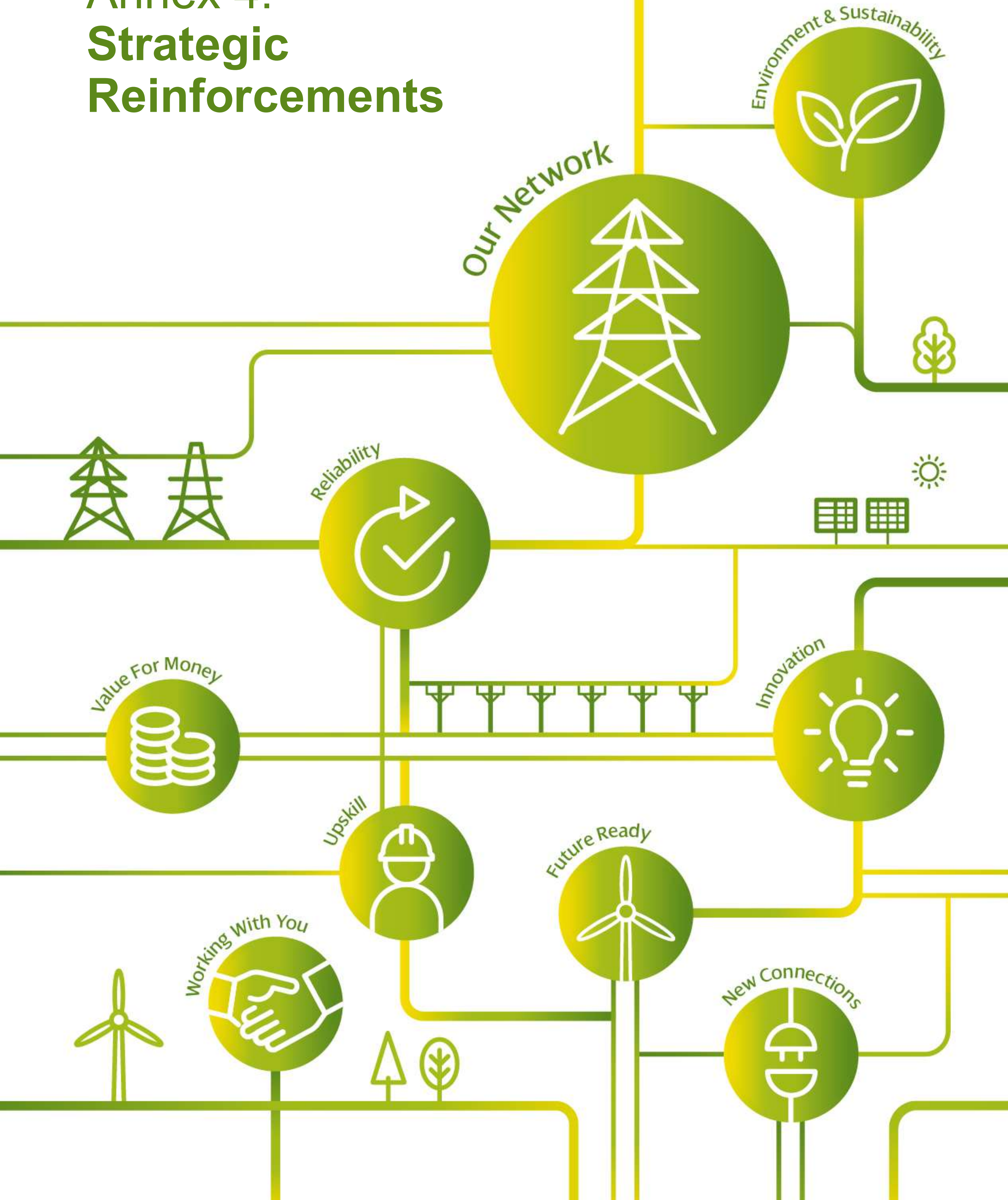
SP Energy Networks, RIIO-T2 Business Plan
December 2019 Submission

Annex 4:
Strategic Reinforcements



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EXECUTIVE SUMMARY

This annex provides a summary of the strategic reinforcements that are detailed in the SPT RIIO-T2 business plan on pages 75-78. It also provides a strategic narrative to the various engineering justification papers relating to boundary upgrade projects.

A joint working group has been established by the three GB onshore Transmission Owners (TOs) SHE Transmission (SHET), SP Transmission (SPT) and National Grid (NGET), supported by National Grid Electricity System Operator (ESO) to determine a coordinated strategic approach to the reinforcement of the eastern side of the GB Transmission network. This document summarises the current work carried out by the working group in addition to the normal network planning activities including the annual Network Options Assessment (NOA) process, and is intended to be a reference document explaining the strong and urgent need for coordinated reinforcement on the eastern side of the GB Transmission network, from Boundary B2 to Boundary B8, but focuses on the requirements of the SPT system only.

The ESO's cost benefit and least worst regret analysis provides an overwhelmingly positive economic case for reinforcement of the eastern side of the GB transmission network against a wide range of generation scenarios and sensitivities. The optimal combination of onshore plus offshore reinforcements have shown to give positive net present values ranging from £11,660million to £18,350million, based upon the East Coast Reinforcement CBA completed in 2019.

The optimal reinforcement pathway comprises several discrete projects with different costs and capacities, at different levels of maturity and spanning a horizon of around ten years that combine to give the optimal investment strategy. The development of such a large programme of works is therefore challenging, requiring all three TOs to work together to deliver the most economic, efficient and coordinated reinforcement strategy.

The first projects to be delivered as part of the eastern reinforcement strategy are the Scottish incremental onshore transmission upgrade works, Eastern Onshore 275kV Upgrade (ECU2) and Eastern Onshore 400kV Incremental Reinforcement (ECUP), predominantly utilising existing assets.

Other onshore reinforcements proposed solely within SPT's area are the Denny to Wishaw 400kV Reinforcement (DWNO), and the Eccles hybrid shunt compensation project (ECVC), which provides dynamic voltage support, system strength and real-time rating for some critical circuits. The Denny – Wishaw reinforcement is currently programmed to deliver in 2028 but will require significant works within this price control period to maintain its earliest in-service date (EISD). The Eccles shunt compensation project is programmed to deliver in 2025.

The economic analysis carried out, including the ESO's cost benefit analysis indicates all of the above projects have strong economic benefits, are robust against a variety of sensitivities and would not be regretted with or without the completion of the larger reinforcements. The design and development of these projects are well advanced.

For this reason, the Scottish incremental onshore transmission projects are included in the RIIO-T2 Baseline Wider Works (BWW) submission for delivery in 2023 and 2026 respectively, by SHE Transmission and SP Transmission, as well as the funds required over this period to deliver DWNO in 2028 by SP Transmission.

The other projects in the optimal reinforcement pathway include;

- Two new 2GW HVDC links, one from Torness in SPT's area and one from Peterhead in SHE Transmission's area to two separate landing points in NGET's area north of B8, to be delivered between 2027 and 2029.
- Reinforcement across B7 to B8 in NGET's area, to accommodate the additional capacity of the Eastern HVDC links to align with these completion dates.

The former are less well advanced in their design and development and therefore it is proposed that these projects be submitted to Ofgem for approval separately from the RIIO-T2 Business Plan submission, at the earliest opportunity under an uncertainty mechanism such as the Strategic Wider Works (SWW) process.

The conclusions from this work are consistent with the recommendations and outputs from NOA 2018/19[1] in that the NOA report recognises a strong need for two further 2GW HVDC links over and above the completed Western HVDC Link between Scotland and Northern England, in addition to onshore works spanning boundaries B2 to B8. At the time of

[1] https://www.nationalgrideso.com/document/137321/download

writing, the NOA 2019/20 (NOA5) report has not been published, however early economic analysis indicates a consistent result, with further reinforcement required in addition to the works covered within this report.

The NOA report also outlines the complete reinforcement strategy for the eastern transmission network, including the requirement for two new HVDC links. It clearly demonstrates the strong economic case for reinforcement and the range of works that are required to deliver the required boundary capacity uplifts to reduce the congestion forecast under a range of generation scenarios.

Further to justifying the overall need, this document outlines the variety of options available to alleviate constraints across these boundaries. This document also acts as a strategic optioneering report, using the output of the Electricity System Operator's (ESO) Network Options Assessment 2018/19 (NOA) and the output of a specific East Coast Strategic Wider Works (SWW) Cost Benefit Analysis to optimise the suite of reinforcements put forward.

This strategic optioneering report concludes;

- There is a need for significant reinforcement comprising multiple projects across several boundaries from B2 to B8 to be delivered over the next ten years.
- The ESO's CBA results strongly support proceeding with onshore reinforcement in Scotland in addition to two east coast Anglo-Scottish HVDC reinforcements.
- The onshore works in Scotland are recommended to proceed at the earliest practicable date. The CBA has shown them to be economic in conjunction with the HVDC offshore links and **there is no regret in delivering these works on their earliest in services dates, even if the other schemes do not proceed**.
- Two HVDC links are economic and are recommended to proceed to Final Needs Case at the earliest practicable date.

Wider works specific to the SPT network area that have been considered within the background network as 'enabling works' for the larger boundary reinforcements to be included for delivery within the RIIO-T2 plan are:

- Windyhill to Lambhill to Longannet 275kV Circuit Turn-In to Denny North (WLTI)
- Hunterston East – Neilston 400kV Reinforcement (HNNO)
- Eccles Shunt Compensation and Real Time rating system (ECVC)

All other assumed network reinforcements are as per ETYS 2017.

1. INTRODUCTION

A joint working group has been established by the three GB onshore Transmission Owners SHE Transmission, SP Transmission and National Grid Electricity Transmission, supported by National Grid Electricity System Operator (ESO) to determine a coordinated strategic approach to the reinforcement of the eastern side of the GB Transmission network. This document details the current work carried out by the working group with a particular emphasis on the RIIO-T2 business plan requirements for SPT and is intended to be a reference document explaining the strong and urgent need for coordinated reinforcement on the eastern side of the GB Transmission network, from Boundary B2 to Boundary B8. The technical aspects of each of SPT's projects can be found within the specific engineering justification papers submitted with the RIIO-T2 business plan.

Engineering justification papers submitted with SPT's RIIO-T2 business plan[2]:

- East Coast 275kV Upgrade (ECU2)
- East Coast 400kV Incremental Reinforcement (ECUP)
- Denny to Wishaw 400kV Reinforcement (DWNO)
- Windyhill to Lambhill to Longannet 275kV Circuit Turn-In to Denny North (WLTI)
- Hunterston East – Neilston 400kV Reinforcement (HNNO)
- Eccles Shunt Compensation and Real Time Rating System (ECVC)

1.1. Network Requirements and Economic Investment

The scope of reinforcement works under consideration is unusual in that it spans across all three onshore transmission owner's licensed areas from the north east side of Scotland to the north east of England, crossing several transmission boundaries and comprising several discrete projects. This paper focuses on the requirements of the SPT network.

To address the shortfall in capacity, a range of reinforcement options have been developed by each TO and collaboratively, these comprising a range of discrete projects of varying capability, technology and cost with different risks and construction programmes that span a horizon of around ten years. The development of such a large programme of works is therefore challenging and requires all three TOs and the ESO to work together to identify the most economic, efficient and coordinated plan.

A critical part of the need assessment is the cost benefit analysis (CBA), further to that within the NOA process, undertaken by the ESO to examine the existing transmission network and forecast the potential congestion under a range of future generation scenarios. This is the counterfactual reference against which the reinforcement options proposed by the TOs are examined to determine the economic benefit provided by individual projects and also in combination to find the optimal solution.

The objective of this coordinated exercise is to confirm that the reinforcement strategy for the eastern side of the GB network is economically justifiable and to identify which grouping of reinforcement options combine to give the optimal investment strategy.

1.2. Regulatory Process

The projects capable of early delivery have been identified for SPT and have a well evidenced need case, and as the project maturity is sufficiently well advanced it is proposed that these works should be considered as baseline wider works to RIIO-T2. For these projects, this report provides the background need and economic justification for the works.

[2] EJP_SPT_SPT200108_ECU2, EJP_SPT_SPT200110_ECUP, EJP_SPT_SPT200106_DWNO, EJP_SPT_SPT200119_WLTI, EJP_SPT_SPT200112_HNNO, EJP_SPT_SPT200120_ECVC.

However, where project timeframes are longer and maturity is not sufficiently well developed it is envisaged that those projects will be taken forward via the strategic wider works (SWW) or equivalent process within RIIO-T1, recognising that the bulk of the project spend will take place in RIIO-T2 and RIIO-T3. The SWW process allows for large transmission developments that benefit consumers to be brought forward during the price control period on a case by case basis, and protects consumers from potential investments in large projects that were not sufficiently well justified at time of the RIIO-T2 business plan submission.

For those projects to be submitted under the SWW process, this report will outline need and economic justification as part of the overall need for eastern reinforcement. However, this will be further reviewed and updated formally at a later date as part of the SWW process.

The SWW process requires four sequential hold points where information is presented to Ofgem to assess whether the project is in the best interest of consumers. These hold points comprise;

- An eligibility statement, where the TOs formally notify Ofgem of the reinforcement proposal under the SWW arrangements.
- An initial needs case assessment (INC), where the TOs outline the requirement for reinforcement and examine the options available with indicative costs and timelines.
- A final needs case (FNC), when the project need is well justified both technically and economically and where substantive progress has been made on consenting, programme and costs
- A detailed project assessment, which will examine the proposed reinforcement to ensure that the project is ready for delivery with a robust delivery plan, appropriate risk management and costs that are efficiently incurred.

The INC for the Eastern HVDC projects referenced in this report is expected to be submitted in 2020 and will reiterate the basis of the need, including a review of the project drivers and the range of reinforcement options that span the eastern side of the Scottish system and the north east of England region of the GB transmission system.

Given the extensive area under investigation it was important to identify not only the individual reinforcement options but also how these could be combined to give the overall optimal and efficient solution. The process of evaluating the reinforcement options resulted in a series of options being taken forward to detailed CBA. The alignment in timing with the Networks Options Assessment 2018/19 process allowed further scrutiny of the same options to be factored into this CBA. The output from the CBA and the 2018/19 NOA demonstrated the need for an incremental investment strategy, to give the optimal scope, timing and deliverability. At the time of writing, the NOA 2019/20 report has not yet been published, however early indications from the economic analysis mirror the results of previous analysis, providing strong signals to continue with the projects outlined within this report, and additional reinforcements supplementary to these.

1.3. Project History

The requirement for reinforcement on the eastern side of the GB transmission network was highlighted as far back as 2009 as part of the Electricity Networks Strategy Group[3] (ENSG) report[4], “A Vision for 2020”. A subsequent report[5] issued in February 2012 gave an updated view from the ENSG on how the electricity network might need to be reinforced to facilitate the Government’s 2020 renewable targets. However, with reinforcement in the west being advanced in the form of the western submarine HVDC link and the series compensation of existing Anglo-Scottish cross border AC circuits, along with generation uncertainty, the further reinforcement on the east was not justified at that time. The requirement for reinforcement in the east has continued to be closely monitored by the TOs and the need and timing for the reinforcement works has now been confirmed as outlined in Chapters 5 and 8. The project development history is outlined in more detail in Appendix 2.

[3] https://www.gov.uk/government/groups/electricity-networks-strategy-group
[4] ENSG report 2009: ‘Our Electricity Transmission Network: A Vision For 2020’
[5] ENSG updated report 2012: ‘Our Electricity Transmission Network: A Vision For 2020’

2. TRANSMISSION OWNER LICENCE OBLIGATIONS AND STANDARDS

Each Transmission Owner holds a licence under Section 6 of the Electricity Act 1989 authorising it to participate in the transmission of electricity within its licence area. Under section 9(2) of the Act it is our statutory duty to develop and maintain an efficient, coordinated and economical system of electricity transmission and to facilitate competition in the supply and generation of electricity. These statutory obligations are reflected in the transmission licence that has been granted to us.

Standard Licence Condition 6I obliges TOs to notify the Authority (Ofgem) of our investment proposals for new SWW outputs. This requires us to submit the associated Needs Case, CBA and Project Assessment for the SWW outputs along with programme and delivery timescales.

Standard Licence Condition D3 obliges us, at all times, to plan and develop our transmission system in accordance with the SQSS[6] and the STC[7] and in doing so requires us to take into account the ESO's obligations under its licence to coordinate and direct the flow of electricity onto and over the national electricity transmission system (NETS).

The STC sets out the terms whereby the NETS is to be planned, developed or operated and transmission services are to be provided.

The SQSS sets out a coordinated set of criteria and methodologies that the transmission licensees shall use in the planning and operation of the NETS. The standard sets out both planning and operational criteria which determine the need for services provided by the transmission licensee, including transmission equipment. The planning criteria set out the requirements for the transmission capacity for the NETS and also require consideration to be given to permit the satisfactory operation and maintenance of the NETS.

3. PROJECT GOVERNANCE

The collaborative nature of the wider network strategy discussed within this paper has driven joined-up working since the outset. The governance for this joint planning of the GB transmission system comes under the STC which requires the Licensees to plan and develop their respective grid systems in an efficient, coordinated and economic manner. To facilitate this process and to comply with the STC, a Joint Planning Committee (JPC) exists which co-ordinates investment planning, connection and transmission system performance activities.

Under the STC arrangements each party carries out the necessary pre-construction works and bears its own costs, except in the case where the parties agree to jointly engage a service provider. Under these circumstances any costs would be shared between TOs as appropriate and as jointly agreed. Such arrangements would allow established costs and reporting arrangements within each company to continue pending establishment of a specific project vehicle, if appropriate, at a later date.

The scope of the proposed east coast reinforcement works spans across all three onshore transmission owner's licensed areas, from the north east of Scotland to the north east of England. It is therefore essential for SHET, SPT and NGET to work together, in collaboration with the ESO, to develop and evaluate reinforcement proposals and jointly prepare this document.

Given the scale of the potential projects involved and the requirement for specific pre-construction development tasks, SHE Transmission, SPT and NGET have established a project structure comprising a project supervisory board (set at an appropriately senior level from each TO), a project management committee and several working groups including System Requirements, Development and Delivery, Technology and Land and Consents. These working groups will continue to grow and develop as appropriate as the projects moves through the development process.

Coordination between the three TOs is critical to delivering the eastern reinforcement projects, particularly in determining a strong technical and economic Needs Case in conjunction with the ESO, but also in coordinating pre-construction works including the long lead items such as the seabed surveys which allow the HVDC links to be delivered on time.

[6] National Electricity Transmission Security and Quality of Supply Standard
[7] System Operator Transmission Owner Code

4. TRANSMISSION NETWORK AND GENERATION BACKGROUND

The GB transmission network is planned to make sure there is sufficient transmission capacity to send power securely and economically from areas of generation to areas of demand. Limiting factors on transmission capacity include thermal circuit ratings, voltage constraints and/or issues with transient and dynamic stability. From network studies, the most onerous known limitation is used to determine the network capability.

For analysis purposes, the GB transmission network is split up by notional boundaries around major generation and demand centres and across significant route corridors. These allow the TOs and the ESO to determine the capability and security of the system. The existing transmission network and boundaries are illustrated on the GB transmission map shown in Figure 1 below and in Appendix 1.

The strategy developed by the three TOs consists of reinforcements of the existing GB transmission network in the north and east of Scotland characterised by boundaries B2, B4 and B5, the Anglo-Scottish region characterised by boundary B6 and the north east of England comprising the transmission network across and north of the Midlands to South boundary. This region is characterised by boundaries B7, 7a and B8. Further detailed background information on the existing GB transmission network can be obtained from the published ETYS[8] and NOA[9].

[8] Electricity Ten Year Statement (ETYS), ESO November 2019; https://www.nationalgrideso.com/insights/electricity-ten-year-statement-etys
[9] Network Options Assessment (NOA), ESO January 2019; www.nationalgrideso.com/insights/network-options-assessment-noa

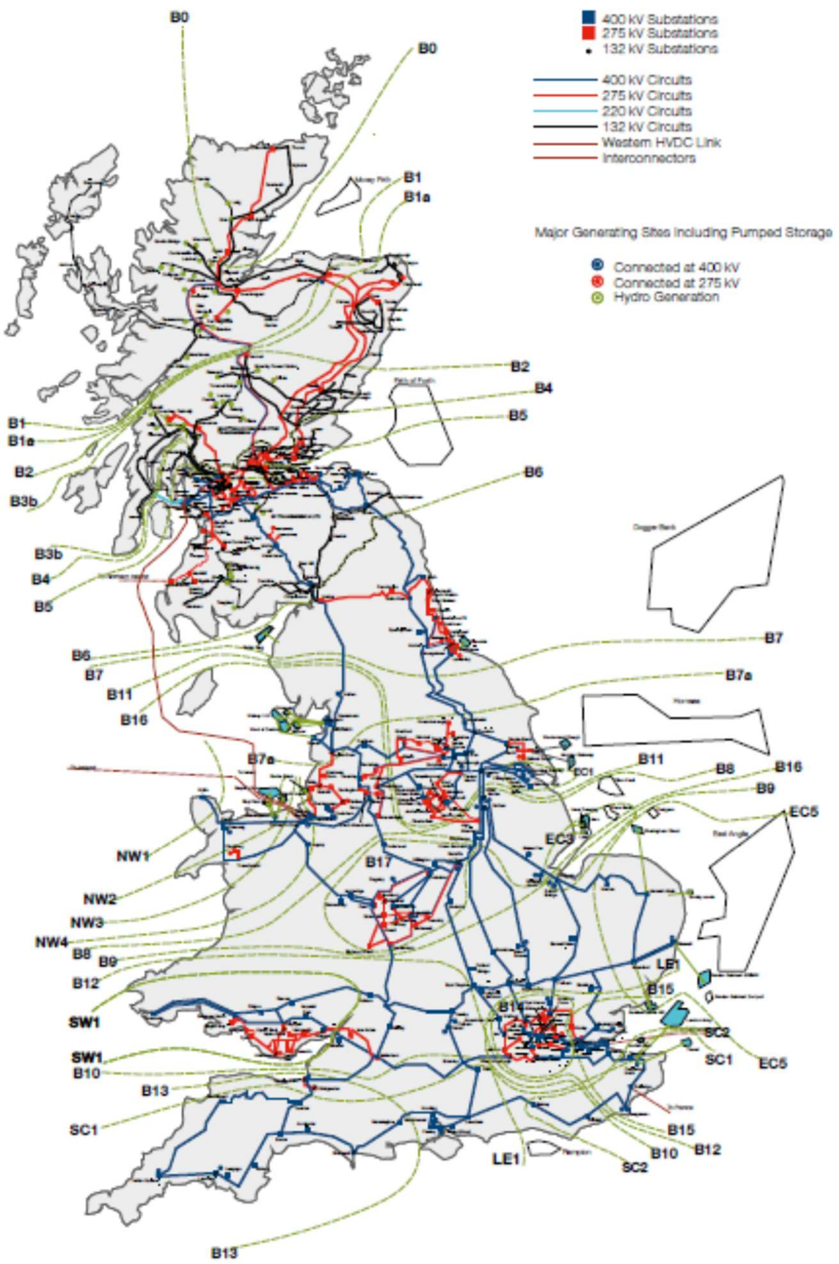

Figure 1: GB Transmission Map with Boundaries from ETYS

Wherever possible, within any of the proposed reinforcement schemes, existing infrastructure has been utilised to ensure the most economic, efficient and coordinated system is developed. In doing so, it has been necessary for each TO to consider the condition of the existing transmission assets and coordinate plans with non-load programmes to prevent unnecessary capital expenditure, network constraints and to reduce system outages.

4.1. Base Transmission Networks

The base transmission network for each TO, against which the need for reinforcement is assessed, is a combination of the TO's existing network plus any infrastructure works that have already been authorised for construction or Enabling Works that have been committed as a result of connection contracts with developers. Enabling Works is a term defined in Section 13 of the Connection and Use of System Code (CUSC)[10] that is used to define the works that must be completed prior to developers connecting to the network. They are determined by studies to achieve compliance with the SQSS and the

[10] https://www.nationalgrideso.com/codes/connection-and-use-system-code-cusc

"Connect and Manage" access rules. Developers have signed connections agreements with the ESO and have provided the required economic underwriting of the works.

4.1.1. The SPT Base Network

SPT has three main transmission network boundaries: boundary B4 in the north, shared with SHE Transmission, boundary B5, which divides the network area in two, and boundary B6 in the south shared with NGET.

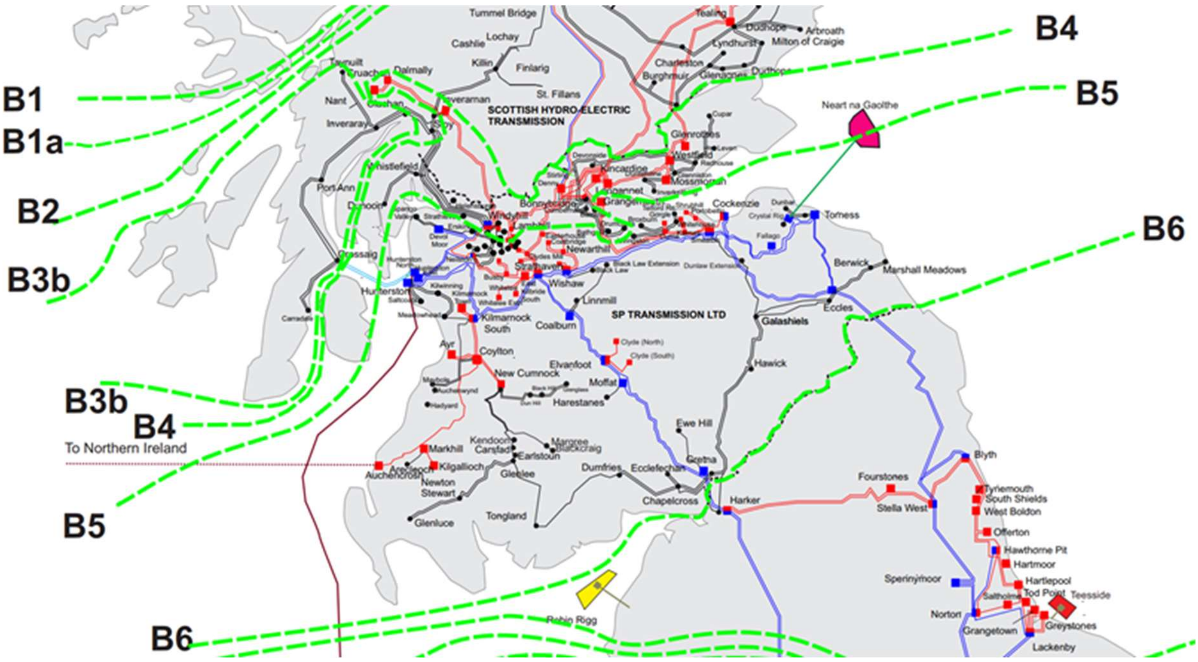

Figure 2 : SPT Map

The B4 boundary is crossed by two 275kV double circuits, one from Kintore/Tealing to Kincardine and one from Tealing to Westfield in the east, two 132kV double circuits from Sloy to Windyhill in the west, two 275/132kV supergrid auto-transformer circuits at Inverarnan and the double circuit from Beauly to Denny North, one circuit of which operates at 400kV and the other at 275kV. The Kintyre to Hunterston 220kV subsea cable link provides two additional circuits crossing B4 between the 132kV substation at Crossaig in Kintyre and the 400kV network at Hunterston in Ayrshire.

Boundary B5 is currently crossed by three double circuits, two at 275kV and the third in the west, one side of which operates at 400kV and the other at 275kV. In addition, the Kintyre to Hunterston subsea link provides an additional two circuits that cross B5. This boundary splits the SPT area into two zones.

Boundary B6 is the interface point between SPT in the north and NGET. The existing transmission network across the B6 boundary primarily consists of two double-circuit 400kV routes and a 2.2GW HVDC link. There are also some limited capacity 132kV circuits across the boundary. The key 400kV routes are from Gretna to Harker and from Eccles to Blyth/Stella West and the recently completed Western HVDC link from Hunterston in Ayrshire to Connah's Quay in North Wales. Since the early 1990's, works have been completed in order to maximise the capability of the existing AC network over B6 to enable larger power transfers predominantly in the north to south direction. These works include the uprating of existing circuits from 275kV to 400kV, modifications to existing generators for improved system damping and the installation of both series- and shunt- compensation. On top of the AC system improvements, additional boundary transfer capability has recently been completed with the commissioning of the Western HVDC Link.

4.1.2. Asset Condition

The east coast 275kV circuits shared between SPT and SHE Transmission, date back to the early 1970s and although the tower structures are in good condition, the conductors are approaching the end of life. By the completion date for the proposed 400kV project (ECUP) in 2026, the conductors on the XL route to be uprated will be 65 years old.

Following condition assessment, the conductor will require minor refurbishment in the RIIO-T2 period, which aligns with the timing of ECU2. The requirement for conductor replacement will be reconsidered via future condition assessment for completion early RIIO-T3 (starting in 2026).

These non-load related works will be considered along with the proposed east coast onshore reinforcement works to achieve an overall economic and efficient delivery programme. This will take account of any savings which can be made by optimising the scope and timing of the related works to reduce any stranding or abortive works and, importantly, optimise outage requirements.

4.2. Generation Scenarios

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4.3. Large Discrete Offshore Windfarms

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4.4. Interconnectors

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5. THE NEED FOR REINFORCEMENT

The first step in identifying the need for reinforcement is to establish the capability of the existing network across a range of generation and demand scenarios. The network can then be analysed to check for compliance against the SQSS and to determine the levels of congestion across relevant transmission boundaries.

The need for eastern reinforcement is further detailed in the 2019 Electricity Ten Year Statement (ETYS), published by the ESO in November 2019.

The generation scenarios which drive the reinforcement need are discussed in Section 4.2.

A critical part of justifying the need for reinforcement is the cost benefit analysis which is described in detail in Chapter 8. This was carried out by the ESO and examines the potential reduction in forecast constraint costs that can be achieved by the various reinforcement options.

5.1. Transmission Boundary Transfer Requirements

High boundary transfer requirements across the SPT network area have been consistently highlighted in the ETYS over a number of years. This is illustrated in the figures below where boundary capabilities and future required transfers are compared against forecast power transfers for each boundary.

Corresponding reinforcement solutions were assessed and subsequently recommended to proceed in the NOA 2016/17 report. This demonstrated an underlying driver for reinforcement, the need for which has only increased under all subsequent NOA and FES generation backgrounds.

The boundary capability is determined from the SQSS security and economic criteria;

- **Security criterion** – evaluates boundary transfer requirements to satisfy demand without reliance on intermittent generators or imports from interconnectors.
- **Economy criterion** – evaluates boundary transfer requirements when demand is met by a range of generation sources including from intermittent and low carbon generators and imports from interconnectors. This is to ensure that transmission capacity is adequate to transmit power from an economic dispatch of generation types without undue constraint.

The ETYS boundary graphs below show a distribution of power flow for each generation scenario, in addition to the current boundary capability (winter 2018/19) and the forecast SQSS required transfers for the next twenty years. A separate chart is provided for each of the four 2018 Future Energy Scenarios and each scenario has different generation and demand that produce different boundary power flow expectations.

The SQSS sets the methodology to determine the wider boundary planning requirements, i.e. the Economy and Security criteria discussed above. These are shown in the graphs as a solid coloured line for Economy required transfer (Economy RT) and a dashed coloured line for Security required transfer (Security RT).

The current authorised boundary capability, in accordance with SQSS requirements, is represented as a solid black flat line on the graphs. The boundary capability will change over time as the network, generation and demand change, all of which are uncertain. Therefore, to show system future needs and opportunities for each boundary a single straight capability line based on the present conditions is shown.

Two shaded areas are shown on each boundary graph which represents the distribution of annual power flow. The darker shaded area shows an area in which 50% of the annual power flows lie. In percentile terms, 75% of annual power flows are lower than the upper edge of the darker shaded area and 75% are higher than the lower edge. The lighter and darker shaded areas together show an area in which 90% of the annual power flows lie. In percentile terms, 95% of annual power flows are lower than the upper edge of the lighter shaded area and 95% are higher than the lower edge.

The calculations of the annual boundary flow are based on unconstrained market operation, meaning network restrictions are not applied. This way, the minimum cost generation output profile can be found. By looking at the free market power flows in comparison with boundary capability, it can be seen where future growing needs can be expected.

The key SPT boundaries being targeted by this strategic piece of work are detailed below.

5.1.1. Boundary B4

For B4, the boundary capability is thermally limited to around 3,300MW whereas the economy required transfers and a large proportion of the projected MW flows from 2023 onwards and across all FES scenarios significantly exceed this.

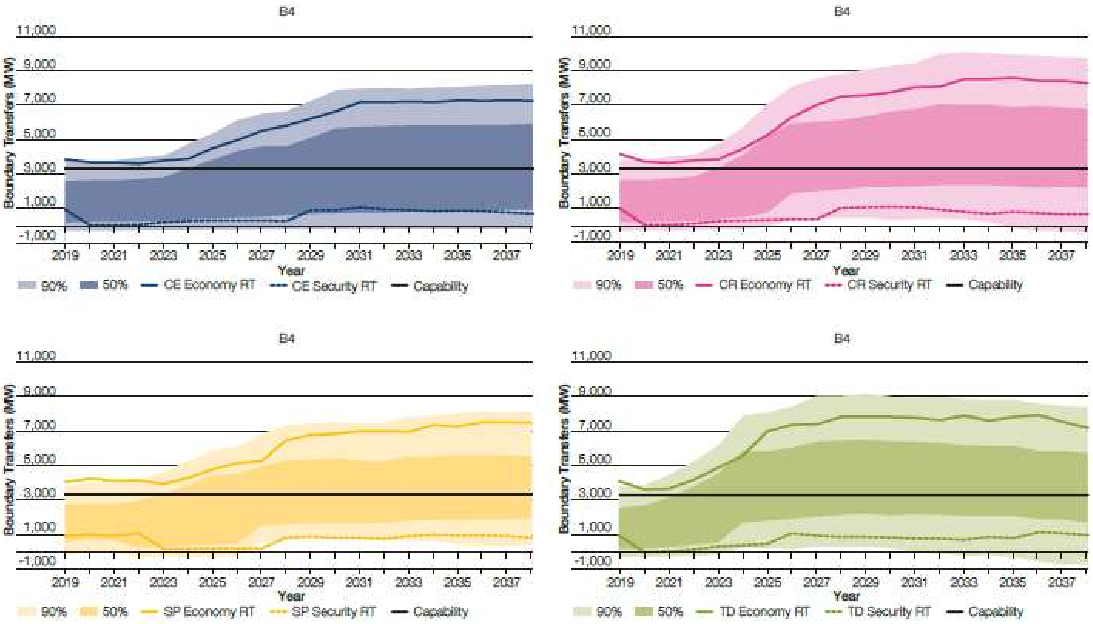


Figure 3 : Boundary flows and base capability for boundary B4

5.1.2. Boundary B5

The boundary internal to SP Transmission's area is B5 (see **Figure 7**). As illustrated in Figure 4 for B5, the boundary capability is approximately 3,700MW whereas the economy required transfers and a large proportion of the projected MW flows across all FES scenarios significantly exceed this.

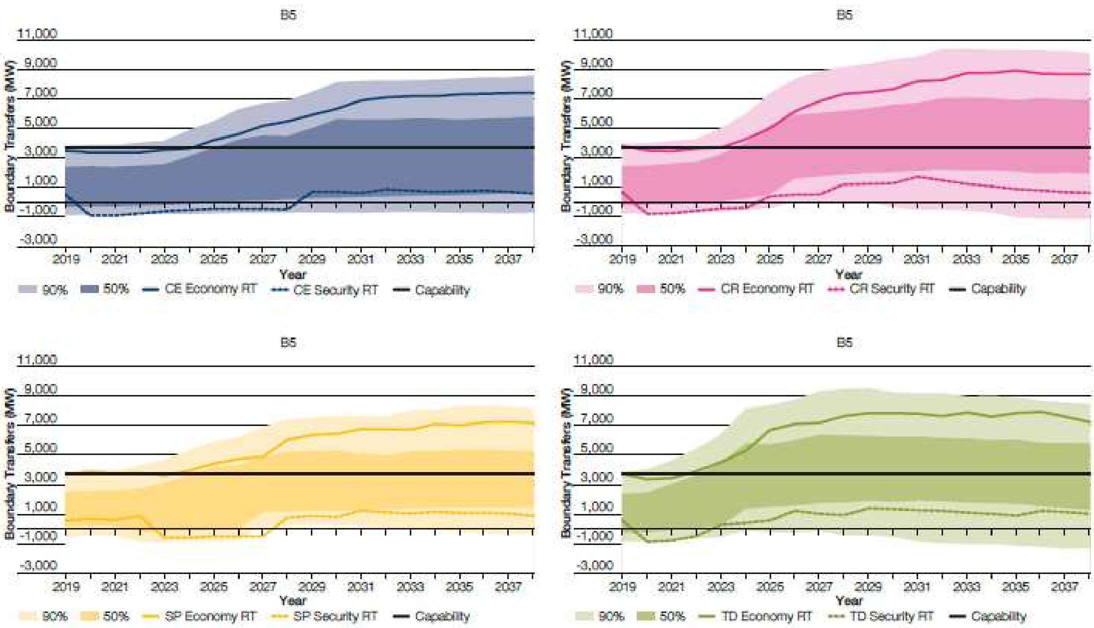


Figure 4 : Boundary flows and base capability for boundary B5

5.1.3. Boundary B6

For B6, the interface between SP Transmission and NGET, the boundary capability of 5,700MW is limited by the rating of transformers at NGET's Harker substation. The economy required transfers and a large proportion of the projected MW flows across all FES scenarios significantly exceed the actual boundary capability.

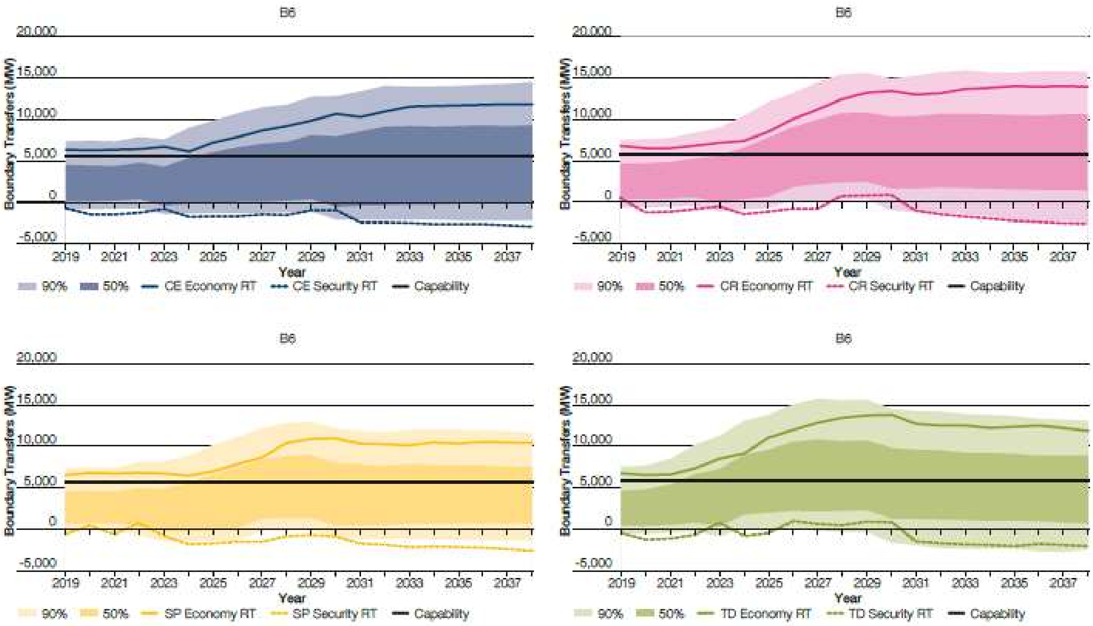


Figure 5 : Boundary flows and base capability for boundary B6

5.2. The Network Option Assessment Report - Recommendations

The Network Options Assessment is an annual mechanism for assessing and developing an efficient, coordinated and economic electricity transmission system, consistent with the requirements of the NETS SQSS. Its purpose is to economically assess a range of network reinforcement options to address shortfalls in boundary capabilities identified within the ETYS and to make recommendations to the TOs across Great Britain as to which major NETS reinforcement projects combine to give an optimal and economic development path to meet the future network requirements. The NOA methodology was initially developed with input from industry including the TOs and Ofgem and is revised and publicly consulted on annually.

The first NOA (2015/16) indicated that East Coast 275kV Upgrade (ECU2) would be required across all four scenarios, with a delivery date ranging from 2022 and 2024. At this time the generation background was such that the uprating to 400kV would not be required. This was reiterated in NOA 16/17 (published in January 2017), when the ESO provided the TOs the signal that ECU2 completed by 2023 would provide an economic system benefit. In NOA 17/18, again ECU2 had a strong proceed to be delivered by 2023 across the four scenarios, but generation profiles had increased significantly to give an additional strong signal for the 275kV works to be closely followed by East Coast 400kV Incremental Reinforcement (ECUP) for completion in 2026, also across all four scenarios. Both of these projects then received the same result for proceeding in 18/19. Each year, the alternative option of East Coast 400kV Reinforcement (ECU4) was considered, which would not deliver a boundary uplift until 2025, but would deliver uprating of magnitude in line with ECUP, however in each case where the 400kV upgrade was required, the benefit of delivering the incremental uplift two years earlier is always justified through the economic analysis.

The output recommendation from the first NOA (2015/16) gave a proceed signal for the Peterhead to Hawthorn Pit HVDC reinforcement (E4DC) but this was caveated to "minimise any spend" due to the Government energy policy on renewable generation and market uncertainty at the time. The NOA 2016/17 then indicated that both offshore links from Peterhead and Torness into Hawthorn Pit, as well as the Torness to Lackenby 400kV onshore, should continue to be developed with minimal spend. The NOA 2017/18 recommendation gave strong signals to proceed and maintain earliest in-service dates (EISD) for both the Peterhead and Torness HVDC links to Hawthorn Pit (E4DC and E2DC) on the eastern side of the GB system, having determined that the onshore 400kV option from Torness to Lackenby delivered too late to most effectively manage the constraints over B6. In NOA 2017/18 the onshore reinforcement works in Scotland (ECU2, ECUP and DWNO) were also given proceed recommendations, given that the earliest in service dates stated for these projects now met the required year.

Following on from the NOA 2017/18 assessment, the TOs considered it appropriate to explore the effectiveness of more southerly landing points for the HVDC links, below B7, for at least one of the HVDC links. As a result, two additional landing points at Drax and Cottam were included in the assessment process for NOA 2018/19.

Of the different HVDC landing point options, the NOA 2018/19 report favoured the earliest completion date for the HVDC link between Torness to Hawthorn Pit (E2DC) to provide early boundary uplift and constraint relief across B6, and the longer HVDC link between Peterhead and Drax (E4D3) to provide further economic boundary capability increase across the wider B2 to B8 region. The Peterhead to Drax option (E4D3) is £240 million lower in capital spend compared to the HVDC link between Peterhead and Cottam (E4D2). The NOA 2018/19 report recommends not to proceed with the HVDC link between Peterhead and Hawthorn Pit (E4DC), mainly due to its inability to provide benefit to the B7a and B8 boundaries.

The ESO identified that in order to benefit from the connection of an Eastern Link into Hawthorn Pit in NGET's area, significant onshore reinforcements are required, leading to programme dependencies between each project. If there were delays to either aspect, onshore or offshore, the advantage of delivering a link into Hawthorn Pit is greatly diminished and delays of even one year will lead to the recommended path changing considerably.

The recommendations from NOA 2018/19 demonstrated that the Torness to Hawthorn Pit (E2DC) and the Peterhead to Drax (E4D3) HVDC links are the most efficient and beneficial reinforcements, when delivered in combination with relevant onshore works. These onshore works include the east coast onshore 275kV then 400kV incremental works, ECU2 and ECUP in the east of Scotland, and Denny to Wishaw 400kV reinforcement (DWNO) to create a 400kV central corridor down the centre of SPT's area.

To directly compare the benefit of onshore and offshore options on B6, an overhead line from the Torness area to a connection point in the north east of England (TLNO) was included in the NOA option assessment. The NOA 2016/17 recommendation for TLNO was to proceed with this option whereas the NOA 2017/18 recommendation was to 'Hold for SWW' given that the benefit of this reinforcement is delivered much later than the indicated boundary constraints required, but with recognition that there is requirement for development within the SWW process for comparison against offshore options. The NOA 2018/19 recommendation for TLNO was 'Do not Start' which indicates the project is currently non-optimal.

The NOA 2018/19 report explored the requirement for additional reinforcement beyond the current recommended reinforcement projects in the form of 'notional' reinforcements. These provide a boundary uplift without defining the actual works required. The assessment indicated that additional reinforcement across the main boundaries from B4 to B8 could be economic if completed by 2032. These 'notional' projects do not diminish the need for the recommended projects and will not be critical for a number of years so there is time to develop suitable projects and monitor their effectiveness in future NOA reports.

Based on the recommendations from all four NOA reports to date, there are clear signals that major onshore and offshore reinforcements are required to release transmission congestion on the eastern side of the GB transmission system. In the later NOA reports it is clear the recommended reinforcements are critical and required on their earliest in-service date to maximise GB consumer benefit.

At the time of writing, system analysis has been completed for NOA 2019/20 based upon the FES 2019, and the economic analysis has almost completed. The required transfers seen from FES 2019 are higher than any previous year. In response to this, new reinforcement projects have been proposed for inclusion within this year's NOA to achieve the level of boundary capability required. Each of these projects are considered within the NOA in addition to the existing projects outlined within this paper for inclusion within the RIIO-T2 plan and planned SWW projects, and ultimately demonstrate a stronger requirement for well-developed projects to be delivered as quickly as possible to meet the growing need, with the view to continue to develop further projects to build upon these. Initial indications are that ECU2, ECUP, DWNO and HNNO are still economic to deliver on their EISDS:. In addition, this year ECVC has proven economic, with a move from delivery in line with the Eastern Link from Torness in 2027, to delivery on its EISD in 2026 due to the uplift it can provide on B6. Within NOA 2019/20, the cost estimate for each of the Eastern HVDC link options have increased following project development and engagement with the market. The anticipated NOA 2019/20 recommendations are that recommended the two Eastern HVDC links that have begun the SWW process (one from Peterhead and one from Torness) will again be recommended to proceed, given the benefits of delivering two of these links, together with the additional recommendation for a second HVDC link from Peterhead to northern England in 2031 (i.e. third new 2gw HVDC link overall).. The first draft of NOA 2019/20 results also indicate that the onshore option between Torness and Lackenby (TLNO), now with a revised EISD of 2036 following further development of this project, should be progressed.

5.3. National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS)

The Security and Quality of Supply Standard sets out the criteria and the methodology for planning and operating the National Electricity Transmission System (NETS). The ESO are the administrator for the SQSS, which they maintain together with the other TOs.

The current version of the SQSS is v2.4 and dated 1st April 2019[11]. If SQSS amendments are active, the potential impacts of these amendments are also considered as part of this network study process.

5.3.1. NETS SQSS, Chapter 4. Design of the Main Interconnected Transmission System

Chapter 4 of the SQSS details the Planning Criteria for the Main Interconnected Transmission System (MITS). The Minimum Transmission Capacity Requirements shall meet the criteria set out in Chapter 4 of the NETS SQSS in conjunction with the Economy & Security Planned Transfers and boundary allowance as described in Appendix D, E & F of the NETS SQSS.

System capability is assessed against the security and economy criteria of Chapter 4 in the NETS SQSS for peak demand system conditions and using winter circuit ratings. The main driver for north to south reinforcement in Scotland and North of England is predominately wind generation. The economy criteria apply scaling factors to the generation depending on technology and for wind generation the scaling factor (DT) is set to 0.7 (70% of full output capacity). DT for interconnectors in the economy criteria is set to 1.

In summary the following planning criteria are assessed:

- For an intact system (N) equipment loading should not exceed winter pre-fault ratings.
- For a planned outage of a single transmission circuit (N') equipment loading should not exceed winter pre-fault ratings.
- For a fault outage of a double circuit overhead line (N-D) on the supergrid system equipment loading should not exceed winter pre-fault ratings. Note that the supergrid system refers to the transmission system operating at a nominal voltage of 275kV and above.

Other criteria also have to be satisfied.

The network reinforcement options are designed and developed by the TOs to meet the required boundary transfers as determined by Chapter 4.

5.3.2. NETS SQSS, Chapter 5 - Operation of the Onshore Transmission System

Chapter 5 of the NETS SQSS defines the security standard to which the transmission network is operated by the ESO. This is the basis against which to determine volumes of year-round constraints that can be avoided on a congested system when reinforcements are considered. Year round analysis is carried out by the ESO based on the requirements of Chapter 5 using BID3 to simulate market driving power flows and calculate year round constraint costs based on seasonal boundary capability provided the TOs.

[11] https://www.nationalgrideso.com/codes/security-and-quality-supply-standards

6. EASTERN NETWORK REINFORCEMENT OPTION ASSESSMENT

6.1. Reinforcement Options

A range of potential reinforcement options were developed for technical and economic evaluation by each TO in coordination with each other to address the shortfalls in boundary capabilities across the eastern part of the GB transmission network from B2 to B8, as already outlined in Section 5. These included a range of incremental onshore and offshore reinforcement options covering a variety of different technologies with variations in capital costs and offering different boundary capacity uplifts:

- New overhead line routes and reconfiguration of the network.
- Voltage uprating of existing overhead lines with related substation changes.
- Re-profiling and re-conductoring of existing overhead lines with related substation changes.
- New substations.
- Reactive compensation.
- HVDC offshore links.

The discrete reinforcement options identified were the most beneficial and cost effective designs which could provide additional boundary capacity in reasonable timescales to facilitate the increasing north to south power transfers. The project then considered combinations of these onshore and offshore reinforcements to develop complete solutions.

6.2. HVDC Link Connection Point Option Assessment

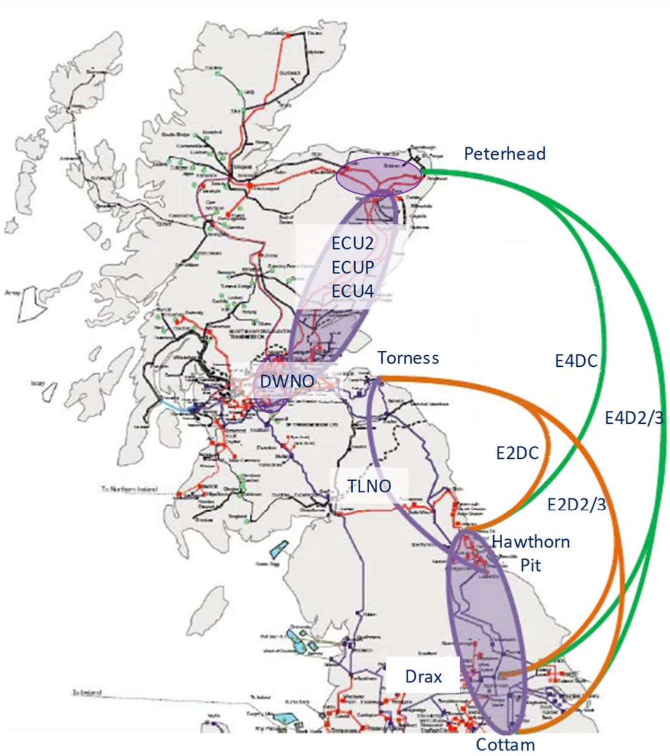
Multiple landing points across Scotland and the north of England have been considered to determine options that provide different solutions to be considered within the CBA. This results in links of different lengths crossing various transmission network boundaries which allows the CBA to identify the most economic and optimal reinforcement solution for the consumer. The northern connection points put forward to this CBA are Peterhead in the SHE Transmission area, which lies between boundaries B1 and B2 and Torness in SPT's area above boundary B6. The southern landing points are all within NGET's area, and are Hawthorn Pit, below B6, Drax, below B7a, and Cottam, below B8.

As an alternative to the HVDC option, an onshore AC option has been identified, which is the construction of a new 400kV double circuit between Torness in SPT's area to Lackenby in NGET's area. This option would provide boundary uplift on boundary B6 only.

6.3. Reinforcement Options included in CBA

The main reinforcement options that were carried forward to the CBA analysis are summarised in Figure 6 and **Error! Reference source not found.** below.

Further incremental AC reinforcement options were included by NGET in the CBA for reinforcement of boundaries B7 to B8 to provide a like for like analysis of each large reinforcement proposed.



Onshore:

- **ECU2 -** East Coast onshore 275kV upgrade - 2023
- **ECUP -** East Coast onshore 400kV- 2026 incremental reinforcement (builds on ECU2).
- **ECU4 –** East Coast onshore 400kV – 2025 direct reinforcement to 400kV
- **DWNO** – Denny Wishaw 400kV reinforcement - 2028
- **TLNO -** Torness to northeast England AC reinforcement – 2030

Offshore:

- **E4DC:** Peterhead – Hawthorn Pit
- **E4D2:** Peterhead – Cottam
- **E4D3:** Peterhead – Drax
- **E2DC:** Torness – Hawthorn Pit
- **E2D2:** Torness – Cottam
- **E2D3:** Torness – Drax

Figure 6 : Onshore and Offshore Reinforcement Options

Table 1. Reinforcement Option Timing from Eastern-Specific CBA

NOA code	Description	Earliest In-Service Date
ECU2	East Coast onshore 275kV upgrade	2023
ECUP	East Coast onshore 400kV incremental reinforcement	2026
ECU4	East Coast onshore 400kV reinforcement	2025
DWNO	Denny – Wishaw 400kV OHL reinforcement	2028
E4DC	Peterhead - Hawthorn Pit HVDC	2028
E4D2	Peterhead – Cottam HVDC	2029
E4D3	Peterhead – Drax HVDC	2029
E2DC	Torness - Hawthorn Pit HVDC	2027
E2D2	Torness – Cottam HVDC	2028
E2D3	Torness – Drax HVDC	2028
TLNO	Torness to northeast England AC reinforcement	2031

6.4. Reinforcement Combinations

The options included in the CBA assessment aim to cover a wide range of reinforcement options with varying degrees of investment and boundary capacity uplift. The purpose of this is to fully assess the level and combinations of reinforcement required in order to develop an economic, efficient and coordinated transmission network that allows an optimal economic dispatch of generation in GB.

Given the strong recommendations from the ESO for large reinforcements across multiple boundaries, the CBA was carried out in order to be able to firstly assess the benefits of each of the proposed reinforcements in turn, and then in combination to determine the benefits of each potential 'package' of options, resulting in comparable levels of uplift across each boundary.

All options were assessed against a base network of the currently authorised system. This gives a comparison of reinforcement investments against a 'do nothing' approach. This allows the CBA to determine the net benefit that the consumer would receive as a direct result of the reinforcement.

Option set A - Scottish onshore options in isolation

- These provide a view of how the Scottish onshore reinforcement options alone perform. The benefit and any regret associated with completing the onshore works and no further eastern HVDC reinforcement will be identified.

Option set B – Single major reinforcement options in isolation

- These provide a view of how the individual longer options perform in comparison to each other in the absence of further onshore network reinforcement.

Option set C – Single major reinforcement options with onshore incremental works

- These provide view of how individual longer options perform alongside combinations of the Scottish onshore network reinforcements as well as NGET onshore incremental reinforcement works.

Option set D – Multiple major reinforcement options with onshore incremental works

- This expand on 'Option set C' by exploring the benefit in having multiple major reinforcements at different connection points, evaluating the impact of offshore versus onshore reinforcements for the southern connection points and testing these alongside both Scottish onshore works and NGET onshore works.

The combinations to be studied as Option Set D in the CBA analysis assume two major reinforcements do not start or end at the same location. This is due to the level of onshore reinforcement that would be required to accommodate the power flows from the connection of more than one link in one location.

Reinforcements in 'Option set C and D' are accompanied by further NGET onshore works in the B6-B8 area. These incremental works (namely NGET_B6_B8_INC) build up to make 'packages' of onshore NGET reinforcements. These 'packages' aim to achieve a similar boundary capability to that of the highest increase following a major reinforcement, hence ensuring these major reinforcements are assessed like-for-like.

For example, a HVDC connection to Cottam crosses B6-B8, and therefore should achieve a large boundary capability increase across all four boundaries. Similarly, a HVDC connection to Hawthorn Pit only crosses B6, and so to compare these options like-for-like, further onshore works will be required in the NGET area to achieve a comparable boundary increase for all boundaries, B6–B8. These further onshore 'packages' of works, NGET_B6_B8_INC, are assessed alongside the options isolation as part of option categories C and D.

These incremental works are to be completed by the earliest date of the major Anglo-Scottish reinforcement option, either subsea HVDC or onshore OHL, is in service.

7. TECHNOLOGY REVIEW

7.1. Onshore/Offshore Reinforcement

Both onshore and offshore reinforcement options were considered to provide the required boundary capability increase. For HVAC infrastructure it is more economic to utilise onshore overhead line technology, in conjunction with short lengths of underground cable where necessary, compared to the wholesale installation of land or subsea cables.

However, for HVDC technology, which is more economic over long distances between two connection points, it is beneficial to consider offshore subsea cable installation.

7.2. HVAC Technology Review

Conventional HVAC technology, both overhead lines and underground cables, form the basis of the onshore reinforcement options. Dynamic reactive power devices such as SVC and/or Statcoms provide the required network voltage support and security. HVAC technology is well understood by all TOs who have extensive experience in delivering these types of projects.

7.3. HVDC Technology Review

A detailed review of HVDC technology including assessment of the most appropriate converter design, link topology and HVDC cable technology is currently being carried out by the Eastern Reinforcement Technology workstream to inform the Eastern HVDC initial needs case in 2020.

The current working assumptions for use in the initial CBA are for the HVDC link design to progress on the following basis;

- HVDC converter to be a VSC design.
- HVDC link topology to be based on a bipole design.
- HVDC link voltage to be optimised following detailed design phase.
- HVDC cable design to be mass impregnated (MI) paper insulated design.

The final decision on differing HVDC technology and configuration will be informed following further technology review and specific CBA to determine relative benefits ahead of final needs case submission.

8. COST BENEFIT ANALYSIS SUMMARY

Working in collaboration with the TOs, the ESO has undertaken a comprehensive cost benefit and least worst regret analysis to examine the economics of reinforcing the eastern side of the GB transmission network. This has been carried out by assessing boundary congestion on the existing network as the counterfactual and analysing the potential reduction in constraints that can be achieved by implementing the different reinforcement options across a range of generation scenarios including FES and local generation sensitivities.

The TOs provided a range of input data for the CBA including boundary uplifts provided by the different reinforcement options as well as costs, timing, local generation sensitivities and outage requirements. All inputs to the CBA issued from the TOs to the ESO are detailed within a CBA input document which is available on request.

The ESO's CBA final report in its entirety can also be made available on request.

8.1. CBA Conclusions

The ESO's CBA analysis provides an overwhelmingly positive economic case for reinforcement of the eastern side of the GB transmission network. The optimal combination of onshore plus offshore reinforcements gives positive net present values (NPV) ranging from £11,660million to £18,350million.

The sensitivity and least worst regret analysis also demonstrate that the recommended optimal combination of reinforcement options provides a stable and robust solution.

The ESO's CBA main conclusions can be summarised as follows;

- The incremental onshore reinforcement in Scotland, comprising the reinforcement options ECU2 and ECUP, provide early congestion relief across B4 and are strongly recommended to proceed to delivery in accordance with their earliest in-service dates (EISD), 2023 and 2026 respectively. It has also been shown that these reinforcements would not be regretted even if later subsequent reinforcements were not undertaken.
- The incremental reinforcement comprising the reinforcement option DWNO provides congestion relief across B5 and is strongly recommended to proceed to be delivered in accordance with its EISD date, 2028.
- Two HVDC links on the East Coast between Peterhead and the north of England and Torness and the north of England that provide boundary uplift across all network boundaries between B1 to B8 are strongly recommended to proceed to be delivered as early as practicable. The two combinations that came out strongest from the CBA are Peterhead to Hawthorn Pit (E4DC) and Torness to Drax (E2D3), and Peterhead to Drax (E4D3) and Torness to Hawthorn Pit (E2DC), however further works are required to confirm the most beneficial combination of links to be delivered.

Given the overwhelming need for the delivery of the reinforcements included within the analysis, supported by both the yearly NOA and this Eastern Reinforcement CBA completed by the ESO, all projects will continue to be progressed by the TOs, with further development works carried out to determine which combination of Eastern Link options deliver the most economic, efficient and coordinated transmission system.

9. PROJECT TIMELINE AND DELIVERY STRATEGY

9.1. Project Delivery Strategy

The projects forming this programme of strategic works will be subject to different delivery strategies dependent on their requirements, complexity and their interfaces.

For the ECU2 and ECUP projects, SHE Transmission and SPT will deliver the items within their respective scopes, whilst coordinating outages on the network and works where interfaces exist, such as at the boundaries where overhead lines cross and at remote end substations. The proposals will see the TOs undertaking the necessary studies, designs, consenting activities and engagement with their respective contractors.

For the HVDC projects the project development will be initially coordinated among the three TOs and that the programmes will run in parallel between the two schemes. This includes aligning the tasks related to tendering to market, surveys, studies, consenting, and potentially establishing a single procurement strategy for the whole project to provide best value, best resource and outage coordination.

9.2. Subsea and Onshore Route Surveys

In terms of the ECU2 and ECUP projects, the proposals are to upgrade existing overhead lines, therefore establishment of a route corridor is not required in this instance via surveys. However, surveys required to inform the design works, including confirming the required extent of overhead line conductor re-profiling for ECU2 and establishing access routes, are to be undertaken.

The ECUP project again does not require identification of a route corridor however does require submission of a Section 37 Application to allow the increased operational voltage of 400kV. This will require additional surveys to be carried out on the existing Overhead Line to inform an Environmental Impact Assessment supplied with the Section 37 Application.

For each of the six potential HVDC options, it is proposed to undertake seabed surveys beginning 2019 through to 2020 to inform both the submission of a Marine Consent and for the preparation of Final Needs Cases. Currently, an initial desktop based assessment has been conducted for all of these options to identify the marine corridors between the landing points which have been defined. This has considered known constraints, such as environmental or infrastructure, to inform the Seabed Survey Contractors and to assist with refining the corridor to a preferred cable alignment.

In conjunction with the works to survey the seabed, a desktop based assessment of onshore infrastructure routes is being undertaken to identify the corridors in which the transmission infrastructure will be taken from the landing points through to the convertor stations and the subsequent connection to the existing transmission system. This will inform an Environmental Impact Assessment and subsequent optioneering of the preferred solution for the projects.

10. CONCLUSION & RECOMMENDATIONS

The work undertaken by all three onshore Transmission Owners, SHE Transmission, SP Transmission and National Grid in collaboration with National Grid Electricity System Operator has demonstrated a strong technical, economic and urgent need for coordinated reinforcement on the eastern side of the GB Transmission network.

The ESO’s cost benefit and least regret analysis has recommended an economic optimal reinforcement pathway comprising the following works;

- The incremental onshore reinforcement in Scotland, comprising the reinforcement options ECU2 and ECUP, to provide early congestion relief across B4. Strongly recommended to proceed to delivery in accordance with their earliest in-service dates (EISD), 2023 and 2026 respectively. These reinforcements would not be regretted even if later subsequent reinforcements were not undertaken.
- The reinforcement option DWNO provides congestion relief across B5 and is strongly recommended to proceed to be delivered in accordance with its EISD date, 2028.
- Two 2GW new HVDC links, one from Torness in SPT’s area and one from Peterhead in SHE Transmission’s area to two separate landing points in NGET’s area north of B8, to be delivered between 2027 and 2029.

The incremental Scottish onshore reinforcement projects ECU2 and ECUP are regarded as sufficiently well proven and mature to be progressed through the RIIO-T2 baseline wider works submission to Ofgem in December 2019.

Further technical and economic analysis is required to determine the combination of specific HVDC links that give the best overall outcome, given the marginal results of the CBA carried out by the ESO.

The HVDC links projects will be progressed through the Strategic Wider Works process. The Initial Needs Case for these works is due to be submitted to Ofgem in 2020.

APPENDIX 1 – GB TRANSMISSION MAP WITH BOUNDARY LOCATIONS

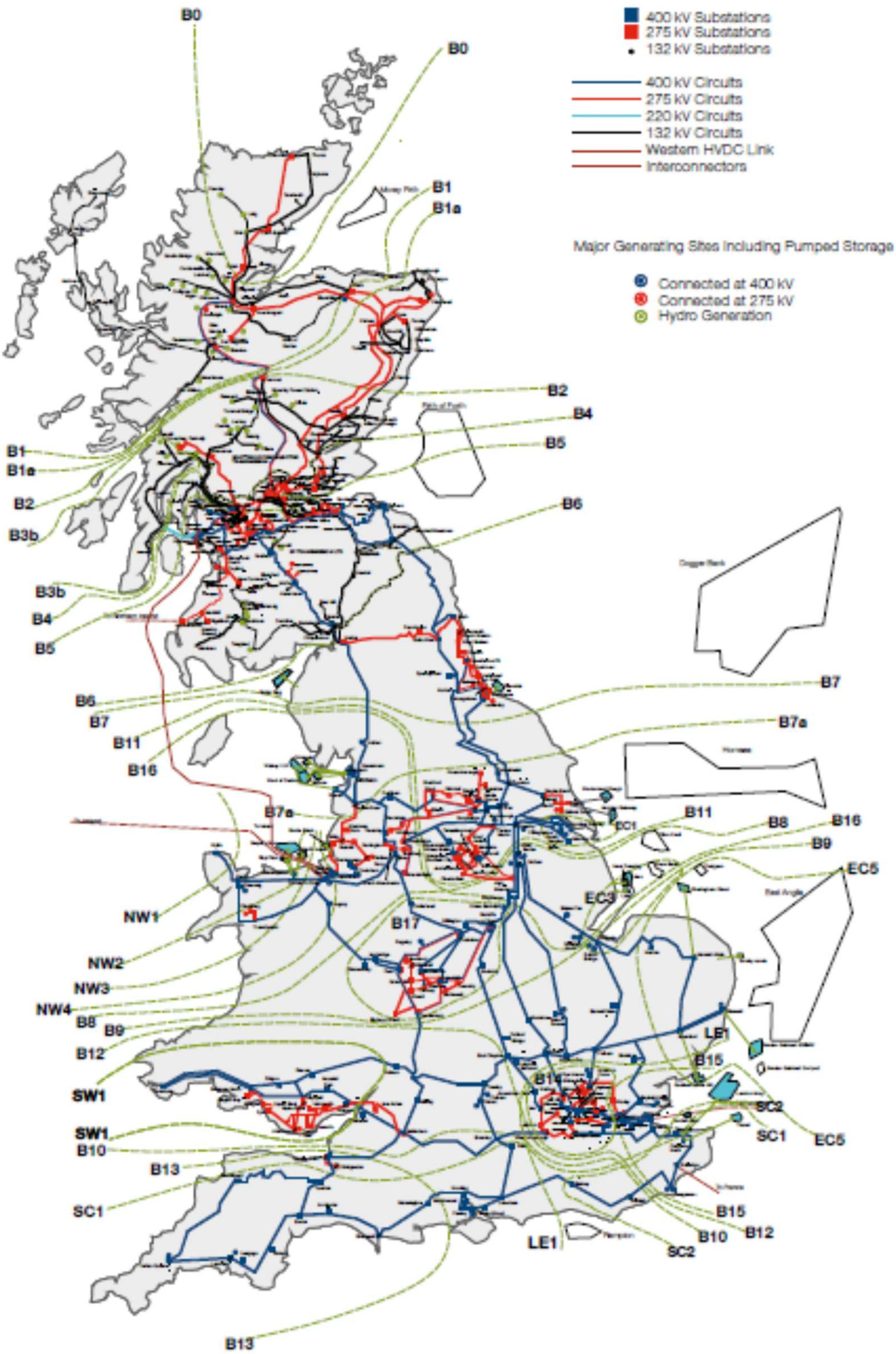


Figure 7. Geographic Diagram from ETYS

APPENDIX 2 - PROJECT BACKGROUND

In 2008, following the Transmission Access Review, the Government and Ofgem recognised that the potentially long lead times for expanding transmission capacity could impact upon meeting the 2020 renewables target. A high-level forum called the Electricity Networks Strategy Group (ENSG) was established to bring together key stakeholders in electricity networks to work together to support Government in meeting the long-term energy challenges of tackling climate change and ensuring secure, clean and affordable energy. The Group was jointly chaired by the Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (Ofgem) and its broad aim was to identify and co-ordinate strategy to help address key strategic issues that affect the electricity networks in the transition to a low-carbon future. As part of this process the Transmission Owners were asked to set out the strategic transmission network investment options that might be required to ensure that sufficient renewable and low carbon generation could be accommodated on the network.

The 2009 ENSG Report, “A Vision for 2020”, was welcomed by stakeholders in industry and the wider community as recognition of the urgency of network investment to help meet the UK’s energy and climate change goals and contained a commitment to ensure that appropriate investment was taken forward in a timely manner.

During the period 2010 to 2011, the ENSG and the TOs continued to work together and in February 2012 an updated ENSG report was published.

Among a range of regional reinforcements, the report identified the need for reinforcement on the eastern side of the GB transmission network including several incremental onshore projects in Scotland in conjunction with an HVDC submarine link of circa 2GW connecting Peterhead to the north of England. The possibility of a second east coast Anglo-Scottish HVDC submarine link was also identified. The purpose of these reinforcements was to relieve boundary transfer constraints and facilitate the continued connection of new generation in Scotland and its transmission south into the wider GB transmission system.

The reinforcements identified represented the next major Anglo-Scottish transmission system reinforcement that was envisaged to follow on from the Western HVDC link and the series compensation of the existing cross border ac overhead line circuits. Based on the future energy scenarios available at the time, a delivery date for the eastern HVDC link of 2018 was proposed. The Western HVDC link went into service between Hunterston and Deeside in December 2017.

In 2011 a connection application was made to National Grid from the wind farm developer, Seagreen, for the 2.6GW second and third phases of their 3.6GW Round 3 offshore wind farm to be located in the Firth of Forth adjacent to the SP Transmission (SPT) network area. This led National Grid to issue a connection offer that was based on the development of a 2GW submarine HVDC link between eastern central Scotland, in SPT’s network area, and the north east of England, in NGET’s network area.

It was considered that developing two separate HVDC links (SHE Transmission – NGET and SPT – NGET) may not represent the most efficient system reinforcement option for the consumer. Therefore, SPT agreed to work with SHE Transmission and NGET to investigate a coordinated design that could meet the transmission capacity needs of all parties, whilst also facilitating the connection of the Firth of Forth offshore wind generation. From 2011 onwards, the three Transmission companies have worked together to develop potential solutions.

System study work and Cost Benefit Analysis was initially carried out using the 2011 versions of National Grid’s future energy scenarios. This work concluded that pre-construction development of the project should continue with the preferred design option at that stage being a multi-terminal submarine HVDC link that linked the north east of Scotland, the central belt of Scotland, and the north east of England. This option provided additional capacity across the B2, B4, B5, and B6 system boundaries and provided a good NPV return under the Gone Green future energy scenario. Although some other design options could give a slightly higher NPV return under the Gone Green scenario, the multi-terminal design was preferred as it offered the potential to be reduced in scope to a single link should the Slow Progression future energy scenario outturn. This flexibility would reduce the risk of over investment. Both the multi-terminal and reduced scope single link designs provided the additional capacity required to allow connection of the Firth of Forth offshore wind generation.

In addition to the potential HVDC link designs, both SHE Transmission and SPT were investigating potential onshore AC reinforcements in the eastern parts of their networks to address regional shortfalls in boundary transfer requirements.

At the time, economic analysis demonstrated that the need for further reinforcement following the completion of Western Link was not strong enough to justify continuing with the development of a large Eastern reinforcement. In order to ensure that these conclusions remained valid, a full review of the design options and cost benefit analysis was undertaken in 2013. Since this time, the need for reinforcement in the east has continued to be reviewed and analysed by the three TOs and has been reported annually within the ETYS and NOA reports published by the ESO.

High boundary transfers on the east coast boundaries have been consistently highlighted in recent ETYS documents. Corresponding reinforcement solutions were assessed and recommended to proceed in the NOA 2016/17 report. This demonstrated an underlying driver for reinforcement which has remained unchanged under all subsequent NOA and FES generation backgrounds.

Previous work undertaken 2010 – 2013 by three TOs:

- Seabed survey 2012
- Some planning consents secured (Peterhead)
- Desktop onshore routing study for alternative cross-border overhead line