table 6.3 and Table 6.4 in the following section.

6.2 Proposed strategic options

6.2.1 Four strategic options that achieve the need case of the provision of 4,000 MW of East-West transfer capacity in Northern England were proposed for detailed appraisal. These are outlined in Table 6.3 below.

6.2.2 Five strategic options that achieve the need case of the provision of transmission capacity to connect 748.28 MW of generation in the Gala area and 1,225 MW of generation in the Teviot area of Scotland, to support the provision of 10,392 MW of B6 Boundary capacity by providing 6,930 MW of the required capacity, were proposed for detailed appraisal. These are outlined in Table 6.4 below.

6.2.3 Where options are very closely aligned then options will be included for appraisal to ensure possible solutions that are of very similar capability are captured.

6.2.4 Undertaking this appraisal ensures stakeholders can see how NGET have made judgements and balanced the relevant factors in accordance with NGET’s legal duties.

Table 6.3: Proposed strategic options for Carlisle to Newcastle appraisal

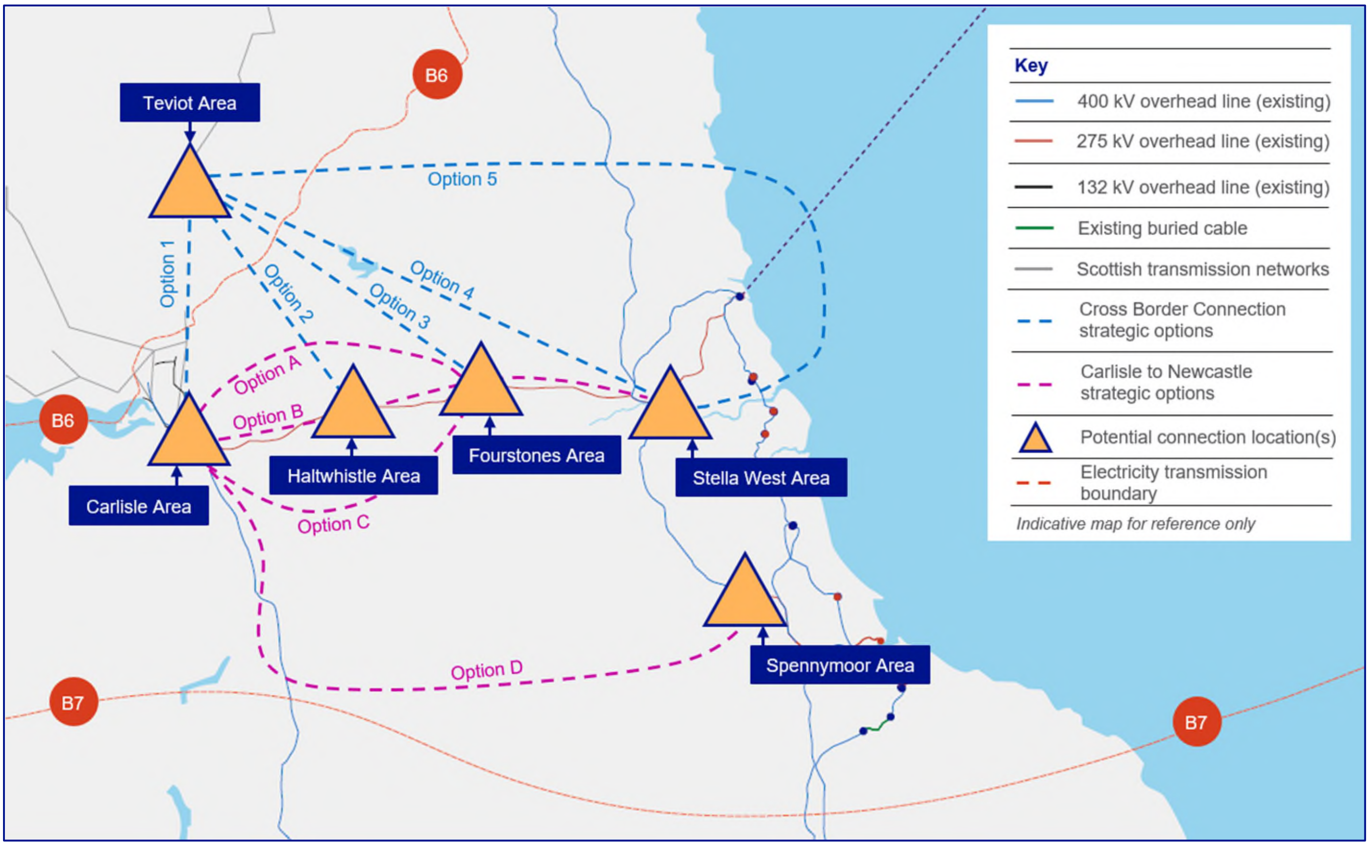
Proposed strategic option title	Option description
East-West strategic option A: Carlisle Area to Stella West Area – Northern Zone	98 km new 400 kV transmission connection
East-West Strategic Option B: Carlisle Area to Stella West Area – Central Zone	92 km new 400 kV transmission connection
East-West Strategic Option C: Carlisle Area to Stella West Area – Southern Zone	98 km new 400 kV transmission connection
East-West Strategic Option D: Carlisle Area to Spennymoor Area	174 km new 400 kV transmission connection

Table 6.4: Proposed strategic options for Cross Border Connection appraisal

Proposed strategic option title	Option description
North-South Strategic Option 1: Teviot to Carlisle Area	58 km new 400 kV transmission connection
North-South Strategic Option 2: Teviot to Haltwhistle Area	69 km new 400 kV transmission connection
North-South Strategic Option 3: Teviot to Fourstones Area	74 km new 400 kV transmission connection
North-South Strategic Option 4: Teviot to Stella West Area	104 km new 400 kV transmission connection
North-South Strategic Option 5: Teviot to Stella West Area (subsea HVDC)	146 km new 525 kV subsea transmission connection

6.2.5 Note that lengths provided above and in the following sections of the SOR correspond to straight-line points between the two locations. Further details on this are provided in Chapter 7.

Figure 6.1 – Map view of all Carlisle to Newcastle and Cross Border Connection strategic options



6.3 NGET's approach to appraising the proposed strategic options

6.3.1 Each proposed strategic option has been checked for compliance with SQSS standard and appraised against environmental, socio-economic, technical, and cost considerations. Undertaking this appraisal ensures stakeholders can see how NGET have made judgements and balanced the relevant factors in accordance with NGET's legal duties.

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

6.3.3 The assessment process considers the following areas:

- Environmental assessment 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 international and national 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 international and national important receptors.

- 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 would cause system operability issues.
- Capital and lifetime costs considers a range of factors, which are listed below;
  - Capital cost of the substation and wider works
  - Capital cost of the circuit costs for each technology appraised
  - Circuit lifetime costs, including circuit capital cost, cost of loses over 40 years and cost of operation over 40 years.

Appraisal assumptions

6.3.4 Circuit lifetime costs, including circuit capital cost, cost of losses over 40 years and cost of operation over 40 years. When considering each strategic option, we estimate circuit cost information for the following technology options for all land-based options:

- 400 kV Alternating AC OHL
- 400 kV AC underground cable (AC cable)
- 400 kV AC Gas Insulated Line (GIL)
- 525 kV HVDC underground cable and converter stations

6.3.5 When considering each strategic option, we provide 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

6.3.6 A full evaluation and costs used can be found in the Appendices.

6.3.7 In this appraisal, all strategic 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 would only be considered further in the assessment process should they become differentiating factors in the selection of the strategic option that best meets NGET's environmental and legal obligations. If these issues of delivery timescales and risk do become differentiating factors in selection of an option, the issue would be set out clearly in the options conclusion. If it is not differentiating the factor will not be considered further for this assessment.

6.3.8 At the initial appraisal stage, NGET prepare 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, NGET make equivalent assumptions for each option. Final project costs for any solution taken forward following detailed design, consenting and mitigation will be in excess of any high-level appraisal cost. However, all strategic options would incur these increases proportional to initial estimate in the development of a detailed solution. This methodology ensures that all strategic options for appraisal proposes are compared on a like for like basis.

6.3.9 Strategic options are identified at a very high level as being electrical solutions between geographic points. Therefore, the initial 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.

6.3.10 In the case of the Carlisle to Newcastle strategic options, East-West Strategic Options A, B and C use the same start and end points, with East-West Strategic Option B considered as a straight line between the two points, and East-West Strategic Options A and C providing alternatives to the North and South of East-West Option B, each of which will have a slightly deviated and longer circuit length. Where an offshore alternative is presented, straight lines will be used to a midpoint offshore and 20% added to provide variation in route length.

6.3.11 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 would be subject to detailed routeing and siting for any strategic option taken forward as a preferred option(s).

6.3.12 The strategic 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.

Summary points

6.3.13 Five strategic options that address the North-South element, and four strategic options that address the East-West element of the need case have been proposed for detailed appraisal. All of these options demonstrate comparable environmental, technical, capital and lifetime costs (including initial capital expenditures and long-term maintenance and operating costs), and socio-economic benefits. The details and results of the appraisal follow in Chapter 7 onwards.

Collaboration and co-ordination between NGET and SPT

6.3.14 For the purpose of co-ordination and to fulfil their license obligations, NGET and SPT regularly engage with each other to ensure that they are informed about the emerging options for their respective projects. This enables both parties to have in mind the approaches adopted to meet the north-south need that is addressed in this document.

6.3.15 NGET and SPT have set up a joint steering committee for Cross Border Connection project to aid co-ordination of joint approaches and activities.

6.3.16 At certain intervals, such as the conclusion of NGET's strategic options process, NGET and SPT undertake joint reviews to take outcomes into account and to assess potential impacts on their processes afterwards.

7. The results of NGET's appraisal of strategic options

7.1 Introduction

7.1.1 This chapter presents a summary of the findings of the appraisal process undertaken for each of the nine strategic options identified for the Cross Border Connection and the Carlisle to Newcastle projects. This chapter will discuss each of the options, looking at the merits and shortcomings of each option from a technical, environmental, socio-economic and cost perspective.

7.1.2 As discussed in Chapter 4, the uprating of the East-West circuits in the North of England is needed to provide the required East-West transfer capacity in Northern England, and the 400 kV connection from Scotland to England is required in order to enable the relevant generation projects to connect to the transmission network and to provide the required boundary capacity to the B6 boundary. For the purpose of this SOR, and the appraisal process that informed this SOR, the East-West Strategic Options were considered in the first instance. This was then followed by the Cross Border Connection appraisal.

7.1.3 This is because there are four strategic options to address East-West power flows, and of these, three are in alignment with NGET's existing XB line corridor, but one strategic option is located further to the south. If the options in the corridor of the XB line were to be preferred, then they would enable the possibility of connections to the Teviot substation area along that line in order to address the requirements of Scottish generation and the B6 boundary reinforcement – North-South Strategic Options 2-5. The fourth option for East-West power flows would be likely to result in different strategic options being developed for the Scottish generation and B6 boundary reinforcement needs, although North-South Strategic Option 1 would remain a possibility, due to its endpoint in the Carlisle area. If East-West Option D is discounted, the five strategic options addressing the Scottish generation and B6 boundary reinforcement needs could be addressed.

7.1.4 For each of the proposed Carlisle to Newcastle strategic options, a new substation will be needed in the Carlisle area. This would be regardless of the preferred solution for the Cross Border Connection project. Therefore, to ensure that the cost appraisal leads to a fair comparison of all options, the costs and technical considerations associated with this new substation are considered within the Carlisle to Newcastle strategic options and are not duplicated elsewhere within the appraisal (i.e. within the Cross Border Connection costs).

7.1.5 If the Cross Border Connection project connects in the Carlisle area (North-South Strategic Option 1) then construction of this project would not require simultaneous delivery of the Carlisle to Newcastle project to accommodate East-West power flows as it would not connect at a point along the XB transmission line. Although the Carlisle to Newcastle project is still required in order to deliver East-West transfer capacity in Northern England, NGET are not obliged to deliver this project at the same time as the Cross Border Connection project, because SQSS compliance allows NGET to connect and manage new connections.

7.1.6 With a connection in the Carlisle area, the Cross Border Connection project is therefore not reliant on the Carlisle to Newcastle project at the date of connection as capacity can be managed in the short term.

7.1.7 This means that, where the Cross Border Connection project connects in the Carlisle area, it could then be constructed separately from, and ahead of, the Carlisle to Newcastle project (although east/west transfer capacity would still require to be delivered through the Carlisle to Newcastle project in the short to medium term).

7.1.8 We also note that the Cross Border Connection project will require works within the licence areas of both SPT (the Transmission Owner across Southern Scotland) and NGET (the Transmission Owner across England and Wales). Where relevant, the environmental and socio-economic appraisal has considered cross-border issues, including areas within the licence areas of both SPT and NGET. Within this SOR, the lengths of the study areas, and associated circuit costs, account for the total distance from the starting point in Scotland to the end point in England. The technical appraisal, including NGET's view on required substation works, does not account for works required at substations owned and operated by SPT, or new substations that may be required within SPT's licence area.

7.1.9 The environmental and socio-economic appraisal of the strategic options primarily considers the use of OHL technology. However, where relevant, the use of underground cables is considered and discussed within the appraisal. Reference can be made to the assessment principles that will need to be applied with regard to the consideration and application of alternative solutions, such as underground cables, as set out in Section 3.5. This particularly applies to the case where an OHL route would affect the environmental and socio-economic character of a strategic option, in which case consideration of the overall benefit of feasible alternatives (e.g., undergrounding of cables) that could substitute an OHL will need to be demonstrated, as stated in paragraph 2.9.14 of the NPS for Electricity Networks Infrastructure (EN-5). However, with respect to paragraph 2.9.22 of the aforementioned NPS, to elaborate on the use of undergrounding routeing practices, undergrounding will not be required if it is unfeasible in engineering terms or "if the harm that it causes is not outweighed by its corresponding landscape, visual amenity and natural beauty benefits". With this in mind, where relevant, the strategic options appraisals presented within this SOR, take into consideration OHL alternatives, including the suitability of undergrounding, in line with the aforementioned NPS.

7.2 Appraisal of the East-West strategic options (Carlisle to Newcastle)

7.2.1 NGET are currently examining the condition of the existing infrastructure between Harker – Fourstones – and Stella West to ascertain whether it can be retrofitted, but it is considered more likely that the upgrade will need to be delivered through the construction of new infrastructure.

7.2.2 An additional consideration to the feasibility of retrofitting the existing line is to understand the potential for system outages of the existing 275 kV line. It is essential to maintain the existing 275 kV circuits in service while the new 400 kV infrastructure is being constructed, as these circuits are critical to the operation of the existing system. Any redundant parts of the existing circuits can only be removed when the new East-West circuit is operational, and the system no longer requires the 275 kV circuits for operational compliance with the NETS SQSS.

7.2.3 For the purposes of the appraisal of East-West Strategic Options A, B and C, NGET have assumed that the existing 275 kV XB line from Harker to Fourstones will be removed following the delivery of the preferred East-West Strategic Option. There is a possibility that the remainder of the XB line, from Fourstones to Stella West, could be retained, in order to maintain supply to the DNO connected at Fourstones, however, this cannot be confirmed at this stage of the project development. Where relevant, the impact that this partial retention of the existing XB line may have on NGET's appraisal is discussed within this chapter.

7.2.4 The possibility of this partial retention, including its impact, will be considered as the project develops.

7.2.5 For the purposes of the appraisal of East-West Strategic Option D, NGET have assumed that the existing 275 kV XB route is unlikely to be removed, as a minimum the section between Stella West and Fourstones would be retained.

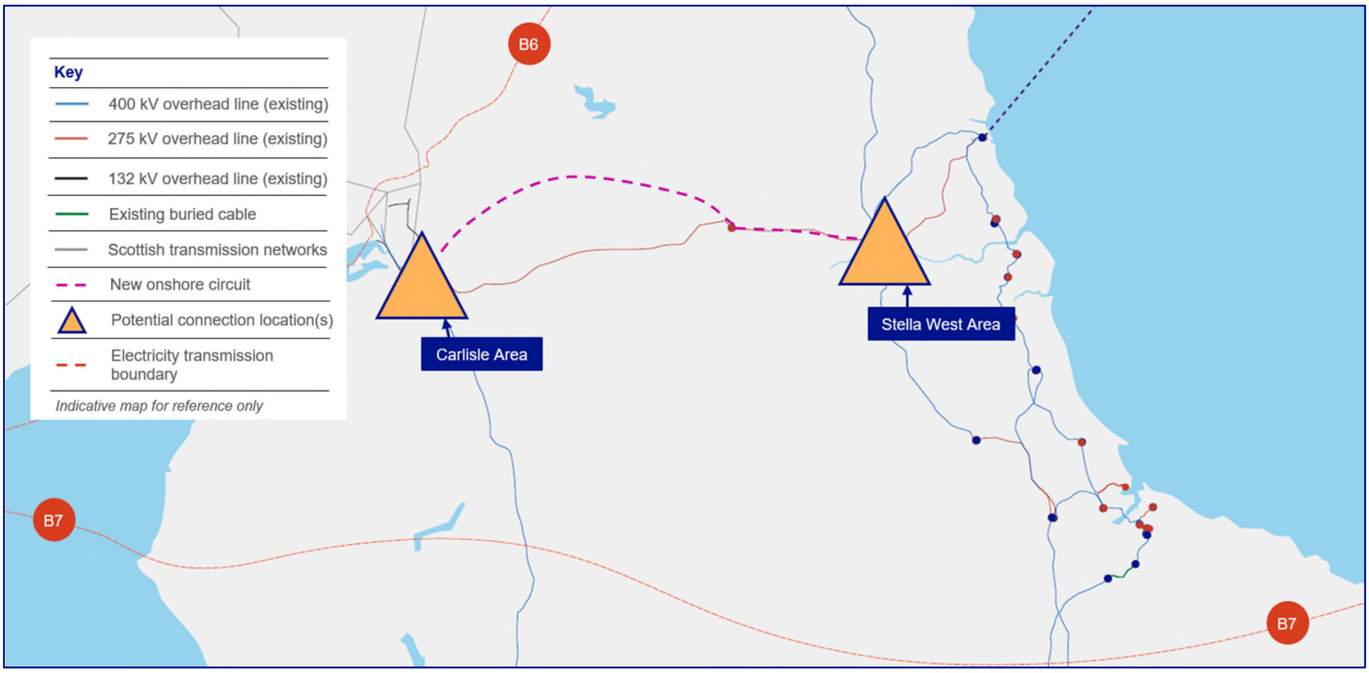
7.2.6 When considering the study area for the East-West Strategic Options, NGET have used a different approach for Options A, B and C compared to Option D, due to the geographic proximity of these options to each other. East-West strategic Options A, B and C have a study area with a 10 km width and a 5 km buffer zone, whereas, East-West Strategic Option D has a 20 km width and a 10 km buffer zone.

East-West Strategic Option A: Carlisle Area to Stella West Area – Northern Zone

Description of East-West Strategic Option A

7.2.7 East-West Strategic Option A, Carlisle Area to Stella West Area – Northern Zone, proposes the replacement of the existing 275 kV XB route with a new 400 kV line in the vicinity of the existing line, from a new 400 kV substation in the Carlisle area to the existing Stella West 400 kV substation, which will require an extension. This option considers the zone to the north of the existing XB route. A new 400 kV substation in the Fourstones area may also be required due to the existing substation’s connection to the local DNO. The study area, considered for the purposes of this appraisal, spans approximately 98 km in length and 10 km in width, based on a 5 km buffer of the centre line depicted in Figure 7.1.

Figure 7.1 – East-West Strategic Option A



Summary of the environmental appraisal

Biological Environment

7.2.8 There are a number of international and national designated ecological sites present throughout the appraisal study area comprising of SACs, SSSIs and Ramsar sites. These range in scale from smaller discrete sites that are readily avoidable to larger sites that whilst avoidable could materially influence route selection. The most notable of these are:

- River Eden and tributaries SAC and SSSI
- Components of the Border Mires, Kielder-Butterburn SAC
- Spadeham Mires SSSI, Kielder Mires SSSI and Irthinghead Mires Ramsar
- Roman Walls Loughs SAC, Roman Wall Escarpments SSSI and Greenlee Lough National Nature Reserve (NNR)
- Ryton Willows SSSI
- Hallow Hill SSSI

7.2.9 Ecological constraints occupy a significant area within the study area on the margins of and within the Northumberland National Park creating a significant pinch point. Given the location within the National Park, it is assumed that routes through this area would be comprised of underground cables, as detailed in paragraph 7.1.9. The nature of some of the designated sites, a number of which are groundwater dependents increases their sensitivity to potential impacts from underground cable routes.

7.2.10 Within the study area the scale and distribution of such constraints is such that avoidance may not be possible. In particular the section between Bewcastle and Wark where a number of designated sites are present, opportunities for avoidance are limited and the directness of route options would be affected.

7.2.11 In order to mitigate potential impacts on ecological interests as far as possible it is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard.

Physical Environment

7.2.12 Neither underlying geology or water environment constraints are considered to significantly constrain the replacement of the existing XB OHL route between the Carlisle area and Stella West.

7.2.13 Superficial geology is variable; till is present throughout, silt, sand and gravel are also present, largely following watercourses, while some small areas of peat deposits are also present.

7.2.14 There are a number of surface waterbodies present throughout the study area including the River Lyne, River North Tyne and River Tyne. None are considered to present a significant constraint to this strategic option.

7.2.15 Environment Agency (EA) Flood Maps have been reviewed to identify the extent of the study area at risk of flooding. The majority of the study area is not at risk of flooding, however, there are areas where the flood plain is relatively larger including on the River Eden east of Harker Substation and along the River South Tyne around Hexham, Corbridge and Prudhoe.

Historic Environment

7.2.16 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area, comprising a WHS - the Frontiers of the Roman Empire (Hadrian's Wall), scheduled monuments, listed buildings and registered battlefield sites.

7.2.17 The WHS extends across the study area in a broadly East-West direction. The WHS comprises of Hadrian’s Wall as well as a buffer zone which extends to the North and South of the Wall and narrows significantly around Carlisle. The buffer is not uniform either side of the Wall but is intended to provide additional protection.

7.2.18 Dependant on routeing and siting should the option proceed there is a potential need to cross the WHS as part of this option. This is a significant constraint to this option and introduces a high value receptor which could experience significant effects.

7.2.19 Consideration would need to be given to (1) the location and (2) the form of the crossing (i.e. whether by OHL or underground cable). While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.2.20 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology.

7.2.21 Subject to route selection there is potential for a replacement OHL to impact on the WHS and its setting, including a potential requirement to cross the WHS. This could include larger towers and/or towers in closer proximity to the WHS. However, there may also be opportunities for some improvements or enhancements where a replacement route increases separation distances from the WHS in comparison to the existing 275 kV XB line, although this could result in setting impacts on other scattered historic environment sites to the north of the WHS, including a number of scheduled monuments in the Bewcastle area. Should any section of the existing XB route be retained in addition to a replacement route there would be the potential for additional wirescape related impacts on the WHS and its setting. Where the replacement route and retained sections are in close proximity these could combine to increase impacts on the setting of the WHS.

7.2.22 There are approximately 203 scheduled monuments present within the study area. The majority of these are Roman features related to Hadrian's Wall and include the Wall, forts and camps. Given the distribution of scheduled monuments within the study area some setting impacts are unavoidable, in particular around Bewcastle in the West where there are clusters of scheduled monuments and in the East where there is a potential requirement to cross the Hadrian's Wall. The scale setting impacts will depend on the nature of works undertaken, for example increases in tower heights or increased proximity to scheduled monuments would increase the potential for setting impacts. Given the potential requirement to cross the Wall impacting scheduled monument(s), Scheduled Monument Consent (SMC) is likely to be required.

7.2.23 There are approximately 1,139 listed buildings present within the study area. The majority of these are located within settlements and/or coincide with individual rural properties which are avoided by the existing XB route, however, given their presence within the study area the potential remains for some setting impacts.

Landscape and Visual

7.2.24 Landscape constraints would significantly influence route selection and/or choice of technology within the study area. A route to the North of the existing XB OHL must cross a section of the Northumberland National Park. While undergrounding could prevent and reduce some impacts on the National Park, subject to route selection the loss of certain landscape features (for example forestry) could result in permanent impacts on the landscape character within the National Park.

7.2.25 At a strategic level, the primary form of mitigation is careful routeing in order to avoid nationally designated or important sites as far as possible. However, the southern end of Northumberland National Park extends across the study area meaning that there is no opportunity to avoid it. Any route through the National Park (approximately 15 km) would likely be undergrounded, as detailed in paragraph 7.1.9.

7.2.26 While undergrounding could minimise permanent landscape impacts associated with OHL towers, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts, subject to the nature of land crossed (i.e. removal of forestry and or impacts on peat/moorland).

Summary of the socio-economic appraisal

Settlement and Population

7.2.27 There are no settlement constraints or impacts which are considered to preclude or prevent further consideration of an option between the Carlisle area and Stella West. Careful routeing and siting as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

7.2.28 To the West and East of the study area at Carlisle and Stella West, settlement density is much higher with both substations being located on the margins of more urbanised areas. Much of the study area, particularly on the western end, where it may cross the WHS, is more rural and sparsely settled. Within the eastern part of the study area there are a number of smaller settlements including Hexham and Prudhoe.

7.2.29 Subject to route selection there is the potential for the new route to result in amenity impacts (noise and visual), both shorter-term temporary impacts during construction as well as longer term impacts during operation.

Tourism and Recreation

7.2.30 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present including parts of Northumberland National Park, the Pennine Way National Trail, Hadrian's Wall and Hadrian's Wall Path, also a National Trail. Potential impacts on these features comprise amenity-related impacts on visitors.

7.2.31 Impacts on the amenity of users of the Trails mentioned above would be closely inter-related with impacts on the National Park and WHS itself. A new route could be required to cross the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users. As the Pennine Way is in the National Park long-term impacts on it are likely to be avoidable due to the use of underground cables, however, Hadrian's Wall Path could be required to be crossed and subject to route selection be in close proximity to a new OHL route.

7.2.32 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. This would include making best use of landform, vegetation and other development to screen, filter or backcloth views of the route from the Trails and reduce amenity-related impacts. However, where there is a requirement to cross through the National Park, as described above, it is assumed that underground cables will be used, which will minimise permanent impacts on amenity.

Land use and other infrastructure

7.2.33 Land use and infrastructure constraints are not considered to prevent the further consideration of this strategic option, however, additional mitigation may be required in relation to potential impacts on aviation interests.

7.2.34 Part of the study area crosses a MoD (Ministry of Defence) TTA (Tactical Training Area) 20T used for low flying training between 100 and 250 feet (30 and 76 m). OHL towers carrying 400 kV circuits are expected to be between 40 m and 60 m tall. As a result, towers could pose hazard and/or restrict low flying activities. Mitigation in relation to aviation interests would be subject to consultation with the MoD and Carlisle Airport. In similar situations wind farm developers are required to utilise infrared lighting on wind turbines so it is anticipated that similar could be required for OHL towers.

7.2.35 Agricultural land classifications (ALCs) indicate that much of the study area is classed as grade 2, however, there are areas of grade 5 around Haltwhistle and Muckle Moss. Notable infrastructure includes other transmission and distribution network infrastructure particularly around Harker, Fourstones and Stella West as well as Carlisle Lake District airport.

Summary of the technical appraisal

7.2.36 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that East-West Strategic Option A would satisfy the NETS SQSS, whilst providing 4,000 MW of East-West transfer capacity in Northern England.

7.2.37 Technical analysis of this strategic option is as follows:

- This strategic option establishes a new 400 kV route, in the vicinity of the existing 275 kV XB line, between the Carlisle area and the Stella West area.
- A new substation in the Carlisle area will be required. This will be a 14-bay substation which will have a connection to the existing Harker substation.
- The existing 400 kV substation at Stella West will need to be extended, with space restrictions being apparent, due to existing structures and proximity to River Tyne.
- This option may also require a new 400 kV Fourstones substation due to the existing substation's connection to the local DNO and the need to replace the existing 275 kV XB route with a new 400 kV line. This will be an offline build.
- In terms of crossings, temporary diversion will be needed for crossing the existing XB route during construction.

Summary of the cost appraisal

7.2.38 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.2.39 East-West Strategic Option A may require the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New 400 kV substation in the Carlisle area (14 feeder bays)
  - Stella West 400 kV substation extension (2 new feeder bays)
  - New 400 kV Fourstones substation (4 feeder bays and a Super-Grid Transformer (SGT))

Table 7.1 – Capital costs for East-West Strategic Option A

Item	Capital Cost			
Substation and Wider Works	£217m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (98 km)	£390.0m	£4,210.2m	£4,239.5m	£2,511.6m
Total Capital Cost	**£607.0m**	**£4,427.2m**	**£4,456.5m**	**£2,728.6m**

7.2.40 Table 7.2 below 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 Appendix D.

Table 7.2 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£390.0m	£4,210.2m	£4,239.5m	£2,511.6m
Net Present Value (NPV) of Cost of Losses over 40 years	£274.9m	£204.6m	£127.6m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£5.7m	£19.5m	£5.8m	£172.2m
Lifetime Cost of New Circuits	**£671m**	**£4,434m**	**£4,373m**	**£3,155m**

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

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

7.2.42 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.2.43 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.2.44 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

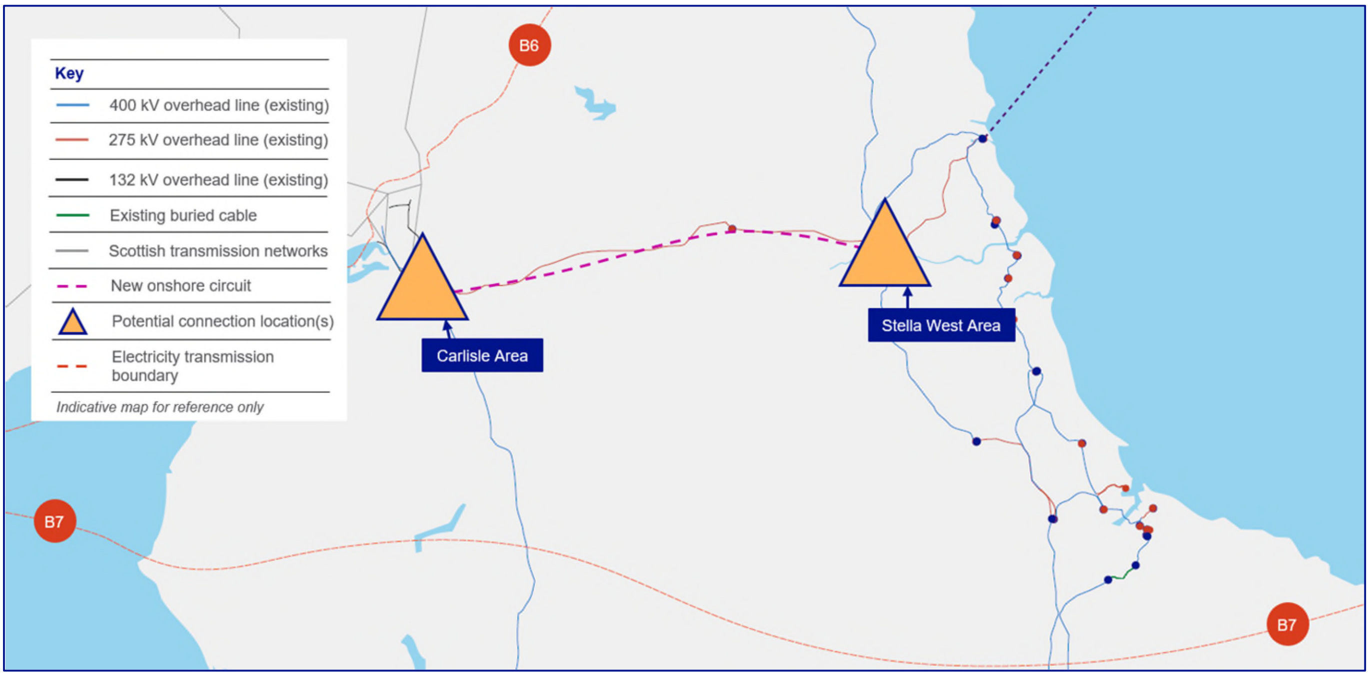
7.2.45 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for East-West Strategic Option A is a 98 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

East-West Strategic Option B: Carlisle Area to Stella West Area – Central Zone

Description of East-West Strategic Option B

7.2.46 East-West Strategic Option B, Carlisle Area to Stella West Area – Central Zone, proposes the replacement of the existing 275 kV XB route with a new 400 kV line in the vicinity of the existing line, starting at a new 400 kV substation in the Carlisle area and terminating at the existing Stella West substation. This option considers the central zone along the existing XB route. A new 400 kV Fourstones substation may be required, as well as an extension of the existing Stella West substation, to facilitate the strategic option. The study area, considered for the purposes of this appraisal, spans approximately 92 km in length and 10 km in width, based on a 5 km buffer of the centre line as depicted in Figure 7.2.

Figure 7.2 – East-West Strategic Option B



Summary of the environmental appraisal

Biological Environment

7.2.47 There are a number of international and national designated ecological sites present throughout the appraisal study area comprising SACs, SSSIs and Ramsar sites. These are typically smaller scale discrete sites that are readily avoidable with careful routeing. The most notable of these are:

- River Eden and tributaries SAC and SSSI
- Components of the Border Mires, Kielder-Butterburn SAC, including Kielder Mires SSSI and Muckle Moss SSSI and NNR

- North Pennine Moors SPA and SAC, Whitfield Moor, Plenmeller and Ashholme Commons SSSI
- Roman Walls Loughs SAC, Roman Wall Escarpments SSSI and Greenlee Lough NNR

7.2.48 There are no ecological constraints or impacts which are considered to prevent further consideration of this strategic option. Ecological designations are largely considered to be avoidable subject to other routeing considerations.

7.2.49 There are some areas where larger designations are present which would significantly influence route selection, in particular the section of the study area between Haltwhistle and Haydon Bridge where The Northumberland National Park and North Pennines National Landscape extend from the north and south to create a pinch point.

7.2.50 Within the study area the scale and distribution of such constraints is such that, subject to other factors, they are largely avoidable by careful routeing. In identifying a route, consideration should be given to the proximity of designated sites and maximising separation distance as much as possible.

7.2.51 A number of designations are water and/or groundwater based so depending on the proximity of works there is the potential for pollution, sedimentation and/or dewatering impacts. Other sites are designated for woodland or other flora as well as geological reasons. Good practice construction methods following pollution prevention guidance and effective construction drainage should prevent significant impacts from occurring.

Physical Environment

7.2.52 Neither underlying geology nor water environment constraints are considered to significantly constrain this strategic option.

7.2.53 Superficial geology is variable; till is present throughout, silt, sand and gravel are also present largely following watercourses while some small areas of peat deposits are also present to the South of the study area coinciding with the North Pennine Moors.

7.2.54 There are a number of surface waterbodies present throughout the study area including the River Eden, River Irthing, River Gell, River South Tyne and River Tyne. None are considered to present a significant constraint to routeing. Subject to route selection there is potential for pollution related impacts.

7.2.55 EA Flood Maps have been reviewed to identify the extent of the study area at risk of flooding. The majority of the study area is not at risk of flooding, however, there are areas where the flood plain is relatively larger including on the River Eden East of Harker Substation and along the River South Tyne around Hexham, Corbridge and Prudhoe.

Historic Environment

7.2.56 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area comprising a WHS - the Frontiers of the Roman Empire (Hadrian's Wall), scheduled monuments, listed buildings and registered battlefield sites.

7.2.57 Dependant on routing and siting should the option proceed, there is a potential need to cross the WHS as part of this option. This is a significant constraint to this option and introduces a high value receptor which could experience significant effects.

7.2.58 Consideration would need to be given to (1) the location and (2) the form of the crossing (i.e. whether by OHL or underground cable). While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.2.59 Where the existing XB route is replaced by a new route this could potentially minimise impacts to the setting in the long-term, however, where sections of the existing XB route are retained in the long-term in addition to the replacement route, this could result in increased impacts due to the additional wirescape. Careful route selection would be required to ensure a new OHL does not result in significantly increased impacts on the setting of the WHS while opportunities to improve the setting, for example through tower placement should be considered. In addition, the existing XB route would need to remain in place during construction and facilitation of the new line, meaning that, for a period of time, two lines would be present in that area.

7.2.60 The existing XB OHL is well established within the buffer zone of the WHS and the setting of Hadrian's Wall, along with its associated scheduled monuments. While some impacts on the setting are unavoidable due to the extensive presence of historic environment interests, these impacts must be considered in the context of the existing OHL infrastructure.

7.2.61 The WHS and its buffer zone extend predominantly from west to east across the study area. Much of the current XB route lies within this buffer zone or is routed to the south of it, and it is notably established in the vicinity of Hadrian's Wall, including a crossing to the east of Harker Substation.

7.2.62 As plans for a potential replacement OHL are considered, there is a possibility of impacting the WHS and its setting, which may necessitate crossing the WHS itself. This could involve the installation of larger towers or positioning them closer to the WHS. However, there may also be opportunities to enhance the situation by selecting a replacement route that increases the separation distance from the WHS in comparison to the existing 275 kV XB line, thereby minimising potential impacts.

7.2.63 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology.

7.2.64 There are approximately 243 scheduled monuments present within the study area. The majority of these are Roman features related to Hadrian's Wall and include the Wall, forts and camps. Given the distribution of scheduled monuments within the study area some setting impacts are unavoidable.

7.2.65 The scale of setting impacts will depend on the nature of works undertaken, for example increases in tower heights or increased proximity to scheduled monuments would increase the potential for setting impacts. However, there may also be some opportunities for improvement by increasing separation distances from scheduled monuments, for example east of the A68 where the existing XB route is located on a scheduled monument. Given the potential requirement to cross the Hadrian's Wall impacting scheduled monument(s), SMC is likely to be required.

7.2.66 There are approximately 1,720 listed buildings present within the study area. The majority of these are located within settlements and/or coincide with individual rural properties which are avoided by the existing XB route, however, given their presence within the study area the potential remains for some setting impacts.

Landscape and Visual

7.2.67 Landscape constraints would significantly influence route selection and/or choice of technology within the study area. Landscape designations are considered to be avoidable, however, subject to other routeing considerations there is the potential for routes to be in close proximity to them or cross them. This is particularly the case for the section between Greenhead-Haltwhistle-Haydon Bridge-Fourstones where the National Park extends from the North, and the National Landscape from the south to create a pinch point.

7.2.68 The southern end of Northumberland National Park slightly extends into the northern part of the study area between Greenhead and Walwick. The existing XB route is located to the South the National Park.

7.2.69 At a strategic level, the primary form of mitigation is careful routeing in order to avoid nationally designated or important sites as far as possible. Subject to route selection an OHL would impact on landscape: a route to the North through the National Park directly impacting it or a route to the south which may impact on its setting or views from it. Any route through the National Park would likely be undergrounded, as set out in paragraph 7.1.9. Subject to route selection this could be in the order of 22 km.

7.2.70 While undergrounding could minimise permanent landscape impacts associated with OHL towers, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts.

7.2.71 The North Pennines National Landscape lies to the South of the study area extending into it South of Brampton and South of Haydon Bridge. Potential impacts on the National Landscape will depend on route selection. It can be avoided to the North, however, there is the potential for impacts on its setting.

7.2.72 If it is not avoided, the National Landscape would require to be crossed by underground cables. These would minimise permanent impacts associated with towers, however, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts.

Summary of the socio-economic appraisal

Settlement and Population

7.2.73 There are no settlement constraints or impacts which are considered to prevent further consideration of an option between the Carlisle area and the Stella West area. Careful routeing as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

7.2.74 A number of towns and villages as well as individual properties are present within the study area, typically located adjacent to the River South Tyne. From West to East this includes Carlisle, Warwick Bridge, Brampton, Haltwhistle, Wylam, Heddon on the Wall and Ryton. Larger settlements are present at either side of the study area.

7.2.75 Subject to route selection and proximity to settlements there is the potential for amenity-related impacts (noise and visual). This includes shorter-term temporary impacts during construction as well as longer term impacts on amenity during operation.

Tourism and Recreation

7.2.76 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present including parts of Northumberland National Park, the Pennine Way National Trail, Hadrian's Wall and Hadrian's Wall Path, also a National Trail. The route of both Trails is such that a new OHL route could parallel them and provide extended views of long sections of a new route. Potential impacts on these features comprise amenity-related impacts on visitors.

7.2.77 Impacts on the amenity of users of the Trails mentioned above would be closely inter-related with impacts on the National Park and WHS itself. Any route would be required to run close to and potentially parallel to sections of the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users. Subject to route selection there is the potential for a new route to impact on visitors to the park and Hadrian's Wall as well as users of the National Trails. Should the route be routed through the National Park it is assumed it will be underground which will minimise permanent impacts on amenity, however, elsewhere within the study area mitigation would be focused on route selection

7.2.78 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible, making best use of landform, vegetation and other development to screen, filter or backcloth views would be required to reduce impacts.

Land use and other infrastructure

7.2.79 There are no land use or infrastructure constraints or impacts which are considered to prevent the further consideration of this strategic option.

7.2.80 ALCs indicate that much of the study area is classed as grade 3, however, there are areas of grade 5 around Haltwhistle and Muckle Moss which coincide with peaty ground conditions.

7.2.81 Notable infrastructure includes other transmission and distribution network infrastructure particularly around Harker, Fourstones and Stella West as well as transport infrastructure including Carlisle Lake District Airport which is 2 km of the existing XB route and the Tyne Valley Railway line which is routed across parts of the study area and may require to be crossed, subject to route selection. Airport aviation-related mitigation may be required.

Summary of the technical appraisal

7.2.82 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that East-West Strategic Option B would satisfy the NETS SQSS, whilst providing 4,000 MW of East-West transfer capacity in Northern England.

7.2.83 Technical analysis of this strategic option is as follows:

- This strategic option establishes a new 400 kV route, in the vicinity of the existing 275 kV XB line, between the Carlisle area and the Stella West area.
- A new substation in the Carlisle area will be required. This will be a 14-bay substation which will have a connection to the existing Harker substation.

- The existing 400 kV substation at Stella West will need to be extended (four bays and an SGT), with space restrictions being apparent, due to existing structures and proximity to River Tyne.
- This option may also require a new 400 kV Fourstones substation due to the existing substation's connection to the local DNO and the need to replace the existing 275 kV XB route with a new 400 kV line. This will be an offline build.
- In terms of crossings, temporary diversion will be needed for crossing the existing XB route during construction.
- This option aims to facilitate the new 400 kV connections on both ends of the existing 400 kV GIS substation, navigating spatial constraints posed by surrounding geography and infrastructure.

Summary of the cost appraisal

7.2.84 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.2.85 East-West Strategic Option B may require the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New 400 kV substation in the Carlisle area (14 feeder bays)
  - Stella West 400 kV substation extension (2 new feeder bays)
  - New 400 kV Fourstones substation (4 feeder bays and an SGT)

Table 7.3 – Capital costs for East-West Strategic Option B

Item	Capital Cost			
Substation and Wider Works	£217m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (92 km)	£366.2m	£3,953.4m	£3,979.9m	£2,456.0m
Total Capital Cost	**£583.2m**	**£4,170.4m**	**£4,196.9m**	**£2,673.0m**

7.2.86 Table 7.4 below 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 Appendix D.

Table 7.4 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£366.2m	£3,953.4m	£3,979.9m	£2,456.0m
NPV of Cost of Losses over 40 years	£258.1m	£190.1m	£119.8m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£5.4m	£18.5m	£5.4m	£172.2m
Lifetime Cost of New Circuits	**£630m**	**£4,162m**	**£4,105m**	**£3,099m**

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

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

7.2.88 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.2.89 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.2.90 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

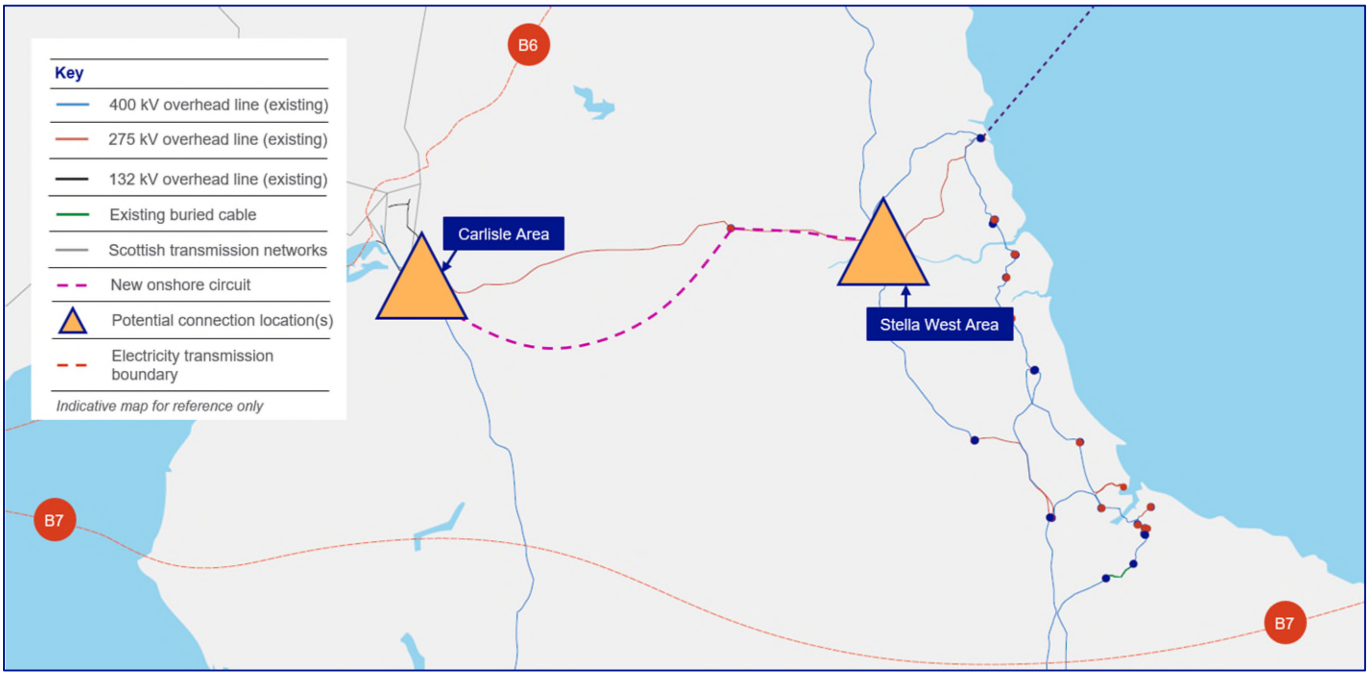
7.2.91 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for East-West Strategic option B is a 92 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

East-West Strategic Option C: Carlisle Area to Stella West Area – Southern Zone

Description of East-West Strategic Option C

7.2.92 East-West Strategic Option C, Carlisle Area to Stella West Area – Southern Zone, proposes the replacement of the existing 275 kV XB route with a new 400 kV line in the vicinity of the existing line, starting at a new 400 kV substation in the Carlisle area and terminating at the existing Stella West substation. This option considers the zone to the south of the existing XB route. A new 400 kV Fourstones substation may be required, as well as an extension of the existing Stella West substation, to facilitate the strategic option. The study area, considered for the purposes of this appraisal, spans approximately 98 km in length and 10 km in width, based on a 5 km buffer of the centre line depicted in Figure 7.3.

Figure 7.31 – East-West Strategic Option C



Summary of the environmental appraisal

Biological Environment

7.2.93 There are a number of international and national designated ecological sites present throughout the appraisal study area comprising SACs, SSSIs and Ramsar sites. These range in scale from smaller discrete sites that are readily avoidable to larger sites that, whilst avoidable, could materially influence route selection. The most notable of these are:

- River Eden and tributaries SAC and SSSI
- Unity Bog SSSI
- North Pennine Moors SAC, SPA and Area of Outstanding Natural Beauty (AONB)
- Geltsdale & Glendue Fells SSSI, Whitfield Moor, Plenmeller and Ashholme Commons SSSI and Hexhamshire Moors SSSI

7.2.94 Ecological constraints comprising the North Pennine Moors SPA and SAC (and associated SSSIs) designated principally in respect of its blanket bog and peat habitat, occupy a significant area within the study area, creating a significant pinch point. This area coincides with the National Landscape where it is expected any route would be comprised of underground cables, as detailed in paragraph 7.1.9. The nature of some of the designated sites, a number of which are groundwater dependents, increases their sensitivity to potential impacts from underground cable routes.

7.2.95 Within the study area there is some scope to avoid the North Pennine Moors SAC, North Pennine Moors SPA, Geltsdale & Glendue Fells SSSI, Whitfield Moor, Plenmeller and Ashholme Commons SSSI and Hexhamshire Moors SSSI, however, this is limited to a narrow part of the study area on its northern extent. Should these sites be unavoidable, careful micro-routeing would be required, taking account of the habitats/species for which they are designated. Where any area coincides with the National Landscape and underground cables are expected to be used, the construction footprint should be minimised as far as possible to reduce disturbance, and habitats reinstated following construction.

7.2.96 It is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard.

Physical Environment

7.2.97 Neither underlying geology nor water environment constraints are considered to significantly constrain this strategic option.

7.2.98 Superficial geology is variable; till is prevalent to the North of the study area with some areas of silt, sand and gravel also present largely following watercourses. Large areas of peat are present extending from the South of the study area northwards coinciding with the ecological designations identified above.

7.2.99 Peat/peaty soils could impact on, as well as be impacted by, new electricity transmission infrastructure. Peat does not provide suitable ground conditions for construction and is more complex in engineering terms. Impacts include increases in peat slide risks and the loss of peat or peaty soils which would otherwise act as a carbon sink.

7.2.100 There are a number of surface waterbodies present throughout the study area including the River Eden, River South Tyne, River West Allen and River Tyne. None are considered to present a significant constraint to this strategic option.

7.2.101 EA Flood Maps have been reviewed to identify the extent of the study area at risk of flooding. The majority of the study area is not at risk of flooding, however, some areas in the immediate vicinity of rivers and other watercourses are within flood risk zones.

Historic Environment

7.2.102 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area, comprising a WHS - the Frontiers of the Roman Empire (Hadrian's Wall), scheduled monuments, listed buildings and registered battlefield sites.

7.2.103 The WHS extends across the study area in a broadly East-West direction. The WHS comprises Hadrian’s Wall as well as a buffer zone which extends to the North and South of the Wall and narrows significantly around Carlisle. The buffer is not uniform either side of the Wall but is intended to provide additional protection.

7.2.104 Dependant on the routing and siting should the option proceed, there is a potential need to cross the WHS as part of this option. This is a significant constraint to this option and introduces a high value receptor which could experience significant effects.

7.2.105 Consideration would need to be given to (1) the location and (2) the form of the crossing (i.e. whether by OHL or underground cable). While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.2.106 Where the existing XB route is replaced by a new route in the southern part of the study area this could result in some positive impacts on the setting of the WHS in comparison to the existing 275 kV XB line, however, where sections of the existing XB route are retained in the long-term, in addition to the new route, this could result in increased impacts due to the additional wirescape. Careful route selection would be required to ensure a new OHL does not result in significantly increased impacts on the setting of the WHS while opportunities to improve the setting, for example through tower placement should be considered.

7.2.107 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology

7.2.108 While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS. However, eastwards of the crossing the study area spans South of the Hadrian's Wall and could result in some positive impacts through localised improvements to its setting.

7.2.109 There are approximately 134 scheduled monuments present within the study area, some of which relate to Hadrian's Wall and include the Wall, forts and camps. The scale and distribution of the majority of scheduled monuments within the study area is such that direct physical impacts are unlikely to occur, however, some setting impacts are unavoidable. The scale or magnitude of the setting impacts will depend on route selection.

7.2.110 With regard to Hadrian's Wall, it is comprised of a number of scheduled monuments ranging from the remains of the Wall itself to forts or encampments. A crossing of Hadrian's Wall could be required, directly impacting scheduled monument(s) and would require SMC due to the potential for disturbance.

7.2.111 There are approximately 1,805 listed buildings present within the study area. The majority of these are located within settlements and/or coincide with individual rural properties which are avoided by the existing XB route, however, given its proximity the potential remains for some setting impacts.

Landscape and Visual

7.2.112 Landscape constraints would significantly influence route selection and/or choice of technology within the study area. A route to the South of the existing XB route is significantly constrained by the extent of the North Pennine Moors National Landscape within the study area. While there may be some opportunities to avoid the National Landscape, these are limited to a narrow section of the area. Where the National Landscape is unavoidable, undergrounding would likely be required. This will prevent and reduce some impacts on the National Landscape but subject to route selection and reinstatement, there is the potential for permanent landscape impacts. Therefore, as detailed in paragraph 7.1.9, the visual benefits associated with undergrounding will need to be considered alongside any potential impacts or harms to the local environment.

7.2.113 At a strategic level, the primary form of mitigation is careful routeing in order to avoid nationally designated landscapes or sites as far as possible. The northern parts of the North Pennines National Landscape extend into the study area occupying significant sections of it, between the South/Southeast of Brampton and South/Southwest of Hexham. There are some limited opportunities to avoid it within a narrow section to the North of the study area. Any route through the National Landscape (approximately 38 km) would likely be undergrounded, as detailed in paragraph 7.1.9.

7.2.114 While undergrounding could minimise permanent landscape impacts associated with OHL towers, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts subject to the nature of land crossed (i.e. removal of forestry and or impacts on peat/moorland).

Summary of the socio-economic appraisal

Settlement and Population

7.2.115 There are no settlement constraints or impacts which are considered to prevent further consideration of this strategic option. Careful routeing as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

7.2.116 Population density within the study area is variable with relatively more urbanised areas to the West and East coinciding with Harker and Stella West Substations and more rural areas to the South and middle of the study area coinciding with the North Pennines.

7.2.117 Subject to route selection and proximity to settlements there is the potential for amenity-related impacts (noise and visual). This includes shorter-term temporary impacts during construction as well as longer term impacts on amenity during operation.

Tourism and Recreation

7.2.118 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present including the Pennine Way National Trail, Hadrian's Wall and Hadrian's Wall Path, also a National Trail. Potential impacts on these features comprise amenity-related impacts on visitors.

7.2.119 Impacts on the amenity of users of the Trails mentioned above would be closely inter-related with impacts on the WHS and North Pennines National Landscape. A new route could potentially be required to cross both the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users. The scale of impacts on the amenity of trail users would be subject to how (i.e. overhead or underground) and where the Trails are crossed.

7.2.120 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. Subject to route selection there is the potential for a new route to impact on visitors to Hadrian's Wall as well as on users of the National Trail. Mitigation in relation to the WHS (i.e. the location of the crossing of the Wall/trail and technology) would also influence impacts on users of Hadrian's Wall Path.

7.2.121 Mitigation in relation to the North Pennines National Trail would depend on where it is crossed. A large section is outside of the National Landscape where it is assumed it would be crossed by an OHL , in which case mitigation would be focused on making best use of landform and/or vegetation to screen, filter or backcloth views of the route from the Trail and reduce amenity-related impacts. Inside the National Landscape it is assumed it would be crossed by an underground cable which would minimise permanent impacts on amenity.

Land use and other infrastructure

7.2.122 There are no land use or infrastructure constraints or impacts which are considered to prevent the further consideration of this strategic option.

7.2.123 ALCs indicate the much of the study area is classed as grade 2 (very good quality agricultural land) or 3 (good to moderate quality agricultural land), however, there are areas of grade 5 (poor quality agricultural land) in the central and southern part of the study area between Brampton and Haydon Bridge.

7.2.124 Notable infrastructure includes other transmission and distribution network infrastructure particularly around Harker and Stella West Substations.

Summary of the technical appraisal

7.2.125 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that East-West Strategic Option C would satisfy the NETS SQSS, whilst providing 4,000 MW of East-West transfer capacity in Northern England.

7.2.126 Technical analysis of this strategic option is as follows:

- This strategic option establishes a new 400 kV route, in the vicinity of the existing 275 kV XB line, between the Carlisle area and the Stella West area.
- A new substation in the Carlisle area will be required. This will be a 14-bay substation which will have a connection to the existing Harker substation.
- The existing Stella West substation will need to be extended, with space restrictions being apparent, due to existing structures and proximity to the River Tyne.
- This option may also require a new 400 kV Fourstones substation due to the existing substation’s connection to the local DNO and the need to replace the existing 275 kV XB route with a new 400 kV line. This will be an offline build.
- In terms of crossings, temporary diversion will be needed for crossing the existing XB route during construction.

Summary of the cost appraisal

7.2.127 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.2.128 East-West Strategic Option C may require the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New 400 kV substation in the Carlisle area (14 feeder bays)
  - Stella West 400 kV substation extension (2 new feeder bays)
  - New 400 kV Fourstones substation (4 feeder bays and an SGT)

Table 7.5 – Capital costs for East-West Strategic Option C

Item	Capital Cost			
Substation and Wider Works	£217m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (98 km)	£390.0m	£4,210.2m	£4,239.5m	£2,511.6m
Total Capital Cost	**£607.0m**	**£4,427.2m**	**£4,456.5m**	**£2,728.6m**

7.2.129 Table 7.6 below 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 Appendix D.

Table 7.6 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£390.0m	£4,210.2m	£4,239.5m	£2,511.6m
NPV of Cost of Losses over 40 years	£274.9m	£204.6m	£127.6m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£5.7m	£19.5m	£5.8m	£172.2m
Lifetime Cost of New Circuits	**£671m**	**£4,434m**	**£4,373m**	**£3,155m**

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

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

7.2.131 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.2.132 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance.

The same applies for the crossing that would be required for the roads and rail lines involved.

7.2.133 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

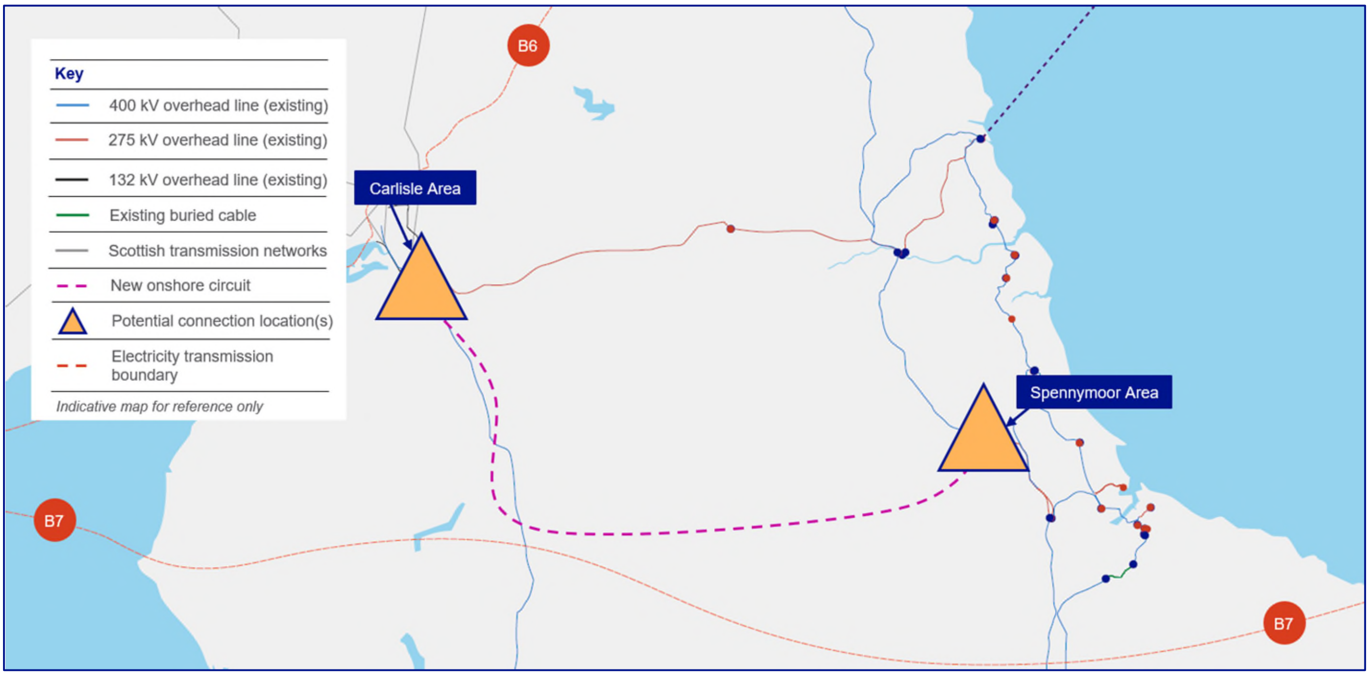
7.2.134 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for East-West Strategic Option C is a 98 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

East-West Strategic Option D: Carlisle Area to Spennymoor Area

Description of East-West Strategic Option D

7.2.135 A new (174 km) 400 kV line from a new substation in the Carlisle area to the existing 400 kV substation in the Spennymoor area, which will require an extension. This option would not be proximate to Fourstones substation and therefore in order to maintain supply to the DNO connected at Fourstones a separate connection to the substation would be required. The existing 275 kV XB route is unlikely to be removed, as a minimum the section between Stella West and Fourstones would be retained. This East-West option would not facilitate a connection with North-South options 2-5. The study area, considered for the purposes of this appraisal, spans approximately 146 km in length and 20 km in width, based on a 10 km buffer of the centre line and is depicted in Figure 7.4.

Figure 7.4 – East-West Strategic Option D



Summary of the environmental appraisal

Biological Environment

7.2.136 There are a number of international and national designated ecological sites present within or on the margins of the appraisal study area comprising SPAs, SACs, SSSIs and Ramsar sites. These range in scale from smaller discrete sites that are readily avoidable to larger sites that whilst avoidable could materially influence route selection. The most notable of these are:

- River Eden and tributaries SAC and SSSI
- Lazonby Fell and Wan Fell SSSIs
- Asby Complex SAC
- Crosby Ravensworth Fell, Great Asby Scar and Sunbiggin Tarn & Moors and Little Asby Scar SSSIs
- North Pennine Moors SAC and SPA
- Cotherstone Moor, Lune Forest and Bowes Moor SSSIs

7.2.137 Ecological constraints occupy significant sections within the study area, in particular the North Pennine Moors SPA and SAC (and associated SSSIs) designated principally in respect of its blanket bog and peat habitat which cannot be avoided in the section between Appleby-in-Westmorland and Barnard Castle. These sites are a significant routeing constraint with potential to experience significant impacts and would affect the availability of mitigation and feasibility of this option.

7.2.138 Within the study area the scale and distribution of many constraints is such that, subject to other factors, they are largely avoidable by careful routeing. However, the scale of some sites mean that they will require to crossed by route options. Where sites are unavoidable, crossings of them should be as direct as possible to reduce the potential for impacts.

7.2.139 It is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard. This would prevent or reduce potential impacts on designated sites which are surface water and/or ground water dependent.

7.2.140 Due to the proximity to the North Pennine Moors SPA, site specific mitigation may be required to reduce impacts on protected bird species.

Physical Environment

7.2.141 While physical environmental constraints are not considered to prevent the further consideration of an option within the study area, the extensive peat deposits between Brough and Bowes would significantly influence design.

7.2.142 Superficial geology is variable throughout the study area. Much of the area is underlain by till with silt, sand or clay present along the river valleys, such as in the vicinity of the River Eden. Large areas of peat deposits are present between Brough and Bowes, largely coinciding with North Pennine Moors SAC and associated SSSIs. Peat does not provide suitable ground conditions for construction and is more complex in engineering terms. Impacts include increases in peat slide risks and the loss of peat or peaty soils which would otherwise act as a carbon sink.

7.2.143 There are a large number of surface waterbodies present throughout the study area including main rivers and ordinary watercourses. The River Eden flows broadly south to north through a significant section between Kirkby Stephen and Carlisle with a number of watercourses draining from the West and East.

7.2.144 None of the waterbodies or watercourses are considered to present a significant constraint to routeing within the study area as they can all be spanned by OHL routes, however, subject to route selection and tower positioning there is potential for impacts from pollution and sedimentation during construction.

7.2.145 EA Flood Maps have been reviewed to identify the extent of the study area at risk of flooding. The majority of the study area is not at risk of flooding. There are some larger areas at risk of flooding present along the River Eden, however, these are avoidable.

Historic Environment

7.2.146 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area, comprising a WHS - the Frontiers of the Roman Empire (Hadrian's Wall), scheduled monuments, listed buildings and registered battlefield sites.

7.2.147 Dependant on routing and siting should the option proceed, there is a potential need to cross the WHS as part of this option. This is a significant constraint to this option and introduces a high value receptor which could experience significant effects.

7.2.148 While the majority of historic environment constraints are considered to be avoidable with careful routeing and/or siting, there is high potential for setting impacts due to the number and distribution of designated sites. Assuming that this option replaces the existing XB route, with the new 400 kV line not being located within the vicinity of the WHS, it would result in positive impacts on the setting of the WHS and associated scheduled monuments through the removal of the majority of the existing line. However, it would remain necessary to maintain a portion of the existing XB route to serve Fourstones Substation and maintain supplies to the DNO connected at that location.

7.2.149 Consideration would need to be given to (1) the location and (2) the form of the crossing (i.e. whether by OHL or underground cable). While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.2.150 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology.

7.2.151 While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.2.152 There are approximately 429 scheduled monuments present within the study area, some of which relate to Hadrian’s Wall and the WHS. The scale and distribution of the majority of scheduled monuments within the study area is such that direct physical impacts are unlikely to occur, however, some setting impacts are unavoidable. The scale or magnitude of the setting impacts will depend on route selection. With regard to Hadrian’s Wall, it is comprised of a number of scheduled monuments ranging from the remains of the Wall itself to forts or encampments.

7.2.153 There are approximately 4,425 listed buildings present within the study area. The majority of these are located within settlements and/or coincide with individual rural properties. Due to their relative small-scale, impacts on listed buildings are considered to be avoidable with careful routeing, however, there is the potential for setting impacts.

Landscape and Visual

7.2.154 Landscape constraints would significantly influence route selection and/or choice of technology within the study area. The North Pennines National Landscape is paralleled and then crossed by the study area. Subject to route selection close to and within the National Landscape there is the potential for permanent impacts on landscape character within and in the setting of the designation.

7.2.155 The study area is located adjacent to the western boundary of the North Pennines National Landscape for a significant proportion of its length (c.50 km). Where the study area follows the boundary, subject to route selection, there is the potential for impacts on the setting of the National Landscape as well as on views from within it. There is a requirement to cross the National Landscape between Brough and Bowes.

7.2.156 At a strategic level, the primary form of mitigation is careful routeing in order to avoid nationally designated or important sites as far as possible. Subject to route selection a crossing would be in the order of 12-25 km long. Any route through the National Landscape would likely be undergrounded, as detailed in paragraph 7.1.9, subject to this being acceptable in terms of impacts on other receptors such as irreplaceable habitats.

7.2.157 While undergrounding could minimise permanent landscape impacts associated with OHL towers, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts subject to reinstatement.

Summary of the socio-economic appraisal

Settlement and Population

7.2.158 There are no settlement constraints or impacts which are considered to prevent the further consideration of an option within the study area. Careful routeing as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible. Settlement density within the study area is highly variable with a large number of settlements present ranging from large towns to villages as well as individual rural properties or small clusters of properties. Notable settlements include Carlisle, Penrith, Appleby-in-Westmorland, Barnard Castle, Newton Aycliffe and Bishop Auckland.

7.2.159 Subject to route selection and proximity to settlements there is the potential for amenity-related impacts (noise and visual). This includes shorter-term temporary impacts during construction as well as longer term impacts on amenity during operation.

Tourism and Recreation

7.2.160 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions are present including part of Hadrian's Wall and Hadrian's Wall Path (also a National Trail) and sections of the Pennine Way National Trail. Hadrian's Wall and the related Trail would be crossed by the route to the southeast of Harker with potential impacts on users of the Trail and/or visitors to the Wall.

7.2.161 Impacts on the amenity of users of the Trails mentioned above would be closely inter-related with impacts on the National Landscape and WHS itself. Any route would be required to run close to and potentially parallel to sections of the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users.

7.2.162 The Pennine Way route is such that subject to routeing there may be views of an OHL where routes may parallel the Trail as well as cross the Trail. Where the Trail requires to be crossed it coincides with the National Landscape so is assumed to be crossed by an underground cable. Potential impacts on the Trail relate to amenity-related impacts (visual and noise) on users of the Trail.

7.2.163 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. This would include making best use of landform, vegetation and other features in the landscape to screen, filter or backcloth views of the route from the Trail and reduce amenity-related impacts. Where the Trail is crossed in the National Landscape it is assumed routes will be underground which will minimise permanent impacts on amenity.

Land use and other infrastructure

7.2.164 There are no land use or infrastructure constraints or impacts which are considered to prevent or significantly influence further consideration of a route within the study area between the Carlisle area and Spennymoor.

7.2.165 ALCs indicate that much of the study area is classed as grade 3 (good to moderate quality agricultural land) to the west and east of the Pennines with small areas of grade 2 (very good quality agricultural land). A large area within the Pennines is classed as grade 5 (very poor-quality agricultural land) which coincides with peaty ground conditions identified by the British Geological Survey (BGS).

7.2.166 Notable infrastructure includes other transmission and distribution network infrastructure particularly around Harker. This includes the ZX route which is located within the study area for a significant section. Major road and railway corridors are present within the area including the M6 and A66 as well as part of the West Coast Mainline which provide established linear features which could be followed subject to other routeing constraints.

Summary of the technical appraisal

7.2.167 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that this East-West Strategic Option D would satisfy the NETS SQSS, whilst providing 4,000 MW of East-West transfer capacity in Northern England.

7.2.168 Technical analysis of this strategic option is as follows:

- This strategic option establishes a new 400 kV route between the Carlisle area and the existing 400 kV substation in the Spennymoor area.

- In terms of crossings, there is the potential crossing of the existing ZX route, with routing to be facilitated along the M6 motorway.
- This would be the longest of the route options and would increase technical management of the circuit.
- This strategic option would also require retention of portion of the existing XB line.

Summary of the cost appraisal

As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.2.169 East-West Strategic Option D requires the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New 400 kV substation in the Carlisle area (14 feeder bays)
  - Extension to Spennymoor (2 new feeder bays)

Table 7.7 – Capital costs for East-West Strategic Option D

Item	Capital Cost			
Substation and Wider Works	£147m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (174 km)	£692.5m	£7,507.7m	£7,527.2m	£3,216.1m
Total Capital Cost	**£839.5m**	**£7,654.7m**	**£7,674.2m**	**£3,363.1m**

7.2.170 Table 7.8 below 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 Appendix D.

Table 7.8 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£692.5m	£7,507.7m	£7,527.2m	£3,216.1m
NPV of Cost of Losses over 40 years	£488.1m	£371.7m	£226.6m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£10.2m	£35.7m	£10.2m	£172.9m
Lifetime Cost of New Circuits	**£1,191m**	**£7,915m**	**£7,764m**	**£3,860m**

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

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

7.2.172 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.2.173 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.2.174 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

7.2.175 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for East-West Strategic Option D is a 174 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

7.3 Appraisal of the strategic options (Cross Border Connection)

7.3.1 When considering the study area for the North-South Strategic Options, NGET have used the same approach for all options. They all have a study area with a 20 km width and a 10 km buffer zone.

North-South Strategic Option 1: Teviot to Carlisle Area

Description of North-South Strategic Option 1

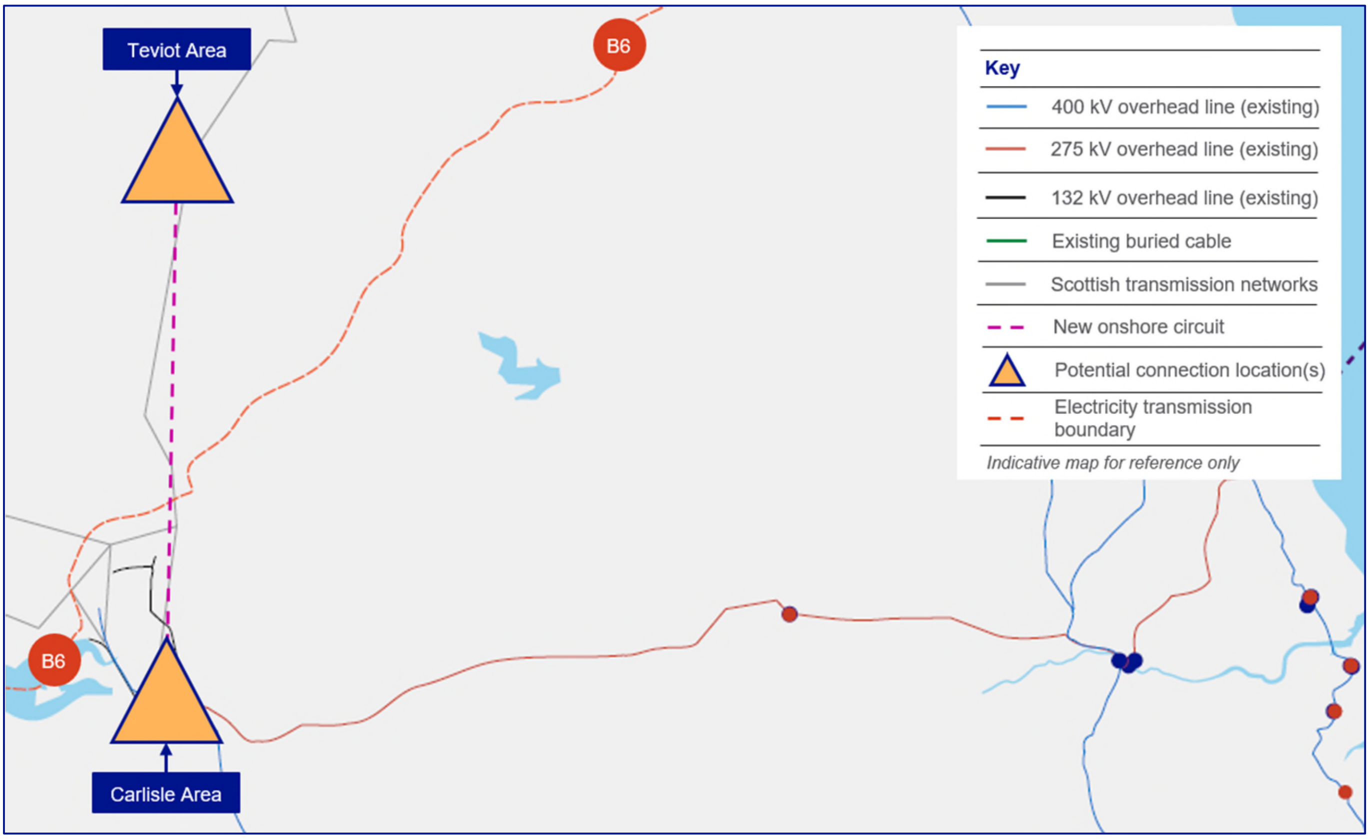
7.3.2 North-South Strategic Option 1, Teviot to Carlisle Area, proposes the establishment of a new 400 kV transmission connection from the Teviot area in Scotland to a new 400 kV substation in the Carlisle area, as proposed by the East-West options as, discussed in Chapter 6.

7.3.3 At this early stage it can already be predicted that the Harker Substation cannot be used for the intended connection to Teviot as part of this project, due to lack of resilience within the network in this region. In the event of unavailability of Harker Substation, the network would experience loss of connection to the whole East of Scotland and loss of transfers on the East Coast of England. On that basis in this scenario, Harker substation would be a single point of connection and system constraint, and hence this solution is less resilient and results in the need for a new substation in the Carlisle Area.

7.3.4 Additionally, a new Carlisle substation will facilitate a connection point to future regional reinforcement projects as identified in NESO Beyond 2030 report. The new substation is critical in resolving the regional need to deliver a number of network improvements through regional projects whilst recognising these projects are at different stages of maturity. The Cross Border Connection project as the first Project to come forward will deliver the substation and provide the connection point to future projects representing a coordinated approach to the development of Projects in the region.

7.3.5 The study area, considered for the purposes of this appraisal, spans approximately 58 km in length and 20 km in width, based on a 10 km buffer of the centre line and is depicted in Figure 7.5.

Figure 7.5 – North-South Strategic Option 1



Summary of the environmental appraisal

Biological Environment

7.3.6 There are a number of international and national designated ecological sites present throughout the appraisal study area comprising SPAs, SACs, SSSIs and Ramsar sites. These range in scale from smaller discrete sites that are readily avoidable to larger sites that whilst avoidable, could materially influence route selection. The most notable of these are:

- Langholm-Newcastleton Hills SPA, SSI and Important Bird Area (IBA)
- Border Mires Kielder-Butterburn SAC and Kielder Mires SSSI
- Bolton Fell Moss SAC and Walton Moss SAC
- Bolton Fell and Walton Mosses SSSI and NNR
- Solway Firth SPA and SAC and Upper Solway Flats & Marshes SSSI
- River Eden SAC and River Eden and Tributaries SSSI

7.3.7 There are no ecological constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and the Carlisle area.

7.3.8 Careful routeing and adoption of appropriate mitigation measures would be required to avoid and/or reduce potential impacts as far as possible. The nature, scale and distribution of ecological designations provides opportunities to develop OHL routes and substation sites which can avoid designated sites, however, subject to other constraints, new electricity transmission infrastructure could be located in close proximity to designated sites.

7.3.9 It is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard. This would prevent or reduce potential impacts on designated sites which are surface water and/or ground water dependent.

7.3.10 There are two notable areas where additional site-specific mitigation may be required subject to route selection: the Langholm-Newcastleton Hills SPA, SSSI and IBA (including land which is classed as Functionally Linked Land (FLL) and the Solway Firth SPA and Upper Solway Flats & Marshes SSSI. The proximity to sites designated for bird species may require site specific mitigation to reduce impacts on protected bird species

Physical Environment

7.3.11 Underlying geology is not considered to prevent the further consideration of an OHL route between Teviot and a new substation in the Carlisle area. However, at detailed routeing stage consideration would require to be given to avoiding areas of known or potential peat deposits to avoid risks of peat movement and impacts on deposits such as dewatering.

7.3.12 The Carbon and Peatland Map of Scotland shows the distribution of carbon and peatland classes (from class 1 which is representative of nationally important carbon rich soils and deep peat, to class 5 which is representative of peat soils). Between Teviot and the Scotland-England border there are a number of areas of peat/peaty soils present including areas of class 1, class 3 and class 5 peat.

7.3.13 Peat/peaty soils could impact on as well as be impacted by new electricity transmission infrastructure. Peat does not provide suitable ground conditions for construction and is more complex in engineering terms. Impacts include increases in peat slide risks and the loss of peat or peaty soils which would otherwise act as a carbon sink.

7.3.14 There are a large number of surface waterbodies present throughout the study area. None are considered to present a significant constraint to OHL routeing within the area as they can all be spanned by OHL routes.

7.3.15 Flood risk zones are present throughout the southern end of the study area but are generally avoidable with the possible exception of the River Esk between Longtown and Harker. In this area the extent of the flood zone may require OHL routes to be routed through it. In the Carlisle area, although there are several watercourses and associated flood risk zones, they are not deemed to hinder further consideration of OHL routes.

7.3.16 Overall, water environment considerations (surface waterbodies and flood risk zones) are not considered to prevent further consideration of this strategic option. While some watercourses are unavoidable, those which are present can be spanned by an OHL (subject to other constraints) and therefore do not prevent routes being considered further within the study area.

7.3.17 Works within flood zones (either OHL traversing them, or substations works within them) are largely avoidable with careful routeing and siting, however, where these are not avoided this could require land raising to mitigate flood risk.

Historic Environment

7.3.18 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area comprising scheduled monuments, listed buildings, registered battlefield sites and a WHS - the Frontiers of the Roman Empire (Hadrian's Wall).

7.3.19 Dependant on routing and siting should the option proceed, there is a potential need to cross the WHS as part of this option.

7.3.20 While the majority of historic environment constraints or impacts are not considered to prevent the further consideration of an OHL route between Teviot and a new substation in the Carlisle area, the possible requirement to cross the WHS could introduce a significant constraint and high value receptor which could lead to significant impacts to early delivery.

7.3.21 Other than the WHS, the small geographic scale and distribution of other historic environment constraints (e.g. scheduled monuments and listed buildings) provides opportunities to develop route and site options which avoid them. Direct or physical impacts on such sites are therefore considered unlikely but there is some potential for setting impacts to occur.

7.3.22 The WHS extends across the south of the study area in a broadly East-West direction. The WHS comprises Hadrian's Wall as well as a buffer zone which extends to the North and South of the Wall and narrows significantly around Carlisle. The buffer is not uniform either side of the Wall but is intended to provide additional protection.

7.3.23 Consideration would need to be given to (1) the location and (2) the form of the crossing (i.e. whether by OHL or underground cable). While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.3.24 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology.

7.3.25 There are approximately 140 scheduled monuments present throughout the study area, including a mix of individual schedules monuments of different sizes, small clusters or groups of scheduled monuments as well as linear features. These monuments are typically avoidable with careful OHL routeing, with the exception of the inter-related scheduled monuments that form Hadrian's Wall. However, setting impacts can potentially occur, the nature of which will vary for each monument. An option that would be directly impacting the scheduled monument would require SMC due to the potential to disturb the monument(s).

7.3.26 There is a single Registered Battlefield within the study area; the Battle of Solway Moss, occupying an area of approximately 360 hectares (ha) south of Longtown. Routeing across or within the vicinity of a battlefield site is likely to increase the potential to encounter archaeological interests or impact its setting.

7.3.27 There are approximately 1,153 listed buildings present throughout the study area. The majority of these are located within settlements (particularly Carlisle) and/or coincide with individual rural properties. Due to their relatively small scale, impacts on listed buildings are considered avoidable with careful routeing, however, there is the potential for setting impacts.

Landscape and Visual.

7.3.28 There are no landscape constraints or impacts which are considered to prevent further consideration of an OHL route between Teviot and the Carlisle area. The Solway Coast National Landscape to the western extent of the study area is avoidable but is located in area where other constraints may result in routes being in closer proximity resulting in a greater potential for impacts.

7.3.29 The Northumberland National Park is approximately 12 km to the east at its closest point, while the North Pennines National Landscape lies to the east of the study area, within around 1.5 km at its closest point. While direct impacts on the National Landscape are unlikely, subject to route and/or site selection there could be impacts on its setting or on views from within it.

7.3.30 The Solway Coast National Landscape (formerly an AONB) lies on the western margins of the study area approximately 3 km west of the existing Harker Substation. The National Landscape is avoidable, as only a small section extends into the area, however, it does create a narrow pinch point with the settlement of Carlisle. Impacts on the landscape character of the National Landscape are likely to be avoidable with careful routeing, however, subject to route and/or site selection there could be impacts on its setting or on views from within it.

7.3.31 The Solway Coast National Landscape should be avoided by potential routes and/or sites as much as possible. More generally the approach to mitigating landscape effects would be based on following the Holford Rules (particularly rules 3-6), see Chapter 7, which address routeing considerations with the objective of reducing landscape impacts as much as possible. This includes using landform and vegetation as much as possible to screen or backcloth OHL and reduce impacts. Similarly, the Horlock Rules would be applied to the siting of any new substation in the Carlisle area.

7.3.32 The North Pennines National Landscape lies to the East of the study area, within around 1.5 km at its closest point. While direct impacts on the National Landscape are unlikely, subject to route and/or site selection there could be impacts on its setting or on views from within it.

Summary of the socio-economic appraisal

<u>Settlement and Population</u>

7.3.33 There are no settlement constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and the Carlisle area, however, the settlement of Carlisle occupies a significant area to the south of the study area and would heavily influence route options (either to the west or east of it). Careful routeing and adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential amenity-related impacts as much as possible.

7.3.34 Population density within the northern part of the study area is generally low, reflecting the rural and/or upland nature of much of it. Larger settlements in this part include Newcastleton and Langholm. Moving south, settlement pattern tends to increase with more urban settlements, such as Carlisle, present south of the A689. However, south of Carlisle this returns to a more characteristically rural area with settlements typically comprising small villages or scattered residential properties.

7.3.35 Potential impacts on settlement and population relate to both shorter-term temporary impacts during construction as well as longer term impacts on amenity (noise and visual effects) from the OHL and new substation during operation. The potential for amenity-related impacts increases around the Carlisle area which is more densely settled and would need to be avoided.

Tourism and Recreation

7.3.36 For the majority of the study area there are no tourism or recreation constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and the Carlisle area. However, this option may lead to the requirement to cross the WHS which is closely related with the Hadrian's Wall National Trail. Impacts on the amenity of users of the trail would therefore be closely inter-related with impacts on the WHS itself.

7.3.37 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present towards the south, comprising Hadrian's Wall and Hadrian's Wall Path, a National Trail. Potential impacts on these comprise to amenity-related impacts on visitors.

7.3.38 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. As noted above, there is the potential to impact the WHS which would include users of the National Trail. Mitigation to reduce impacts on users of the trail would be similar to that of the WHS and should focus on the location of the crossing point of the WHS, as well as the most appropriate form of that crossing (i.e. OHL or underground cable).

Land use and other infrastructure

7.3.39 There are no land use or other infrastructure constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and the Carlisle area. Careful routeing would be required to avoid potential technical clashes or interfaces with other infrastructure while for particular impacts or risks more bespoke mitigation may be required, for example infrared lighting or compensatory woodland planting.

7.3.40 In Scotland, higher elevations coincide with a reduction in land use capability meaning that only a relatively small part of the study area is suitable for crops. At the southern extent of the area, land within England is classed as Grade 5 (very poor-quality agricultural land), which is the lowest ALC grade.

7.3.41 There are a number of existing and planned wind farms either partly or wholly within the study area. Routeing in proximity to wind turbines can result in wake effect which can cause increased movement of conductors and shorten asset life. The area around Teviot includes two proposed large-scale wind farms; Teviot and Liddesdale. Electricity Networks Association (ENA) guidance advises a buffer is applied to individual wind turbine locations based on three times their rotor diameter, as outside of this area wake effect should be reduced.

7.3.42 The study area crosses MoD TTA 20T used for low flying training between 100 and 250 feet (30 and 76 m). OHL towers carrying 400 kV circuits are expected to be between 40 and 60 m tall. As a result, towers could pose a hazard and/or restrict low flying activities. RAF Spadeadam, an Electronic Warfare Tactics Facility, also lies on the eastern margins of the study area. Mitigation in relation to aviation interests would be subject to consultation with the MoD and Carlisle Airport. In similar situations wind farm developers are required to utilise infrared lighting on wind turbines so it is anticipated that similar could be required for OHL towers where they pose a risk to low-flying aircraft.

Summary of the technical appraisal

7.3.43 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that a transmission connection between Teviot and the Carlisle area would satisfy the NETS SQSS, whilst providing additional transmission capacity across boundary B6.

7.3.44 Technical analysis of this strategic option is as follows:

- The route starts in the Teviot area in Scotland and connects into the new 400 kV substation in the Carlisle area, which is triggered by the East-West options discussed in Section 7.1.2. This new Carlisle area substation would require a two-bay extension to enable this connection.
- Outage review will be necessary to investigate the requirement of an underground solution or duck under for the potential V route crossing from Gretna to Harker. More outage reviews will also be necessary to determine the requirement of realignment or underground cabling for the potential ZV route crossing at the New Harker site as well as for the potential crossing of ZX.
- Works will require crossing of the M6 motorway which will necessitate night workings for access, as well as gantry/scaffolding installation with protection nets.

Summary of the cost appraisal

7.3.45 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.3.46 North-South Strategic Option 1 requires the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - Extension to Carlisle 400 kV substation (2 new feeder bays)

Table 7.9 – Capital costs for North-South Strategic Option 1

Item	Capital Cost			
Substation and Wider Works	£14m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (58 km)	£230.8m	£2,472.9m	£2,509.1m	£2,140.8m
Total Capital Cost	**£244.8m**	**£2,486.9m**	**£2,523.1m**	**£2,154.8m**

7.3.47 Table 7.10 below 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 Appendix D.

Table 7.10 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£230.8m	£2,472.9m	£2,509.1m	£2,140.8m
NPV of Cost of Losses over 40 years	£162.7m	£114.6m	£75.5m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£3.4m	£11.0m	£3.4m	£171.9m
Lifetime Cost of New Circuits	**£397m**	**£2,599m**	**£2,588m**	**£2,784m**

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

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

7.3.49 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.3.50 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.3.51 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

7.3.52 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for North-South Strategic Option 1 is a 58 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

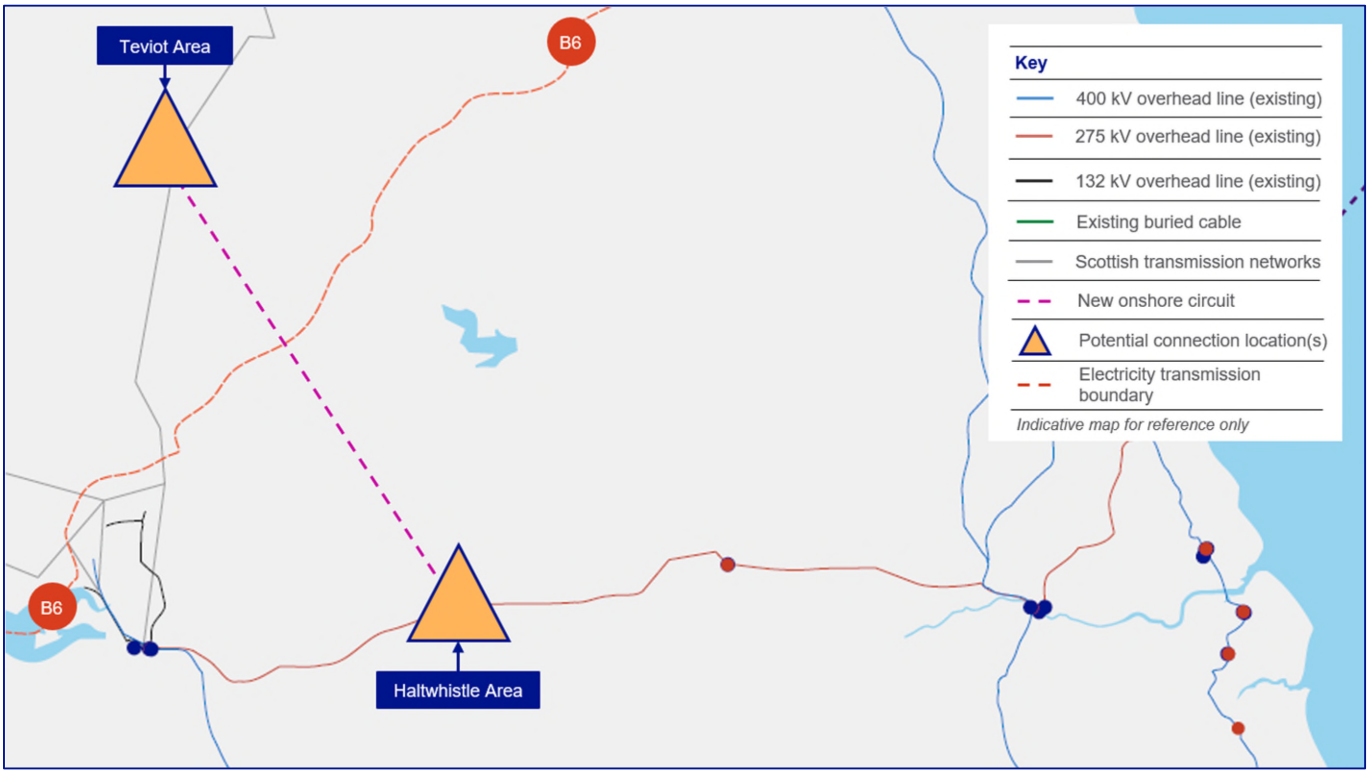
North-South Strategic Option 2: Teviot to Haltwhistle Area

Description of North-South Strategic Option 2

7.3.53 North-South Strategic Option 2, Teviot to Haltwhistle Area, proposes the establishment of a new 400 kV transmission connection from the Teviot area in Scotland to a new 400 kV substation in the Haltwhistle area as proposed by East-West Option A-C. If East-West

Option D is taken forward, North-South Option 2 will not be available. The study area, considered for the purposes of this appraisal, spans approximately 69 km in length and 20 km in width, based on a 10 km buffer of the centre line and is depicted in Figure 7.6.

Figure 7.6 – North-South Strategic Option 2



Summary of the environmental appraisal

Biological Environment

7.3.54 There are a number of international and national designated ecological sites present throughout the appraisal study area comprising SPAs, SACs, SSSIs and Ramsar sites. The most notable of these are listed below:

- Langholm-Newcastleton Hills SPA, SSSI and IBA
- The Border Mires Kielder-Butterburn SAC and Kielder Mires SSSI
- The Roman Wall Loughs SAC and SSSI and Roman Walls Escarpments SSSI
- River Eden SAC and River Eden and Tributaries SSSI
- The North Pennine Moors SPA and SAC as well as related SSSIs (Geltsdale & Glendue Fells SSSI and the Whitfield Moor, Plenmeller and Ashholme Commons SSSI)

7.3.55 Ecological constraints, such as those listed above, occupy a significant area within the study area between Teviot and a new substation in the Haltwhistle area. While these do not necessarily prevent the further consideration of an OHL route and new substation, the scale and distribution of constraints within the area would heavily influence the identification of route and site options.

7.3.56 Subject to route selection between Teviot and the Haltwhistle area, additional mitigation measures (in addition to typical good practice construction measures), such as those discussed below, may be required.

7.3.57 Where the route is comprised of underground cables, for example where the route crosses Northumberland National Park, it is assumed that crossings of watercourses (particularly those which drain into designated sites) would be by trenchless methods. This would prevent or reduce potential impacts on designated sites which are surface water and/or ground water dependent including the Border Mires Kielder-Butterburn SAC and associated SSSIs, the Roman Wall Loughs SAC and SSSI as well as the River Eden SAC and River Eden and Tributaries SSSI.

7.3.58 Good practice mitigation would still apply during construction; however, additional mitigation would be required to ensure cable routes (e.g. trenches/ducts) do not alter the hydrology and hydrogeology supporting the sites. This could include permanent drainage to ensure baseflow to protected sites is not affected.

7.3.59 Subject to route selection and proximity to the Langholm-Newcastleton Hills SPA, SSSI and IBA (including land, which is classed as FLL, additional site-specific mitigation may be required.

7.3.60 Subject to substation site selection in the Haltwhistle area and proximity to water-dependent designations, site drainage may require additional attenuation and treatment prior to being discharged.

7.3.61 Substation siting in the Haltwhistle area would require avoiding a number of designated sites including parts of Border Mires Kielder-Butterburn SAC and Roman Wall Loughs SAC.

Physical Environment

7.3.62 Physical environment constraints are not considered to prevent the further consideration of a route between Teviot and a new substation in the Haltwhistle area, however, the extensive peat deposits within the study area would significantly influence design.

7.3.63 Some constraints, such as areas of peat (and waterbodies) coincide with statutory ecological designation and should be avoided in the development of the project in order to prevent impacts on them.

7.3.64 Other constraints, including areas of peat (which do not coincide with designations) are present throughout the study area, however, there are some opportunities to avoid these towards the west.

7.3.65 The Carbon and Peatland Map of Scotland shows the distribution of carbon and peatland classes (from class 1 which is representative of nationally important carbon rich soils and deep peat, to class 5 which is representative of peat soils). The distribution of peat/peaty soils is consistent with the superficial geology described above. There are some small areas of class 1 peat to the north of the study area around Teviot as well as small area extending across the Scotland-England border to the west of Kielder. These are bounded by class 3 and class 5 soils running along the border area meaning any route would be required to cross these.

7.3.66 Peat/peaty soils could impact on as well as be impacted by new electricity transmission infrastructure. Peat does not provide suitable ground conditions for construction and is more complex in engineering terms. Impacts include increases in peat slide risks and the loss of peat or peaty soils which would otherwise act as a carbon sink.

7.3.67 There are a large number of surface waterbodies present throughout the study area including lakes and loughs as well as main rivers and ordinary watercourses.

7.3.68 None of the waterbodies or watercourses are considered to present a significant constraint to OHL routeing within the study area as they can all be spanned by OHL routes, however, subject to route selection and tower positioning there is potential for impacts from pollution and sedimentation during construction. Substation siting would need to consider proximity to waterbodies in particular, how they may impact on drainage and/or water quality.

7.3.69 Works within flood zones (either OHL traversing them or substations works within them) are largely avoidable with careful routeing and siting, however, where these are not avoided this could require land raising to mitigate flood risk.

Historic Environment

7.3.70 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area comprising a WHS - the Frontiers of the Roman Empire (Hadrian's Wall), scheduled monuments, listed buildings and registered battlefield sites.

7.3.71 While the majority of historic environment constraints are considered to be avoidable with careful routeing and/or siting, there is high potential for setting impacts due to the number and distribution of designated sites.

7.3.72 A crossing of the WHS and associated scheduled monuments, as well as new infrastructure in its immediate vicinity is a potential requirement of this option. This is a significant constraint to this option and introduces a high value receptor which could experience significant effects.

7.3.73 The WHS extends across the south of the study area in a broadly East-West direction. The WHS comprises Hadrian's Wall itself, as well as a buffer zone which extends to the north and south of the wall. The buffer is not uniform either side of the Wall but is intended to provide additional protection.

7.3.74 If detailed routeing and siting, should the option proceed, leads to the WHS needing to be crossed, then consideration would need to be given to (1) the location and (2) the form of the crossing (i.e. whether by OHL or underground cable). While an OHL would potentially directly impact on the WHS and its setting there is also the potential for an underground cable to impact previously unrecorded archaeology associated with the WHS.

7.3.75 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology

7.3.76 There are approximately 201 scheduled monuments present throughout the study area. This includes a mix of individual scheduled monuments of different sizes, small clusters or groups of scheduled monuments as well as linear features. Direct impacts are considered unlikely as scheduled monuments can generally be avoided with careful routeing, however, the number and distribution of scheduled monuments within this part of the study area would influence route selection and some setting impacts would be unavoidable.

7.3.77 With regard to Hadrian's Wall, it is comprised of a number of scheduled monuments ranging from the remains of the Wall itself to forts or encampments. In the area to the north of Haltwhistle there are a number of scheduled monuments present which could experience a combination of direct impacts associated with the diversion of the XB route as well as setting impacts from both OHL and a new substation. Given the potential for this option to directly impact scheduled monument(s), it is expected it would require SMC.

7.3.78 There are approximately 276 listed buildings present throughout the study area. The majority of these are located within settlements and/or coincide with individual rural properties. Due to their relative small-scale, impacts on listed buildings are considered to be avoidable with careful routeing, however, there is the potential for setting impacts.

Landscape and Visual

7.3.79 Landscape constraints would significantly influence route selection and/or choice of technology as well as substation siting within the study area between Teviot and the Haltwhistle area. The National Park and National Landscape are both significant constraints. At a strategic level, the primary form of mitigation is careful routeing in order to avoid these nationally designated or important sites as far as possible. Should routes through the National Park, which extends into the eastern part of the study area between Butterburn and Haltwhistle, be unavoidable they would require to be undergrounded consistent with the statement set out in paragraph 7.1.9.

7.3.80 While undergrounding will prevent and reduce some impacts on the National Park, subject to route selection the loss of certain landscape features (for example forestry) could result in permanent impacts on the landscape character within the National Park.

7.3.81 Substation siting to the north of Haltwhistle should avoid the National Park, while to the south of Haltwhistle it should avoid the North Pennines National Landscape. The Northumberland National Park occupies a significant part of the study area to the north of Haltwhistle extending some way across the area. The North Pennines National Landscape extends across a relatively large part of the southern extents of the study area, however, assuming a connection to the north of Haltwhistle this would not be significantly affected. In this part, the National Park comprises a mix of open moorland and commercial forestry. The National Park boundary largely follows the River Irthing as it flows broadly north to south.

7.3.82 The Northumberland National Park can be partly avoided with careful routeing to the west of the study area, however, should routes through the park be unavoidable for other reasons, these would require to be undergrounded. Where undergrounding is required, it is assumed that the working corridor would be reinstated to its pre-construction condition. The location and extent of the North Pennines National Landscape means that there should not be a requirement for new electricity transmission infrastructure within it.

7.3.83 More generally the approach to mitigating landscape effects would be based on following the Holford Rules (particularly rules 3-6) which address routeing considerations with the objective of reducing landscape impacts as much as possible. This includes using landform and vegetation as much as possible to screen or backcloth OHL and reduce impacts. Similarly, the Horlock Rules would be applied to the siting of any new substation in the Haltwhistle area having regard to the proximity to and views from the National Park. The requirement for a new substation in the Haltwhistle area could also impact on the

National Park. Given the extent of the National Park within the southern part of the study area, there are few opportunities to avoid it other than a small area to the northwest of Gillsland. A new substation within the National Park would have a significant impact on it, while siting outside of it (either to the north of it or to the northwest of it) would increase the length of new routes within it (either the XB route from the south or the new route from Teviot).

7.3.84 The location of the North Pennines National Landscape at the south of the study area, south of the Haltwhistle area means that impacts should be avoided, however, subject to site selection a new substation in close proximity to the designation could result in setting impacts as well as impacts on north-facing views from within it.

Summary of the socio-economic appraisal

Settlement and Population

7.3.85 There are no settlement constraints or impacts which are considered to prevent the further consideration of an option between Teviot and the Haltwhistle area. Careful routeing and siting, as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

7.3.86 Population density within the study area is generally low reflecting the rural and/or upland nature of much of it. The largest settlements include Haltwhistle and Gilsland to the south of the study area as well as Newcastleton to the north. Smaller villages, clusters of properties and individual properties are present throughout, particularly to the west of the area outside of commercial forestry and to the south in the Tyne Valley, where the potential for impacts increases.

7.3.87 Potential impacts on settlement and population relate to both shorter-term temporary impacts during construction as well as longer term impacts on amenity (noise and visual effects) from the OHL and extended or new substation during operation. The potential for impacts increases further south towards the Haltwhistle area where population density increases.

Tourism and Recreation

7.3.88 For the majority of the study area there are no tourism or recreation constraints or impacts which are considered prevent the further consideration of a route between Teviot and a new substation in the Haltwhistle area, however, subject to route selection this would require mitigation including potential undergrounding through the National Park. This option may require the crossing of the WHS, which is closely related with the Hadrian's Wall National Trail. Impacts on the amenity of users of the trail would therefore be closely inter-related with impacts on the WHS itself.

7.3.89 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present towards the south, comprising Northumberland National Park, Hadrian's Wall, Hadrian's Wall Path, a National Trail and the Pennine Way, also a National Trail. Potential impacts on these comprise to amenity-related impacts on visitors.

7.3.90 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. As noted above there is the potential to impact the National Park as well as the WHS which would include users of the National Trails.

Mitigation to reduce impacts on visitors to the park would be similar to that described above (i.e. undergrounding), however, there would be temporary impacts during construction.

7.3.91 Mitigation to reduce impacts on visitors to the park would be similar to that described above (i.e. undergrounding), however, there would be temporary impacts during construction. Mitigation to reduce impacts on users of the Hadrian's Wall National Trail would be similar to that of the WHS and should focus on the location of the crossing point of the WHS (e.g. spanning where it is at its narrowest or where other infrastructure such as existing OHL or transport corridors are present) as well as the most appropriate form of that crossing (i.e. OHL or underground cable).

Land use and other infrastructure

7.3.92 There are no land use or other infrastructure constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and the Haltwhistle area. Careful routeing would be required to avoid potential technical clashes or interfaces with other infrastructure while for particular impacts or risks more bespoke mitigation may be required, for example infrared lighting or compensatory woodland planting.

7.3.93 In Scotland higher elevations coincide with a reduction in land use capability meaning that only a relatively small part of the study area is suitable for crops. In England much of the study area is identified as not being suitable for agriculture. This section coincides with the eastern part of the study area where peat and peat-related designations are present. Some smaller sections to the west of the corridor and to the south within the Tyne Valley are classed as Grades 3 (good to moderate quality agricultural land) and 4 (poor quality agricultural land) ALC, however, overall, the study area is not considered to be significantly constrained by agricultural land use.

7.3.94 There are a number of existing and planned wind farms within the Scottish Borders area. Within the study area this includes parts of the proposed Liddesdale Wind Farm which is located to the south and east of Teviot. Routeing in proximity to wind turbines can result in wake effect which can cause increased movement of conductors and shorten asset life. ENA guidance advises a buffer is applied to individual wind turbine locations based on three times their rotor diameter as outside of this area wake effect should be reduced.

7.3.95 The study area crosses MoD TTA 20T used for low flying training between 100 and 250 feet (30 and 76 m). OHL towers carrying 400 kV circuits are expected to be between 40 and 60 m tall. As a result, towers could pose a hazard and/or restrict low flying activities. Mitigation in relation to aviation interests would be subject to consultation with the MoD. In similar situations, wind farm developers are required to utilise infrared lighting on wind turbines so it is anticipated that similar could be required for OHL towers.

Summary of the technical appraisal

7.3.96 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that a transmission connection between Teviot and the Haltwhistle area would satisfy the NETS SQSS, whilst providing additional transmission capacity across boundary B6.

7.3.97 Technical analysis of this strategic option is as follows:

- The route starts at the Teviot area in Scotland and connects into a new 400 kV substation in the Haltwhistle area as proposed by East-West Option A-C. If

East-West Option D is taken forward, North-South Option 2 will not be available.

- The new substation in the Haltwhistle area will be an 8-bay substation which will have a connection to the existing Harker substation.
- Access to be determined with potential haul road. There are no local roads for access as the substation is within Northumberland National Park. Therefore, a haul road of about 15 km will be required to the nearest road (B318).
- Works will require additional feeders in Harker with the potential of a new substation being required there as well.
- In terms of crossings, temporary crossing solution will be required since the connection from North will cross the existing XB route.
- There is the potential for crossing of road A69 as well as crossing of railway lines, which will potentially require temporary possession of the line.

Summary of the cost appraisal

7.3.98 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.3.99 North-South Strategic Option 2 requires the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New Haltwhistle 400 kV substation (8 new feeder bays)

Table 7.11 – Capital costs for North-South Strategic Option 2

Item	Capital Cost			
Substation and Wider Works	£79m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (69 km)	£274.6m	£2,946.6m	£2,984.9m	£2,242.8m
Total Capital Cost	**£353.6m**	**£3,025.6m**	**£3,063.9m**	**£2,321.8m**

7.3.100 Table 7.12 below 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 Appendix D.

Table 7.12 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£274.6m	£2,946.6m	£2,984.9m	£2,242.8m
NPV of Cost of Losses over 40 years	£193.6m	£142.6m	£89.9m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£4.0m	£12.9m	£4.1m	£172m
Lifetime Cost of New Circuits	**£472m**	**£3,102m**	**£3,079m**	**£2,886m**

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

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

7.3.102 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.3.103 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.3.104 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

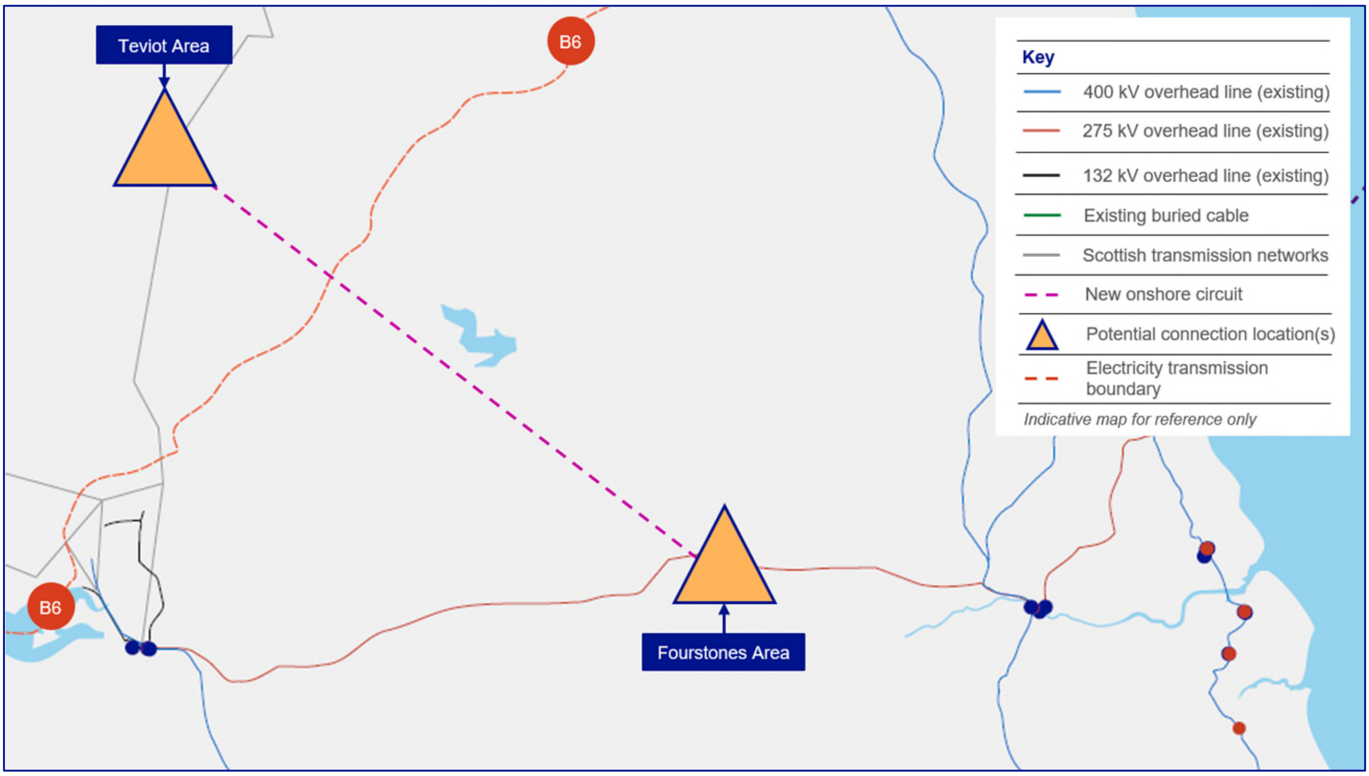
7.3.105 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for North-South Strategic Option 2 is a 69 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

North-South Strategic Option 3: Teviot to Fourstones Area

Description of North-South Strategic Option 3

7.3.106 North-South Strategic Option 3, Teviot to Fourstones area, proposes the establishment of a new 400 kV transmission connection from the Teviot area in Scotland to Fourstones area and would trigger a new 400 kV substation in the Fourstones area, as proposed by the East-West options A-C. If East-West Option D is taken forward, North-South Option 3 will not be available. The study area, considered for the purposes of this appraisal, spans approximately 74 km in length and 20 km in width, based on a 10 km buffer of the centre line and is depicted in Figure 7.7.

Figure 7.7 – North-South Strategic Option 3



Summary of the environmental appraisal

Biological Environment

7.3.107 There are a number of international and national designated ecological sites present throughout the appraisal study area comprising SPAs, SACs, SSSIs and Ramsar sites. These range in scale from smaller discrete sites that are readily avoidable to larger sites that whilst avoidable could materially influence OHL routeing. The most notable of these are:

- Langholm-Newcastleton Hills SPA, SSSI and IBA
- Components of the Border Mires Kielder-Butterburn SAC
- Kielder Mires SSSI
- Kielderhead and Emblehope Moors and Kielderhead NNR
- Butterburn Flow and Lampert Mosses
- The Roman Wall Loughs SAC and SSSI
- The Roman Walls Escarpments SSSI

7.3.108 While there are a number of ecological constraints present within the study area, including those listed above, these are relatively widely dispersed providing opportunities to avoid them. Notwithstanding this, routes may be in close proximity to protected sites subject to other routeing considerations.

7.3.109 Careful routeing of OHL /underground cables and adoption of appropriate mitigation measures would be required to avoid and/or reduce potential impacts as far as possible.

7.3.110 It is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard. This would prevent or reduce potential impacts on designated sites which are surface water and/or ground water dependent including the Border Mires Kielder-Butterburn SAC and associated SSSIs and the Roman Wall Loughs SAC and SSSI.

7.3.111 Where these sites coincide with Northumberland National Park (discussed below – Landscape and Visual) it is assumed the route will comprise underground cables. Good practice mitigation would still apply during construction; however, additional mitigation would be required to ensure cable routes (e.g. trenches/ducts) do not alter the hydrology and hydrogeology supporting the sites. This could include permanent drainage to ensure baseflow to protected sites is not affected.

7.3.112 Subject to route selection and proximity to the Langholm-Newcastleton Hills SPA, SSSI and IBA (including land, which is classed as FLL, additional site-specific mitigation may be required.

Physical Environment

7.3.113 Physical environmental constraints are not considered to prevent the further consideration of a route between Teviot and a new substation in the Fourstones area.

7.3.114 Some constraints such as peat and waterbodies coincide with ecological designations and should be avoided in the development of the project in order to prevent impacts on them.

7.3.115 Other constraints including areas of peat (which do not coincide with designations) and areas at risk of flooding would require to be considered at detailed routeing/siting stage but do not significantly constrain the study area.

7.3.116 The Carbon and Peatland Map of Scotland shows the distribution of carbon and peatland classes (from class 1 which is representative of nationally important carbon rich soils and deep peat, to class 5 which is representative of peat soils). Between Teviot and the Scotland-England border there are a number of areas of peat/peaty soils present including areas of class 1, class 3 and class 5 peat.

7.3.117 Peat/peaty soils could impact on as well as be impacted by new electricity transmission infrastructure. Peat does not provide suitable ground conditions for construction and is more complex in engineering terms. Impacts include increases in peat slide risks and the loss of peat or peaty soils which would otherwise act as a carbon sink. Where peat is present within the National Park it is assumed that the route would be installed by underground cables. Impacts would include the removal/loss of peat for cable trenches. While it is feasible to install cables through peat it is preferable to avoid it for engineering reasons.

7.3.118 There are a large number of surface waterbodies present throughout the study area including lakes and loughs as well as main rivers and ordinary watercourses. Topography means that the predominant flow of surface water is southwest to northeast with a number of watercourses in the north of the study area draining to Kielder Water.

7.3.119 None of the waterbodies or watercourses within the study area are considered to present a significant constraint to OHL routeing within the study area as they can all be avoided or spanned by OHL routes. However, subject to route selection and tower positioning there is potential for impacts from pollution and sedimentation during construction.

7.3.120 Works within flood zones (either OHL traversing them or substations works within them) are largely avoidable with careful routeing and siting, however, where these are not avoided this could require land raising to mitigate flood risk.

Historic Environment

7.3.121 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area comprising scheduled monuments, listed buildings, registered battlefield sites and a WHS - the Frontiers of the Roman Empire (Hadrian's Wall).

7.3.122 While the majority of historic environment constraints or impacts are not considered to prevent the further consideration of an option route between Teviot and the Fourstones area; the WHS is a significant constraint to this option and introduces a high value receptor which could experience significant effects that would influence routing and siting. The small geographic scale and distribution of other historic environment constraints (e.g. scheduled monuments and listed buildings) provides opportunities to develop route and site options which avoid them, however, in some localised areas where constraints are clustered there is increased potential for setting impacts.

7.3.123 The WHS extends across the south of the study area in a broadly East-West direction. The WHS comprises Hadrian’s Wall itself as well as a buffer zone which extends to the north and south of the Wall. The buffer is not uniform either side of the Wall but is intended to provide additional protection. Within the study area, the buffer is up to 6 km wide, however, it narrows to approximately 3 km to the east of Fourstones.

7.3.124 Dependant on the routing and siting, there is a potential need to cross the WHS as part of this option.

7.3.125 Should the routing and siting result in the need to cross the WHS, consideration would need to be given to (1) the location of the crossing and (2) the form of the crossing (i.e. whether by OHL or underground cable) while also taking account of whether the route is within Northumberland National Park where it is assumed that it will be undergrounded.

7.3.126 If this option leads to the requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology

7.3.127 There are approximately 215 scheduled monuments present throughout the study area. This includes a mix of individual scheduled monuments of different sizes, small clusters or groups of scheduled monuments as well as linear features. Direct impacts are considered unlikely as scheduled monuments can generally be avoided with careful routeing, however, the number and distribution of scheduled monuments within this part of the study area would influence route selection and some setting impacts would be unavoidable. In particular to the east of the study area between Bellingham and Great Swinburne there are number of scheduled monuments present. The distribution of these would affect the directness of route options and increases the potential for setting impacts due to proximity to the sites.

7.3.128 With regard to Hadrian’s Wall, it is comprised of a number of scheduled monuments ranging from the remains of the Wall itself to forts or encampments. In the area around Fourstones there are a number of scheduled monuments present which could experience a combination of impacts associated with the crossing of the monument as well as setting impacts from a new substation. Given the potential for this option to directly impact scheduled monument(s), it is expected it would require SMC.

7.3.129 There are approximately 791 listed buildings present throughout the study area. The majority of these are located within settlements and/or coincide with individual rural properties. Due to their relative small-scale, impacts on listed buildings are considered to be avoidable with careful routeing, however, there is the potential for setting impacts.

Landscape and Visual

7.3.130 Landscape constraints would significantly influence route selection and/or choice of technology within the study area. Northumberland National Park occupies a significant section of the study area meaning that it must be crossed by any route between Teviot and the Fourstones area. Subject to route selection through the National Park, the loss of certain landscape features (for example forestry) could result in impacts on the landscape character within the National Park.

7.3.131 The Northumberland National Park boundary is variable across the study area meaning the precise length of any crossing of it also varies from approximately 8 km to potentially 17 km. The National Park comprises a mix of open moorland and commercial forestry.

7.3.132 At a strategic level, the primary form of mitigation is careful routeing in order to avoid nationally designated or important sites as far as possible. Where National Parks or Areas of Outstanding Natural Beauty (now National Landscapes) cannot be avoided, OHL within these areas should be undergrounded, as detailed in paragraph 7.1.9. of this SOR.

7.3.133 While undergrounding could minimise permanent landscape impacts associated with OHL towers, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts through the establishment of a permanent wayleave through forested areas.

7.3.134 Subject to substation site selection there is the potential for the substation to be sited within or on the margins of the National Park. The National Park extends across part of the study area to the north of Fourstones (north of the WHS) but could be avoided by siting towards the east. A new substation to the north of Fourstones within the National Park would have a significant impact on the landscape designation. A new substation to the south or east of Fourstones outside of the National Park could result in impacts on its setting and/or impacts on views from within the park.

7.3.135 The North Pennines National Landscape extends partly into the south of the study area to the southwest of Hexham but can be avoided and is therefore unlikely to be impacted subject to substation site selection.

Summary of the socio-economic appraisal

Settlement and Population

7.3.136 There are no settlement constraints or impacts which are considered to preclude or prevent the further consideration of an option between Teviot and Fourstones area. Careful routeing and siting as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

7.3.137 Population density within the study area is generally low. This reflects the rural and/or upland nature of much of it as well as the presence of the Northumberland National Park.

There are small, scattered settlements and individual properties to the north of the study area, but parts of the central area are largely uninhabited. Moving south through the study area, settlement pattern increases, particularly once outside of the National Park. To the south and south east, there are a number of smaller settlements present including Bellingham, Redesmouth, Great Swinburne, Barrasford and Humshaugh. The area around Fourstones is relatively well-settled with Fourstones village and scattered rural properties present.

7.3.138 Potential impacts on settlement and population relate to both shorter-term temporary impacts during construction as well as longer term impacts on amenity (noise and visual effects) from the OHL (or underground cable) and new substation during operation. The potential for impacts generally increases further south and east within the study area, moving towards the Fourstones area.

Tourism and Recreation

7.3.139 For the majority of the study area there are no tourism or recreation constraints or impacts which are considered prevent the further consideration of a route between Teviot and a new substation in the Fourstones area. Any route would be required to cross the National Park through which the Pennine Way National Trail is routed. Assuming this is undergrounded, long-term impacts on the amenity of park visitors/Trail users should be avoided. A route may also be required to cross the WHS which is closely related with the Hadrian's Wall National Trail. Impacts on the amenity of users of the trail would therefore be closely inter-related with impacts on the WHS itself.

7.3.140 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present towards the south, comprising Northumberland National Park, Hadrian's Wall, Hadrian's Wall Path, a National Trail and the Pennine Way, also a National Trail. Potential impacts on these comprise to amenity-related impacts on visitors.

7.3.141 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. As noted above there is the potential to impact the National Park as well as the WHS which would include users of the National Trails. Mitigation to reduce impacts on visitors to the park would be similar to that described above (i.e. undergrounding), however, there would be temporary impacts during construction.

7.3.142 Mitigation in relation to the National Park and Pennine Way would be similar to that described above (i.e. undergrounding), however, there would be temporary impacts during construction. Mitigation to reduce impacts on visitors to Hadrian's Wall and users of the Hadrian's Wall National Trail would be similar to that for the WHS and should focus on the location of the crossing point of the WHS (e.g. spanning where it is at its narrowest or where other infrastructure such as existing OHL exist) as well as the most appropriate form of that crossing (i.e. OHL or underground cable).

Land use and other infrastructure

7.3.143 There are no land use or other infrastructure constraints or impacts which are considered prevent the further consideration of an option between Teviot and the Fourstones area. Careful routeing would be required to avoid potential technical clashes or interfaces with other infrastructure while for particular impacts or risks more bespoke mitigation may be required, for example infrared lighting or compensatory woodland planting.

7.3.144 In Scotland higher elevations coincide with a reduction in land use capability meaning that only a relatively small part of the study area is suitable for crops. In England, much of the study area is identified as not being suitable for agriculture. This area coincides with the sections where peat and peat-related designations are present.

7.3.145 There are a number of existing and planned wind farms within the Scottish Borders area. Within the study area, this includes parts of the proposed Liddesdale Wind Farm which is located to the south and east of Teviot. A route from Teviot to Fourstones has limited opportunities to avoid crossing land within the Liddesdale boundary. Routeing in proximity to wind turbines can result in wake effect which can cause increased movement of conductors and shorten asset life. ENA guidance advises a buffer is applied to individual wind turbine locations based on three times their rotor diameter, as outside of this area wake effect should be reduced.

7.3.146 The study area crosses MoD TTA 20T used for low flying training between 100 and 250 feet (30 and 76 m). OHL towers carrying 400 kV circuits are expected to be between 40 and 60 m tall. As a result, towers could pose a hazard and/or restrict low flying activities. Mitigation in relation to aviation interests would be subject to consultation with the MoD. In similar situations wind farm developers are required to utilise infrared lighting on wind turbines so it is anticipated that similar could be required for OHL towers.

Summary of the technical appraisal

7.3.147 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that a transmission connection between Teviot and Fourstones would satisfy the NETS SQSS, whilst providing additional transmission capacity across boundary B6.

7.3.148 Technical analysis of this strategic option is as follows:

- The route starts in the Teviot area in Scotland and connects to Fourstones area. This option would trigger a new 400 kV substation in Fourstones area, as proposed by East-West options A-C to facilitate this connection. If East-West Option D is taken forward, North-South Option 3 will not be available.
- This new Fourstones substation triggered by this option would need an extension (four feeder bays) to facilitate the connection.
- Access required from nearby roads.
- Works will require additional feeders in Harker with the potential of a new substation being required there as well.
- There is potential of crossing existing XB route from the circuits from Scotland.

Summary of the cost appraisal

7.3.149 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

- a) 400 kV AC OHL
- b) 400 kV AC underground cable
- c) 400 kV AC GIL
- d) 525 kV HVDC underground cable and converter stations

7.3.150 North-South Strategic Option 3 requires the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - Extension to new Fourstones 400 kV substation (4 new feeder bays)

Table 7.13 – Capital costs for North-South Strategic Option 3

Item	Capital Cost			
Substation and Wider Works	£39m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit (74 km)	£294.5m	£3,164.5m	£3,201.2m	£2,289.1m
Total Capital Cost	**£333.5m**	**£3,203.5m**	**£3,240.2m**	**£2,328.1m**

7.3.151 Table 7.14 below 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 Appendix D.

Table 7.14 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£294.5m	£3,164.5m	£3,201.2m	£2,289.1m
NPV of Cost of Losses over 40 years	£207.6m	£146.9m	£96.4m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£4.3m	£14.5m	£4.4m	£172.0m
Lifetime Cost of New Circuits	**£506m**	**£3,326m**	**£3,302m**	**£2,932m**

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

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

7.3.153 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.3.154 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.3.155 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

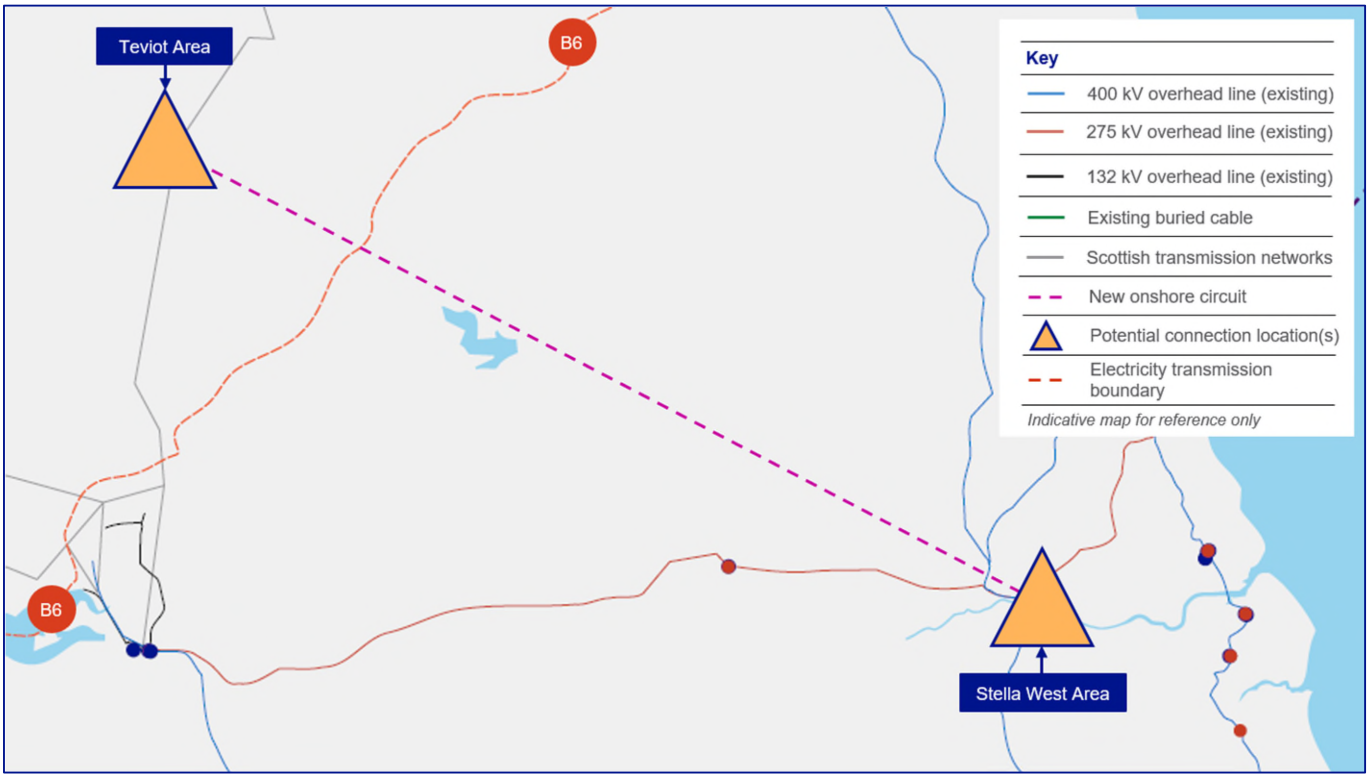
7.3.156 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for North-South Strategic Option 3 is a 74 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

North-South Strategic Option 4: Teviot to Stella West Area

Description of North-South Strategic Option 4

7.3.157 North-South Strategic Option 4, Teviot to Stella West Area, proposes the establishment of a new 400 kV transmission connection from the Teviot area in Scotland to a new substation in the Stella West area. The study area, considered for the purposes of this appraisal, spans approximately 104 km in length and 20 km in width, based on a 10 km buffer of the centre line and is depicted in Figure 7.8.

Figure 7.8 – North-South Strategic Option 4



Summary of the environmental appraisal

Biological Environment

7.3.158 There are a number of international and national designated ecological sites present throughout the study area comprising SPAs, SACs, SSSIs and Ramsar sites. These range in scale from smaller discrete sites that are readily avoidable to larger sites that whilst avoidable could materially influence OHL routeing. The most notable of these are:

- Langholm-Newcastleton Hills SPA, SSSI and IBA
- Kielderhead Moor SSSI
- Component of the Border Mires Kielder-Butterburn SAC and Kielder Mires SSSI
- Component of the Kielderhead and Emblehope Moors SSSI
- Kielderhead and Whitelee Moor NNR

7.3.159 There are no ecological constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and Stella West, however, the combined extent of designated sites in the area between the Scotland-England border and east of the Northumberland National Park would influence route selection.

7.3.160 Careful routeing and adoption of appropriate mitigation measures would be required to avoid and/or reduce potential impacts as far as possible. The nature, scale and distribution of ecological designations provides opportunities to develop OHL routes which can avoid designated sites, however, subject to other constraints, there remains the potential for routes to be in close proximity to sites.

7.3.161 It is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard. This would prevent or reduce potential impacts on designated sites which are surface water and/or ground water dependent. Where the route is comprised of underground cables it is assumed that crossings of watercourses (particularly those which drain into designated sites) would be by trenchless methods.

Physical Environment

7.3.162 Underlying geology is not considered to prevent the further consideration of an option between Teviot and Stella West. However, at detailed routeing stage consideration would require to be given to avoiding areas of known or potential peat deposits to avoid risks of peat movement and impacts on deposits such as dewatering.

7.3.163 Similarly, water environment considerations (surface waterbodies and flood risk zones) are not considered to prevent further consideration of the strategic option. While some watercourses are unavoidable, those which are present can be spanned by an OHL (subject to other constraints) and therefore do not prevent routes being developed within the study area. Flood risk zones are present throughout but are generally avoidable.

7.3.164 The Carbon and Peatland Map of Scotland shows the distribution of carbon and peatland classes (from class 1 which is representative of nationally important carbon rich soils and deep peat, to class 5 which is representative of peat soils). Between Teviot and the Scotland-England border there are a number of areas of peat/peaty soils present including areas of class 1, class 3 and class 5 peat.

7.3.165 Peat/peaty soils could impact on as well as be impacted by new electricity transmission infrastructure. Peat does not provide suitable ground conditions for construction and is more complex in engineering terms. Impacts include increases in peat slide risks and the loss of peat or peaty soils which would otherwise act as a carbon sink. Where peat is present within Northumberland National Park it is assumed that the route would be installed by underground cables. Impacts would include the removal/loss of peat for cable trenches. While it is feasible to install cables through peat it is preferable to avoid it for engineering reasons.

7.3.166 There are a large number of surface waterbodies present throughout the study area including the Kielder Water and River North Tyne.

7.3.167 None are considered to present a significant constraint to routeing within the area as they can either be avoided or be spanned by OHL routes.

Historic Environment

7.3.168 There are international and national designated or important historic environment and cultural heritage sites present throughout the study area comprising scheduled monuments, listed buildings, registered battlefield sites and a WHS - the Frontiers of the Roman Empire (Hadrian's Wall).

7.3.169 While the majority of historic environment constraints are considered to be avoidable with careful routeing and/or siting, there is high potential for setting impacts due to the number and distribution of designated sites. A potential crossing of the WHS and associated scheduled monuments as well as new infrastructure in its immediate vicinity is a significant constraint to this option and introduces a high value receptor which could experience significant effects.

7.3.170 The WHS extends across the south of the study area in a broadly East-West direction. The WHS comprises Hadrian’s Wall itself as well as a buffer zone which extends to the north and south of the Wall. The buffer is not uniform either side of the Wall but is intended to provide additional protection. Within the study area, the buffer is variable is size, as it narrows to a few hundred metres in the east (coinciding with a more urbanised area) but extends to approximately 4 km towards the west. In order to route a new OHL to the Stella West area, there is a potential crossing of the WHS and its buffer zone.

7.3.171 Consideration would need to be given to (1) the location of the crossing and (2) the form of the crossing (i.e. whether by OHL or underground cable). Subject to location and technology there is the potential for setting impacts as well as impacts on previously unrecorded archaeology associated with the WHS.

7.3.172 If there is a requirement to cross the WHS including its buffer zone (as well as scheduled monuments), specific mitigation will be necessary, while considering permanent impacts on unrecorded or unknown archaeology

7.3.173 There are approximately 282 scheduled monuments present throughout the study area. This includes a mix of individual scheduled monuments of different sizes, small clusters or groups of scheduled monuments as well as linear features. Significant clusters of scheduled monuments are present along the A68 in the vicinity of Otterburn. The majority of scheduled monuments are typically avoidable with careful OHL routeing meaning that physical impacts on them are unlikely. However, there is the potential for setting impacts to occur. The nature and scale of setting impacts will vary for scheduled monuments as this can include the physical elements of its surroundings, relationships with other historic features, natural or topographic features and its wider relationship and visibility within its landscape.

7.3.174 With regard to Hadrian’s Wall, it is comprised of a number of scheduled monuments ranging from the remains of the Wall itself to forts or encampments. Within the study area, there are a number of scheduled monuments present which could experience a combination of impacts associated with the crossing of the monument as well as setting impacts from a new substation. Given the potential for this option to directly impact scheduled monument(s), it is expected it would require SMC.

7.3.175 There is a single Registered Battlefield within the study area; the Battle of Newburn Ford, occupying an area of approximately 300 ha including the existing Stella West Substation. Because the battlefield is on the periphery of an urbanised area the potential to encounter previously unrecorded archaeology is somewhat reduced.

7.3.176 There are approximately 1,196 listed buildings present throughout the study area. The majority of these are located within settlements and/or coincide with individual rural properties. Due to their relative small-scale, impacts on listed buildings are considered to be avoidable with careful routeing, however, there is the potential for setting impacts.

Landscape and Visual

7.3.177 Landscape constraints would significantly influence route selection and/or choice of technology within the study area. The Northumberland National Park occupies a significant area extending across the study area, meaning that it must be crossed by any route between Teviot and Stella West, the length of the crossing would depend on route selection but could be between 10-12 km. It is assumed that any route through the National Park would be undergrounded to reduce permanent landscape impacts, however, subject to underground cable route selection, the loss of certain landscape features (for example forestry) could result in impacts on the landscape character within the National Park.

7.3.178 The Northumberland National Park boundary is variable across the study area, meaning the precise length of any crossing of it also varies from approximately 10 km to potentially 12 km. The National Park comprises a mix of open moorland and commercial forestry.

7.3.179 At a strategic level, the primary form of mitigation is careful routeing in order to avoid nationally designated or important sites as far as possible. Where National Parks or Areas of Outstanding Natural Beauty (now National Landscapes) cannot be avoided, OHL within these areas should be undergrounded, as set out in the statement in paragraph 7.1.9.

7.3.180 While undergrounding could minimise permanent landscape impacts associated with OHL towers, the requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts through the establishment of a route through forested areas.

Summary of the socio-economic appraisal

Settlement and Population

7.3.181 There are no settlement constraints or impacts which are considered to preclude or prevent the further consideration of an option between Teviot and Stella West, however, closer to Stella West routeing is more constrained. Careful routeing would be required to avoid settlements and reduce potential impacts as much as possible.

7.3.182 Population density within the study area is variable. For the western part, extending from the Scotland-England border to east of the National Park, it is generally low reflecting the rural and upland nature of the study area. However, moving east elevation reduces and settlement pattern increases with a number a smaller village and scattered individual rural properties present. At the eastern end, Stella West lies in a much more urbanised location on the outskirts of Newcastle where population density is much higher.

7.3.183 Potential impacts on settlement and population relate to both shorter-term temporary impacts during construction as well as longer term impacts on amenity during operation. The majority of larger settlements within the study area are considered to be avoidable through route selection, however, closer to Stella West avoidance becomes more difficult due to the built-up nature of land around it.

Tourism and Recreation

7.3.184 For the majority of the study area there are no tourism or recreation constraints or impacts which are considered prevent the further consideration of a route between Teviot and Stella West. Any route would be required to cross the National Park through which the Pennine Way National Trail is routed. Assuming this is undergrounded long-term impacts on the amenity of Park visitors/Trail users should be avoided. A route could potentially be required to cross the WHS which is closely related with the Hadrian's Wall National Trail. Impacts on the amenity of users of the trail would therefore be closely inter-related with impacts on the WHS itself.

7.3.185 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present towards the south.

7.3.186 This includes Northumberland National Park and the Pennine Way, a National Trail crossing the study area broadly north to south and Hadrian's Wall and Hadrian's Wall Path, also a National Trail broadly routed East-West. Potential impacts on these comprise to amenity-related impacts on visitors.

7.3.187 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. As noted above there is the potential to impact the National Park as well as the WHS which would include users of the National Trails. Mitigation to reduce impacts on visitors to the park would be similar to that described above (i.e. undergrounding), however, there would be temporary impacts during construction.

7.3.188 Mitigation to reduce impacts on users of the trail would be similar to that of the WHS and should focus on the location of the crossing point of the WHS (e.g. spanning where it is at its narrowest or where other infrastructure such as existing OHL or transport corridors are present) as well as the most appropriate form of that crossing (i.e. OHL or underground cable).

Land use and other infrastructure

7.3.189 There are no land use or other infrastructure constraints or impacts which are considered to prevent the further consideration of an OHL route between Teviot and Stella West. Careful routeing would be required to avoid potential technical clashes or interfaces with other infrastructure while for particular impacts or risks more bespoke mitigation may be required, for example infrared lighting or compensatory woodland planting.

7.3.190 Land use capability for agriculture (Scotland) and ALCs (England) have been reviewed. To the west of the study area, higher elevations coincide with a reduction in land use capability meaning that only a relatively small part of the area is suitable for crops. Moving east, the reduction in elevation results in an improvement of land use capability with much of the study area being underlain by land classed as Grade 4.

7.3.191 There are a number of existing and planned wind farms either partly or wholly within the study area. Along the Scotland-England border there is a proposed wind farm (Liddesdale) which extends along much of the border (in two separate parts). This limits opportunities for routes to cross the border avoiding the site. Routeing in proximity to wind turbines can result in wake effect which can cause increased movement of conductors and shorten asset life. ENA guidance advises a buffer is applied to individual wind turbine locations based on three times their rotor diameter, as outside of this area wake effect should be reduced.

7.3.192 The study area crosses MoD TTA 20T used for low flying training between 100 and 250 feet (30 and 76 m). OHL towers carrying 400 kV circuits such are expected to be between 40 and 60 m tall. As a result, towers could pose a hazard and/or restrict low flying activities. Mitigation in relation to aviation interests would be subject to consultation with the MoD and Newcastle International Airport. In similar situations wind farm developers are required to utilise infrared lighting on wind turbines so it is anticipated that similar could be required for OHL towers.

7.3.193 Newcastle International Airport is located on the southeastern extent of the study area. Subject to route selection there is the potential for OHL towers in proximity to flight paths to be a hazard.

Summary of the technical appraisal

7.3.194 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that a transmission connection between Teviot and the Stella West area would satisfy the NETS SQSS, whilst providing additional transmission capacity across boundary B6.

7.3.195 Technical analysis of this strategic option is as follows:

- The route starts in the Teviot area in Scotland and connects into a new Stella West 400 kV substation.
- This new substation will consist of 12 feeder bays and is required to facilitate the new connection.
- In terms of crossings, there are potential crossings of YG, which will require some of the crossings solutions available. Temporary diversion is also necessitated for crossing the existing XB route during construction.
- The potential crossing of 4ZY may require duck-under crossings or building a cable-sealing compound due to spatial constraints and the need for maintaining safety clearances.
- The crossing of A68 will require scaffolding and safety nets, as well as potential temporary lane closures.
- Option spans in proximity to Newcastle Airport and has crossings of River Tyne in its design.

Summary of the cost appraisal

7.3.196 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.3.197 North-South Strategic Option 4 requires the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New Stella West 400 kV substation (12 feeder bays)

Table 7.15 – Capital costs for North-South Strategic Option 4

Item	Capital Cost			
Substation and Wider Works	£117m			
New Circuits	**AC OHL**	**AC Cable**	**AC GIL**	**HVDC**
New Circuit	£413.9m	£4,467.0m	£4,499.0m	£2,567.2m
Total Capital Cost	**£530.9m**	**£4,584.0m**	**£4,616.0m**	**£2,684.2m**

7.3.198 Table 7.16 below 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 Appendix D.

Table 7.16 – Lifetime cost by Technology Option

Land Based Option	AC OHL	AC Cable	AC GIL	HVDC
Capital Cost of New Circuits	£413.9m	£4,467.0m	£4,499.0m	£2,567.2m
NPV of Cost of Losses over 40 years	£291.7m	£219.0m	£135.5m	£471.2m
NPV of Operation & Maintenance costs over 40 years	£6.1m	£20.5m	£6.1m	£172.3m
Lifetime Cost of New Circuits	**£712m**	**£4,706m**	**£4,641m**	**£3,211m**

7.3.199 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.

- 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.

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

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

7.3.201 For the appraisal of onshore options of significant distance, an OHL would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.3.202 Use of OHL is low risk in terms of construction complexity and standard construction, and access techniques can be adopted for this option, as well as operation and maintenance. The same applies for the crossing that would be required for the roads and rail lines involved.

7.3.203 Technology implemented is well established, relatively straightforward to construct, operate and maintain. Multiple interfaces to manage and mitigate asset crossings to be considered.

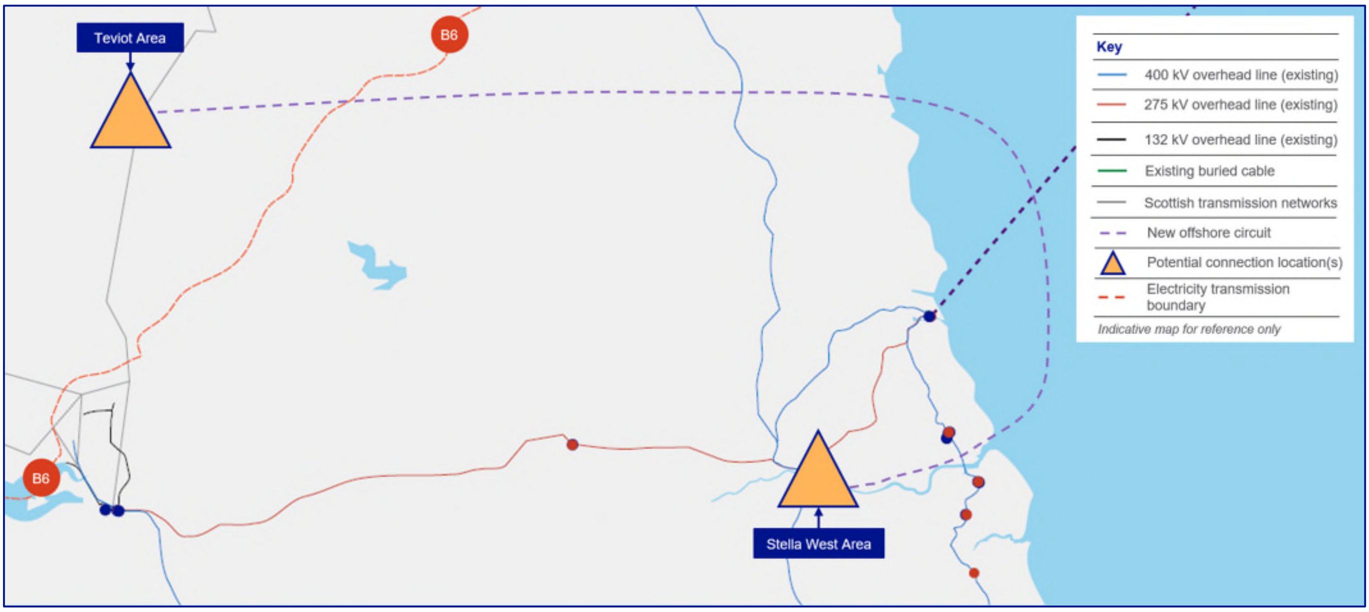
7.3.204 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for North-South Strategic Option 4 is a 104 km connection, configured as an AC circuit. In light of this analysis, NGET's starting presumption for further development of this option, should it be selected, would be for a majority OHL connection.

North-South Strategic Option 5: Teviot to Stella West Area (subsea HVDC)

Description of North-South Strategic Option 5

7.3.205 North-South Strategic Option 5, Teviot to Stella West Area (subsea HVDC), proposes the establishment of a new subsea HVDC connection from the Teviot area in Scotland to a new Stella West 400 kV substation in the Newcastle region. The study area, considered for the purposes of this appraisal, spans approximately 146 km, and is depicted in Figure 7.9.

Figure 7.9 – North-South Strategic Option 5



Summary of the environmental appraisal

Biological Environment

7.3.206 There are a number of international and national designated ecological sites present within or on the margins of the appraisal study area, comprising SPAs, SACs, SSSIs and Ramsar sites as well as MCZs. These range in scale from smaller discrete sites that are readily avoidable, to larger sites that, whilst avoidable, could materially influence route selection. The most notable of these are:

- Kielderhead Moors SSSI
- Component of the Border Mires Kielder-Butterburn SAC
- Kielderhead and Emblehope Moors SSSI
- Kielderhead and Whitelee Moor NNR
- Otterburn Mires SSSI
- Harbottle Moors SAC and SSSI
- Simonside Hills SAC and SSSI
- Northumberland Marine SPA, Northumberland Dunes SAC and Northumberland Shore SSSI
- Coquet to St Marys MCZ
- Berwick to St Mary's MCZ

7.3.207 Overall, ecological constraints occupy significant areas within the study area, both onshore and offshore (near landfalls) which cannot be avoided in developing HVDC links. These sites present major constraints with potential to experience significant impacts and would therefore likely affect the feasibility of this option.

7.3.208 It is assumed that good construction practice measures to reduce dewatering, sedimentation and other potential pollution related impacts would be adopted as standard.

7.3.209 In coastal areas where landfalls require to cross designated sites it is assumed that this would be by trenchless methods in order to prevent direct habitat loss.

7.3.210 Works within or close to SPA may require to be subject to seasonal working restrictions subject to proximity to and potential for disturbance of protected bird species.

Physical Environment

7.3.211 Underlying geology is not considered to prevent the further consideration of HVDC links between Teviot and the Stella West area.

7.3.212 However, at detailed routeing stage, consideration would need to be given to avoiding areas of known or potential peat deposits to avoid risks of peat movement and impacts on deposits such as dewatering, as well as informing subsea cable route development through seabed surveys.

7.3.213 Large areas of peat are present towards the west, coinciding with some of the ecological designations identified above. Moving eastwards peat deposits are present but in smaller more widely dispersed areas with till much more prevalent. Closer to the coast there are smaller pockets of sand and gravel and in the immediate vicinity of Blyth some clay and silt. In the south the superficial geology is largely comprised of till.

7.3.214 Peat/peaty soils could impact on, as well as be impacted by, new electricity transmission infrastructure. Peat does not provide suitable ground conditions for construction. Impacts include increases in peat slide risks and loss of peat or peaty soils which would otherwise act as a carbon sink.

7.3.215 Offshore geology has been reviewed with reference to the Online BGS Geoindex Offshore Viewer. Seabed sediments are variable within the study area, comprising sand and mud with some gravel present. A key consideration for subsea cables is the ability to bury them so hard or stiff sediments such as rock or clay are less preferable to route through.

7.3.216 The Scottish Environment Protection Agency (SEPA) and EA flood risk maps have been reviewed. Neither identify significant areas of flood risk that could impact potential converter station sites or cable routes.

7.3.217 Works within flood zones (either OHL traversing them or substations works within them) could require land raising to mitigate flood risks.

Historic Environment

7.3.218 There are nationally designated or important historic environment and cultural heritage sites present throughout the study area comprising scheduled monuments, listed buildings, and registered battlefield sites.

7.3.219 There are no historic environment constraints or impacts which are considered to prevent the further consideration of HVDC links between Teviot and the Stella West area.

7.3.220 This option provides opportunities to avoid physically crossing the WHS and its buffer zone.

7.3.221 Careful routeing and adoption of appropriate mitigation measures would be required to avoid and/or reduce potential impacts as far as possible.

7.3.222 In general, the small-scale and distribution of scheduled monuments, listed buildings and protected wrecks provides opportunities to develop route and site options which avoid them. Direct or physical impacts on such sites are therefore considered unlikely.

7.3.223 Subject to route and site selection there is the potential for setting impacts to occur onshore, particularly in areas where scheduled monuments are clustered together, however, the nature of these and opportunities to mitigate will depend on detailed routeing and siting.

7.3.224 There are a number of scheduled monuments present throughout the study area. This includes a mix of individual scheduled monuments of different sizes, as well as small clusters or groups of scheduled monuments. Significant clusters of scheduled monuments are present along the A68 in the vicinity of Otterburn. Scheduled monuments are typically avoidable with careful routeing meaning that physical impacts on them are unlikely, however, in some areas the concentration of such features would impact route selection and the directness of route options. Subject to converter station site selection and underground cable routeing there is the potential for setting impacts to occur.

7.3.225 The nature and scale of setting impacts will vary for scheduled monuments as this can include the physical elements of its surroundings, relationships with other historic features, natural or topographic features and its wider relationship and visibility within its landscape.

7.3.226 There are a number of listed buildings present throughout the study area. The majority of these are located within settlements and/or coincide with individual rural properties. Due to their relative small-scale, impacts on listed buildings are considered to be avoidable with careful routeing, however, there is the potential for setting impacts.

7.3.227 Large sections of the coastline are designated Heritage Coastlines; however, these should not be significantly affected by underground cable routes/landfalls. There are a number of historically significant shipwrecks present within inshore waters within the study area. The distribution of these would influence subsea cable route selection.

Landscape and Visual

7.3.228 The Northumberland National Park occupies a significant section extending across the study area meaning that it must be crossed by any route between Teviot and the coast. It is assumed that the route would be underground which should minimise permanent landscape effects, however, subject to underground cable route selection, the loss of certain landscape features (for example forestry) could result in impacts on the landscape character within the National Park.

7.3.229 Routes would be required to cross the Northumberland National Park for approximately 20 km and subject to landfall selection may also be required to cross the Northumberland Coast National Landscape.

7.3.230 The Northumberland National Park cannot be avoided without a longer route outside of the study area. Any route through the park is assumed to be underground with working corridor reinstated to its pre-construction condition. However, given the nature of the landscape (forestry and moorland) some permanent landscapes may occur as some features may not be feasible to reinstate. Where routeing is within forestry consideration should be given to using breaks/access tracks to reduce potential tree removal.

7.3.231 It is assumed that the HVDC links would be comprised of underground cables therefore permanent landscape impacts would depend on route selection and preservation or reinstatement of important landscape features. The requirement to establish a working corridor in which underground cables could be installed would result in temporary, and potentially some permanent, landscape impacts through the establishment of a permanent wayleave through forested areas.

Summary of the socio-economic appraisal

7.3.232 Settlement and Population

7.3.233 There are no settlement or population related constraints or impacts which are considered prevent the further consideration of HVDC links between Teviot and the Stella West area. Careful siting and routeing and adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

7.3.234 Population density within the study area is generally low but does increase in coastal areas. Larger settlements are typically located towards the south within the Humber region including Peterlee and Hartlepool. The majority of settlements within the study area, particularly in the north are smaller settlements which can be more readily avoided subject to careful siting and routeing. Potential impacts on settlement and population relate to both shorter-term temporary impacts during installation of underground cables as well as longer term impacts on amenity (noise and visual effects) from the converter stations during operation.

Tourism and Recreation

7.3.235 There are no tourism or recreation constraints or impacts which are considered prevent the further consideration of HVDC links between Teviot and the Stella West area.

7.3.236 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area, however, other notable attractions or sites are present. This includes Northumberland National Park and the Pennine Way, a National Trail crossing the area broadly north to south. Potential impacts on these comprise to amenity-related impacts on visitors.

7.3.237 At a strategic level, the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. Given the route will be comprised of underground cables, impacts on amenity of visitors to the park or users of the Trail would be limited to the construction phase.

Land use and other infrastructure

7.3.238 There are no land use or other infrastructure constraints or impacts which are considered prevent the further consideration of HVDC links between Teviot and the Humber region, however, there are some constrained areas that could significantly influence routeing. Wind farms in the border area, as well as the Otterburn Ranges training area which partly extend into the study area, are likely to significantly influence route options in the western half of the area.

7.3.239 There are no other sea user related constraints (shipping, fisheries, other infrastructure) which would prevent the further consideration of HVDC links between Teviot and the

Humber region, however, areas of high shipping density around Tyne Mouth may influence route selection.

7.3.240 Towards the west, higher elevations coincide with a reduction in land use capability meaning that only a relatively small part of the study area is suitable for crops. Moving east, the reduction in elevation results in an improvement of land use capability with much of the study area towards the coastal sections (north and south) being underlain by land classed as Grade 3.

7.3.241 There are a number of existing and planned wind farms either partly or wholly within the study area. Along the Scotland-England border there is a proposed wind farm (Liddesdale) which extends along much of the border (in two separate parts). This limits opportunities for routes to cross the border avoiding the site. ENA guidance advises a buffer is applied to individual wind turbine locations based on three times their rotor diameter, as outside of this area wake effect should be reduced.

7.3.242 Part of the study area is occupied by the Otterburn Ranges, a MoD training area which extends from the north towards the A68. The range is used for live fire exercises which may limit routeing opportunities through this part and direct routes towards the north.

7.3.243 The majority of subsea infrastructure (e.g. other cables or pipelines) makes landfall to the south of Hartlepool and is therefore considered to be avoidable or does not significantly influence subsea cable route selection.

7.3.244 While there are no active aggregate extraction sites, the Marine Plan identifies part of the coast adjacent to the southern landfall area as a potential marine aggregate extraction area.

7.3.245 Subject to route selection, there is the potential to cross high density shipping routes associated with shipping traffic entering/exiting the River Tyne at Tynemouth. High density traffic routes extend northwest to southeast across the study area broadly following the coastline. These are not a significant constraint but would influence cable installation methods and programming.

7.3.246 Assuming a route following a corridor traversing inshore waters commercial fishing activity is limited. Maritime Management Organization (MMO) fishing intensity maps indicate that the majority of the study area is generally not subject to highly intensive fishing activity (mobile and static).

Summary of the technical appraisal

7.3.247 Alongside the environmental and socio-economic appraisal of the option, a technical appraisal has established that a transmission connection between Teviot and the Stella West area would satisfy the NETS SQSS, whilst providing additional transmission capacity across boundary B6.

7.3.248 Technical analysis of this strategic option is as follows:

- This route starts in the Teviot area in Scotland and connects into a new Stella West 400 kV substation.
- This new substation will consist of 12 feeder bays and is required to facilitate the new connection.
- This connection at Stella West is also expected to trigger the need for new 400 kV double circuits in the area and further reinforcement works in the Yorkshire area.

- The new substation site will also need to be expanded to site the new converter station.

Summary of the cost appraisal

7.3.249 As set out in Chapter 6, NGET undertake a cost evaluation of the following four technologies for onshore options evaluation:

a) 400 kV AC OHL

b) 400 kV AC underground cable

c) 400 kV AC GIL

d) 525 kV HVDC underground cable and converter stations

7.3.250 North-South Strategic Option 5 requires the following transmission works to satisfy the requirements of the SQSS:

- Substation Works
  - New Stella West 400 kV substation (12 feeder bays)

Table 7.17 – Capital costs for North-South Strategic Option 5

Item	Capital Cost	
Substation and Wider Works	117.0	
New Circuits	**Subsea AC Cable**	**Subsea HVDC**
New Circuit (146 km)	£9,085.4m	£2,366.6m
Total Capital Cost	**£9,202.4m**	**£2,483.6m**

7.3.251 Table 7.18 below 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 Appendix D.

Table 7.18 – Lifetime cost by Technology Option

Land Based Option	AC Subsea Cable	AC Subsea HVDC
Capital Cost of New Circuits	£9,085.4m	£2,366.6m
NPV of Cost of Losses over 40 years	£337.5m	£314.1m
NPV of Operation & Maintenance costs over 40 years	£43.7m	£115.5m
Lifetime Cost of New Circuits	**£9,467m**	**£2,796m**

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

- AC Subsea HVDC has the lowest capital cost of new circuits.

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

7.3.253 For the appraisal of subsea options of significant distance, an HVDC option would normally be expected to offer the most economic, efficient, and co-ordinated development and would meet NGET's obligations under Section 9 of the Electricity Act.

7.3.254 Offshore cable installation, compared to onshore, offers the delivery advantage of having the ability to carry significant lengths of cable on a large vessel for deployment. This way, cable laying campaigns of up to 100 km carried by a single vessel can be utilised, whereas land cables would need to be deployed in drum lengths of around 1 km for delivery to site. The technology that would be implemented is well established; however, constructability risk is increased, and maintenance is more challenging, considering its offshore location and there would be multiple interfaces to manage, and mitigation of asset crossings will need to be considered.

7.3.255 From the environmental and technical appraisal considered, alongside capital and circuit lifetime costs, the preferred technology option for North-South Strategic Option 5 is a 146 km connection, configured as a subsea HVDC cable.

8. Comparison of the appraisal of the strategic options

8.1 Overview

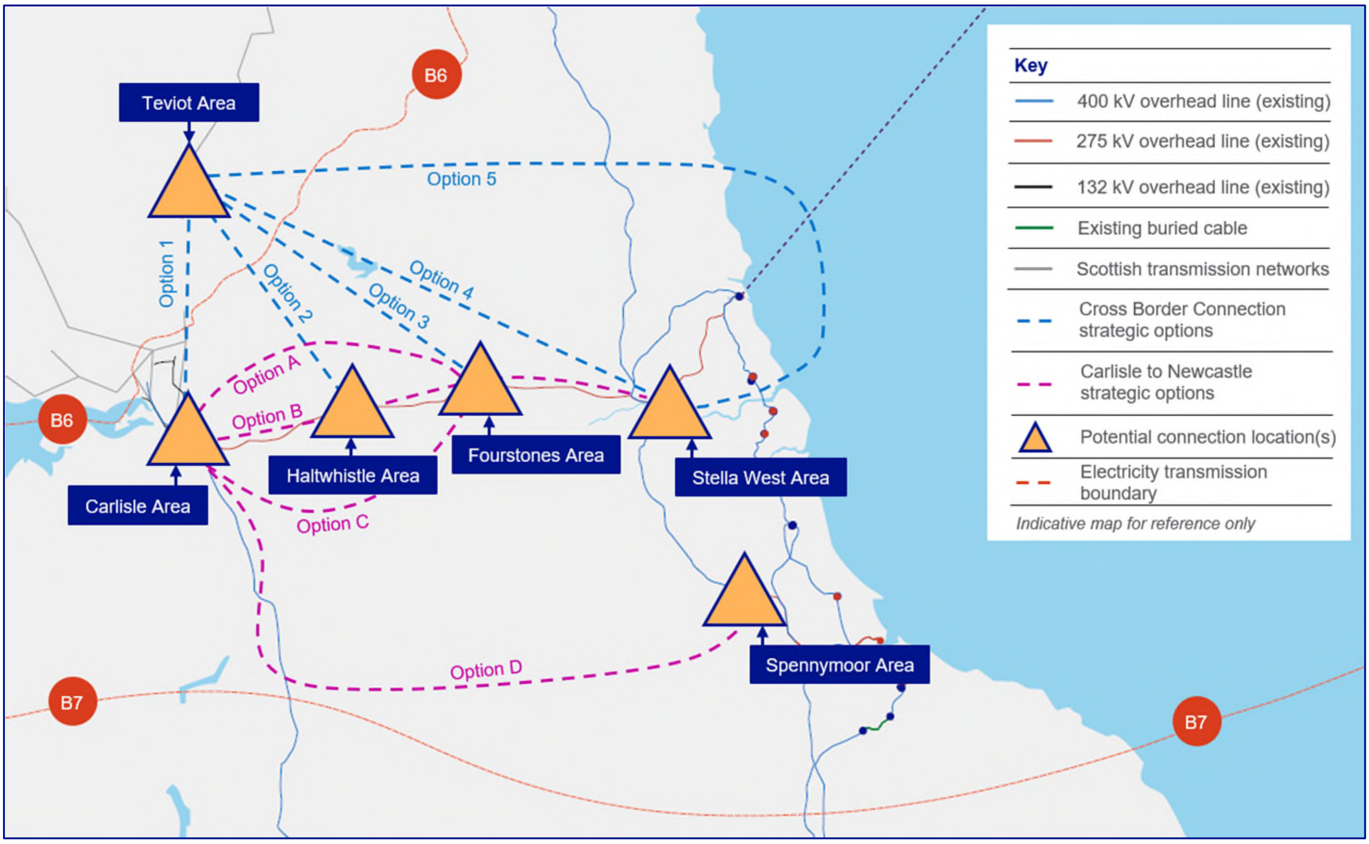
8.1.1 For the strategic options appraised in Chapter 7, this subsequent review considers the following comparative points:

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

8.1.2 This chapter summarises these considerations across the preferred strategic options by comparing the two sets of solutions (Carlisle to Newcastle and Cross Border Connection) separately, as a first step. An overview of the cumulative impact and considerations associated with the interactions between the preferred options for the Carlisle to Newcastle and Cross Border Connection solutions will subsequently be presented in this chapter.

8.1.3 Figure 8.1 below presents each of the strategic options that have been considered as part of NGET's appraisal.

Figure 8.1 – Map View of all Carlisle to Newcastle and Cross Border Connection Strategic options



8.2 Comparison of Carlisle to Newcastle Strategic Options

Environmental constraints

Biological Environment

8.2.1 With regards to ecological and biological environment constraints, East-West Strategic Option A, Carlisle Area to Stella West Area (Northern), proposes a study area that is occupied by ecological constraints related to the Northumberland National Park, creating a significant pinch point on the margins of and within the National Park. For this reason, routes through the National Park would need to be undergrounded, which could increase the potential impacts to other sensitivities and receptors e.g. unknown archaeology and peat.

8.2.2 East-West Strategic Option B, Carlisle Area to Stella West Area (Central zone), has no constraints that could be considered to prevent the further consideration of this strategic option, with most ecological designations being avoidable subject to alternative routeing considerations. Larger designations are present in the section of the study area between Haltwhistle and Haydon Bridge, where designations extend into the area from the north and the south to create a pinch point. These designations could significantly influence route selection.

8.2.3 With regards to East-West Strategic Option C, Carlisle Area to Stella West Area (Southern zone), this option is more significantly constrained. Constraints comprising the North Pennine Moors SAC and SPA, as well as associated SSSIs, occupy a significant section within the study area (up to 40 km of underground (UG) cable route crossing to be required through the North Pennines National Landscape), creating a significant pinch point. There is some scope to avoid these ecological designations, however, this is limited to a narrow part towards the area's northern extent and careful micro-routeing would be necessitated, were these sites to be considered unavoidable.

8.2.4 For East-West Strategic Option D, Carlisle Area to Spennymoor Area, ecological constraints take up a significant area, more specifically, towards the North Pennine Moors SPA and SAC and associated SSSIs, which cannot be avoided in the section of the study area between Appleby-in-Westmorland and Barnard Castle. These sites pose a significant routeing constraint with the potential of measurable impacts that would impact the feasibility of this option, from an environmental perspective. Similar to East-West Option C, there is a crossing of the North Pennines National Landscape, however, this can be potentially reduced by crossing the site at a narrower point, shortening the crossing requirement to 12 -20 km instead of 40 km).

8.2.5 In terms of biological environment: East-West Option A is significantly occupied by ecological constraints, creating a pinch point on the margins of and within the National Park. East-West Option B has no notable constraints that would prevent further consideration of the option. East-West Options C and D exhibit more ecological constraints, due to the extensive occupancy of the North Pennine Moors SAC, SPA and SSSIs within the study area.

Physical Environment

8.2.6 For East-West Strategic Options A and B, no underlying geology or water environment constraints are considered to significantly constrain these strategic options. A number of surface waterbodies are present throughout the study area, the majority of which is not at risk of flooding. Notable areas of larger flood plains, across these two options, are River Eden and River South Tyne around Hexham, Corbridge and Prudhoe.

8.2.7 East-West Strategic Option C, similarly, has no physical environment constraints that would prevent the further consideration of this strategic option, nor do any of the surface waterbodies present a significant constraint to this option. Most of the study area is not at risk of flooding, with some notable areas existing in the vicinity of rivers and other watercourses within flood risk zones.

8.2.8 East-West Strategic Option D is more geologically constrained as it is characterised by extensive peat deposits within the study area between Brough and Bowes, which would significantly impact design, as peat does not provide suitable ground conditions for construction. In terms of the water environment, a large number of surface waterbodies are present, none of which present measurable constraints to this option. The majority of the study area is not at risk of flooding, with some notable areas of increased flood risk existing along the River Eden. These areas are also avoidable and do not pose a constraint.

8.2.9 In terms of the physical environment: East-West Strategic Options A, B and C have no underlying geology or water environment constraints that would prevent the further consideration of the development of the route to Stella West. East-West Strategic Option D, on the other hand, is more geologically constrained due to the extensive peat deposits within the study area (specifically Brough and Bowes), which would impact construction, with water environment designations being largely avoidable.

Historic Environment

8.2.10 The significant historic constraint point for all East-West Strategic Options is the proximity of the Frontiers of the Roman Empire (Hadrian's Wall) WHS and its buffer zone. There are also potential impacts to the setting of the WHS, regardless of whether it would need to be crossed. For all East-West Strategic Options, the potential requirement to cross the WHS, and the location of this crossing, is largely dependent on routing and siting within the study area.

8.2.11 With regard to East-West Strategic Option B, the existing XB route is well established in the buffer zone and the overall WHS setting, with some setting impacts being unavoidable. East-West Strategic Options A and C offer the chance for extended sections of routes to be set back from the WHS and the buffer zone towards the northern and southern section accordingly, with potential setting impacts on scattered sites towards the north of the WHS being amplified if routeing north with East-West Option A. For East-West Strategic Option D, by replacing the majority of the existing XB route with a new 400 kV line that would not be in the vicinity of the WHS, would have a positive effect on the WHS setting through the removal of the existing line, with minor changes to the overall setting and the local area.

8.2.12 Within the study areas of the East-West options, there are 203 scheduled monuments, and 1,139 listed buildings present for East-West Option A, 243 scheduled monuments and 1,720 listed buildings present for East-West Option B, 134 scheduled monuments and 1,805 listed buildings present for East-West Option C and 429 scheduled monuments, and 4,425 listed buildings present for East-West Option D. These monuments are unlikely to cause direct physical impacts; however, some setting impacts are unavoidable, the scale of which will depend on the route selection of each option.

8.2.13 In terms of historic environment: The significant historic environment consideration point is the potential crossing of the Hadrian’s Wall WHS and its buffer zone, although there are potential impacts to the setting of the WHS, regardless of whether it would need to be crossed, e.g. visual impacts looking towards the study area. Each of the East-West Strategic Options may require crossing the WHS, with East-West Option D minimising the changes to the WHS setting and the local area. Although, the existing 275 kV XB route is unlikely to be completely removed, as a minimum, the section between Stella West and Fourstones would be retained.

Landscape and Visual

8.2.14 For East-West Strategic Option A, landscape constraints would significantly impact route selection and choice of technology within the study area. The southern end of Northumberland National Park extends across the study area, meaning that there is no opportunity to avoid it. Any route through the National Park (approximately 15 km) would require to be undergrounded.

8.2.15 For East-West Strategic Option B, landscape constraints would significantly impact route selection and choice of technology within the study area. Landscape designations are considered avoidable, however, there is the potential for routes to exist in close proximity to them or cross them. This is particularly the case for the section between Greenhead-Haltwhistle-Haydon Bridge-Fourstones, where the Northumberland National Park extends into the study area from the north (between Greenhead and Walwick), and the North Pennine Moors National Landscape extends into the study area from the south (south of Brampton and Haydon Bridge), creating a potential pinch point.

8.2.16 Similarly for East-West Strategic Option C, landscape constraints would impact route selection and technology utilisation. Routeing to the south of the existing XB route is constrained by the extent of the National Landscape occupying that part of the study area (between south/southeast of Brampton and south/southwest of Hexham), with limited opportunities to avoid it. Route through the National Landscape would be approximately 38 km in length, which would be required to be placed underground to cross it, affecting the extent of land and habitat in the vicinity.

8.2.17 With regard to East-West Strategic Option D, landscape constraints would impact route selection and technology choice. The study area of this option is routed adjacent to the western boundary of the National Landscape for approximately 50 km of its length and would require crossing through it (12-25 km of crossing between Brough and Bowes), increasing the potential for impacts on the National Landscape's setting and the views within it. The undergrounding of this route would cause the aforementioned issues of impact to the landscape and habitat in the vicinity.

8.2.18 In terms of landscape and visual: for all East-West Strategic Options, landscape constraints would significantly impact route selection and choice of technology. East-West Strategic Option A would require routing through the National Park for approximately 15 km and East-West Option B exhibits a potential pinch point where the National Park extends into the study area from the north and the national landscape from the south. East-West Strategic Options C and D will need to route through the National Landscape for approximately 38 km and 12-25 km, respectively.

Socio-economic constraints

Settlement and Population

8.2.19 There are no settlement constraints or impacts which are considered to prevent further consideration of any of the East-West Strategic Options. Careful routeing as well as adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential impacts as much as possible.

8.2.20 Subject to route selection and proximity to settlements, all East-West options have the potential for amenity-related impacts (noise and visual). This includes shorter-term temporary impacts during construction as well as longer term impacts on amenity during operation.

Tourism and Recreation

8.2.21 None of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area for any of the East-West Options, however, other notable attractions or sites are present.

8.2.22 East-West Strategic Options A, and potentially B, have amenity-related impacts related to users of the National Park and WHS, whereas, East-West Strategic Option C and D have amenity-related impacts to the WHS and North Pennines National Landscape, although impacts to the WHS from East-West Option D are significantly reduced. Long-term impacts for East-West Strategic Option A are likely to be avoidable with underground cabling; however, Hadrian's Wall Path may have the requirement to be crossed and subject to route selection be near a new OHL route. For East-West Strategic Options B and D, careful route selection would be required to reduce impacts to the Hadrian's Wall

Path, and for East-West Option C, the scale of impacts would be subject to how and where the trails are potentially crossed.

8.2.23 For all East-West Strategic Options the primary form of mitigation is careful routeing in order to avoid visitor attractions as far as possible. Should the routes be through the National Park or National Landscape, it is assumed it will be underground which will minimise permanent impacts on amenity.

8.2.24 For East-West Strategic Options A and B, there is the potential for a new route to impact on visitors to the park and Hadrian's Wall as well as users of the National Trails. Other than the National Park, elsewhere within the study area, mitigation would be focused on route selection. This would include making best use of landform, vegetation and other development to screen, filter, or backcloth views of the route from the Trails and reduce amenity-related impacts.

8.2.25 For East-West Strategic Option C, there is also potential for a new route to impact on visitors to Hadrian's Wall as well as users of the National Trails. Mitigation in relation to the WHS (i.e. the location of the crossing of the Wall/trail and technology) would also influence impacts on users of Hadrian's Wall Path. Mitigation in relation to the North Pennines National Trail would depend on where it is crossed. A large section is outside of the National Landscape where it is assumed it would be crossed by an OHL, in which case mitigation would be focused on making best use of landform and/or vegetation to screen, filter or backcloth views of the route from the Trail and reduce amenity-related impacts.

8.2.26 For East-West Strategic Option D, Hadrian's Wall and the related Trail could be crossed by the route to the southeast of Harker with potential impacts on users of the Trail and/or visitors to the Wall. Although, where the Trail requires to be crossed, it coincides with the National Landscape, so it is assumed to be crossed by an underground cable, hence, potential impacts on the Trail will be amenity-related.

8.2.27 In terms of Tourism and Recreation: East-West Strategic Options A and B have amenity-related impacts with regards to the WHS and the National Park, whereas East-West Options C and D have amenity-related impacts on the WHS and the North Pennines National Landscape, although impacts to the WHS and the National Park from East-West Option D are reduced. None of the top 20 visitor attractions in England or Scotland are present within any of these East-West option study areas. For East-West Strategic Options A, B and C, there is the potential for a new route to impact the WHS, the National Park and the users of the National Trails. For East-West Strategic Option D, a new route would potentially impact the amenity of Trail users, as the route would span close to, and sometimes in parallel with, sections of the Pennine Way and the WHS Trails.

<u>Land use and other infrastructure</u>

8.2.28 There are no land use or infrastructure constraints or impacts which are considered to prevent further consideration of any of the East-West Strategic Options. However, for East-West Option A, additional mitigation may be required in relation to potential impacts on aviation interests.

8.2.29 ALCs indicate that much of the study area is classed as grade 2 for East-West Strategic Options A and C, and grade 3 for East-West Strategic Options B and D. However, there are areas classed as grade 5 included in all East-West options as well.

8.2.30 For East-West Strategic Option A, part of the study area crosses MoD TTA 20T, used for low flying training between 100 and 250 feet (30 and 76 m). OHL towers carrying 400 kV circuits are expected to be between 40m and 60 m tall. As a result, towers could pose hazard and/or restrict low flying activities. Mitigation in relation to aviation interests would be subject to consultation with the MoD and Carlisle Airport. In similar situations wind farm developers are required to utilise infrared lighting on wind turbines so it is anticipated that similar measures could be required for OHL towers.

8.2.31 For East-West Strategic Options B, C and D, notable infrastructure includes other transmission and distribution network infrastructure, particularly around Harker.

8.2.32 East-West Strategic Option B also involves transport infrastructure including Carlisle Lake District Airport which is 2 km from the existing XB route and the Tyne Valley Railway line which is routed across parts of the study area and may require to be crossed, subject to route selection. Airport aviation-related mitigation may be required.

8.2.33 East-West Strategic Option D includes the ZX route which is located within the study area for a significant section. Major road and railway corridors are present, including the M6 and A66, as well as part of the West Coast Mainline which provide established linear features which could be followed subject to other routeing constraints.

8.2.34 In terms of land use and other infrastructure: none of the East-West options are considered to be affected significantly by any land use or infrastructure constraints, however, East-West Strategic Option A may require additional mitigation with respect to aviation interests, as part of its study area crosses a MoD TTA. East-West Strategic Option B includes the Carlisle Lake District Airport and the Tyne Valley Railway line, which might require airport aviation-related mitigation. East-West Strategic Option D includes the existing ZX route, as well as major road and railway corridors, such as the M6 and A66, and part of the West Coast Mainline.

Technical benefit and considerations

8.2.35 The four East-West Strategic Options, presented earlier, mainly implement onshore technologies in the form of new OHL connections. Overall, for onshore solutions, there is extensive experience in the use and operation of OHL and UG cables, but limited experience of the GIL technology and onshore HVDC systems.

8.2.36 A major requirement is ensuring NETS SQSS compliance, which is achieved by all East-West options, all of which will be included in the following technical comparison.

8.2.37 All East-West Strategic Options are expected to provide the required 4,000 MW of East-West transfer capacity in Northern England.

8.2.38 With regard to existing and proposed new infrastructure that would be needed for these options, East-West Strategic Options A, B and C are all similar, as they all route from the Carlisle area to Stella West, differentiating with regards to the direction of the route along the way.

8.2.39 Each of these three options will require a new 400 kV substation to be constructed in the Carlisle area as well as a new 400 kV substation to be constructed near Fourstones. In addition to these new substations, an extension will be required at the Stella West 400 kV substation. These options are characterised by fairly similar OHL route lengths, with 92 km for East-West Strategic Option B and 98 km for East-West Strategic Options A and C.

8.2.40 East-West Strategic Option D (Carlisle Area to Spennymoor Area) involves the longest OHL build at 174 km, showing a considerable increase in comparison to the other East-West options and, hence, raising the technical complexity that would be involved. The option also requires a new 400 kV substation to be constructed in the Carlisle area. At the east end of this option, the Spennymoor 400 kV substation will require an extension to facilitate this option. This option assumes to require retention of portion of XB line.

8.2.41 From this, it is apparent that East-West Strategic Option D would employ the most amount of associated new infrastructure to facilitate its connection to Spennymoor.

8.2.42 In terms of crossings associated with these East-West options, the options routeing to the Stella West area (A, B and C) will require temporary diversion for crossing the existing XB route during construction. The potential crossing of 4ZY might be exhibited for these routes, which may require duck-under crossings or building a cable-sealing compound due to spatial constraints and in order to maintain safety clearances. For East-West Strategic Option D, there is the potential crossing of the existing ZX route, with routeing to be facilitated along the M6 motorway.

Cost considerations

8.2.43 Table 8.1 below sets out an overview of the capital and lifetime cost impacts of each East-West Strategic Option. This table provides a comparison of options based on the most economical technology choice for each option i.e. AC OHL.

Table 8.1 Capital and Lifetime cost Impact – Carlisle to Newcastle Strategic Options

Options	Onshore Options			
	A. Carlisle Area to Stella West Area – Northern Zone	B. Carlisle Area to Stella West Area - Central Zone	C. Carlisle Area to Stella West Area - Southern Zone	D. Carlisle Area to Spennymoor Area
Economic Technology (Capacity)	OHL 4,000 MW 98 km	OHL 4,000 MW 92 km	OHL 4,000 MW 98 km	OHL 4,000 MW 174 km
Total capital cost including non-circuit works	£607.0m	£583.2m	£607.0m	£839.5m
New Circuits Only 40-year lifetime NPV cost	£671m	£630m	£671m	£1,191m

8.2.44 All of the strategic options considered in the table above meet the technical appraisal requirements of the need case and are compliant with the NETS SQSS.

8.2.45 East-West Strategic Option D, Carlisle Area to Spennymoor Area, has the highest capital cost at £839.5m and the highest lifetime cost at £1,191m. East-West Strategic Option D requires the longest OHL length at 174 km, resulting in this option being the most expensive among the East-West options considered.

8.2.46 East-West Strategic Option B, Carlisle Area to Stella West Area – Central Zone, has the lowest capital cost at £583.2m and the highest lifetime cost at £630m. East-West

Strategic Option B requires the shortest OHL length at 92 km, resulting in this option being the most cost-effective among the East-West options considered.

8.2.47 East-West Strategic Option A, Carlisle Area to Stella West Area – Northern Zone, has a comparable capital and lifetime cost to that of East-West Strategic Option B cost at £607m and £671m. East-West Strategic Option A requires an OHL length of 98 km.

8.2.48 East-West Strategic Option C, Carlisle Area to Stella West Area – Southern Zone, has the same capital and lifetime cost (as well as OHL length) as East-West Strategic Option A.

8.3 Comparison of Cross Border Connection Strategic Options

Environmental constraints

Biological Environment

8.3.1 North-South Strategic Option 1, Teviot to Carlisle Area, has no constraints that could be considered to prevent further consideration of an OHL route. The most notable site across the study area is the Langholm-Newcastleton Hills SPA, which occupies a significant area towards its western half.

8.3.2 North-South Strategic Option 2, Teviot to Haltwhistle Area, is characterised by a number of ecological constraints that occupy a significant section within the study area. Even though these would not prevent the further consideration of an OHL route for this option, the scale and distribution of constraints within the study area would heavily influence routeing and siting, making this option considerably ecologically constrained. The most notable ecological constraints for this option are the Langholm – Newcastleton Hills SPA and components of the Border Mires, Kielder-Butterburn SAC and Kielder Mires SSSI, which are designated for a range of habitats and should be avoided.

8.3.3 For North-South Strategic Option 3, Teviot to Fourstones Area, ecological constraints are present, however, they are largely confined to the margins of the study area, and they could be avoided with careful traversing and routeing, hence, this option is not significantly constrained in terms of biological environment. The most noteworthy ecological constraint for this option is the Langholm-Newcastleton Hills SPA towards the north.

8.3.4 North-South Strategic Option 4, Teviot to Stella West Area, has no constraints that could be considered to prevent further consideration the development of the strategic option. However, the combined extent of sites in the area between the Scotland-England border and the east of the National Park would influence route selection. The option coincides with notable sites, such as the Langholm-Newcastleton Hills SPA, SSSI and IBA, as well as components of the Border Mires Kielder-Butterburn SAC and others.

8.3.5 North-South Strategic Option 5, Teviot to Stella West Area (subsea HVDC), is characterised by a number of onshore and offshore ecological constraints that occupy significant parts within the study area. These constraints cannot be avoided in developing the HVDC link and they present major issues with potential to cause significant impacts to associated sites and affect the feasibility of this option. Large-scale sites are present around the Scotland-England border with opportunities to avoid them, however, the directness of potential routes would be compromised. On the coast, several ecological designations are present, a number of which c be potentially impacted. The most notable of these are the Berwickshire & North Northumberland Coast SAC, Northumberland SPA and the Coquet to St Marys and Berwick to St Mary's MCZ.

8.3.6 In terms of biological environment: North-South Strategic Option 1 is considered to be the least constrained route. North-South Strategic Option 3 exhibits constraints on the margins of its study area and North-South Strategic Option 2 is more heavily constrained, hence, impacting the routeing and siting for this option. The extent of designations within the study area of North-South Strategic Option 4 deems it as not severely constrained, however, routeing would still be influenced. Subsea North-South Strategic Option 5 is heavily constrained, both onshore and offshore, hence, affecting its feasibility.

Physical Environment

8.3.7 Regarding physical environment and underlying geology, North-South Strategic Options 1 and 4 have no geology or water environment-related constraints that would prevent their further consideration at this stage, nor are their study areas at risk of flooding. However, during detailed routeing stage, consideration would need to be given to avoiding areas of known or potential peat deposits to avoid risks of peat movement and impacts on deposits, such as dewatering. Flood risk zones are generally avoidable across the study areas of these North-South options, with the notable possible exception of the River Esk between Longtown and Harker, for North-South Strategic Option 1, which may require OHL routes to be routed through it.

8.3.8 The development of a route for North-South Strategic Options 2 and 3 is not considered to be unfeasible by physical environment constraints, including underlying geology and water environment-related aspects. Areas of peat that do not coincide with designations are present throughout the study areas for these two options, however, there are opportunities to avoid these towards the west. For areas of peat and waterbodies that do not coincide with statutory designations, they should be avoided during project development. Overall, the designated sites for North-South Strategic Options 2 and 3 coincide with extensive areas of peat deposits which provide more challenging and less suitable ground conditions for construction.

8.3.9 For North-South Strategic Option 5, underlying onshore and offshore geologies are not considered to prevent the further consideration of the development of an HVDC link. Larger areas of peat are present towards the west and should be avoided to steer clear of risks of peat movement and impacts on deposits. No significant areas of flood risk have been identified that could impact potential project works related to this option.

8.3.10 In terms of the physical environment: North-South Strategic Options 1 and 4 have no geology or water environment constraints that would be considered to prevent their further consideration. North-South Strategic Options 2 and 3 and their designated sites coincide with more extensive areas of peat deposits which would make construction more challenging and complex. Offshore North-South Strategic Option 5 has some large areas of peat towards the west of the study area; however, they are avoidable, and the option is not significantly constrained.

Historic Environment

8.3.11 In terms of historic environment: the main historic environment constraint across all North-South options is the Frontiers of the Roman Empire (Hadrian's Wall) WHS, this includes potential impacts to the setting of the WHS, regardless of whether it would need to be crossed.

8.3.12 For North-South Strategic Options 1, 2, 3 and 4, the crossing of the WHS is potentially required, dependant on detailed routeing and siting.

8.3.13 For North-South Strategic Option 5, crossing the WHS can be physically avoided.

8.3.14 The crossing of the WHS would result in likely significant impacts, whether routeing above with OHL or routeing underground with cables, with the potential of the latter impacting previously unrecorded archaeology inter-related to the WHS.

8.3.15 However, the potential requirement to cross the WHS is not considered to prevent the further consideration of the development of an OHL route and there are opportunities to develop route and site options which minimise or avoid these constraints.

8.3.16 The study area of North-South Strategic Option 1 is populated by approximately 140 scheduled monuments and 1,153 listed buildings, which can be considered avoidable with careful routeing, and a single Registered Battlefield (Battle of Solway Moss), routeing across which would increase the potential to encounter archaeological impacts.

8.3.17 The study area of North-South Strategic Option 2 is populated by approximately 201 scheduled monuments and 276 listed buildings, which can be considered avoidable with careful routeing and siting.

8.3.18 The study area of North-South Strategic Option 3 is populated by 215 scheduled monuments and 791 listed buildings, which can be considered avoidable with careful routeing and siting.

8.3.19 The study area of North-South Strategic Option 4 is populated by 282 scheduled monuments and 1,196 listed buildings, which can be considered avoidable with careful routeing and siting.

8.3.20 For North-South Strategic Option 5, being a subsea option, there are no historic environment constraints or impacts that would prevent the further consideration of the development of the HVDC link. With this option, crossing the WHS can be physically avoided. Direct or physical impacts on the number of scheduled monuments and listed buildings present across the study area of North-South Strategic Option 5 can be considered unlikely, as avoidance is possible through careful routeing of the HVDC link. However, significant clusters of scheduled monuments exist along the A68 in the vicinity of Otterburn, which can impact selection and directness of the route in some areas.

8.3.21 In terms of the historic environment: the significant historic environment consideration point is the potential crossing of the Hadrian's Wall WHS and its buffer zone, although there are potential impacts to the setting of the WHS, regardless of whether it would need to be crossed, e.g. visual impacts looking towards the study area. For North-South Strategic Options 1, 2, 3 and 4, the crossing of the WHS is a potential outcome of detailed routeing and siting.

8.3.22 For North-South Strategic Option 5, crossing the WHS can be physically avoided.

Landscape and Visual

8.3.23 There are no landscape constraints or impacts which are considered to prevent the further consideration of the development of on OHL route for North-South Strategic Option 1. A major site that lies within the western margins of the study area is the Solway Coast National Landscape, which, although avoidable, could potentially create a pinch point, in combination with the extent of Carlisle, and result in routes being in closer proximity, leading to increased potential for impacts and should, hence, be avoided as much as possible. This option does not interact with the Northumberland National Park as it is at approximately 12 km to the east at its closest point to the study area, while the North Pennines National Landscape lies towards the east, within around 1.5 km at its closest point.

8.3.24 With respect to North-South Strategic Option 2, landscape constraints would significantly influence route selection and choice of technology within the study area. The Northumberland National Park occupies a significant area to the south and limits opportunities for a new substation towards the north of the Haltwhistle area. In addition, a new substation within the National Park would have a significant effect on the National Park, while siting outside of it would increase the length of new routes within.

8.3.25 Similarly for North-South Strategic Option 3, landscape constraints would significantly impact route selection and technology implementation within the study area. Again, the Northumberland National Park occupies a significant section across the study area (8-17 km approximate length of any crossing), meaning that it would need to be crossed by any route starting at Teviot and terminating in the Fourstones area, also raising visual impacts from the south of the National Park for any new substation within the area. Moreover, the North Pennines National Landscape extends partly into the south of the study area to the southwest of Hexham but can be avoided and is unlikely to be impacted, subject to substation site selection.

8.3.26 On a similar note, North-South Strategic Option 4 would require crossing the National Park for approximately 10-12 km, as the park occupies a significant section across the study area, meaning that the crossing is inevitable for a route between Teviot and Stella West, hence, making this option significantly constrained around landscape implications.

8.3.27 Regarding North-South Strategic Option 5, routes would be required to cross the Northumberland National Park for approximately 20 km and subject to landfall substation selection, they may also require crossing the Northumberland Coast National Landscape. The park occupies a significant section extending across the study area, meaning that it must be crossed by any route between Teviot and the coast. It is assumed that the route would be underground which should minimise permanent landscape effects, however, subject to underground cable route selection, the loss of certain landscape features, such as forestry, could result in impacts on the landscape character within the National Park.

8.3.28 In terms of landscape and visual impacts: North-South Strategic Option 1 is the only option that has no significant landscape and visual impacts or constraints as it avoids the main designation within the area, which is the Northumberland National Park. North-South Strategic Options 2 and 3 are quite heavily constrained by the National Park, which occupies a significant section within their study area. North-South Strategic Option 5 is also affected by the National Park, as any route between Teviot and the coast would need to cross it.

Socio-economic constraints

Settlement and Population

8.3.29 No settlement constraints nor impacts can be considered to prevent the further consideration of any of the North-South options from the Cross Border Connection project. For all North-South options, careful routeing and adoption of appropriate mitigation measures would be required to avoid settlements and reduce potential amenity-related impacts as much as possible. However, with North-South Strategic Option 1, smaller clusters of properties and individual properties may still be more difficult to avoid, and the Carlisle area is more densely settled and would require to be avoided, limiting OHL route options to the west or east of the study area. The settlement of Carlisle occupies a significant area towards the south and would heavily influence route options.

Tourism and Recreation

8.3.30 For all North-South Strategic Options there are no tourism or recreation constraints or impacts which are considered to prevent their further consideration. However, for North-South Strategic Option 4, there is a potential requirement to cross a WHS that is closely related with the Hadrian's Wall National Trail as part of North-South Strategic Options 1, 2, 3 and 4 and is subject to detailed routeing and siting. Long-term impacts on the amenity of park visitors/trail users should be avoided if the route is developed underground.

8.3.31 Furthermore, for all North-South options, none of the top 20 visitor attractions in England (as identified by Visit Britain) or top 20 visitor attractions in Scotland (as identified by Visit Scotland) are present within the study area. However, all North-South options will have amenity-related impacts on visitors/users of other notable attractions and sites in proximity.

Land use and other infrastructure

8.3.32 There are no land use or other infrastructure constraints or impacts which are considered to prevent the further consideration of any of the North-South Strategic Options.

8.3.33 Careful routeing would be required to avoid potential technical clashes or interfaces with other infrastructure while for particular impacts or risks, more bespoke mitigation may be required, for example infrared lighting or compensatory woodland planting. However, for North-South Strategic Option 5, there are some constrained areas that could significantly influence routeing. Wind farms in the border area as well as the Otterburn Ranges training area which partly extend into the study area are likely to significantly influence route options in the western half of the area, as will areas of high shipping density around Tyne Mouth. North-South Strategic Options 1, 2 and 3 are developed on lands which are predominantly unsuitable for crops, and the land is overall not constrained by agricultural land use. However, North-South Strategic Option 5 does eventually see an improvement on the land use capability as the land elevation reduces further down this option's route and the land classification improves from grade 5 to grade 3.

8.3.34 There are a number of existing and planned wind farms either partly or wholly within the study area of all North-South options. North-South Strategic Options 1, 2, 3 and 4 have study areas that cross MoD TTA 20T used for low flying training between 100 and 250 feet (30 and 76 m). As OHL towers carrying 400 kV circuits are expected to be between 40 and 60 m tall, towers could pose a hazard and/or restrict low flying activities. Hence, mitigation in relation to aviation interests would be subject to consultation with the MoD, and Carlisle airport for North-South Strategic Option 1. However, for North-South Strategic Option 5, part of the study area is occupied by a MoD training area which extends into the reinforcement zone from the north towards the A68. The range is used for live fire exercises which may limit routeing opportunities and direct routes to the north of the study area.

8.3.35 North-South Strategic Option 5 has the potential to cross high density shipping routes which is not a significant constraint but would influence cable installation methods and programming.

8.3.36 In terms of land use and other infrastructure: none of the North-South options are considered to be affected significantly by any land use or infrastructure constraints. For North-South Strategic Option 5, there are some constrained areas that could influence routeing, with wind farms in the border area, as well as the Otterburn Ranges training area, extending into the western half of the study area. North-South Strategic Options 1, 2, 3 and 4 cross MoD TTA and, hence, require mitigation in relation to aviation interests. For North-South Strategic Option 5, routeing might be limited by an MoD Training Area that extends into the study area from the north towards the A68. Additionally, subsea North-South Strategic Option 5 has the potential to cross high density shipping routes with shipping traffic entering/exiting the River Tyne and Tynemouth, extending northwest and southeast across the study area and following the coastline, which is not a significant constraint but would influence cable installation methods and programming.

Technical benefit and considerations

8.3.37 From the five potential North-South options considered, four of them implement onshore technologies in the form of new OHL, whereas one option employs an offshore solution in the form of a subsea HVDC cable. There is generally extensive experience with regards to the operation of OHL and UG cables but limited experience of GIL, onshore HVDC systems and 400 kV AC subsea cables for the connection distances considered. There is, however, more operational experience of offshore HVDC systems.

8.3.38 One major requirement for all North-South options to meet is compliance with NETS SQSS. From the five options considered, all options comply with the standard and are included in this technical benefit comparison.

8.3.39 Each North-South option has been assessed as to whether it can meet the identified boundary reinforcement requirements and additional inherent system benefits, as well as to the extent to which the technical aspect of works is practicable and beneficial.

8.3.40 All North-South options provide a similar uplift to boundary B6, satisfying the need case to reinforce the network in the Teviot area of Scotland and the North of England regions.

8.3.41 Considering existing and proposed new infrastructure and line builds that would be required for these solutions, North-South Strategic Option 4 – Teviot to Stella West Area, is characterised by the largest OHL build from the onshore options, due to the increased distance needed to be covered at approximately 104 km. This increased OHL build also raises the technical consenting risk involved. The rest of the onshore solutions have OHL builds at 58 km for North-South Strategic Option 1 – Teviot to Carlisle Area, 69 km for North-South Strategic Option 2 – Teviot to Haltwhistle Area and 74 km for North-South Strategic Option 3 – Teviot to Fourstones Area. These OHL lengths are similar between each other and considerably shorter than North-South Strategic Option 4. The offshore solution, North-South Strategic Option 5 – Teviot to Stella West Area (subsea HVDC), is characterised by the longest build of all North-South options, at approximately 146 km of subsea HVDC cable.

8.3.42 Expanding on the substation infrastructure requirement, onshore North-South Strategic Options 2, 4 and 5 will include the construction of one new substation at the southern end of the study area, whilst North-South Strategic Options 1 and 3 will connect into new substations triggered by the East-West options.

8.3.43 In terms of crossings associated with each North-South option and its relevant works, the four onshore options are affected by potential crossings to existing routes and roads/railway lines. More specifically, North-South Strategic Option 3 has the potential of only crossing the existing XB route from the circuits from Scotland, hence having the least amount of crossing constraints from the North-South set of solutions. North-South Strategic Option 1 is characterised by the potential crossing of the existing V, ZV and ZX routes as well as the crossing of the M6 motorway which would necessitate night workings and gantry/scaffolding installation. North-South Strategic Option 2 would require a crossing of the existing XB route and could also potentially cross A69 road and railway lines along the route, hence necessitating temporary possession of the line. Finally, North-South Strategic Option 4 could potentially cross existing YG, XB and 4ZY routes, with the latter also including duck-under crossings or cable-sealing compound implementation due to spatial constraints. North-South Strategic Option 4 would, additionally, cross the A68 road and would span in proximity to Newcastle Airport and the River Tyne, thus needing crossings of the river, making it the most constrained onshore North-South option in terms of crossings.

Cost considerations

8.3.44 Table 8.2 below sets out an overview of the capital and lifetime cost impacts of each North-South Strategic Option. This table provides a comparison of options based on the most economical technology choice for each North-South option i.e. (i.e., AC OHL for onshore options, HVDC for the offshore option).

Table 8.2 - Capital and lifetime cost impact – Cross Border Connection strategic options

Options	Onshore options				Offshore option
	1. Teviot to Carlisle Area	2. Teviot to Haltwhistle Area	3. Teviot to Fourstones Area	4. Teviot to Stella West Area	5. Teviot to Stella West Area (Subsea)
Economic Technology (Capacity)	OHL 4,000 MW 58 km	OHL 4,000 MW 79 km	Overhead line 4,000 MW 60 km	Overhead line 4,000 MW 62 km	HVDC Subsea 4000 MW 146 km
Total capital cost including non-circuit works	£230.8m	£353.6m	£333.5m	£530.9m	£2,483.6m
New Circuits Only 40-year lifetime NPV cost	£397m	£472m	£506m	£712m	£2,796m

8.3.45 All of the North-South Strategic Options considered in the table above meet the technical appraisal requirements of the need case and are compliant with the NETS SQSS.

8.3.46 North-South Strategic Option 5, Teviot to Stella West Area (subsea) has the highest capital cost of all North-South options at £2,483.6m and the highest lifetime cost of all North-South options at £2,796m.

8.3.47 North-South Strategic Option 1, Teviot to Carlisle Area, has the lowest capital cost at £230.8m and the lowest lifetime cost at £397m.

8.3.48 When considering North-South Strategic Option 2, 3 or 4 for selection, these options have a higher capital cost and lifetime cost when compared to North-South Strategic Option 1, however they do not provide any significant technical benefit above North-South Strategic Option 1. Therefore, from a cost perspective, potential selection of North-South Strategic Option 2, 3 or 4, these options aren’t likely to be feasible for selection.

8.4 Overview of the strategic options appraisal assessment

Table 8.3 below provides an overview of the strategic options appraisal provided within this section.

Table 8.3 – Overview of the strategic options appraisal assessment

		Considerations / Appraisals			
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
East-West Strategic option A: Carlisle Area to Stella West Area – Northern Zone	98 km new AC OHL 400 kV transmission connection in vicinity of existing line between Carlisle area and Stella West area. This option considers the zone to the north of the existing XB route.	Biological Environment: East-West Strategic Option A proposes a study area that is ecologically constrained regarding the National Park. Physical Environment: No underlying geology or water environment constraints can be considered to significantly constrain this strategic option. Majority of the study area is not at risk of flooding. Historic Environment: Most historic environment constraints are considered to be avoidable with careful routeing and siting. The significant constraint is considered to be the potential crossing of the WHS and its buffer zone, although there are potential impacts to the setting of the WHS, regardless of whether it would need to be crossed, e.g., visual impacts looking towards the study area. East-West Strategic Option A offers the chance for extended sections of the route to be set back from the WHS towards the northern part of the study area, with potential setting impacts on scattered sites being amplified towards the north of the WHS. Landscape and Visual: Landscape constraints would significantly impact route selection and technology choice. Southern end of the National Park extends across the study area and	Settlement and Population: East-West Strategic Option A is not significantly affected by settlement constraints or impacts. Settlement density is higher to the west and east of the study area. Tourism and Recreation: None of the top 20 visitor attractions in England and Scotland are present within the study area and there are no constraints that would prevent the further consideration of this option, with other notable attractions/sites present, such as the National Park, the Pennine Way National Trail and Hadrian's Wall Path. A new route would be required to cross the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users. Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of East-West Strategic Option A. Mitigation may be required in relation to potential impacts on aviation interests, as part of the study area crosses a MoD TTA.	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. East-West Strategic Option A requires the construction of a new 400 kV substation in the Carlisle area able to accommodate 12 bays and utilisation of two new feeder bays at the existing Stella West 400 kV substation. This option also requires the construction of a new Fourstones 400 kV substation, comprising of four feeder bays and an SGT. East-West Strategic Option A requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £201m. The capital cost for the most economical circuit technology choice	This option meets the needs of the system requirements of providing 4,000 MW of East-West transfer capacity in Northern England. Route is 98 km in length and connects from a new 400 kV in the Carlisle area to the existing Stella West 400 kV substation, which is to be extended. A new Fourstones 400 kV substation will be required to be constructed to facilitate connection. This option considers the zone to the north of the existing XB route. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		cannot be avoided, with any route through it being approximately 15 km and requiring to be undergrounded.		for this option, AC OHL, is £390.0m. Thus, the total capital cost of the most economical solution for this option is £591.0m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £274.9m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £5.7m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £671m, which includes the capital cost of £390.0m.	
East-West Strategic option B: Carlisle Area to Stella West Area – Central Zone	92 km new AC OHL 400 kV transmission connection in vicinity of existing line between Carlisle area and Stella West area. This option considers the central zone along the existing XB route.	Biological Environment: East-West Strategic Option B has no constraints that can be considered to prevent the further consideration of the strategic option of the route. Some larger designations between Haltwhistle and Haydon Bridge can create a pinch point and could significantly influence route selection. Physical Environment: No underlying geology or water environment constraints can be considered to significantly constrain this strategic option. Majority of the study area is not at risk of flooding. Historic Environment: Most historic environment constraints are considered to be avoidable with careful routeing and siting. The significant constraint point is the potential crossing of the WHS and its buffer zone. Within the study area of East-West Strategic Option B, an opportunity is provided to reduce the extent of the impact on the WHS and its inter-related monuments, since the existing XB route is well established, with some settings impacts being unavoidable.	Settlement and Population: East-West Strategic Option B is not significantly affected by settlement constraints or impacts. Towns, villages and individual properties are present within the study area, adjacent to the River South Tyne. Tourism and Recreation: None of the top 20 visitor attractions in England and Scotland are present within the study area and there are no constraints that would prevent the further consideration of this option, with other notable attractions/sites present, such as the National Park, the Pennine Way National Trail and Hadrian's Wall Path. Any route would be required to run close to and potentially parallel to sections of the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users. Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of East-West Strategic Option B. Mitigation may be required in relation to potential impacts on airport aviation interests, as Carlisle Lake District Airport is 2 km within the existing XB route.	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. East-West Strategic Option B requires the construction of a new 400 kV substation in the Carlisle area able to accommodate 12 bays and utilisation of two new feeder bays at the existing Stella West 400 kV substation. This option also requires the construction of a new Fourstones 400 kV substation, comprising of four feeder bays and an SGT. East-West Strategic Option B requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution.	This option meets the needs of the system requirements of providing 4,000 MW of East-West transfer capacity in Northern England. Route is 92 km in length and connects from a new 400 kV in the Carlisle area to the existing Stella West 400 kV substation, which is to be extended. A new Fourstones 400 kV substation will be required to be constructed to facilitate connection. This option considers the central zone along the existing XB route. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		Landscape and Visual: Landscape constraints would significantly impact route selection and technology choice. Even though most constraints are avoidable, there is the potential for routes to exist in close proximity to them or cross them, particularly in the section between Greenhead and Walwick, where the National Park extends into the study area from the north.		The capital cost of substation and wider works for this option is £201m. The capital cost for the most economical circuit technology choice for this option, AC OHL, is £366.2m. Thus, the total capital cost of the most economical solution for this option is £567.2m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £258.1m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £5.4m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £630m, which includes the capital cost of £366.2m.	
East-West Strategic option C: Carlisle Area to Stella West Area – Southern Zone	98 km new AC OHL 400 kV transmission connection in vicinity of existing line between Carlisle area and Stella West area. This option considers the zone to the south of the existing XB route.	Biological Environment: East-West Strategic Option C is significantly constrained, with designations comprising the North Pennine Moors SAC and SPA and associated SSSIs occupying a measurable area within the study area (up to 40 km of UG cable route required through the National Pennines National Landscape). There is scope to avoid these designations, but it is limited towards a narrow part of the study area on its northern extent. Physical Environment: East-West Strategic Option C has no physical environment constraints or surface waterbodies issues that would prevent the further consideration of the strategic option. Most of the study area is not at risk of flooding. Historic Environment: Most historic environment constraints are considered to be avoidable with careful routeing and siting. The significant constraint point is	Settlement and Population: East-West Strategic Option C is not significantly affected by settlement constraints or impacts. Population density is characterised by more urbanised areas to the west and east and more rural areas to the south and middle of the study area, coinciding with the North Pennines. Tourism and Recreation: None of the top 20 visitor attractions in England and Scotland are present within the study area and there are no constraints that would prevent the further consideration of this option, with other notable attractions/sites present, such as the National Park, the Pennine Way National Trail and Hadrian's Wall Path. A new route could be required to cross both the Pennine Way and Hadrian's Wall National Trails impacting on the amenity of Trail users.	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. East-West Strategic Option C requires the construction of a new 400 kV substation in the Carlisle area able to accommodate 12 bays and utilisation of two new feeder bays at the existing Stella West 400 kV substation. This option also requires the construction of a new Fourstones 400 kV substation, comprising of four feeder bays and an SGT. East-West Strategic Option C requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three	This option meets the needs of the system requirements of providing 4,000 MW of East-West transfer capacity in Northern England. Route is 98 km in length and connects from a new 400 kV in the Carlisle area to the existing Stella West 400 kV substation, which is to be extended. A new Fourstones 400 kV substation will be required to be constructed to facilitate connection. This option considers the zone to the south of the existing XB route. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		the potential crossing of the WHS and its buffer zone. East-West Strategic Option C offers the chance for extended sections of the route to be set back from the WHS towards the southern part of the study area. Landscape and Visual: Landscape constraints would pose a measurable obstacle and would impact route selection and technology choice. South of the existing XB route is constrained by the National Landscape occupying that part of the study area, with limited opportunities to avoid it and routeing through it requiring around 38 km of crossing.	Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of East-West Strategic Option C.	converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £201m. The capital cost for the most economical circuit technology choice for this option, AC OHL, is £390.0m. Thus, the total capital cost of the most economical solution for this option is £591.0m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £274.9m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £5.7m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £671m, which includes the capital cost of £390.0m.	
East-West Strategic Option D: Carlisle Area to Spennymoor Area	174 km new AC OHL 400 kV transmission connection between Carlisle area and Spennymoor.	Biological Environment: Ecological constraints take up a significant area within the study area, specifically towards the North Pennine Moors SPA and SAC and associated SSSIs, which cannot be avoided in the section between Appleby-in-Westmorland and Barnard Castle. Crossing the National Landscape is also required, with the crossing requirement being approximately 12-20 km. Physical Environment: East-West Strategic Option D is geologically constrained as it is characterised by extensive peat deposits within the study area between Brough and Bowes which do not provide suitable ground conditions for construction. Water environment constraints do not prevent	Settlement and Population: East-West Strategic Option D is not significantly affected by settlement constraints or impacts. Settlement density is highly variable across the study area, with a large number of settlements present, ranging from large towns to villages and individual rural properties. Tourism and Recreation: None of the top 20 visitor attractions in England and Scotland are present within the study area and there are no constraints that would prevent the further consideration of this option, with other notable attractions/sites present, such as the Pennine Way National Trail and Hadrian's Wall Path. Any route could be required to run close to and potentially parallel to sections of the Pennine Way	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. East-West Strategic Option D requires the construction of a new 400 kV substation in the Carlisle area able to accommodate 12 bays and utilisation of two new feeder bays at the existing Spennymoor 400 kV substation. East-West Strategic Option D requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection	This option meets the needs of the system requirements of providing 4,000 MW of East-West transfer capacity in Northern England. Route is 174 km in length and connects from a new 400 kV in the Carlisle area to the existing Spennymoor 400 kV substation, which is to be extended. Two new 400 kV substations will be required to facilitate connection. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		the further consideration of this option, and the majority of the study area is not at risk of flooding. Historic Environment: Most historic environment constraints are considered to be avoidable with careful routeing and siting. The significant constraint point is the potential crossing of the WHS and its buffer zone. For East-West Strategic Option D, by replacing the majority of the existing XB route, it would have a positive effect on the WHS setting through the removal of the existing line, with minor changes to the overall setting and the local area. Landscape and Visual: Constraints would raise development concerns and would impact route selection and technology choice. A crossing of 12-25 km would be required through the National Landscape, increasing the potential for impacts on the Landscape's setting and views within it.	and Hadrian's Wall National Trails impacting on the amenity of Trail users. Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of East-West Strategic Option D. Major Road and railway corridors are present within the study area, including the M6 and A66 as well as part of the West Coast Mainline.	rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £131m. The capital cost for the most economical circuit technology choice for this option, AC OHL, is £692.5m. Thus, the total capital cost of the most economical solution for this option is £823.5m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £488.1m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £10.2m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £1,191m, which includes the capital cost of £692.5m.	Technology implemented is well established and straightforward to construct, operate and maintain.
North- South Strategic Option 1: Teviot to Carlisle Area	58 km new AC OHL 400 kV transmission connection between Teviot area and Carlisle area.	Biological Environment: North-South Strategic Option 1 has no constraints that would prevent its further consideration. Physical Environment: There are no geology or water environment constraints that would prevent its further consideration, nor is the study area at risk of flooding. Exception with regard to flood risk zones is that OHL routes might be required to route through the River Esk between Longtown and Harker. Historic Environment: The significant constraint point is the potential crossing of the WHS and its buffer zone. The potential crossing of the WHS will be required for North-South Strategic	Settlement and Population: North-South Strategic Option 1 is not significantly affected by settlement constraints or impacts; however, the settlement of Carlisle occupies a significant section to the south of the study area and would heavily influence route options. Tourism and Recreation: None of the top 20 visitor attractions in England or Scotland are present within the study area and there are no constraints that prevent the further consideration of this option; however, other notable attractions or sites are present within the south of the study area, comprising Hadrian's Wall and Hadrian's Wall Path, a National Trail. This option may lead to	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. North-South Strategic Option 1 requires a two-feeder bay extension of the Carlisle 400 kV substation, triggered by the East-West options. North-South Strategic Option 1 requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six	This option meets the needs of the system requirements to reinforce the B6 boundary. Route is 58 km in length and connects from the new 400 kV in the Carlisle area, proposed by the East-West options. This Carlisle substation will require extension to facilitate connection. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		Option 1, dependant on detailed routeing and siting, however it would not prevent its further consideration. Landscape and Visual: There are no landscape constraints or impacts that are considered to prevent the further consideration of North-South Strategic Option 1. The Solway Coast National Landscape could potentially create a pinch point in combination with the extent of Carlisle in the study area and should, hence, be avoided as much as possible. North-South Strategic Option 1 avoids the National Park and the North Pennines National Landscape (12 km and 1.5 km at their closest point, accordingly).	the requirement to cross the WHS which is closely related with the Hadrian's Wall National Trail. Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of North-South Strategic Option 1. Mitigation may be required in relation to potential impacts on aviation interests, as part of the study area crosses a MoD TTA.	overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £14m. The capital cost for the most economical circuit technology choice for this option, AC OHL, is £230.8m. Thus, the total capital cost of the most economical solution for this option is £244.8m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £162.7m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £3.4m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £397m, which includes the capital cost of £230.8m.	
North-South Strategic Option 2: Teviot to Haltwhistle Area	69 km new AC OHL 400 kV transmission connection between Teviot area and Haltwhistle area.	Biological Environment: North-South Strategic Option 2 is considerably ecologically constrained. The ecological designations, even though they would not prevent the further consideration of the option, the scale and distribution of constraints within the study area would influence routeing and siting. Physical Environment: Geological and water environment constraints are not considered to prevent the further consideration of North-South Strategic Option 2, however, the designated sites within the study area coincide with extensive areas of peat deposits, making construction much more challenging. Historic Environment: The significant constraint point is the potential crossing	Settlement and Population: North-South Strategic Option 2 is not significantly affected by settlement constraints or impacts. Population density within the study area is generally low, with larger settlements existing towards the south and north. Tourism and Recreation: None of the top 20 visitor attractions in England or Scotland are present within the study area and there are no constraints that prevent the further consideration of this option; however, other notable attractions or sites are present within the south of the study area, comprising Northumberland National Park, Hadrian's Wall and Hadrian's Wall Path, a National Trail and the Pennine Way National Trail. This option may require the crossing of the WHS, which is	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. North-South Strategic Option 2 requires the construction of a new Haltwhistle area 400 kV substation to accommodate eight feeder bays. North-South Strategic Option 2 requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be	This option meets the needs of the system requirements to reinforce the B6 boundary. Route is 69 km in length and connects from the Teviot area to a new 400 kV substation in the Haltwhistle area. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		of the WHS and its buffer zone. The crossing of the WHS will be required for North-South Strategic Option 2, dependant on detailed routeing and siting, however it would not prevent its further consideration. Landscape and Visual: Landscape constraints would significantly influence route and technology selection. The National Park occupies a significant area to the south of the study area and limits opportunities of a new substation towards the north of the Haltwhistle area.	closely related with the Hadrian's Wall National Trail. Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of North-South Strategic Option 2. Mitigation may be required in relation to potential impacts on aviation interests, as part of the study area crosses a MoD TTA.	constructed, if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £79m. The capital cost for the most economical circuit technology choice for this option, AC OHL, is £274.6m. Thus, the total capital cost of the most economical solution for this option is £353.6m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £193.6m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £4.0m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £472m, which includes the capital cost of £274.6m.	
North-South Strategic Option 3: Teviot to Fourstones Area	74 km new AC OHL 400 kV transmission connection between Teviot area and Fourstones area.	Biological Environment: Ecological constraints are largely confined to the study area margins and can be avoided through careful traversing and routeing, hence, deeming this Option not significantly constrained. Physical Environment: Geological and water environment constraints are not considered to prevent the further consideration of North-South Strategic Option 3, however, the designated sites within the study area coincide with extensive areas of peat deposits, making construction much more challenging. Historic Environment: The significant constraint point is the potential crossing of the WHS and its buffer zone. The crossing of the WHS will be required for North-South Strategic Option 3, dependant on detailed routeing and	Settlement and Population: North-South Strategic Option 3 is not significantly affected by settlement constraints or impacts. Population density within the study area is generally low, with the settlement pattern increasing towards the south and the area around Fourstones, which is relatively well-settled. Tourism and Recreation: None of the top 20 visitor attractions in England or Scotland are present within the study area and, for the majority of the area, there are no tourism or recreation constraints that prevent the further consideration of this option. Any route would be required to cross the National Park through which the Pennine Way National Trail is routed. A route may also be required to cross the WHS which is closely related with the Hadrian's Wall National Trail.	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. North-South Strategic Option 3 requires a four-feeder bay extension of the Fourstones 400 kV substation, triggered by the East-West options. North-South Strategic Option 3 requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution.	This option meets the needs of the system requirements to reinforce the B6 boundary. Route is 74 km in length and connects from the Teviot area to the new 400 kV substation in the Fourstones area, proposed by the East-West options. The Fourstones substation will require an extension to facilitate this connection. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		siting, however it would not prevent its further consideration. Landscape and Visual: Landscape constraints would significantly influence route and technology selection. The National Park occupies a significant area within the study area (8-17 km approximate length of any crossing), hence, necessitating its crossing requirement by any route starting at Teviot and terminating at Fourstones.	Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of North-South Strategic Option 3. Mitigation may be required in relation to potential impacts on aviation interests, as part of the study area crosses a MoD TTA.	The capital cost of substation and wider works for this option is £39m. The capital cost for the most economical circuit technology choice for this option, AC OHL, is £294.5m. Thus, the total capital cost of the most economical solution for this option is £333.5m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £207.6m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £4.3m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £506m, which includes the capital cost of £294.5m.	
North-South Strategic Option 4: Teviot to Stella West Area	104 km new AC OHL 400 kV transmission connection between Teviot area and Stella West area.	Biological Environment: North-South Strategic Option 4 is not severely constrained by ecological designations, however, the combined extent of sites in the area between the Scotland-England border and the east of the National Park would influence route selection. Physical Environment: There are no geology or water environment constraints that would prevent further consideration of the option, nor is the study area at risk of flooding. Historic Environment: The significant constraint point is the potential crossing of the WHS and its buffer zone. The crossing of the WHS will be required for North-South Strategic Option 4, dependant on detailed routeing and siting, however it would not prevent its further consideration. Landscape and Visual: Landscape constraints would significantly influence	Settlement and Population: North-South Strategic Option 4 is not significantly affected by settlement constraints or impacts. Population density varies within the study area, with the western part exhibiting low density and the easter part noticing an increased settlement pattern. Tourism and Recreation: None of the top 20 visitor attractions in England or Scotland are present within the study area and, for the majority of the area, there are no tourism or recreation constraints that prevent the further consideration of this option. Any route would be required to cross the National Park through which the Pennine Way National Trail is routed. A route may also be required to cross the WHS which is closely related with the Hadrian's Wall National Trail.	Cost appraisal undertaken for four technologies for this option: AC OHL, AC Cable, AC GIL, and HVDC. North-South Strategic Option 4 requires a new Stella West 400 kV substation to accommodate 12 feeder bays. North-South Strategic Option 4 requires the construction of a new AC high-capacity double circuit connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed, if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £117m.	This option meets the needs of the system requirements to reinforce the B6 boundary. Route is 104 km in length and connects from the Teviot area to a new 400 kV substation in the Stella West area. This option to be configured as an AC double circuit OHL with a new AC 400 kV circuit rated at 4,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		route and technology selection. The National Park occupies a significant section within the study area (10-12 km approximate length of any crossing), hence, necessitating its crossing requirement by any route starting at Teviot and terminating at Stella West.	Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of North-South Strategic Option 4. Mitigation may be required in relation to potential impacts on aviation interests, as part of the study area crosses a MoD TTA, as well as the Newcastle International Airport, which is located on the southeastern extent.	The capital cost for the most economical circuit technology choice for this option, AC OHL, is £413.9m. Thus, the total capital cost of the most economical solution for this option is £530.9m. The NPV of Cost of Losses over 40 years for this option (AC OHL) is £291.7m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (AC OHL) is £6.1m. Therefore, the lifetime cost of a new AC OHL circuit for this option is £712m, which includes the capital cost of £413.9m.	
North-South Strategic Option 5: Teviot to Stella West Area (subsea HVDC)	146 km new HVDC 525 kV subsea transmission connection between Teviot area and Stella West.	Biological Environment: North-South Strategic Option 5 is characterised by a number of onshore and offshore ecological constraints that cannot be avoided during development and present major issues with the potential to cause significant impacts and affect the feasibility of this option. Physical Environment: No physical environment constraints nor flood risk areas are considered to prevent the further consideration of the HVDC route. Some larger areas of peat are present in the west of the study area and should be avoided. Historic Environment: The significant constraint point is the potential crossing of the WHS and its buffer zone. These can be physically avoided with North-South Strategic Option 5, and direct or physical impacts can be considered unlikely. However, selection and directness of the route can be impacted in some areas due to the significant	Settlement and Population: North-South Strategic Option 5 is not significantly affected by settlement constraints or impacts. Population density is generally low, but it increases towards the coastal areas, with larger settlements mostly located to the south of the study area within the Humber region. Tourism and Recreation: None of the top 20 visitor attractions in England or Scotland are present within the study area and, for the majority of the area, there are no tourism or recreation constraints that prevent the further consideration of this option. Land use and other infrastructure: Land use and infrastructure constraints do not prevent the further consideration of North-South Strategic Option 5. There are no other sea user-related constraints that would prevent the further consideration of the HVDC development for this option. Part of the study area is occupied by the Otterburn Ranges, and MoD TTA that extends to the north of the	Cost appraisal undertaken for 2 technologies for this offshore option: AC subsea cable and HVDC subsea cable. North-South Strategic Option 5 requires a new Stella West 400 kV substation to accommodate 12 feeder bays. North-South Strategic Option 5 requires the construction of a new AC high-capacity double circuit subsea connection (two 400 KV AC circuits) with a total capacity of up to 4,000 MW. Alternatively, a HVDC connection rated at 6,000 MW with three converters stations at each end, six overall, utilising 525 kV 2,000 MW voltage source links could be constructed if deemed the most cost-effective solution. The capital cost of substation and wider works for this option is £117m.	This option meets the needs of the system requirements to reinforce the B6 boundary. Route is 146 km in length and connects from the Teviot area to a new 400 kV substation in the Stella West area. This option to be configured as an HVDC subsea 525 kV cable rated at 2,000 MW. Technology implemented is well established and straightforward to construct, operate and maintain.

Considerations / Appraisals					
Option	Brief Description	Environmental	Socio-Economic	Cost	Technical
		clusters of monuments along the A68 in the vicinity of Otterburn. Landscape and Visual: North-South Strategic Option 5 is significantly constrained, as routes would be required to cross the National Park for approximately 20 km and, subject to landfall substation location, they might also need to cross the Northumberland Coast National Landscape.	study area towards the A68. For the associated subsea infrastructure, the majority of it is considered avoidable. There is also the potential to cross high density shipping routes associated with shipping traffic entering/exiting the River Tyne at Tynemouth, which are not a significant constraint but would influence cable installation methods and programming.	The capital cost for the most economical circuit technology choice for this option, subsea HVDC cable, is £2,366.6m. Thus, the total capital cost of the most economical solution for this option is £2,483.6m. The NPV of Cost of Losses over 40 years for this option (Subsea HVDC) is £314.1m. Furthermore, the NPV of Operation & Maintenance costs over 40 years for this option (Subsea HVDC) is £115.5m. Therefore, the lifetime cost of a new subsea HVDC circuit for this option is £2,796m, which includes the capital cost of £2,366.6m.	

9. Conclusions and next steps

9.1 Overview of identifying the strategic options

9.1.1 This SOR presents the findings of NGET's options appraisal process and is intended to provide a clear justification and evidence for NGET's decision-making of a preferred strategic option. This report demonstrates that NGET has used its need case to consider the ways in which the project could be delivered and generated 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 we take forward for detailed appraisal have some benefit over other similar options. The report concludes with the identification of two preferred strategic solutions, one for the Carlisle to Newcastle project and one for the Cross Border Connection project, which will be taken forward to the next stage of the project development process – options identification and selection – for further detailed routeing and siting studies.

9.1.2 This SOR will be available for the purpose of the non-statutory consultation, drawn upon when engaging with stakeholders and submitted with the DCO application.

9.1.3 NGET has 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 NGET 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 to develop efficient, co-ordinated and economical solutions, their duty to have regard to the environment in Schedule 9 of the Electricity Act, and the policy, advice and guidance provided by Government through the adopted and emerging NPSs, with particular alignment with policies EN-5 and EN-1, regarding the development of the Carlisle to Newcastle and the Cross Border Connection projects.

9.1.6 For the purpose of this SOR, and the appraisal process that informed this SOR, the East-West Strategic Options were considered in the first instance. This was then followed by the Cross Border Connection appraisal. For each of the proposed East-West Strategic Options, a new substation will be needed in the Carlisle area. This would be regardless of the preferred solution for the Cross Border Connection project. Therefore, to ensure that that the cost appraisal leads to a fair comparison of all options, the costs and technical considerations associated with this new substation are considered within the East-West

Strategic Options and are not duplicated elsewhere within the appraisal (i.e. within the Cross Border Connection costs).

9.1.7 The options appraisal process undertaken by NGET sits alongside the work undertaken by SPT on route options in Scotland which is summarised in Chapter 5. Although SPT is consulting on a preferred route before NGET, the Scottish section of the project will be subject to alignment with the section in England before detailed design.

9.2 The case for the selection of the strategic option (Carlisle to Newcastle)

Environmental factor

9.2.1 In terms of the environmental factor, all four East-West Strategic Options would need to consider interactions with notable constraints, with the specific constraints and designations varying across the East-West options. Despite the potential environmental impacts associated with the extensive areas of peat within the study area for East-West Strategic Option D and the inherent environmental impacts arising from its longer route length and impacts on the setting of designated landscapes, on balance it is considered to perform better in relation to potential impacts on the WHS compared to the other options, principally arising from the opportunity to remove the majority of the existing XB line. As such, subject to availability of suitable mitigation, Option D on balance is considered the best performing East-West option on environmental factors.

Socio-Economic factor

9.2.2 There are no significant constraints in terms of settlement and population or land use and other infrastructure that differentiate these four East-West Strategic Options. However, the main socio-economic factor identified as part of this appraisal would be the expected amenity-related impacts on the WHS, Northumberland National Park, the North Pennines National Landscape and trails associated with these designated areas. East-West Strategic Options A and B are expected to impact on the WHS and the National Park, whilst East-West Strategic Options C and D are expected to impact on the WHS and the National Landscape. However, East-West Strategic Option D is considered to perform better from this perspective due to the relatively short crossing of the National Landscape and the reduced impact on the WHS, compared to the other East-West Strategic Options.

Technical factor

9.2.3 As a summary of the technical comparison of the East-West Strategic Options, all options comply with the NETS SQSS and satisfy the project need case to provide sufficient East-West flows across Northern England. The preferred technology (AC OHL) is well-established and does not add uncertainty or constructability risk to any of the options.

9.2.4 East-West Strategic Options A, B and C perform similarly in terms of the technical factor, exhibiting a similar level of complexity as well as a similar level of required infrastructure. However, East-West Strategic Option D can be considered more technically complex and challenging, due to the longer route needed to connect. This adds additional complexity to the technical delivery of this strategic option, and therefore East-West Strategic Option D is considered as the worst performing strategic option with respect to the technical factor.

Cost factor

9.2.5 The overview of the capital and lifetime cost impacts of each East-West Strategic Option, as set out in Section 7.2, is summarised below:

- East-West Strategic Option A – Carlisle Area to Stella West Area – Northern Zone: Capital cost of £607m and lifetime circuit cost of £671m
- East-West Strategic Option B – Carlisle Area to Stella West Area – Central Zone: Capital cost of £583.2m and lifetime circuit cost of £630m
- East-West Strategic Option C – Carlisle Area to Stella West Area – Southern Zone: Capital cost of £607m and lifetime circuit cost of £671m
- East-West Strategic Option D – Carlisle Area to Spennymoor Area: Capital cost of £839.5m and lifetime circuit cost of £1,191m.

9.2.6 East-West Strategic Option D requires the longest OHL build and requires the highest number of new substations to be constructed. East-West Strategic Option D is therefore the worst performing East-West Strategic Option when considering the cost factor alone. With respect to East-West Strategic Options A, B and C, they are all very similar from a cost perspective, with A and C sharing identical costs.

Carlisle to Newcastle conclusion

9.2.7 Taking all of this into account, to meet the need to provide 4,000 MW of East-West transfer capacity in Northern England, NGET's strategic option proposal at the current stage is to take forward an amalgamation of East-West Strategic Options A, B and C, from the Carlisle area to the Stella West area for further consideration.

9.2.8 The appraisal of the four East-West Strategic Options demonstrated similarities between East-West Strategic Options A, B and C from an environmental and socio-economic perspective, with each of the East-West Strategic Options exhibiting a similar level of constraints to consider across national and international designated areas. Whilst Option D would potentially result in significant environmental impacts, on balance it is considered to perform better in relation to potential impacts to the WHS compared to the other East-West Strategic Options. Whilst impacts on the WHS may be more benign, there is still a potential for impacts on other high value receptors where opportunities for mitigation are relatively challenging. It is considered the best performing East-West Option in respect of overall environmental and socio-economic factors, subject to availability of suitable mitigation options.

9.2.9 With respect to the technical factor East-West Strategic Option D is considered more technically complex and challenging, when compared to East-West Strategic Options A, B and C. East-West Strategic Option D would require a significantly longer circuit route length (174 km) when compared to East-West Strategic Options A (98 km), B (92 km) and C (98 km). For this reason, East-West Strategic Option D is the most unfavourable solution, in terms of technical complexity.

9.2.10 This additional infrastructure also means that East-West Strategic Option D performs worst when considering the cost factor, with significantly higher costs when compared to the other East-West Strategic Options. For example, when considering capital and lifetime costs together, based on NGET's indicative cost estimates, East-West Strategic Option D is £491m more expensive than East-West Strategic Option B and £450m more expensive than East-West Strategic Options A and C, which have the same capital and lifetime costs.

9.2.11 These technical and cost-related considerations would lead to significant risks and challenges associated with the delivery of East-West Strategic Option D, which would be expected to be greatly minimised for each of the other three East-West Strategic Options. Therefore, East-West Strategic Option D is not the preferred strategic option at this stage. However, as the impacts and opportunities for mitigation presented by amalgamated Options A, B and C become better understood, its performance will be reviewed in order to establish that this preference remains.

9.2.12 However, despite the significant technical and cost benefits associated with East-West Strategic Options A, B and C, these three options would need to consider expected interactions with national and international designated areas, with specific complexities and challenges expected to impact each of the strategic options in different ways.

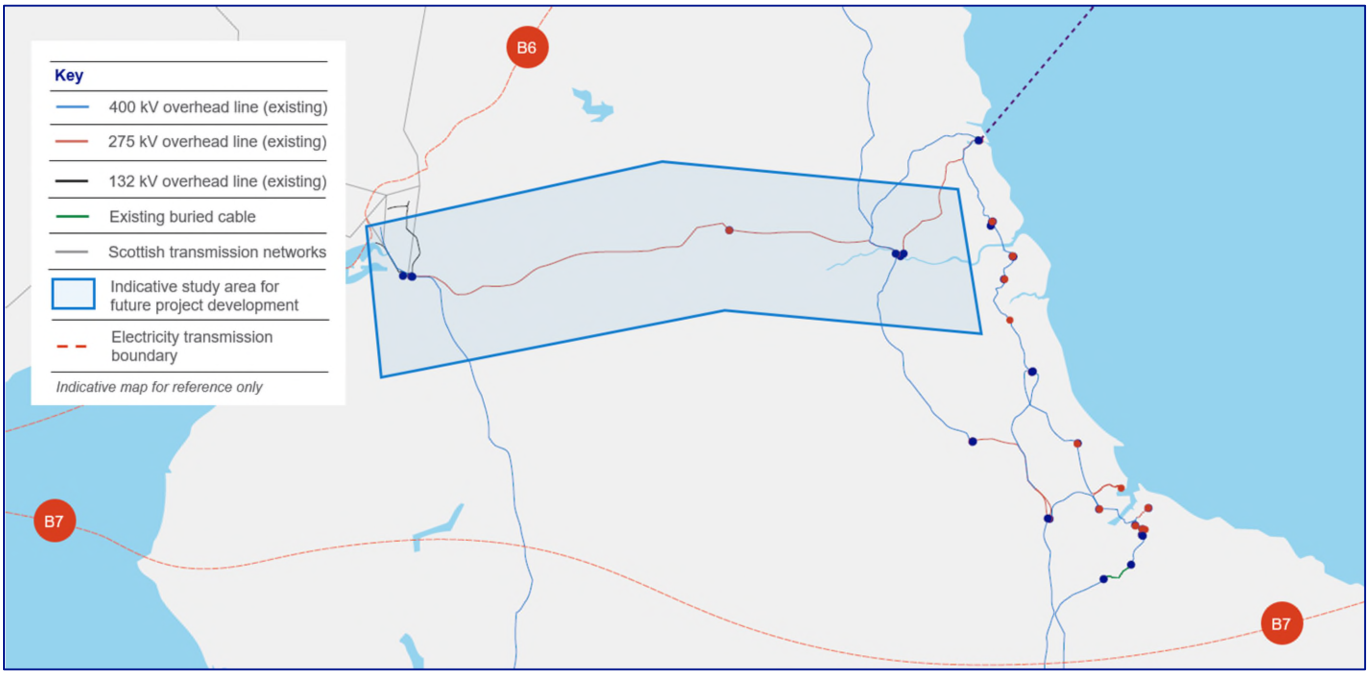
9.2.13 Noting the potential significance of these impacts, whilst also recognising the early development stage of the project, NGET do not consider that it would be prudent to proceed with a single preferred Option for the Carlisle to Newcastle project at this stage.

9.2.14 NGET does not currently have sufficiently granular information to compare the consenting risks and challenges associated with the environmental and socio-economic constraints identified within the study areas for East-West Strategic Options A, B and C. Therefore, in order to ensure that NGET proceeds with the most suitable solution that aligns with its statutory duties, NGET will amalgamate the three zones considered across East-West Strategic Options A, B and C into one study area, as demonstrated in Figure 9.1.

9.2.15 This amalgamated study area will be taken forward into the next stage of the project development. This wider study area will facilitate the required technical and environmental assessment, whilst allowing targeted stakeholder engagement to be undertaken. This assessment and engagement, undertaken across the amalgamated study area will inform the indicative routeing and siting that will be developed, ensuring that impacts on the local constraints can be minimised, and that the identified consenting risks and challenges can be assessed, and then mitigated as effectively as possible.

9.2.16 Figure 9.1 below presents the map view of the indicative amalgamated study area for future project development of East-West Strategic Options A, B and C.

Figure 9.1 – Indicative study area for future project development (Carlisle to Newcastle)



9.2.17 With regards to NGET's proposed next steps for the Carlisle to Newcastle project, reference should be made to the outcomes of the benefits filter and the appraisal factors presented in Section 7.2.

9.3 The case for the selection of the strategic option (Cross Border Connection)

Environmental factor

9.3.1 North-South Strategic Option 1 is the best performing North-South Strategic Option when considering the environmental factor. This option exhibits less constraints across the biological, physical and historical environments, as well as the associated landscape and visual impacts, when compared with the other North-South Strategic Options considered within this appraisal. Most notably, North-South Strategic Option 1 is the only option that provides the possibility of avoiding Northumberland National Park.

Socio-Economic factor

9.3.2 Overall, regarding the socio-economic appraisal aspect, the onshore options of the Cross Border Connection project exhibit similarities with respect to their associated constraints and no North-South option is clearly favoured over another with respect to this appraisal point alone. No North-South option has settlement and population constraints that would prevent its further consideration, with North-South Strategic Option 1 having some more difficulty of avoiding some small clusters of properties and the Carlisle area settlement. The WHS may need to be crossed for North-South Strategic Options 1, 2, 3 and 4 subject to detailed routeing and siting. Offshore North-South Strategic Option 5 will present amenity-related impacts on National Park and National Trail visitors. No North-South option can be considered to be significantly influenced by any land use or infrastructure constraints, with an MoD training area requiring to be crossed by every North-South option.

Technical factor

9.3.3 All North-South options comply with NETS SQSS and satisfy the project need case by providing a sufficient uplift to the B6 boundary. The implemented technologies, both for the four onshore options (AC OHL) and the offshore option (subsea HVDC) are adequately established and do not add any uncertainty risk when implementing them onto the project.

9.3.4 The technical factor comparison has added substantial weight in favour of North-South Strategic Option 1. As with North-South Strategic Option 3, this option involves the simplest build, only requiring an extension of the proposed substation at Fourstones which would be triggered by this option, as proposed by the East-West options. However, the shorter route length associated with North-South Strategic Option 1 reduces the technical complexity of the option when compared to the other North-South Strategic Options, including North-South Strategic Option 3. Crossings associated with the works of North-South Strategic Option 1 vary; however, they do not pose a more significant obstacle than the crossing constraints associated with the other North-South Strategic Options. Therefore, North-South Strategic Option 1 performs the best with respect to the technical factor.

Cost factor

9.3.5 The overview of the capital and lifetime cost impacts of each North-South Strategic Option, as set out in Section 7.3, is summarised below:

- North-South Strategic Option 1 – Teviot to Carlisle Area: Capital cost of £230.8m and lifetime circuit cost of £397m
- North-South Strategic Option 2 – Teviot to Haltwhistle Area: Capital cost of £353.6m and lifetime circuit cost of £472m
- North-South Strategic Option 3 – Teviot to Fourstones Area: Capital cost of £333.5m and lifetime circuit cost of £506m
- North-South Strategic Option 4 – Teviot to Stella West Area: Capital cost of £530.9m and lifetime circuit cost of £712m
- North-South Strategic Option 5 - Teviot to Stella West Area (subsea): Capital cost of £2,483.6m and lifetime circuit cost of £2,796m

9.3.6 North-South Strategic Option 5 is a subsea HVDC option that would require using a considerably costlier technology and would also require the longest route length of these five North-South Strategic Options. North-South Strategic Option 5 is therefore the worst performing North-South Strategic Option when considering the cost factor alone. The best performing North-South option when considering the cost factor is North-South Strategic Option 1, both in terms of capital and lifetime circuit costs, as it avoids the need to construct a new substation and offers the shortest route length. Therefore, North-South Strategic Option 1 offers the best economic performance across the North-South Strategic Options.

Cross Border Connection conclusion

9.3.7 Following the appraisal set out within this SOR, to meet the need to increase capacity across boundary B6 and provide the required capacity for the Teviot and Gala generation group and Northern England region, NGET's proposal at the current stage is to take forward North-South Strategic Option 1. This strategic option proposes a new 400 kV transmission connection between the Teviot area and the Carlisle area.

9.3.8 North-South Strategic Option 1 provides the shortest route length of the proposed North-South Strategic Options, and alongside North-South Strategic Option 3, requires the least amount of substation works, making it the best performing solution with regard to the technical appraisal.

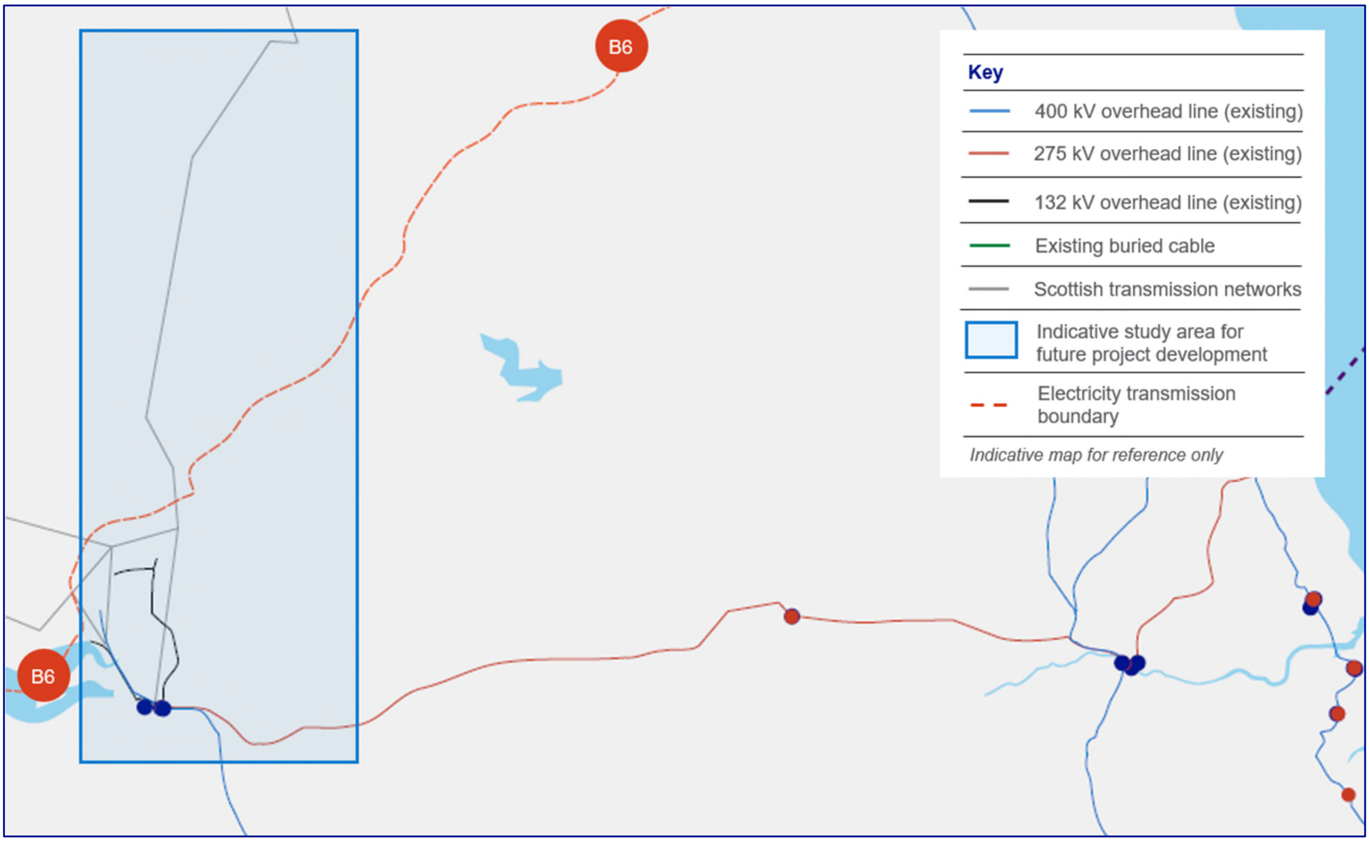
9.3.9 North-South Strategic Option 1 is also the best performing out of the five North-South Strategic Options in terms of cost. Its capital cost is £102.7m cheaper than the next cheapest North-South option (North-South Strategic Option 3).

9.3.10 In addition, North-South Strategic Option 1 performs the best in most aspects of the environmental appraisal when compared to the other four North-South Strategic Options. Notably, North-South Strategic Option 5 will not need to cross the WHS; however, as explained above, this option has the longest and most costly route length, while North-South Strategic Option 1 also exhibits fewer environmental constraints.

9.3.11 NGET will continue to review the work, including any notable changes in circumstances, and will have regard to consultation responses.

9.3.12 Figure 9.2 below presents the map view of the indicative study area to support future project development of the Cross Border Connection project.

Figure 9.2 – Indicative study area for future project development (Cross Border Connection)



9.4 Consideration of cumulative impacts

9.4.1 Having identified the preferred approach for advancing the development of the Carlisle to Newcastle project, as well as the preferred strategic option for the Cross Border Connection project, NGET undertook a further appraisal of the cumulative considerations that may materialise as a result of the delivery of both the Carlisle to Newcastle and the Cross Border Connection projects. This would identify any factors that may not impact on each of the Carlisle to Newcastle or the Cross Border Connection projects on an individual basis but would materialise when the options are considered together.

9.4.2 Each possible combination of the East-West and the North-South Strategic Options were considered. This cumulative appraisal considered the technical, cost, environmental and socio-economic factors associated with the delivery of each different combination of the East-West and North-South Strategic Options. This included the consideration of the cumulative impacts of the options on designated or important sites and areas, including the Frontiers of the Roman Empire (Hadrian's Wall) WHS.

9.4.3 This appraisal would allow NGET to identify if the preferred strategic solutions for the Carlisle to Newcastle and the Cross Border Connection projects, discussed in Section 9.2 and Section 9.3, could still be considered as the most suitable solutions for the projects after the consideration of the cumulative impacts.

9.4.4 From an environmental and socio-economic perspective, the most significant aspect that may impact on the cumulative appraisal of the two project elements is the expected interactions with, and total expected crossings of, the WHS. This is due to the extent to which the WHS spans across the majority of the existing XB route from Harker to Stella West, and the associated considerations that this would lead to for both the Carlisle to

Newcastle and the Cross Border Connection projects. The cumulative consideration of this factor would be largely driven by the site selection for the new substations that would be triggered by both the Carlisle to Newcastle and the Cross Border Connection projects.

9.4.5 Each of the proposed locations of the new substations considered within this SOR (Carlisle area, Haltwhistle area, Fourstones area and Stella West area) covers an area that encompasses potential substation locations both to the North and to the South of the WHS.

9.4.6 Therefore, the total number of WHS crossings that would be required for a combination of an East-West option with a North-South option will depend on the preferred location for the relevant new substation that would be constructed.

9.4.7 This cumulative appraisal at this early stage did not identify any further significant considerations that had not previously been taken into consideration as part of the individual option appraisal and comparison that would change the preferred strategic solutions for the Carlisle to Newcastle and the Cross Border Connection projects, presented above, which remain as the preferred and most suitable route forward for these projects. We will continue to review and back check optioneering as projects mature. As part of each DCO application National Grid will undertake a cumulative impact assessment which will be submitted as part of the application.

9.4.8 From a technical perspective, the cumulative appraisal undertaken at this stage did not identify any further notable considerations that would be expected to impact on the conclusions and preferred solutions, identified within Section 9.2 and 9.3. NGET does not expect the cumulative consideration of the Carlisle to Newcastle and the Cross Border Connection projects to impact on the technical feasibility of the preferred strategic solutions identified at this stage. In addition, NGET does not expect the cumulative considerations to impact on the ability of these strategic solutions to meet the need case set out within this SOR. NGET recognises that the development of more detailed routeing and substation siting may lead to further cumulative considerations; this may include a more informed view and appraisal of aspects such as OHL crossings and substation design. The cumulative appraisal of the two project elements will be re-evaluated as necessary as the project progresses.

9.4.9 From a cost perspective, the cumulative appraisal considered the total cost associated with the combined delivery of each possible combination of the East-West and the North-South Strategic Options. The costs presented within Section 9.2 and 9.3 represent the indicative costs for the delivery of each individual option. Where common infrastructure may be required across both an East-West option and a North-South option (e.g. a new substation), for the purposes of this appraisal, the East-West option is considered to have triggered this new infrastructure, therefore the costs associated with this new infrastructure is included within the cost appraisal of the East-West option. This ensures that as part of the cumulative cost appraisal, no costs were duplicated across the relevant East-West and North-South Strategic Options. At this stage, NGET does not consider the cumulative cost appraisal to impact on the feasibility of the preferred strategic solutions identified at this stage.

9.4.10 Therefore, following this appraisal, NGET believes that the preferred strategic solutions for the Carlisle to Newcastle and the Cross Border Connection projects, discussed in Section 9.2 and Section 9.3, remain as the preferred and most suitable route forward for these projects.

9.4.11 NGET recognises that as the projects in the region develop and aspects such as substation siting and cable routeing become more mature, further cumulative impacts may become more apparent and the cumulative considerations and requirements will become more definitive. Therefore, as East-West, North-South and future regional projects develop, the cumulative impact of projects will be re-evaluated and back checked on a frequent basis with relevant updates considered prior to any decisions being taken on overall project delivery.

9.5 Next steps

9.5.1 The Cross Border Connection project will now be taken forward to the next stage of development. This involves identification of a preliminary route corridor and graduated swathe, which indicates a more likely location for the development. This will be consulted on at non-statutory consultation to seek feedback from consultees and help shape the further development of the projects.

9.5.2 For both the Carlisle to Newcastle and Cross Border Connection projects, the next steps of project development will focus on understanding the Hadrian's Wall component of the UNESCO: Frontiers of the Roman Empire World Heritage Site (the WHS) as a key receptor in greater detail to identify and understand potential opportunities and risks at a regional level. Critically this work will inform and guide work necessary to refine the study area, which alongside some targeted engineering work will help to define project parameters and opportunities to support future routing and siting work. This early work will be supported by engagement with key WHS stakeholders such as Historic England.

9.5.3 The Cross Border Connection project is likely to proceed ahead of the Carlisle to Newcastle project. This is due to the requirement to meet the connection dates of Scottish generation. As a result, the Cross Border Connection project will undertake the siting, consenting and construction of the Carlisle Area substation to achieve the required timescales.

Appendix

nationalgrid

Appendix A Summary of National Grid Electricity Transmission Legal Obligations

1.1 Electricity Transmission Licence

1.1.1 The Electricity Act defines transmission of electricity within Great Britain 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 TO 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 TO 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 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 Coordination (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 TO 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 us to be made of existing TO 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

TOs are required to at all times plan, develop the transmission system in accordance with the NETS SQSS.

A TO 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 is subject to the Authority's consideration of all relevant factors.

1.3.5 Condition D17: Whole Electricity System Obligations

TOs 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 TO 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 B Requirement for Development Consent Order

1.1 Electricity Network Infrastructure Developments

1.1.1 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 which may include:

- planning permission under the Town and Country Planning Act 1990;
- a marine licence under the Marine and Coastal Access Act 2009;
- a DCO under the Planning Act 2008, and/or
- a variety of consents under related legislation.

1.1.2 The Planning Act 2008 defines developments of new electricity OHL of 132 kV and above as NSIPs requiring a DCO. Such an order may also incorporate Consent for other types of work that is associated with new OHL infrastructure development, may be incorporated as part of a DCO that is granted.

1.1.3 Six NPSs for energy infrastructure were designated by the Secretary of State for Energy and Climate Change in July 2011. The relevant NPSs for electricity transmission infrastructure developments are the Overarching National Policy Statement for Energy (EN-1) and the National Policy Statement for Electricity Networks Infrastructure (EN-5), which is read in conjunction with EN-1. In September 2021, Government consulted[19] on proposed updates to the NPS suite including EN-1 and EN-5. The proposed updates include clear linkages of EN-1 with policy objectives in respect of net-zero[20].

1.1.4 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 NPSs therefore provide the primary policy basis for decisions on DCO applications for electricity transmission projects. The NPSs 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.

1.2 Demonstrating the Need for a Project

1.2.1 Part 3 of EN-1 sets out Government policy on the need for new nationally significant energy infrastructure projects. Paragraph 3.1 confirms that the UK needs all of the types of energy infrastructure covered by the NPSs to achieve energy security and to

[19] BEIS Consultation, Planning for new infrastructure: review of energy National Policy Statements, September 2021: https://www.gov.uk/government/consultations/planning-for-new-energy-infrastructure-review-of-energy-national-policy-statements

[20] Energy White Paper: Powering our net zero future, December 2020 https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future

dramatically reduce greenhouse gas emissions. It states that "substantial weight" should be given to the contribution which projects would make towards satisfying each need.

1.2.2 Description of the need for:

- new electricity transmission infrastructure is set out in EN1 and EN5
- new offshore/onshore wind generation is set out in EN1 and EN3, and
- new nuclear generation is set out in EN1 and EN6.

1.2.3 The need for new transmission infrastructure for these projects is described in Section 4 of this Report.

1.3 Assessment Principles Applied by Decision Maker

1.3.1 Part 4 of EN-1 sets out the general policies that are applied in determining DCO applications relating to new energy infrastructure. Paragraphs 2.3-2.5 of EN-5 set out the general assessment principles in the specific context of electricity networks infrastructure.

1.3.2 Principles of particular importance for transmission infrastructure projects include:

1.3.3 Presumption in Favour of Development

- Section 4.1 of EN1 requires the IPC to 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 IPC should take account of potential:
  - benefits (e.g. the contribution to meeting the need for energy infrastructure, job creation and long-term wider benefits), and
  - adverse impacts (e.g. long-term and cumulative impacts but taking into account proposed mitigation measures.

1.3.4 Consideration of Alternatives

- Section 4.4 of EN1 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 2.8.4 of EN5 states that, "wherever the nature or proposed route of an OHL proposal makes it likely that its visual impact will be particularly significant, the applicant should have given appropriate consideration to the potential costs and benefits of other feasible means of connection or reinforcement, including underground and subsea cables where appropriate."
- Section 4.4 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 under the Habitats Directive and the Birds Directive[21].

1.3.5 Adverse Impacts and Potential Benefits

- Part 5 of EN1 covers the impacts that are common across all energy NSIPs and Sections 2.62.9 of EN5 consider impact in the specific context of electricity networks infrastructure.
- Those impacts identified in EN1 include air quality and 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, socioeconomic effects, traffic and transport, 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 these projects. EN5 considers specific potential impacts of electricity networks on biodiversity and geological conservation, landscape and visual, noise and vibration, and electric and magnetic fields.

1.4 Potential impacts of particular importance for electricity transmission infrastructure projects include:

1.4.1 Good Design

- Section 4.5 of EN1 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 EN1 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. Section 2.5 of EN5 identifies a particular need for the applicant to demonstrate the principles of good design were applied in the proposed approach to mitigating the potential adverse impacts which can be associated with OHL.

1.4.2 Climate Change

- Section 4.8 of EN1 explains how the effects of climate change should be taken into account and Section 2.4 of EN5 expands on this in the specific context of electricity networks infrastructure. DCO applications are required to set out the vulnerabilities / resilience of the proposals to flooding, effects of wind on OHL , higher average temperatures leading to increased transmission losses and earth movement or subsidence caused by flooding or drought (for underground cables).

[21] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora; Council Directive 2009/147/EC on the conservation of wild birds.

1.4.3 Networks DCO Applications Submitted in Isolation

- Section 2.3 of EN5 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. EN5 explains that the need for the transmission project can be assessed on the basis of both contracted and reasonably anticipated generation.

1.4.4 Electricity Act Duties

- Paragraph 2.3.5 of EN5 recognises developers' duties pursuant to Section 9 of the Electricity Act to bring forward efficient and economical proposals in terms of network design, taking into account current and reasonably anticipated future generation demand, and its duty to facilitate competition and so provide a connection whenever and wherever one is required.

1.4.5 Adverse Impacts and Potential Benefits

- Part 5 of EN1 covers the impacts that are common across all energy NSIPs and Sections 2.62.9 of EN5 consider impact in the specific context of electricity networks infrastructure.
- Those impacts identified in EN1 include air quality and 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, socioeconomic effects, traffic and transport, 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 these projects. EN5 considers specific potential impacts of electricity networks on biodiversity and geological conservation, landscape and visual, noise and vibration, and electric and magnetic fields.
- Potential impacts of particular importance for electricity transmission infrastructure projects include:

1.4.6 Landscape and Visual

- Paragraph 2.8.2 of EN-5 states that the Government does not believe that development of OHL is generally incompatible in principle with the developer statutory duty under Section 9 of the Electricity Act to have regard to amenity and to mitigate impacts. However, EN-5 recognises that in practice OHL can give rise to adverse landscape and visual impacts, dependent upon their scale, siting, degree of screening and the nature of the landscape and local environment through which they are routed.
- In relation to alternative technologies for electricity transmission projects, paragraph 2.8.9 of EN-5 states that, "each project should be assessed individually on the basis of its specific circumstances and taking account of the fact that Government has not laid down any general rule about when an OHL should be considered unacceptable. The IPC should, however, only refuse consent for OHL proposals in favour of an underground or subsea line if it is

satisfied that the benefits from the non-OHL alternative will clearly outweigh any extra economic, social and environmental impacts and the technical difficulties are surmountable." Paragraph 2.8.7 of EN-5 endorses the Holford Rules which are a set of "common sense" guidelines for routeing new OHL .

Appendix C Technology Overview

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 costs for each technology are 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. 230V 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:

- OHL
- Underground cables
- GIL and
- HVDC.

1.1.6 This Appendix C 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.

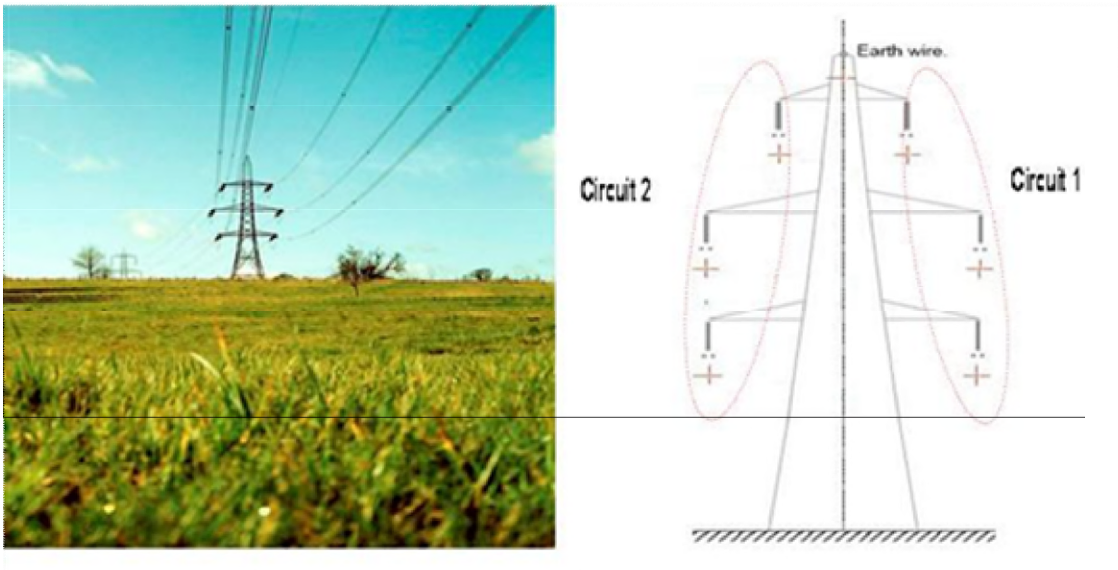
1.2 Overhead lines

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 OHL 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 OHL tend to have two or three conductors per arm.

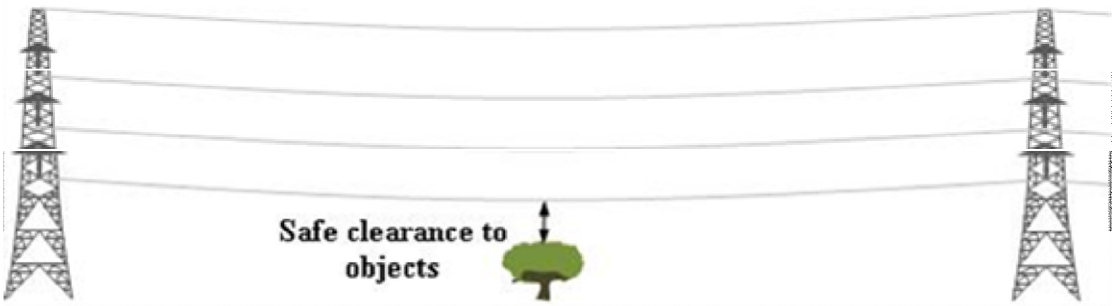
1.2.5 With the conclusion of the Royal Institute of British Architects (RIBA) pylon design competition[22] and other recent work with manufacturers to develop alternative pylon designs, National Grid is now able to consider a broader range of pylon types, including steel lattice and monopole designs. The height and width are different for each pylon type, which may help National Grid to manage the impact on landscape and visual amenity better. Figure C.2, below, shows an image on the monopole design called the T-pylon that was developed by National Grid.

22 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 360m.

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 OHL . Circuits must be taken out of service from time to time for repair and maintenance. However, shorter emergency restoration times are achievable on OHL 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 OHL 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 OHL , 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 OHL 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 OHL (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 OHL .

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.

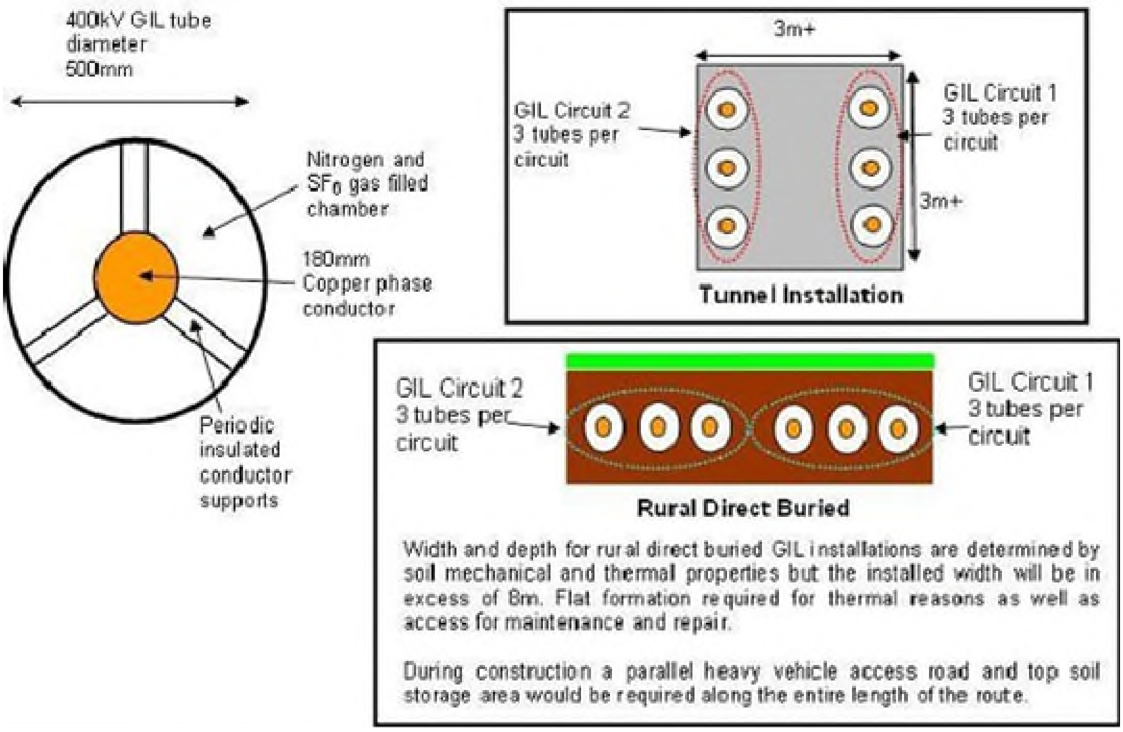
1.3.13 Asset replacement is generally expected at the end of design life. However, National Grid's asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

1.4 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 SF_6 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 below.

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 re-energised immediately after a fault (similar to OHL) whereas a cable requires investigations prior to re-energisation. If the fault was a transient fault, it will remain energised and if the fault was permanent the circuit will automatically and safely de-energise again.

1.4.7 There are environmental concerns with GIL as the SF_6[23] gas used in the insulating gas mixture is a potent greenhouse gas. Since SF_6 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

[23] 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[24]. 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 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.…

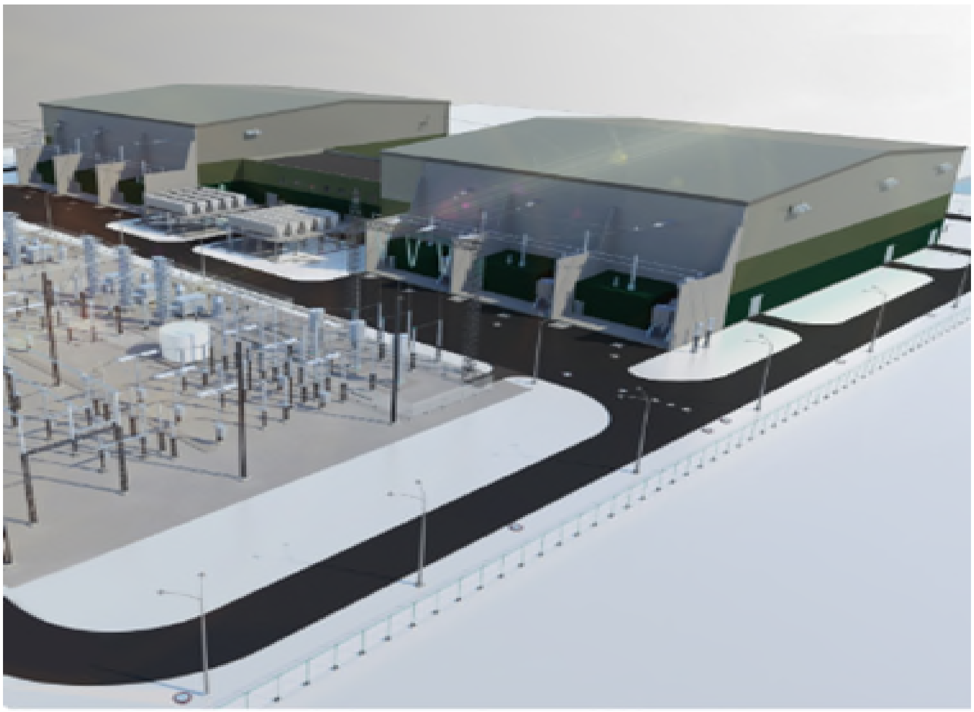
1.5.3 HVDC links may also be used to connect a generating station that is distant from the rest of the electricity system. For example, very remote hydro-electric schemes in China are connected by HVDC technology with OHL .

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. Converter stations can use two types of technology. “Classic” or CSC were the first type of HVDC technology developed and this design was used for National Grid’s Western Link. VSC are a newer design and offer advantages over the previous CSC converters, as they can better support weaker systems and offer more flexibility in the way they operate, including direction of power flow.

[24] 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 (AC 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

1.1.1 As part of the economic appraisal of Strategic Options, National Grid 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 National Grid 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 National Grid uses to assess the NPV of costs that are expected to be incurred during the lifetime of new transmission assets.

1.1.3 In 2025 the IET have published a new comparison of electricity transmission technologies: Cost and characteristics report[25]. This report is an independent assessment of technologies and costs and is separate to the appraisals. The IET report can be used as third-party verification that the technologies and costs within this report are aligned with industry evaluation provided within the IET 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
- 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.

[25] The IET's publication: A comparison of electricity transmission technologies: Costs and characteristics report https://www.theiet.org/impact-society/sustainability-and-climate-change/iet-electricity-transmission-technologies-report

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	Circuit Ratings by Voltage		Technology Configuration			Capital Costs		
Report short-form label	275 kV AC Technologies	400 kV AC Technologies	OHL	AC Underground Cable (AC Cable)	GIL	OHL	AC Underground Cable (AC Cable)	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	3190MVA (2 x 1595MVA) [2000MVA 2 x 1000MVA for AC Cable only]	3190MVA (2 x 1595MVA)	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 [3190MVA 2 x 1595MVA for AC Cable only]	6380MVA (2 x 3190MVA)	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	6930MVA (2 x 3465MVA)	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. 275 kV circuits will often require SGTs to allow connection into the 400 kV system, SGT capital costs are not included above but described later in this appendix.
5. 275 kV 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 275 kV.

1.4.3 Table D.2 provides a summary of the capital costs associated with the key[26] 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 2500 mm^2 cable per phase	5 Mvar/km
Med	275 kV	Two 2500 mm^2 cable per phase	10 Mvar/km
Lo	400 kV	One 2500 mm^2 cable per phase	10 Mvar/km
Med	400 kV	Two 2500 mm^2 cable per phase	20 Mvar/km
Hi	400 kV	Three 2500 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 1000 Mvar per circuit (2000 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

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

reactors (1600 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 below 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 transforms voltages between 275 kV and 400 kV (a 400/275 kV 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 below 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

275 kV Equipment	Capital Cost (SGT - including civil engineering work)
400/275 kV SGT 1100MVA (excluding switchgear)	£7.75m per SGT

1.7 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 OHL 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 above.
- 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. 1 GW 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 3190 MW would require two HVDC links of (1.6 GW capacity each), while “Med” and “Hi” rating 6380 MW-6930 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 below illustrates how comparisons may be drawn using scaling methodology outlined above.

Table D.8 – Illustrative example using scaled 2GW 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 (3190 MW)	£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 (6380 MW)	£9.27m/km (3 x £3.09/km)	£1422m (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 (6930 MW)	£10.32m/km (3 x £3.44/km)	£1818m (6 x £303m [6 converters 3 each end])	£1890m (6 x £315m [6 converter 3 each end])

Notes:

- Costs based on 2GW costs shown in Table D.4 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 NPV 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, 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[27]

"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 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.

[27] 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

	OHL	AC Cable	GIL	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 OHL Conductor Type (complete single circuit resistance for conductor set)	AC Underground Cable Type (complete single circuit resistance for conductor set)	AC GIL Type (complete single circuit resistance for conductor set)
Lo	2 x 570 mm^2 (0.025 Ω/km)	1 x 2500 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 2500 mm^2 (0.0043 Ω/km*)	Two tubes per phase (0.0065 Ω/km)
Losses per 200Mvar Reactor required for AC underground cables			
Reactor Losses	N/A	0.4 MW per reactor	N/A
Additional losses for 275 kV 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	2GW DC Cable Pair Losses	2GW Total Link loss
CSC Technology or "Classic" HVDC	0.5% per converter	Ignored	1% per HVDC Link
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 this appendix.

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 this appendix) of instantaneous losses for each technology option for an example circuit of 40 km "Med" capacity 6380 MVA (two x 3190 MVA).

- OHL = (2 x 3) x 1565.5 A2 x (40 x 0.0184 Ω/km) = 10.8 MW
- Underground Cable = (2 x 3) x1565.5 A2 x (40 x 0.0065 Ω/km) + (6 x 0.4 MW) = 6.2 MW
- GIL = (2 x 3) x 1565.5 A2 x (40 x 0.0086 Ω/km) = 5.1 MW
- CSC HVDC = 34% x 6380 MW x 1% = 21.7 MW
- 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 6380 MVA (two x 3190 MVA).

- OHL annual loss = 10.8 MW x 24 x 365 x £60/MWhr = £5.7m.
- Underground Cable annual loss = 6.2 MW x 24 x 365 x £60/MWhr = £3.3m.
- GIL annual loss = 5.1 MW x 24 x 365 x £60/MWhr = £2.7m
- CSC HVDC annual loss = 21.7 MW x 24 x 365 x £60/MWhr = £11.4m
- 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 3190 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 40 km	OHL	AC Underground Cable (AC Cable)	GIL	CSC HVDC	VSC HVDC
Capital Cost	£145.6m	£1167.6m	£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

1.1.1 This Appendix E 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 textbooks.

1.1.2 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.

1.1.3 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.

1.2 Example Loss Calculation (1) – 40 km 400 kV “Med” Category Circuits

1.2.1 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).

1.2.2 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 D.40 of Appendix D, which for the each of the two circuits in the “Med” category example is calculated as:

P = 34% x 3190 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 x 106/(√3 x 400 x 103) = 1,565.5 Amps

1.2.3 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.

1.2.4 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[28] = 0.0065Ω/km x 40 km = 0.26 Ω

GIL = 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.

1.2.5 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

1.2.6 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

1.2.7 The same methodology is applied for the other AC technology option types for the “Med” category example considered in this Appendix E. The following is a summary of the instantaneous total losses that were assessed for each technology option:

OHL = (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

GIL = (2 x 3) x 1,565.52 x 0.344 = 5.1 MW

1.3 Example Loss Calculation (2) – 40 km 275 kV “Lo” Category Circuits Connecting to a 400 kV part of the National Grid’s transmission system

1.3.1 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 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.

1.3.2 The circuit utilisation power (P) which for the each of the two circuits in the “Lo” category example is calculated as:

[28] 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

1.3.3 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:

$0.0086\Omega/\text{km} \times 40 \text{ km} = 0.344\ \Omega$

1.3.4 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

1.3.5 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[29] is calculated (from information in Appendix d, Table D.10) as 0.2576 Ω.

1.3.6 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.

1.3.7 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

[29] Resistance value referred to the 400 kV side of the transformer.

Appendix F Beyond 2030 Publication

1.1 Pathway to 2030 – HND

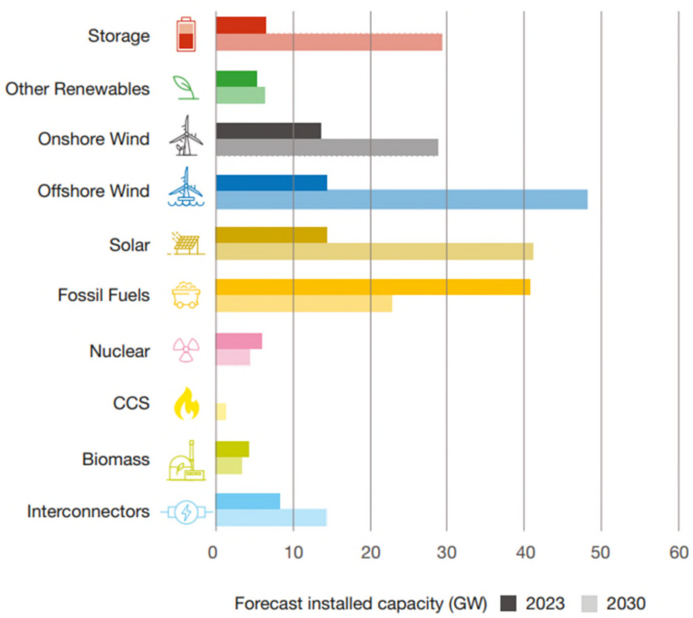
1.1.1 In 2023, 51% of the electricity in Great Britain used was generated by zero-carbon sources. It is expected that by 2030, the electricity system will more commonly run on 100% renewable energy sources for measurable time frames, which will be vital to meet the UK Government's ambition of having 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 OTNR with the goal of developing a HND 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]



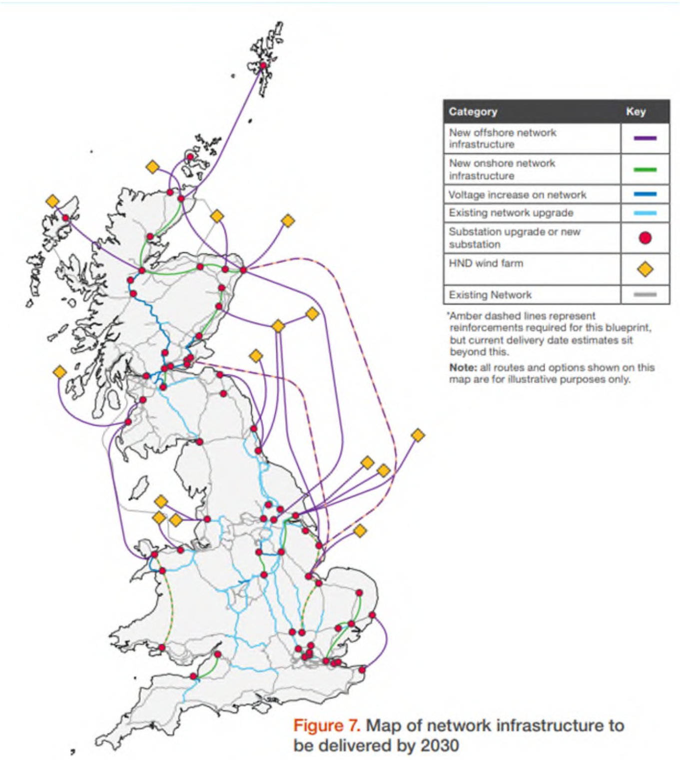
1.1.5 ESO's Pathway to 2030 Holistic Network Design 2022 plan to connect 23 GW of offshore wind in the transmission system seeks to reduce reliance on imports of gas and reduce

CO2 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 Great Britain 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 F.2.

Figure F.2 – Network infrastructure to be delivered by 2030 [source: Beyond 2030, ESO, March 2024]



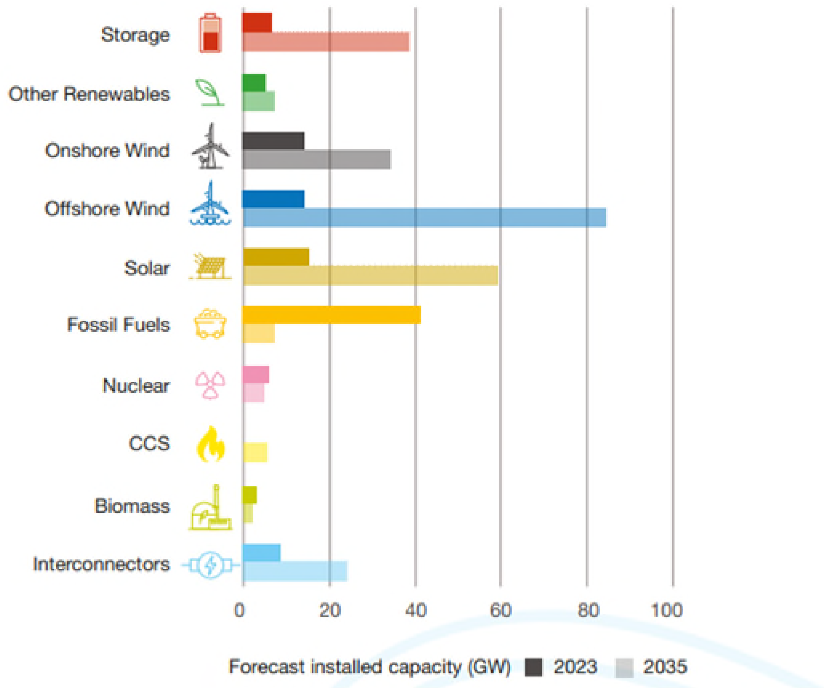
1.2 Beyond 2030 – HND FUE

1.2.1 Scoping beyond 2030, by 2035, several processes will be fully electrified and will be realised even in everyday life activities. New ICE cars will not be sold, with only 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]



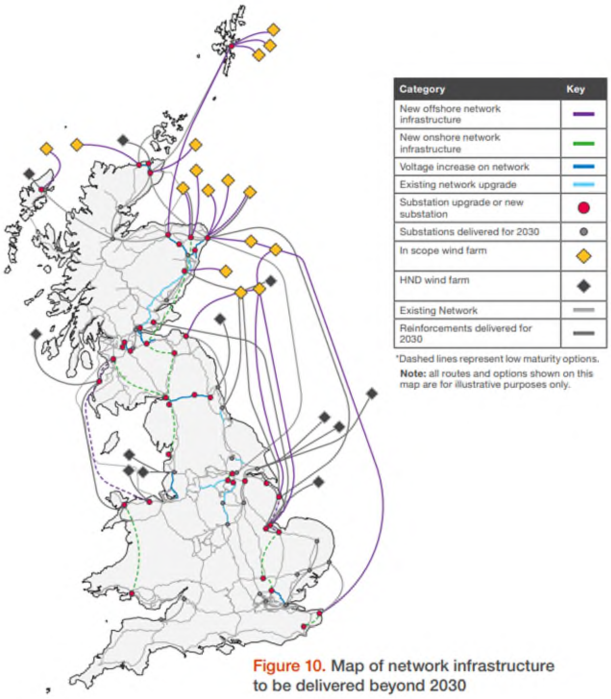
1.2.4 As it stands, the HND scheme is not sufficient by itself to reinforce the transmission system within the Pathway to 2030, as more electricity will be generated than the network can efficiently support and transport. Therefore, the UK Government requested ESO to further develop the HND and enable 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 Great Britain's 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]



1.3 Way forward

1.3.1 The Beyond 2030 report builds on the 2022 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 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 TOs will commence the 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 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.
- 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.
- 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.
- 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.
- NZMR - The objective of the NZMR programme is to outline holistic market design and complementary investment policy for net zero and contribute to the REMA debate from the perspective of Great Britain's ESO.

Appendix G Glossary of Terms and Acronyms

Acronym / Term	Definition
AC	Alternating Current
AC Cable	AC Underground Cable
ACS	Average Cold Spell
ALC	Agricultural Land Classification
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
BGS	British Geological Survey
CBA	Cost Benefit Analysis
CCC	Climate Change Committee
CION	Connection and Infrastructure Options Note
CLN2	The code used to represent a new circuit between North West England and Lancashire
CMN3	The code used to represent the Cross Border Connection project discussed within this report – a new circuit between South East Scotland and North West England
CMNC	The project code previously used for the Cross Border Connection before revision
CNP	Critical National Priority
Conductor	Used to transport power
CP30	Clean Power 2030 - the UK government's plan to decarbonize the electricity system by 2030
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.
DND	Detailed Network Design
DNO	Distribution Network Operator
EA	Environment Agency
ECU	Energy Consents Unit
EGL	Eastern Green Link: This onomatology covers five projects (EGL 1, EGL 2, EGL 3, EGL 4, EGL 5) which are five 2GW HVDC links between Scotland and England
EIA	Environmental Impact Assessment
Electricity Act	The Electricity Act 1989
EN-1	Overarching National Policy Statement for Energy
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
ENA	Electricity Networks Association
ESO	Operator of National Electricity Transmission System, the National Grid Electricity System Operator
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.
EVs	Electric Vehicles
FES	Future Energy Scenarios represent different credible scenarios for the transition to a cleaner greener energy future by 2050.
FLL	Functionally Linked Land
FSU1	The code used to represent the Carlisle to Newcastle project discussed within this report – upgrading the existing network to a higher voltage between Harker and Stella West
GHG	Greenhouse gases
GIL	Gas Insulated Lines
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.

HRA	Habitats Regulations Assessment
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
IPC	Infrastructure Planning Commission
IROPI	Imperative Reasons of Overriding Public Interest
LC	Licence Conditions
LOTI	Large Onshore Transmission Investment
MCZ	Marine Conservation Zone
MCZA	Marine Conservation Zone Assessment
MEEB	Measures of Equivalent Environmental Benefit
MITS	Main Interconnected Transmission System
MMO	Maritime Management Organization
MoD TTA	Ministry of Defence Tactical Training Area
MPS	Marine Policy Statement
NGET	National Grid Electricity Transmission plc
NESO	National Energy System Operator
NETS	National Electricity Transmission System
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.
NETS SQSS	National Electricity Transmission System Security and Quality of Supply Standard
NNR	National Nature Reserve
NOA	Network Options Assessment
NPF4	National Planning Framework 4

NPR	Network Planning Review
NPS	National Policy Statement
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
ONTR	Offshore Transmission Network Review
Pylons	Used to support conductors
REMA	Review of Electricity Market
RESP	Regional Energy Strategic Planners
RIBA	Royal Institute of British Architects
SACs	Special Areas of Conservation
SEPA	Scottish Environment Protection Agency
SF_6	Sulphur Hexafluoride (gas used to provide electrical insulation)
SGT	Super-Grid Transformer
SMC	Scheduled Monument Consent
SOR	Strategic Options Report
SoS	Secretary of State
Span length	Distance between adjacent pylons
SPAs	Special Protection Areas
SP Energy Networks SPT	SP Transmission plc is a wholly owned subsidiary of ScottishPower (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	Site of Special Scientific Interest
STC	System Operator – Transmission Owner Code

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 Acceleration Action Plan
tCSNP2	Transitional Centralised Strategic Network Plan 2
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
UG	Underground
Uprating	The process of increasing the capacity or voltage rating of an existing power line or electrical system, such as upgrading a 275 kV line to a 400 kV line
Volt-ampere (VA)	The SI unit of apparent power 1 kVA = 1,000 VA 1 MVA = 1,000 kVA
Volt-ampere-reactive (VAR or Var)	The SI unit of reactive power 1 kVAR = 1,000 VAR 1 MVAR = 1,000 kVAR
volt (V)	The electrical unit of potential difference 1 kilovolt (kV) = 1,000volts
VSC	Voltage Source Converters
watt (W)	The SI unit of real power 1 kilowatt (kW) = 1,000 watts 1 megawatt (MW) = 1,000 kW 1 gigawatt (GW) = 1,000 MW
Watt-hour (Wh or Whr)	A unit of work/energy which is equivalent to the power of one Watt operating over the course of one hour
WCN2	The code used to represent a new circuit from East Scotland to North Erth easast England
WHS	World Heritage Site
XB	275 kV circuit between Harker – Fourstones – Stella West
XLPE	Cross Linked Polyethylene (solid material used to provide electrical insulation)
YG, ZV, ZX, 4ZY	Existing transmission connection routes within NGET's network

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