Scottish & Southern Electricity Networks

SSEN Transmission

RIIO-T2 Business Plan - T2BP-EJP-0018

East Coast 275kV Upgrade

Engineering Justification Paper

Title Section		
Name of Scheme/Programme	East Coast 275kV Upgrade	
Primary Investment Driver	Load	
Scheme reference/ mechanism or category	SHT2006, SHT2007, SHT2008 & SHT2009	
Output references/type	LRT2SH2006, LRT2SH2007, LRT2SH2008 & LRT2SH2009	
Cost	£166.01m	
Delivery Year	2023	
Reporting Table	B0.7 Load Master B4.2a Scheme Summary	
Outputs included in RIIO T1 Business Plan	There are no outputs associated with this scheme included in our RIIO-T1 plans	
Spend apportionment	**T1**	**T2**
	£10.94m	£155.07m

1 Executive Summary

Our paper "Planning for Net Zero – Scenarios, Certain View and Likely Outturn[1]" sets our methodology for determining the Certain View. The Certain View is every activity and investment that we propose to undertake during the RIIO-T2 period where there is compelling evidence of need. This encompasses capital investment to grow the network and accommodate new renewable generators.

This paper provides justification to establish the East Coast Onshore 275kV Upgrade which has a completion date of 2023. This reinforcement increases the north to south power transfer capability of our network such that the savings in constraint costs are greater than the total cost of the proposed reinforcement works. This reinforcement has been recommended to 'Proceed' by the Electricity System Operator (ESO) through the Network Options Assessment (NOA) in 2017/18 and 2018/19.

The East Coast Onshore 275kV Upgrade is the first part of the phased onshore reinforcement on the east coast – the second part is the East Coast 400kV Incremental Upgrade which has a completion date of 2026. These onshore reinforcements comprise works on existing infrastructure in both our area and the ScottishPower Transmission (SPT) area, with the bulk of the works in our area.

This delivery strategy is further supported by the lifetime Cost Benefit Analysis (CBA) undertaken by the ESO with inputs coordinated by the three Transmission owners; SHE Transmission, SPT and National Grid Electricity Transmission (NGET). Based on the results of its CBA which indicate strong economic benefit and robustness of sensitivity analysis, the ESO recommends that SHE Transmission and SPT progress the eastern onshore projects in Scotland. There is no regret in delivering these projects as early as practicable.

Further detail on how the east coast onshore reinforcement projects are being developed and referenced is available in Appendix A and in our East Coast Onshore Transmission Investment Case paper.

The East Coast Onshore 275kV Upgrade spans SHE Transmission and SPT licence areas, the SHE transmission works only are presented in this Justification Paper. SHE Transmission and SPT will continue to coordinate to ensure these works are effectively and efficiently delivered.

Following a process of optioneering and detailed analysis, the proposed scope of work is:

The proposed East Coast Onshore 275kV Upgrade utilises predominantly the existing OHL assets between Kintore to Kincardine and Tealing to Glenrothes/Westfield, a new substation at Alyth and Power flow control devices at Tealing to balance flows on the system and alleviate limitations observed for north to south power transfer.

[1] RIIO T2 - Planning for Net Zero – Scenarios, Certain View and Likely Outturn

This scheme delivers the following outputs and benefits:

- Increase the capability of the SHE Transmission Network in line with our goal to transport the renewable electricity that, in total, powers 10 million homes
- A B4 boundary uplift of 610MW, which corresponds to a lifetime Net Present Value range of [redacted]
- Facilitate effective competition in the generation and supply of Electricity in line with our licence obligations and our goal to provide network connections to meet our customer needs, on time and on budget.

The total cost of the project is £166.01m, of which the T1 spend is £10.94m and the cost of the works to be undertaken during the RIIO-T2 period is £155.07m. The planned completion date of the project is October 2023.

The East Coast 275kV Upgrade is above both Ofgem's early and late threshold at £166.01m. This scheme is a combination of several components designed to deliver a pre-defined system benefit and are well advanced in the development and tendering of works. We investigated the potential of splitting East Coast Onshore 275kV Upgrade into smaller elements. However, the splitting of responsibilities and introducing new interfaces poses risk to the delivery timescales which the CBA indicates would bring significant inefficiencies and reduce the overall system benefit (e.g. if one element of the project were to be delayed). It is therefore not suitable for the application of early or late competition and is 'unflagged' accordingly.

2 Introduction

This Engineering Justification Paper sets out our plans to undertake network enhancement work during the RIIO-T2 period (April 2021 to March 2026). The planned work is on the East Coast spanning both the SHE Transmission and SPT license areas between Kintore - Kincardine and Tealing - Westfield as shown on the map in Figure 1.

The Engineering Justification Paper is structured as follows:

Section 3: Need

This section provides an explanation of the "need" for the planned works. It provides evidence of the primary and, where applicable, secondary drivers for undertaking the planned works. Where appropriate it provides background information and/or process outputs that generate or support the "need".

Section 4: Optioneering

This section presents all the options considered to address the "need" that is described in Section 3. Each option considered here is either discounted at this Optioneering stage with supporting reasoning provided or is taken forward for Detailed Analysis in Section 5.

Section 5: Detailed Analysis

This section considers in more detail each of the options taken forward from the Optioneering section. Where appropriate the results of Cost Benefit Analysis are discussed and together with supporting objective and engineering judgement contribute toward the identification of a selected option. The section continues by setting out the costs for the selected option.

Section 6: Conclusion

This section provides summary detail of the selected option. It sets out the scope and outputs, costs and timing of investment and where applicable other key supporting information.

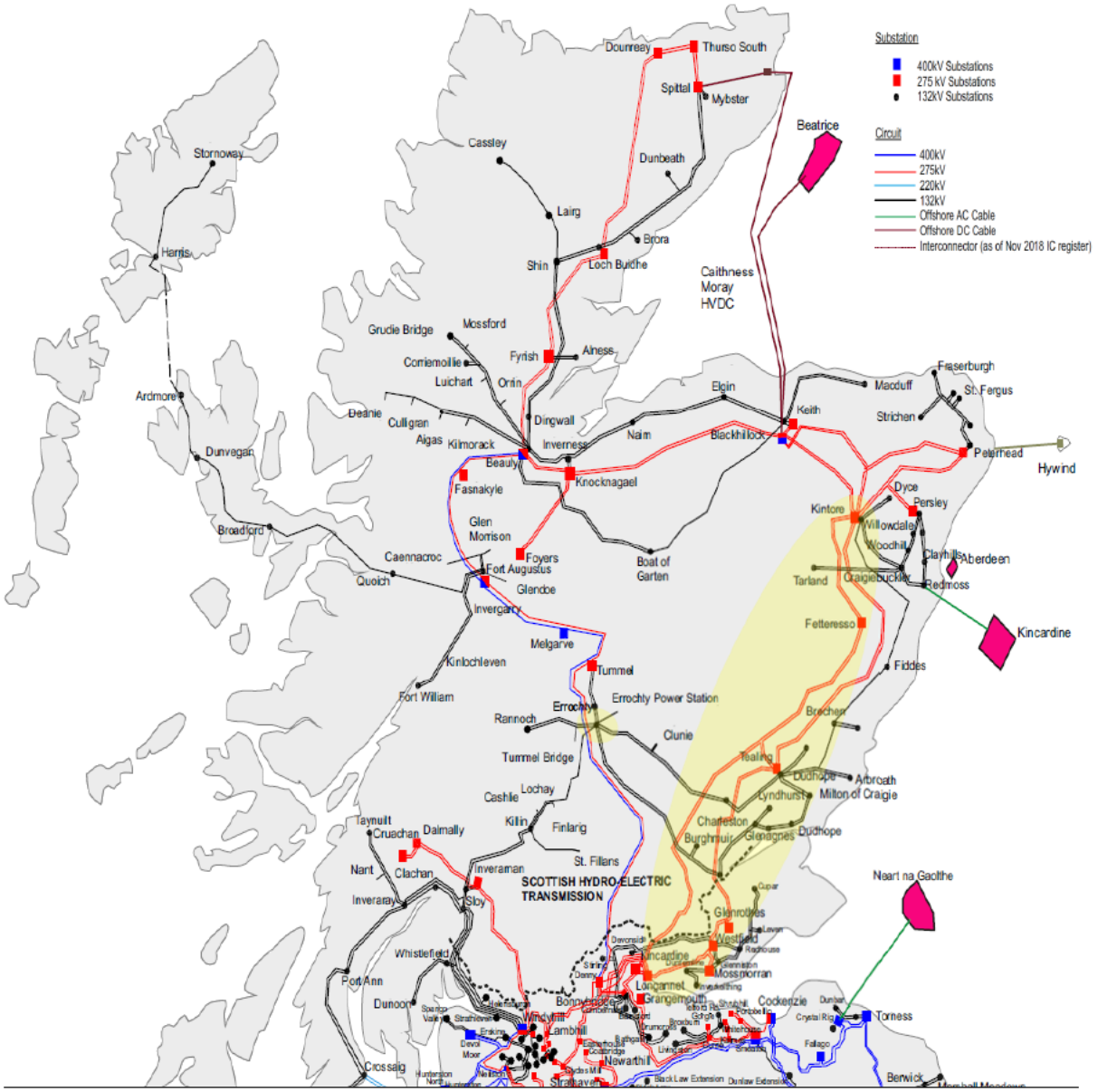
Section 7: Price Control Deliverables and Ring Fencing

This section provides a view of whether the proposed scheme should be ring-fenced or subject to other funding mechanisms.

Section 8: Outputs included in RIIO-T1 Business Plan

This section identifies if some or all the outputs were included in the RIIO-T1 Business Plan and provides explanation and justification as to why such outputs are planned to be undertaken in the RIIO-T2 period.

Figure 1: Existing SHE Transmission Network Map[2]

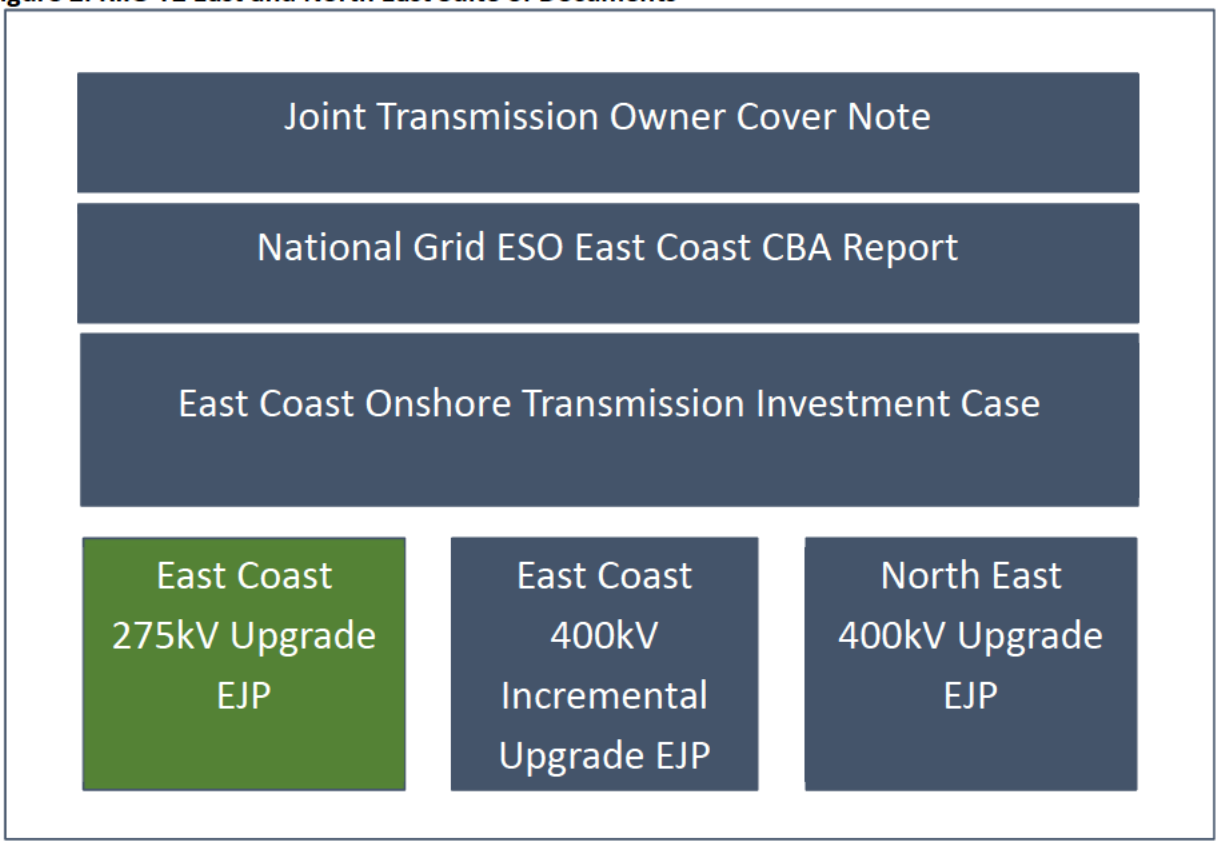


This paper is for the East Coast Onshore 275kV Upgrade and is one of a suite of documents setting out our RIIO T2 East and North East Transmission Reinforcement Plans. The hierarchy of the East and North East suite of documents is shown in Figure 2 and the purpose of each document is as follows;

[2] Electricity Ten Year Statement 2018, Appendix A, Figure A2

- **Joint Transmission Owner Cover Note:** A one-page note detailing the coordinated, TO led Eastern Cost Benefit Analysis (CBA) undertaken by the Electricity System Operator (ESO).
- **National Grid ESO CBA Report**: Presents the detailed CBA and Least Worst Regret Analysis undertaken to economically justify the optimal coordinated reinforcement path for the transmission network from the North of Scotland to the North of England.
- **RIIO-T2 East Coast Onshore Transmission Investment Case**: This document details the Need, sequence, interface and timing of the East Coast onshore projects in the context of the wider GB Network.
- **RIIO T2 Engineering Justification Papers**
  The Individual Engineering Justification Papers detail the background, need, optioneering, delivery strategy, timing and outputs for each project.

Figure 2: RIIO T2 East and North East Suite of Documents



3 Need

This section provides an explanation of the "need" for the planned works. It provides evidence of the primary and, where applicable, secondary drivers for undertaking the planned works. Where appropriate it provides background information and/or process outputs that generate or support the need.

3.1 Background

As set out in our paper "Planning for Net Zero – Scenarios, Certain View and Likely Outturn", the renewable generation connected to the north of Scotland transmission system will reach nearly 10 GW by March 2026 and the total generation will be 11.2 GW.

The SHE Transmission system must continue to adapt and be developed so power can be transported from source to demand, reliably and efficiently. To do this we must continually assess the balance between the cost of investing in the network against the cost of constraints to ensure we invest at the right time and in the right place. To do this we use the Future Energy Scenarios, Electricity Ten Year Statement and Network Options Assessment to annual assess the transmission system need in line with the National Electricity Transmission System Security and Quality of Supply Standard. This process is set out in our RIIO-T2 East Coast Onshore Transmission Investment Case.

The need to increase the north to south power transfer of our network and subsequently reduce constraint costs has been demonstrated through the Network Options Assessment (NOA) process. The NOA proceed recommendations for reinforcement in SHE Transmission are consistent in the 2017/18 and 2018/19 NOA reports.

These NOA recommendations are further supported by the National Grid ESO CBA Report completed by the ESO in Sep 2019. The NOA, ESO CBA recommendations and the coordination of wider system, regional connections and asset based drivers are discussed in detail in our East Coast Onshore Transmission Investment Case.

3.2 Load Driver

3.2.1 Network Capability

The transfer of energy across network boundaries occurs because generation and demand are typically in different locations. When the power transfer across a transmission system boundary is above that boundary's capability, the ESO must reduce the power transfer to avoid overloading the transmission assets. This is referred to as 'constraining' the network. When this happens, the ESO asks generators on the exporting side of the stressed boundaries to limit their output. To maintain an energy balance, the curtailed energy is replaced with generation on the importing side. Balancing the network by switching generation on and off costs money, and if the ESO is regularly constraining the network by large amounts, costs begin to accumulate.

The 2019 SHE Transmission Network map is shown in Figure 1. The east coast 275kV network in the SHE Transmission area is cut by two wider system boundaries, B2 and B4 as shown geographically and on the single line diagrams in Appendix B. The ESO has communicated that B4 is the constrained boundary and will subsequently be used in this paper to demonstrate need and define the output measure.

The B4 boundary separates the transmission network at the SHE Transmission and SPT interface running from the Firth of Tay in the east to the north of the Isle of Arran in the west. The B4 boundary cuts across two 132kV double circuit OHLs, two 275/132kV auto-transformer circuits, two 220kV subsea cables (between Crossaig and Hunterston), and the Melgarve/Braco West – Denny North 400/275kV double circuit OHL on the west coast, and a 275kV double circuit OHL between Kintore, Fetteresso and Kincardine (in SPT's area) as well as a 275kV double circuit OHL between Tealing and Glenrothes/Westfield (in SPT's area) on the east coast.

The 2018/19, B4 boundary capability published in ETYS 2018/19 is 3.3GW with the limiting contingency being the outage of the Melgarve – Denny North 400kV and Braco West – Denny North 275kV double circuit overhead line. The thermal constraint is present on both the Errochty-Killin 132kV circuit and the 275kV circuit between Fetteresso and Kincardine. This is in line with the NETS SQSS, Section 4.6.3; The minimum transmission capacity of the MITS shall be planned such that for the Economy Planned Transfer and for the secured event of a double circuit overhead line fault outage on the supergrid, there shall not be unacceptable overloading of any primary transmission equipment.

3.2.2 Network Requirements and Scenarios

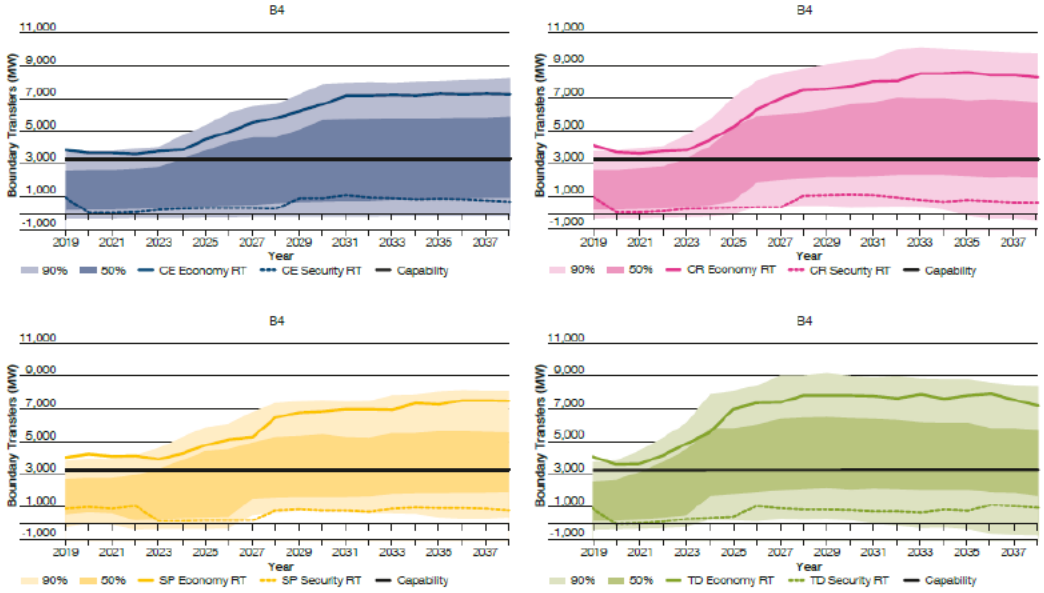
In June 2019 we published our draft Business Plan for the RIIO-T2 price control period from 1 April 2021 to 31 March 2026. Our Plan is what we call the Certain View where all of the activities and investments we propose have a strong, evidence-based need to be done. Our paper "Planning for Net Zero – Scenarios, Certain View and Likely Outturn" sets out our Certain View and how the Certain View compares with future energy scenarios.

Building upon the national political, economic, social and technological possibilities explored by the ESO FES, during 2017 and 2018 we undertook a detailed examination of the many unique factors and drivers that have the potential to influence future development requirements on our network. This resulted in our North of Scotland Future Energy Scenarios (NoS FES). The NoS FES are more appropriate for assessment of local transmission reinforcement with FES being the appropriate national picture for wider system assessment.

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 capability can then be analysed to check against the requirements of the NETS SQSS and to determine the levels of network congestion across relevant transmission boundaries.

In Figure 3 below (taken from the ESO's 2018 ETYS publication) the 2018/19 B4 boundary capability (black line) is plotted alongside anticipated boundary power transfers for the next 20 years, and the economy and security required transfers as calculated according to criteria in the NETS SQSS. The B4 boundary capability of the 2018/19 network is thermally limited to 3.3GW (based on FES2018). The Economy Required Transfers from 2023 onwards across all four FES2018 scenarios significantly exceed this capability.

Figure 3: Boundary flows and base capability for boundary B4[3]



3.3 Asset Condition

The existing double circuit OHL between Kintore, Fetteresso, Tealing and Kincardine substations are steel lattice towers, built between 1972 and 1974, of L8 construction strung with Twin Zebra ACSR conductor operated at 55°C. The double circuit overhead line between Tealing, Glenrothes and Westfield are steel lattice towers of both L2 and L8 construction. The L2 structures were built in 1967/68 and the L8s in 1972/73 and strung with Twin Zebra ACSR conductor operated at 55°C. These circuits have a winter post-fault rating of 955MVA. It is proposed that the existing steel lattice towers will be retained and reinforced as required. The existing 275kV network is single line diagram is shown in Appendix C.

The East Coast 275kV Upgrade does not present an opportunity to undertake overhead line conductor based condition based intervention. The opportunity to coordinate load and non load overhead line works on the East Coast circuits between Kintore, Alyth and the B4 boundary is explored in the East Coast 400kV Incremental Upgrade RIIO T2 Engineering Justification Paper.

[3] National Grid Electricity Ten Year Statement, November 2018

In the event that the load driven East Coast onshore reinforcement projects were deferred or stopped, SHE Transmission would propose to carry out all works identified in the East Coast 275kV OHL Asset Condition Assessment Report[4] as summarised below:

- Steelwork members on all towers showing signs of surface rust are cleared of rust and painted
- All earthwire and phase conductor assemblies, including insulators, dampers, shackles and U-bolts are replaced.
- Replace all spacers
- Replace all step bolts
- Reconductor the phase conductors
- Refurbish concrete muffs and stubs

SHE Transmission propose to reconductor the Tealing to Westfield OHL early in the T3 period. This will be confirmed once the results of the aerial conductor assessment and joint discussions with SPT are concluded.

[4] East Coast 275kV OHL Asset Condition Assessment Report Rev2.00

4 Optioneering

This section presents all the options considered to address the "need" that is described in Section 3. Each option considered here is either discounted at this Optioneering stage with supporting reasoning provided or is taken forward for Detailed Analysis in Section 5.

4.1 System Requirements - Network Options Assessment (NOA)

The SHE Transmission options presented annually to NOA are a combination of; short-lead time, medium cost options that utilise/upgrade existing assets to increase the north to south power transfer capability of the SHE Transmission network and long lead time, high cost options that increase the capability of multiple GB boundaries (refer to Appendix D for GB Boundary Map). An initial desktop assessment of these options filtered out the non-credible or unsuitable options which left a short list of suitable options to be further developed as outlined below.

For the purposes of the NOA, the options that involve SHE Transmission in Table 1 do not include the scope of any non-load works. The non-load works would need to be planned and undertaken regardless of the NOA recommendations. The opportunities and efficiencies of coordinating load and non-load works concurrently are considered when developing our network.

Table 1: Table of Options

Ref Number	Option Description (consistent with NOA option titles)	Earliest In Service Date (EISD)	Detailed Analysis
1	East Coast Onshore 275kV Upgrade (SLD Appendix E)	2023	Progressed
2	East Coast Onshore 400kV Reinforcement	2025	Progressed
3	East Coast Onshore Incremental 400kV Reinforcement	2026	Progressed
4	East Coast HVDC Link from Peterhead to North of England (Hawthorne Pit/Cottam/Drax)	2028/2029/2029	Progressed
5	East Coast Single Circuit 400kV Upgrade	NA	Not Progressed
6	Kintore–Tealing 275kV Rebuild and Tealing–Westfield/Glenrothes 275kV Reconductoring	NA	Not Progressed
7	Kintore – Tealing 275kV Rebuild	NA	Not Progressed
8	Beauly-Denny 400kV Double Circuit Upgrade	NA	Not Progressed

As the NOA process and options are common across the three East and North East Engineering Justification Papers, the high level scope is summarised in Appendix F of this paper and detailed in the overarching East Coast Onshore Transmission Investment Case.

5 Detailed Analysis

This section considers in more detail each of the options taken forward from the Optioneering section. Where appropriate the results of Cost Benefit Analysis are discussed and together with supporting objective and engineering judgement contribute toward the identification of a selected option. The section continues by setting out the costs for the selected option.

5.1 Cost Benefit Analysis

The onshore works in Scotland cannot be economically justified in isolation of the wider GB transmission system, thus SHE Transmission are working with SPT, National Grid Electricity Transmission (NGET) and the ESO to identify the optimal coordinated reinforcement path for the transmission network from the North of Scotland to the North of England. Our East Coast Onshore Transmission Investment Case details the full technical and economic need for a coordinated reinforcement strategy on the eastern side of the GB Transmission network from the north of Scotland to the north of England.

The following list of SHE Transmission reinforcement options were the most beneficial and cost-effective designs which could provide additional boundary capacity in reasonable timescales to facilitate increasing north to south power transfers;

- East Coast Onshore 275kV Upgrade, 2023
- East Coast Onshore 400kV Reinforcement, 2025
- East Coast Onshore 400kV Incremental Reinforcement, 2026
- Eastern HVDC link from Peterhead to Hawthorn Pit/Cottam/Drax, 2029

The East Coast Onshore 275kV Upgrade (Option 1) and the East Coast Onshore 400kV Incremental Upgrade (Option 3) for both NOA 2017/18 and NOA 2018/19 were defined as critical options under all four scenarios in FES 2017 and FES 2018 respectively. As such, neither option was included in the single year least regret analysis as progressing these options to maintain the EISD was determined as the optimum course of action under all scenarios. These reinforcements were therefore determined in NOA 2017/18 and NOA 2018/19 to be key options/components of the optimal wider GB investment strategy.

Further to the NOA economic assessment described above, working in collaboration with the TOs, the ESO has undertaken a comprehensive cost benefit and lifetime least worst regret analysis to examine the economics of reinforcing the eastern side of the GB transmission network. This process and results are set out in our East Coast Onshore Transmission Investment Case addressing the following;

1. Is the 275kV onshore reinforcement sufficient to relieve constraints north of B4 or is there a need to upgrade to 400kV

2. Should we incrementally deliver the onshore 400kV works or go straight to 400kV

3. Will investing in the onshore transmission system be regretted if we later deliver the offshore Eastern HVDC link

The benefit of the incremental approach is that early boundary constraint relief can be achieved by delivering Option 1 in 2023 as oppose to going straight to 400kV (Option 2) and not relieving the B4 boundary until 2025. Factored into the CBA was the recognition that the boundary uplift that is achieved from completing Option 1 in 2023 will in fact be limited during the 2024/25/26 outage seasons as significant construction outages will be required to deliver Option 3. The outcome remained in favor of the two-stage approach (Option 1 followed by Option 3).

The ESO's lifetime CBA and least worst regret analysis indicates that the incremental approach of East Coast 275kV onshore upgrade in 2023 (Option 1) followed by the 400kV upgrade in 2026 (Option 3) is preferred over the East Coast 400kV upgrade in 2025 (Option 2). This reinforcement strategy on the East Coast has strong economic benefits, is robust against a variety of sensitivities and would not be regretted if we later deliver the Eastern HVDC link.

The proposed East Coast Onshore 275kV Upgrade (single line diagram in Appendix E) utilises predominantly the existing OHL assets between Kintore to Kincardine and Tealing to Glenrothes/Westfield, a new substation at Alyth and Power flow control devices at Tealing to balance flows on the system and alleviate limitations observed for north to south power transfer.

The ESO's Cost benefit analysis report[5] recommends that the onshore works in Scotland are progressed as early as practicable and also to progress the Needs Case for the Eastern HVDC Link between Peterhead and the North of England.

As set out in our East Coast Onshore Transmission Investment Case, the need for wider system reinforcement is based on the economic benefit associated with increasing the north to south capability of our network. In addition to this objective, we must also coordinate the local works required to accommodate regional contracted connections in line with Section 2 of the NETS SQSS and also our asset intervention plans as set out in our paper A Risk Based Approach to Asset Management[6].

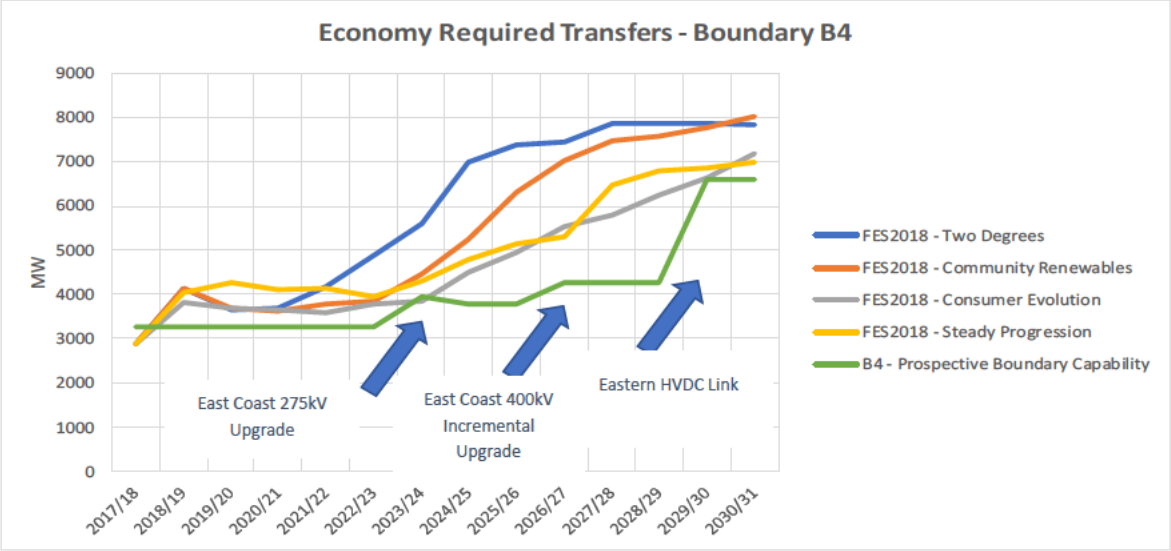
This coordination has led to the preparation of three Engineering Justification Papers to cover the East and North East Upgrades. The scope of the East Coast 275kV, East Coast 400kV Incremental and North East 400kV Upgrades is provided in a Table in Appendix F.

Figure 4 below shows the B4 boundary Economy Planned transfer requirements using the FES2018 scenarios and the boundary uplift provided by the three recommended projects – East Coast 275kV Upgrade, East Coast 400kV Incremental Upgrade and the Eastern High Voltage Direct Current (HVDC)

[5] Joint TO, Eastern CBA report by Nation Grid ESO
[6] A Risk Based Approach to Asset Management

link from Peterhead to the north of England. Even after the Eastern HVDC from Peterhead is complete, there remains a significant need for more capacity. We have submitted further options to the ESO in this year's NOA and we await results in January 2020. The plot in Figure 4 shows the strength of the need to progress with these onshore and offshore reinforcement works in the north of Scotland.

Figure 4: Economy Required Transfers and B4 Capability Uplift



The B4 boundary capability in 2023 without reinforcement is 3390MW, following completion of the East Coast 275kV Upgrade in 2023 the B4 boundary is thermally limited to 4000MW (based on the FES2018 background). This constitutes a B4 boundary uplift of 610MW. The uplift is calculated based on the capability before and after the reinforcement for the same year (and therefore same network model and background except for the exclusion/inclusion of the reinforcement).

The ESOs CBA calculated present values of constraint savings are subtracted from the present value of capital expenditure of the network option (or combination of options), giving the NPV. The NPV for the East Coast 275kV Upgrade ranges from [redacted] across the scenarios and sensitivities assessed (these NPVs assume no further reinforcement beyond East Coast 275kV Upgrade). The NPV and lifetime least worst regret analysis from the ESO are included in the East Coast Onshore Transmission Investment Case.

5.2 Network Study

The 2018/19, B4 boundary capability published in ETYS 2018/19 is 3.3GW with the limiting contingency being the outage of the Melgarve – Denny North 400kV and Braco West – Denny North 275kV double circuit overhead line. The thermal constraint is present on both the Errochty-Killin 132kV circuit and the 275kV circuit between Fetteresso and Kincardine. This is in line with the NETS SQSS,

Section 4.6.3; The minimum transmission capacity of the MITS shall be planned for the secured event of a double circuit overhead line fault outage on the supergrid.

5.2.1 Thermal Study Summary

The B4 capability above is determined in accordance with the NETS SQSS Section 4, Economy Background such that for the secured event of a fault outage of a double circuit overhead line on the supergrid there shall not be unacceptable overloading of any primary transmission equipment.

The configuration of the existing 275kV circuits south of Kintore result in the unbalanced sharing of load, resulting in the circuit between Fetteresso and Kincardine (in SPT's area) reaching its winter post fault thermal limit whilst capacity remains on the adjacent Tealing-Kintore circuit. This imbalance is addressed by introducing a new substation at the tower junction shown as a dashed box in Appendix C, the new Alyth substation.

The existing conductor on the 275kV OHLs between Kintore, Fetteresso, Tealing and Kincardine and between Tealing and Glenrothes/Westfield is twin 400mm^2 Zebra ACSR operated at 55°C, with a winter post-fault rating of 955MVA. The north to south power transfers are thermally limited by this capacity thus re-profiling these circuits, to operate at 65°C, increases the winter post fault rating to 1090MVA giving an incremental capacity of 135MVA per circuit. Seasonal OHL conductor ratings are shown in Appendix G.

SPT will be responsible for the uprating of the 275kV circuits between the SHE Transmission / SPT border and Kincardine and the SHE Transmission / SP Transmission border and Longannet to 65°C operation. SPT will also be responsible for uprating the existing cable sections to match future 400kV OHL ratings and associated SPT substation works.

The Alyth substation and the OHL works release additional capacity on the Kintore to Fetteresso to Alyth and Alyth to Kincardine circuits by improving the power flow balance across these circuits. However, the north to south power transfer capability is also limited by the thermal rating of the Kintore to Tealing 275kV double circuit overhead line, again a result of the non-optimal sharing of power on this double circuit and the 275kV double circuit between Kintore-Fetteresso and Alyth. To utilise the increased capacity of the adjacent reprofiled double circuit overhead line between Kintore-Fetteresso and Alyth, it is proposed to install Phase Shifting Transformers (PSTs) at Tealing, on the limiting Kintore to Tealing 275kV circuits. This will allow the power flow in these circuits to be controlled and encouraged to flow onto the higher capacity Kintore - Fetteresso - Alyth circuits.

On the west side of the network, the single circuit 132kV OHL between Errochty and Killin (132MVA winter post-fault) is a thermal limitation on the B4 boundary for increased power transfer following a double circuit loss south of Tummel on the 400/275kV OHL. The proposal to alleviate this constraint is to install an intertrip scheme that will trip the feeder breakers on the Errochty to Killin 132kV single circuit OHL in the event of a loss of the 400/275kV double circuit OHL south of Tummel substation.

5.2.2 Voltage Study Summary

Having addressed the thermal limitations on the east coast circuits with the scope set out above, the B4 boundary limit is defined by voltage limitations. Voltage criteria are set out in Section 6 of the NETS SQSS, Voltage Limits in Planning and Operating the Onshore Transmission System. For a secured event[7] of a fault outage of a double circuit overhead line on the supergrid there shall not have unacceptable voltage conditions or insufficient voltage performance.

The voltage step change at a location on the network is the dynamic change between the pre-switching voltage level on the intact network and the prevailing voltage immediately after a network asset outage. The key voltage limits relevant to this project which SHE Transmission are required to comply with are:

- A post-fault steady state minimum voltage limit for 275kV of 0.9 per unit in planning timescales (as detailed in part (a) of Table 6.2 within Section 6 of the NETS SQSS)
- A post-fault steady state maximum voltage limit for 400kV of 1.025 per unit in planning timescales (as detailed in part (a) of Table 6.2 within Section 6 of the NETS SQSS)
- A voltage step change limit of +/-6% following infrequent operational switching (as detailed in part (a) 4. of Table 6.5 within Section 6 of the NETS SQSS)
    - This is the maximum operational voltage change permitted from disconnecting an OHL or cable for routine maintenance.
    - Note 9 for part (a) 4. also states that a voltage step exceeding +/-3% for infrequent operational switching is only accepted on a busbar (or circuit) fed directly by the transmission circuit involved in the infrequent operational switching.

For the secured event of a fault outage of the Melgarve – Denny 400kV and Braco West – Denny 275kV double circuit overhead line there is an inability to achieve a steady state voltage of 248kV (90%) at Alyth 275kV substation for increasing north to south transfers. Installing 325MVAr of capacitive reactive compensation at Alyth enables the B4 boundary capability to be increased to 4000MW. Further increasing the size of the reactive compensation scheme at Alyth does not translate to increased boundary capability. Under increased transfers the steady state voltage issue becomes more distributed across the east coast 275kV sites, therefore no longer being a localised issue at Alyth. The next technically logical solution is to uprate voltage because we have reached the capability of a 275kV solution.

[7] A contingency which would be considered for the purposes of assessing system security and which must not result in the remaining NETS being in breach of the security criteria. Secured events are individually specified throughout the text of the NETS SQSS.

At 4000MW (based on the FES2018 background), the east coast 275kV and parallel 132kV network is considered to be at the capability limit of the existing assets. Further increase of B4 capability requires high cost intervention on the existing assets to uprate the Kintore-Fetteresso-Alyth-Kincardine double circuit overhead line to 400kV. The uprate to 400kV further improves the load sharing across parallel 275kV circuits between Kintore and Tealing and Tealing and the B4 boundary, increases thermal capacity and improves voltage performance.

The stochastic nature of renewable generation means that our network is subject to periods of high and low voltage. High north to south transfers (high wind, wet winter) increases the current flowing through the series inductance elements of our circuits thus suppressing the networks voltage profile. Under lightly loaded system conditions (low wind, dry summer), the opposite effect is present with the line capacitive charging causing a high voltage profile.

This is pertinent to the east coast network as the reactive compensation scheme proposed for installation at Alyth 275kV will also need to be suitably designed for operation as the network transitions to 400kV and connects the Eastern HVDC link. System studies were undertaken to determine the systems reactive compensation requirements at Alyth following its transition to 400kV (2026) and also on completion of the Eastern HVDC link (2029). These studies identified a requirement for inductive reactive compensation in the region of 180MVAr to achieve maximum steady state 400kV voltage criteria and dynamic capacitive compensation to mitigate a voltage step of greater than -6% for infrequent operational switching of the of the Eastern HVDC link (NETS SQSS, Table 6.5, Voltage step change limits in Planning & Operational Timescales).

Based on these system studies and consideration of connecting predominantly renewable generation, the proposed Alyth reactive compensation comprises of both dynamic and static elements. This enables the network to comply with the NETS SQSS and to optimise operability and flexibility for the short and long term demands of the network.

The capacity uplift of the 275kV reinforcement is made up of the contribution from the individual elements addressing both thermal and voltage issues that limit the north to south transfers. All components of the reinforcement scope have been tested in the NOA and ESOs lifetime CBA and received a strong signal to proceed.

5.3 Technology Review

The technology considerations explored for each of the elements required to deliver the output of the East Coast 275kV Upgrade are discussed in this section. SHE Transmission will continue to assess new technologies and look to implement subject to maturity and delivery timescales.

Alyth Substation

The Tee point where the Tealing to Alyth 275kV OHL meets the Kintore, Fetteresso to Kincardine 275kV OHL is located near Haughend Farm, Alyth. This was determined through assessment to be the optimum point on the network to install a new substation and reactive compensation.

Environmental and technical surveys, consultation with landowners and assessment of whole life cycle cost resulted in a preferred site being selected on a field to the north of the Tee point situated on Haughend Farm, Alyth.

Both Air Insulated Switchgear (AIS) and Gas Insulated Switchgear (GIS) were considered as options for the Alyth Substation. Technical, environmental and economic advantages and disadvantages of both technologies were explored. An AIS / GIS hybrid solution was selected as this has a smaller substation footprint that can be more easily screened from view of neighbouring and distant receptors and allows for more flexibility for future equipment if required. Further, following a cost evaluation it was determined that the arrangement could save approximately £0.8m over a full AIS solution.

In line with our Sustainability goals, SHE Transmission have made a commitment to reduce the use of new GIS containing SF_6. The use of an AIS / GIS hybrid solution for Alyth Substation has reduced the volume of gas required when compared to a full GIS solution. In addition, tendering contractors have been asked to provide options for SF_6 alternative gases at 400kV.

Alyth Reactive Compensation

The NOA analysis and System Studies Report[8] concluded that a reactive compensation scheme is required on the east coast 275kV network to accommodate increased north to south power transfers. A total of +325MVArs of capacitive reactive compensation was identified as being required to comply with the voltage limits specified in the SQSS under high power transfers and achieve the boundary uplift stated for East Coast 275kV Upgrade.

The system studies report looked beyond the proposed delivery of the East Coast 400kV Incremental Upgrade (2026) and also with the inclusion of the Eastern HVDC link from Peterhead to the North of England (2028/29). This analysis identified a requirement for inductive reactive compensation to address high voltages under lightly loaded system conditions and also voltage step exceedances on loss of the HVDC link. It was concluded that the optimum reactive compensation scheme will comprise 225MVAr of dynamic compensation and 100MVAr of static compensation. The combination of static and dynamic reactive compensation provides operational flexibility and with the static element ensuring that sufficient dynamic voltage support is available post fault event.

A technical assessment of potential reactive compensation solutions for Alyth recommended a Static Synchronous Compensator (STATCOM) with a range of +/-225MVAr rather than a Static Var

[8] East Coast Reactive Compensation Study Report, May 2019

Compensator (SVC) or Synchronous Condenser as the most appropriate solution to provide the required dynamic reactive support, and a Mechanically-Switched Capacitor with damping network (MSCDN) to provide the required 100MVAr static capacitive reactive support. The vendor responses to our request for information indicated a preference for STATCOM technology over alternatives. Also highlighted was that a STATCOM has a smaller footprint and less noise output as compared to other available technologies and offers more flexibility for the control and operation of the network. More information on this can be found in the Technical Assessment paper[9].

Errochty -Killin Intertrip

System analysis has identified that in the event of a double circuit loss south of Tummel substation on the 400/275kV overhead line, the Errochty to Killin 132kV OHL would overload. This limits the B4 boundary transfer capability and is therefore included as part of the East Coast 275kV Upgrade. An operational inter-trip scheme is therefore proposed to trip the Errochty to Killin 132kV OHL in the event of this type of fault.

A review of operational inter-trip schemes has been carried out with a preferred solution selected to ensure the fastest operating times. This requires the installation of new protection and control equipment at Killin and Errochty.

East Coast 275kV OHL Upgrade

The scope of the East Coast 275kV Upgrade includes the requirement to increase the thermal capacity of 185km double circuit overhead line between Kintore, Fetteresso, Tealing, Alyth to the SHE Transmission/SPT border boundary and 35km between Tealing and the SHE Transmission/SPT border. The scope of work between SHE Transmission/SPT border and Kincardine and between the SHE Transmission/SPT border, Glenrothes, Westfield, Mossmorran and Longannet will be completed by SPT. To achieve the uprating of overhead line at 275kV, the operating temperature of the conductors will be increased from 55°C to 65°C. SHE Transmission and SPT will continue to coordinate to ensure these works are effectively and efficiently delivered.

The conductor sample testing described in the Asset Condition section of this report has confirmed the suitability of the conductors to operate at the proposed increased temperature of 65°C.

The OHL cost estimate is based on re-profiling works (works to remove ground to conductor ground clearance infringements as a result of the increased sag which results from an increased operating temperature) along the full length of the OHL routes. A light imaging, detection, and ranging (LIDAR) survey of the OHL has been conducted allowing the OHL's to be modelled for operation at 65°C and clearance infringements identified. The cost estimate for the OHL works includes for Alyth OHL Tie In,

[9] Technical Assessment of Reactive Compensation Solutions for Projects Alyth and Tummel

re-compression of joints on Tealing to Westfield OHL, re-sagging of approx. 7 km of OHL and approx. 140 spans of tree cutting.

The OHL tie-ins to Alyth substation will also be carried out under this project. Options have been reviewed and the preference is to install a temporary diversion to allow new 400kV towers to be constructed on the line of the existing OHL tee point. The towers will be re-strung and the diversion removed. The new towers and conductors will then be reconfigured to terminal towers in 2023 to tie into Alyth substation.

Tealing Phase Shifting Transformers:

Phase Shifting Transformers (PSTs) are required to manage the load being transferred on parallel circuits running between Tealing and Kintore – circuit ID XT1/XT2 (as detailed in Appendix C).

PSTs play an important part in allowing the wider East Coast 275kV Upgrade scheme to deliver the stated capability uplift on the B4 boundary. Options to upgrade XT1 and XT2 were investigated and it was concluded that any reinforcement to this circuit, given the circuit length of 100km, would be extensive, timely and not economical. Installing PSTs to allow control of the power flow on these circuits is an economical solution to realise the capability delivered by East Coast 275kV Upgrade in 2023.

The PST on load angle range has been specified as +10/-10 degrees. Study work has proved that this is adequate to achieve the level of control required on these circuits for a number of system configurations and dispatch scenarios. The rating of the PSTs is 920MVA to ensure that the introduction of these units do not limit the short-term capability of the existing overhead line conductor.

System function/performance of PSTs is not sensitive to their location on the Kintore to Tealing double circuit OHL is not sensitive to their system function. A high-level review of each substation was conducted with Tealing substation preferred due to a number of space constraints at the line entry to Kintore substation.

5.4 Cost, risk and contingency

The cost of the SHE Transmission part of the East Coast 275kV Upgrade works are detailed in the East Coast 275kV Upgrade Project Cost & Efficiency Paper (T2BP-EST-0046). A summary of scope and cost breakdown is shown in Table 2 below.

Table 2: Table of Costs

Component	Cost
Alyth: Establish a new eleven bay double busbar substation at Alyth, constructed to 400kV but initially operated at 275kV. Reconfigure and terminate all overhead line circuits from Fetteresso, Tealing and Kincardine (SPT) on to the new Alyth busbar. Install a reactive compensation scheme at Alyth substation comprising a +225/-225MVar Dynamic and 100MVAr Static. 275kV cables and sealing ends are required to connect the Statcom and MSCDN to the 275kV Busbar. Establishing the new substation will require extensive civil works, access road improvements and protection works at the new site and at remote ends. **Errochty:** Install an operational intertrip scheme that will trip the feeder breakers on the Errochty to Killin 132kV single circuit OHL in the event of a loss of the Beauly to Denny 400/275kV double circuit OHL south of Tummel (275kV)	[redacted]
Tealing: Extend the 275kV substation at Tealing, installing two feeder bays with full busbar selection to connect two PSTs on the Kintore to Tealing 275kV OHL circuits. The PSTs will have a minimum rating of 920MVA and a nominal on-load angle range of +10/-10 degrees.	[redacted]
OHL: Increase the maximum operating temperature 65•C of 185km of existing 275kV OHL between Kintore, Fetteresso, Tealing and Kincardine and 26km between Tealing and Glenrothes/Westfield up to the SHE Transmission/SPT border, by completing the necessary re-profiling works. This provides an uplift in Winter Post fault thermal capacity of 135MVA from 955MVA to 1090MVA. The Alyth tie in requires the construction of three new towers, two diversions, three temp towers to minimise requirement for double circuit outages on east coast strategic circuits.	[redacted]
Total	**£166.01m**

The cost of the preferred option for works at have been developed using rates from existing substation framework contracts and benchmarks from delivered RIIO-T1 projects. These have been applied to indicative quantities obtained from layout drawings. The total project cost at 2018/2019 prices is estimated at £166.01m. Of this cost, £10.94m is estimated pre-construction costs which will be recovered under RIIO-T1 as shown in Table 3.

The split of costs between regulatory periods is shown in Table 3.

Table 3: Spend Apportionment

T1	T2
£10.94m	£155.07m

5.5 Stakeholder Engagement

Initial stakeholder engagement for these projects was carried out between 2011 and 2014. However due to changes in design, it was decided to carry out further stakeholder engagement between April and September 2019 to inform design and support Section 37 and Town and Country Planning Applications.

A public consultation for Alyth Substation took place July 2019. It included details of how the substation fits into the plans for East Coast 275kV and the East Coast 400kV Incremental Upgrades.

Applications for Alyth Substation and associated Public Road Improvements where submitted to Perth & Kinross Council in November 2019. Town and country planning application for Tealing extension logged in July 2019 with approval expected December 2019.

A Section 37 application for the Alyth Tie In was submitted to the Energy Consents Unit in October 2019. We are actively engaging with Perth and Kinross Council and the Energy Consents Unit and will continue to throughout the consenting process.

Interface meetings with SPT have been taking place and will become more regular as the projects progress.

Future engagements will also include ongoing discussion with landowners, neighbouring property owners, local councils and other statutory authorities such as Scottish Natural Heritage (SNH) and the Scottish Environmental Protection Agency (SEPA).

Our stakeholder's input is gathered via meeting of minutes and feedback from public consultation. It is recorded on a central project register. Feedback from public consultations will be complied into a report and circulated to the project teams for review with any questions raised by the public responded to in a timely manner.

5.6 Sensitivity Analysis

As outlined in our core RIIO-T2 business plan document, "A Network for Net Zero", we believe we have a critical role to play in delivering Net Zero ambitions in both the UK and Scotland. Therefore our plan has been carefully designed with the flexibility to deliver pathways to Net Zero. Our policy paper "Planning for Net Zero – Scenarios, Certain View and Likely Outturn" demonstrates that the investments which we are making are consistent with the UK Governments' net zero emissions by 2050 target. In preparing our RIIO-T2 Business Plan, we ensured that our Certain View provides flexibility for the north of Scotland transmission network to accommodate greater volumes of

renewable generation connections during the RIIO-T2 period. The strategic investments included in the Certain View –on the East Coast and near Tummel–are critical to ensuring that flexibility. While the need for these investments can be evidenced now, timely delivery also maintains long term net zero emissions pathways. Our approach to using a 'Certain View' means that there is strong evidence-based need and justification that the load related works are necessary for connections of renewable generation. These works are necessary to meet our legal and regulatory obligations to provide a connection to any customer who requests it. See Table 4.

Table 4: Sensitivity Analysis Table

Sensitivity	Test and impact observed – switching inputs
Ongoing efficiency assumptions	Switching efficiency assumption: increased or decreased. Test would have no impact on (feasible) option selection, the options move in parallel and have no impact on ordering within CBA.
Demand variations	No significant demand variation forecast
Energy scenarios	Sensitivity considered in Section 3 (Need) includes reference to the FES and the East Coast Onshore Transmission Investment Case where lifetime CBA sensitivities are explained in detail. . As we have adopted a "Certain View" approach, as outlined in our "Planning for Net Zero – Scenarios, Certain View and Likely Outturn" policy paper, means that there is strong evidence-based need and justification that the load related works are necessary for connections of renewable generation. These works are necessary to meet our legal and regulatory obligations to provide a connection to any customer who requests it. Reference Section 3 for details.
Asset utilisation	As outlined in the energy scenarios section, we are anticipating increasingly more generation connecting to our Transmission network. As outlined in our "Planning for Net Zero – Scenarios, Certain View and Likely Outturn" policy paper our business plan has been carefully designed with the flexibility to deliver pathways to Net Zero. There is strong evidence-based need and justification that the load related works are necessary for connections of renewable generation. These works are necessary to meet our legal and regulatory obligations to provide a connection to any customer who requests it. We are unable to consider the known unknowns.
Timing / delivery	We have considered timing of investments as part of our CBAs.

Consenting / stakeholders	Where applicable we have considered consenting and stakeholder engagement as part of section 5 (Detailed Analysis) and the impact which this has had on the selection of the preferred solution.
Public policy / Government legislation	We have considered the impact of public policy, government legislation and regulations as part of the need (section 3), optioneering (section 4) and detailed analysis (section 5) and the impacts this has on the selection of the preferred solution. For example the projects have considered the impact of the UK Governments' Net Zero emission by 2050 (2045 for Scotland) target, SQSS and ESQCR.

5.7 Proposed Solution

The scope of the East Coast 275kV Upgrade (Single Line Diagram in Appendix E) is:

SHE Transmission Works

Substation

- **At Alyth:** Establish a new eleven bay, GIS 400kV double busbar arrangement complete with bus section, bus isolators, two bus couplers and busbar selection on all circuits. The substation is to be built to allow 400kV operation but will be initially operated at 275kV. Reconfigure and terminate all overhead line circuits from Fetteresso, Tealing and Kincardine (SPT) on to the new Alyth busbar.

  Install a reactive compensation scheme comprising a +225/-225MVar STATCOM and a 100MVAr MSCDN. This equipment will be installed cognisant of the future 400kV uprating of the Alyth substation, thus efforts to minimise the impact of the transition will be implemented on the East Coast 275kV Upgrade project.

  Include space provision for a future 1200MVA, 400/275kV Super Grid Transformer that will be installed on the Alyth to Tealing Circuits in the East Coast 400kV Incremental Upgrade project (2026).

- **At Tealing**: Extend the AIS 275kV substation at Tealing, installing two feeder bays with full busbar selection to connect two PSTs on the Kintore to Tealing 275kV OHL circuits. The PSTs will have a minimum rating of 920MVA and a nominal on-load angle range of +10/-10 degrees.

- **At Errochty**: Install an operational intertrip scheme that will trip the feeder breakers on the Errochty to Killin 132kV single circuit OHL in the event of a loss of the Beauly to Denny 400/275kV double circuit OHL south of Tummel (275kV).

Overhead Line (OHL)

- Increase the maximum operating temperature to 65°C for the 185km of existing 275kV OHL between Kintore, Fetteresso, Tealing and Kincardine and 36km between Tealing and Glenrothes/Westfield up to the SHE Transmission/SPT border, to operate at 65•C, increasing the winter post-fault rating to 1090MVA.

SPT Works

Overhead Line (OHL)

- Re-profile the existing 275kV circuits between the SPT/SHE Transmission border and Kincardine and the SPT/SHE Transmission border and Glenrothes, Westfield, Mossmorran and Longannet to 65°C operation.
- Uprate existing cables on the SPT/SHE Transmission border to Kincardine to match future OHL ratings.

5.8 Output Measure

As boundary capabilities are sensitive to generation background, and other network developments and factors such as interconnector dispatch behaviours, we use a fixed background based on the FES 2018 Two Degrees scenario for the purposes of setting/measuring the output.

The East Coast 275kV Upgrade increases the capability of the B2 and B4 boundaries (refer to Appendix B for maps and single line diagram). The output measure for this reinforcement will be based on the B4 boundary uplift that this reinforcement provides. The B4 boundary capability in 2023 without reinforcement is 3390MW, following completion of the East Coast 275kV Upgrade in 2023 the B4 boundary is increased to 4000MW (based on the FES 2018 background). This constitutes a B4 boundary uplift of 610MW. The uplift is calculated based on the capability before and after the reinforcement for the same year (and therefore same network model and background except for the exclusion/inclusion of the reinforcement).

The output measure for the East Coast 275kV Upgrade is a B4 boundary uplift of 610MW (based on FES 2018 background).

Furthermore; this scheme delivers the following benefits:

- Increase the capability of the SHE Transmission Network in line with our goal to transport the renewable electricity that, in total, powers 10 million homes
- Facilitate the efficient, economic and co-ordinated operation of the national electricity transmission system
- Facilitate effective competition in the generation and supply of Electricity in line with our licence obligations and our goal to provide network connections to meet our customer needs, on time and on budget.

5.9 Competition

The East Coast 275kV Upgrade is above both Ofgem's early and late threshold at £166.01m. This scheme is a combination of several components designed to deliver a pre-defined system benefit. We investigated the potential of splitting East Coast Onshore 275kV Upgrade into smaller elements. However, the splitting of responsibilities and introducing new interfaces poses risk to the delivery timescales which the CBA indicates would bring significant inefficiencies and reduce the overall system benefit (e.g. if one element of the project were to be delayed).

Due to the scale of contracted generation connections in the north east of Scotland and the required transmission capacity, we do not consider it possible to deliver this scheme via an alternative solution. In addition, the timescales required to run an effective competitive tendering exercise (including pre-qualification etc) could lead to the over process taking 18-24 months. The insufficient time available would lead to any potential consumer benefits being outweighed by the additional constraint costs. This is based on the earliest in-service date and the level of consumer benefits that have been consistently indicated by NOA. The scheme is therefore not suitable for the application of early competition and is 'unflagged'.

In addition, and as highlighted within our Competition Strategy document, given that Ofgem and the ESO are still at the very early stages of developing potential early and late competitive models, and the absence of the required CATO legislation, significant further work will be required before any decision can be made on the application of any new competition model to these projects.

6 Conclusion

The East Coast 275kV Upgrade scope addresses several existing network issues that limit the north to south transfer of power across B4. This includes the unbalanced sharing across circuits, interconnectivity of the 132kV network, thermal capacity of existing OHLs and voltage performance.

The reinforcement spans SHE Transmission and SPT licence areas, the SHE Transmission works only are presented in this Justification Paper. SHE Transmission and SPT will continue to coordinate to ensure these works are effectively and efficiently delivered.

The East Coast 275kV Upgrade completion date is 2023. The Cost Benefit Analysis results provide a Net Present Value for the East Coast 275kV Upgrade (only) ranges from [redacted] across the scenarios and sensitivities assessed. In their CBA report, the ESO states that there is no regret in delivering these works and recommends that SHE Transmission and SPT progress the onshore work in Scotland as early as practicable.

Total project cost at 2018/2019 prices is estimated at £166.01 million. This is split into an estimated pre-construction cost of £10.94 million, to be recovered in the RIIO T1 period, and an estimated construction cost of £155.07 million during the RIIO-T2 price control years of 2021, 2022 and 2023. The output measure for the East Coast 275kV Upgrade is a B4 boundary uplift of 610MW (based on FES 2018 background).

7 Price Control Deliverables and Ring Fencing

This section provides a view of whether the proposed scheme should be ring-fenced or subject to other funding mechanisms.

As set out in our Regulatory Framework paper (section 1.12 and Appendix 3) we support a key principle from Citizens Advice – one that guarantees delivery of outcomes equivalent to the funding received - to ensure that RIIO-T2 really deliver for consumers. At the project level this means that if we don't deliver the output, or a materially equivalent outputs, we commit to returning the ex-ante allowance for the output not delivered.

This means that if the funding for East Coast 275kV Upgrade should be ring-fenced and if it does not go ahead, we will return the allowances of £166.01m in full (minus any justified preconstruction expenditure).

It also means that we commit to delivering 610MW[10] boundary uplift for the costs of £166.01m. If we do not deliver that 610MW[10] boundary uplift, or a materially equivalent output, we commit to returning a proportion of the ex ante allowance. The detailed methodology should be decided at when developing the Close Out methodologies but should apply the same principles of uncertainty mechanisms - that any under delivery should be material.

[10] Based on FES 2018, Two Degrees background. The uplift is calculated based on the capability before and after the reinforcement for the same year (and therefore same network model and background except for the exclusion/inclusion of the reinforcement)

8 Outputs included in RIIO T1 Plans

There are no outputs associated with this scheme included in our RIIO-T1 plans.

Appendices

Appendix A: Background to the East & North East Reinforcements

The need to reinforce the transmission network in the east and north-east of Scotland has been demonstrated through the NOA process and the ESO CBA Report. The latest NOA report, published in January 2019, recommended investment in the east coast onshore network in a two-stage approach, stage one – upgrade at 275kV completing by 2023 and stage 2 – incremental upgrade to 400kV operation by 2026. It also recommended investment in a 2GW High Voltage Direct Current (HVDC) link from Peterhead in the north east of Scotland to Drax in North Yorkshire, England with the associated AC onshore works at both ends by 2029. The proposed North East 400kV works which form part of the scope of the 400kV onshore reinforcement are also driven by regional connections ahead of the 2026 completion date. There is therefore an overlap of NOA reinforcements and works necessary to facilitate regional connections.

The coordination and sequencing of Growth and Asset Condition drivers for the East Coast onshore works to be completed within the RIIO T2 period are detailed in our "East Coast Onshore Investment Case"

East Coast Onshore 275kV Upgrade and East Coast Onshore 400kV Incremental Reinforcement

The NOA options for the east coast onshore reinforcement include (i) the East Coast Onshore 275kV Upgrade (ECU2) in 2023, (ii) the East Coast Onshore 400kV Incremental Reinforcement (ECUP) in 2026, following ECU2 and (iii) the East Coast Onshore 400kV Reinforcement (ECU4) in 2025. The NOA considered two paths for the east coast onshore upgrade to 400kV namely; (a) ECU2 followed by ECUP and (b) ECU4. The NOA CBA results indicated that the combination of ECU2 and ECUP outperforms ECU4 in all 2018 Future Energy Scenarios (FES). The benefit of the phased approach is due to the capacity delivered by the East Coast Onshore 275kV Upgrade earlier in 2023 which significantly reduces constraints on the SHE Transmission/SPT border.

The RIIO T2, East Coast 275kV Upgrade scope remains as presented in NOA 2018/19; comprising the new Alyth substation constructed to 400kV and reactive compensation scheme, increase maximum operating temperature of 185km of overhead line between Kintore, Fetteresso, Tealing, Alyth and the SHE Transmission/SPT border and 36km of the existing 275kV OHL between Tealing and the SHE Transmission/SPT border by undertaking reprofiling works, phase shifting transformers installed at Tealing on the 275kV circuits from Kintore and the Errochty-Killin Inter-trip scheme.

The scope of East Coast Onshore 400kV Incremental Upgrade as presented in NOA 2018/19 comprises the upgrade of the network from Peterhead and Blackhillock in the North East to the SHE Transmission/SPT border to 400kV. Regional contracted generation in the North East requires earlier delivery of elements of this 400kV scope; this subset of works are known for RIIO T2 as the North East 400kV and will be delivered in 2023. The remaining 400kV upgrade scope south of Kintore (and

installation of Phase Shifting Transformers (PSTs) at Blackhillock) will be completed in 2026 and is included in RIIO T2 as the East Coast 400kV Incremental Upgrade.

The condition assessment of the existing conductors between Kintore, Fetteresso, Alyth and the SHE Transmission/SPT border has established that the conductors should be replaced between 2022 and 2033. The benefits of coordinating the load and non-load drivers to reduce project re-mobilisation costs and reduce the impact on constraints during construction outages is demonstrated by Cost Benefit Analysis (CBA). This work concluded that the most coordinated, economic and efficient strategy for delivering the East Coast 400kV Upgrade works is to concurrently reinsulate and reconductor the overhead lines between Kintore, Fetteresso, Alyth and the SHE Transmission/SPT border by 2026.

East Coast 400kV Incremental Upgrade

- Reconductor and Reinsulate 170km overhead line between Kintore-Fetteresso – Alyth – Kincardine for 400kV operation
- Substation works at Kintore, Fetteresso and Alyth to accommodate 400kV
- Install two 275kV Phase shifting transformers at Blackhillock

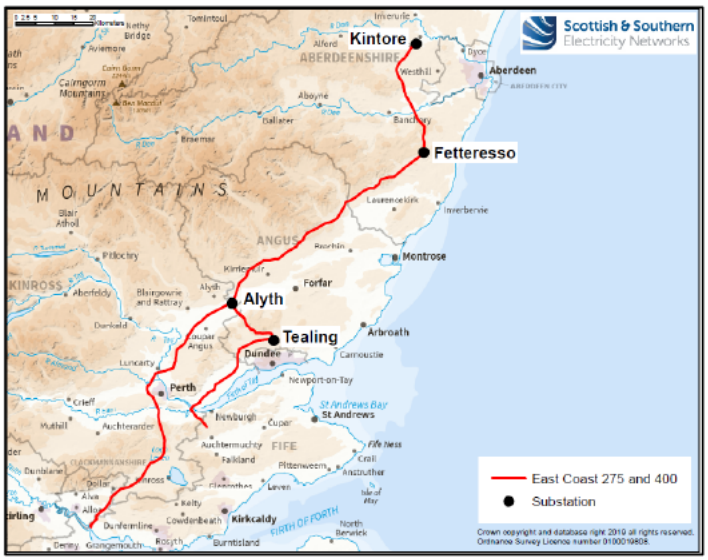


Figure A1: East Coast 400kV

North East 400kV

The local connections driving the North East 400kV reinforcement are contracted connections of the 800MW Moray West Offshore windfarm (2024) at Blackhillock, the 1400MW NorthConnect interconnector to Norway (2023) and the Clashindarroch 2 windfarm, 77MW connection into Cairnford substation. It is therefore planned that the North East 400kV reinforcement would be delivered ahead of the NOA recommended date to facilitate these regional connections.

The condition assessment of the existing conductors between Blackhillock, Rothienorman and Peterhead has established that the conductors should be replaced between 2026 and 2031. The benefits of coordinating the Load and Non-load drivers to reduce abortive and re-mobilisation costs and reduce the constraint impact during construction outages are demonstrated by CBA. This work concluded that the most coordinated, economic and efficient strategy for delivering the North East

400kV reinforcement is to align its delivery with the Peterhead 400kV busbar and the connection of NorthConnect in October 2023 and to concurrently reinsulate and reconductor the overhead lines between Blackhillock, Rothienorman and Peterhead.

North East 400kV

- Reconductor and Reinsulate 83km overhead line between Blackhillock-Rothienorman and Peterhead for 400kV Operation
- Transition New Deer and Rothienorman to 400kV Operation
- Peterhead 400kV Double Busbar
- Install two 1200MVA Super Grid Transformers (SGTs) at Kintore

Figure A2: North East 400kV

Appendix B: SHE Transmission Boundaries Map

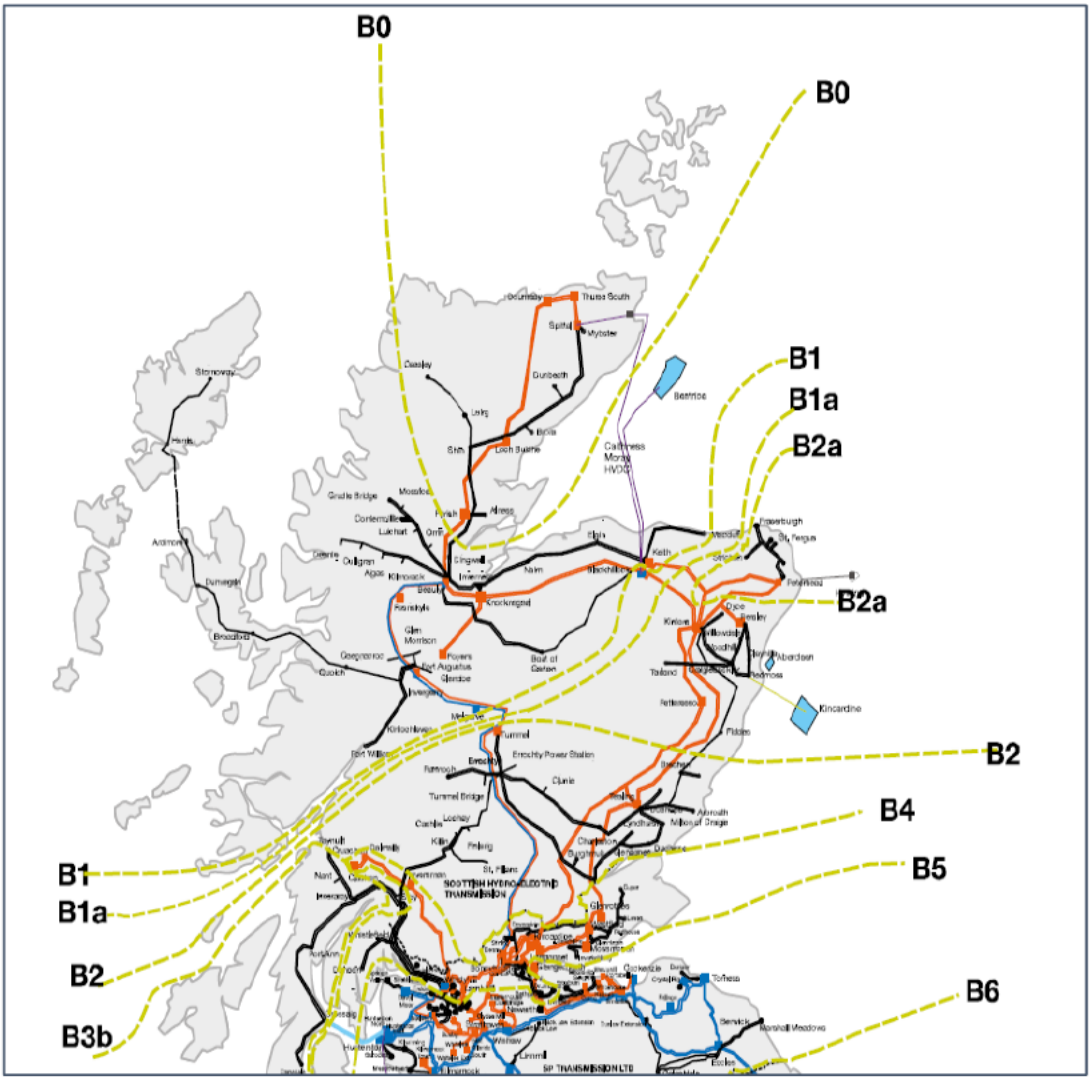


Figure B1: SHE Transmission Boundary Map 2018/19[11]

[11] Electricity Ten Year Statement 2018, Appendix A, Figure A3

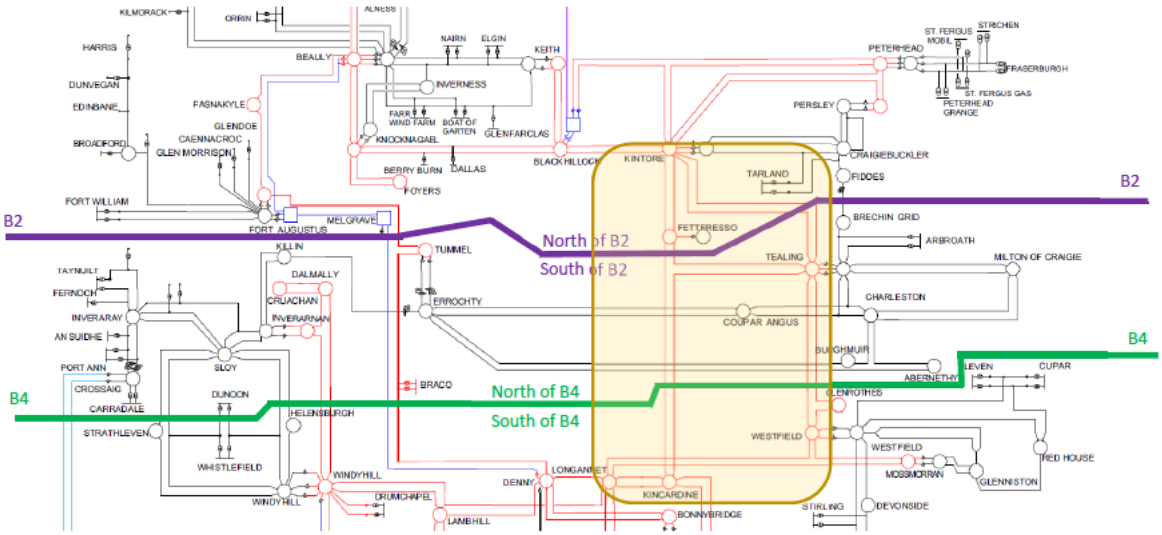
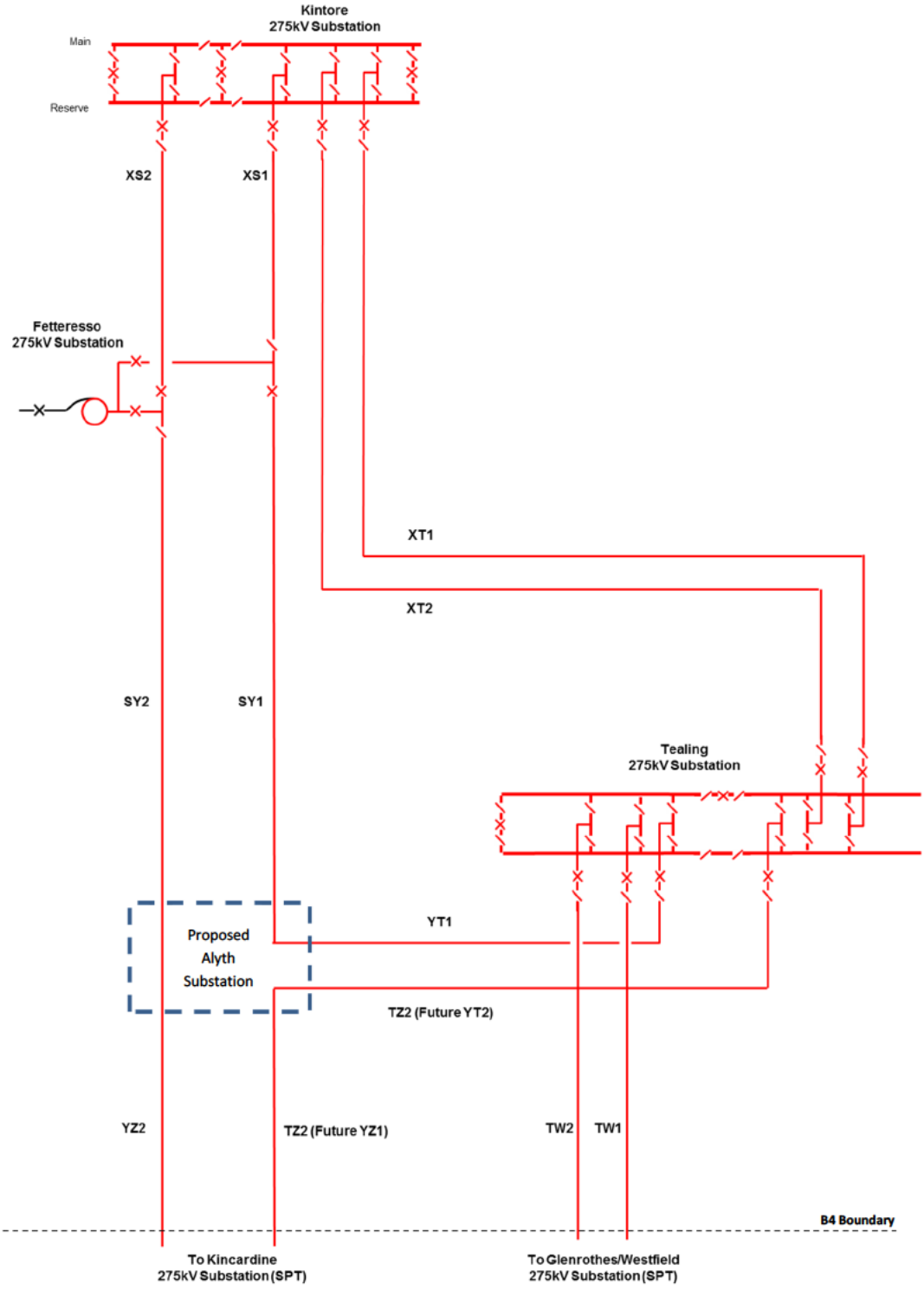


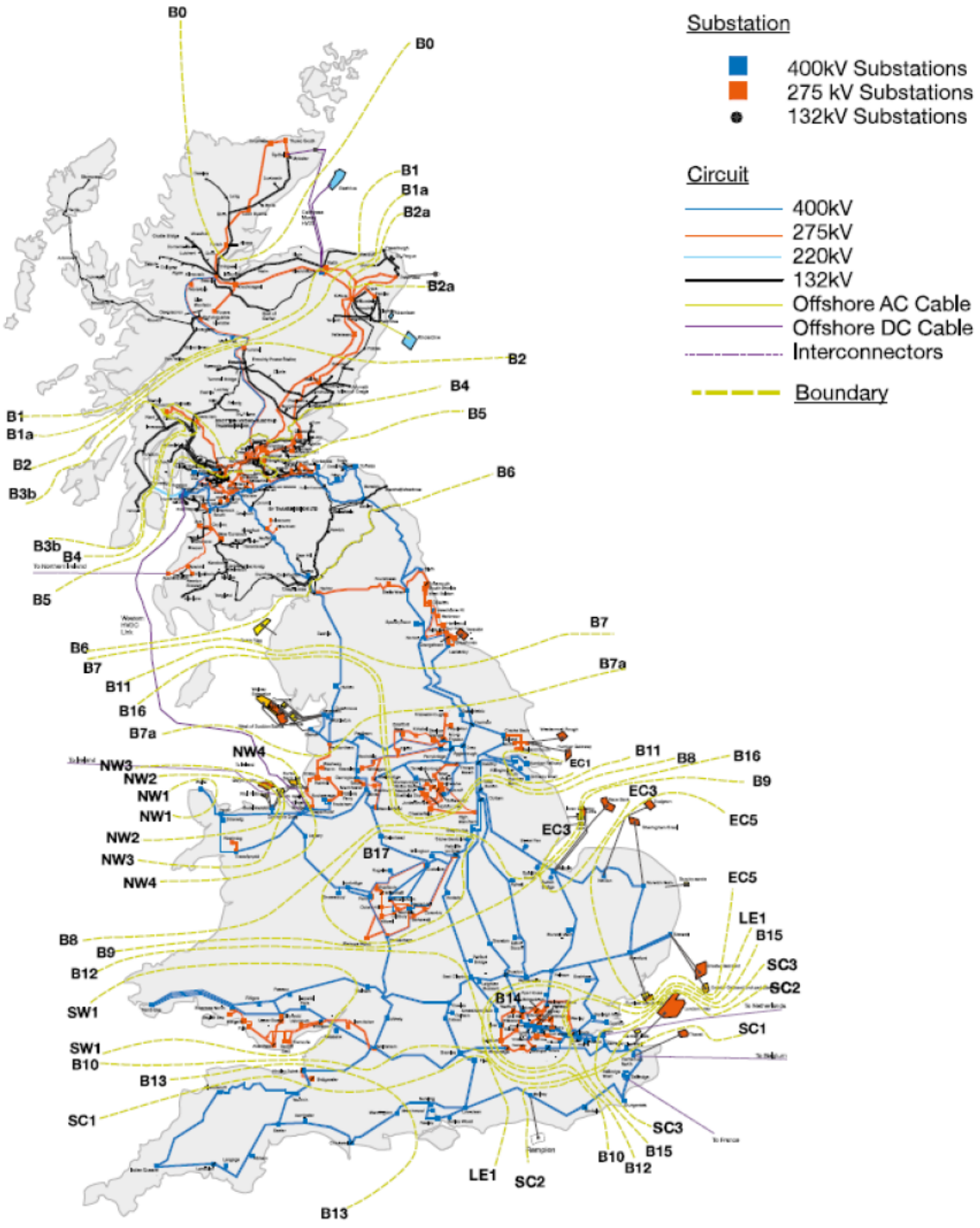
Figure B2: SHE Transmission B2 & B4 Single Line Diagram 2018/19[12]

[12] Electricity Ten Year Statement 2018, Appendix A, Figure A4

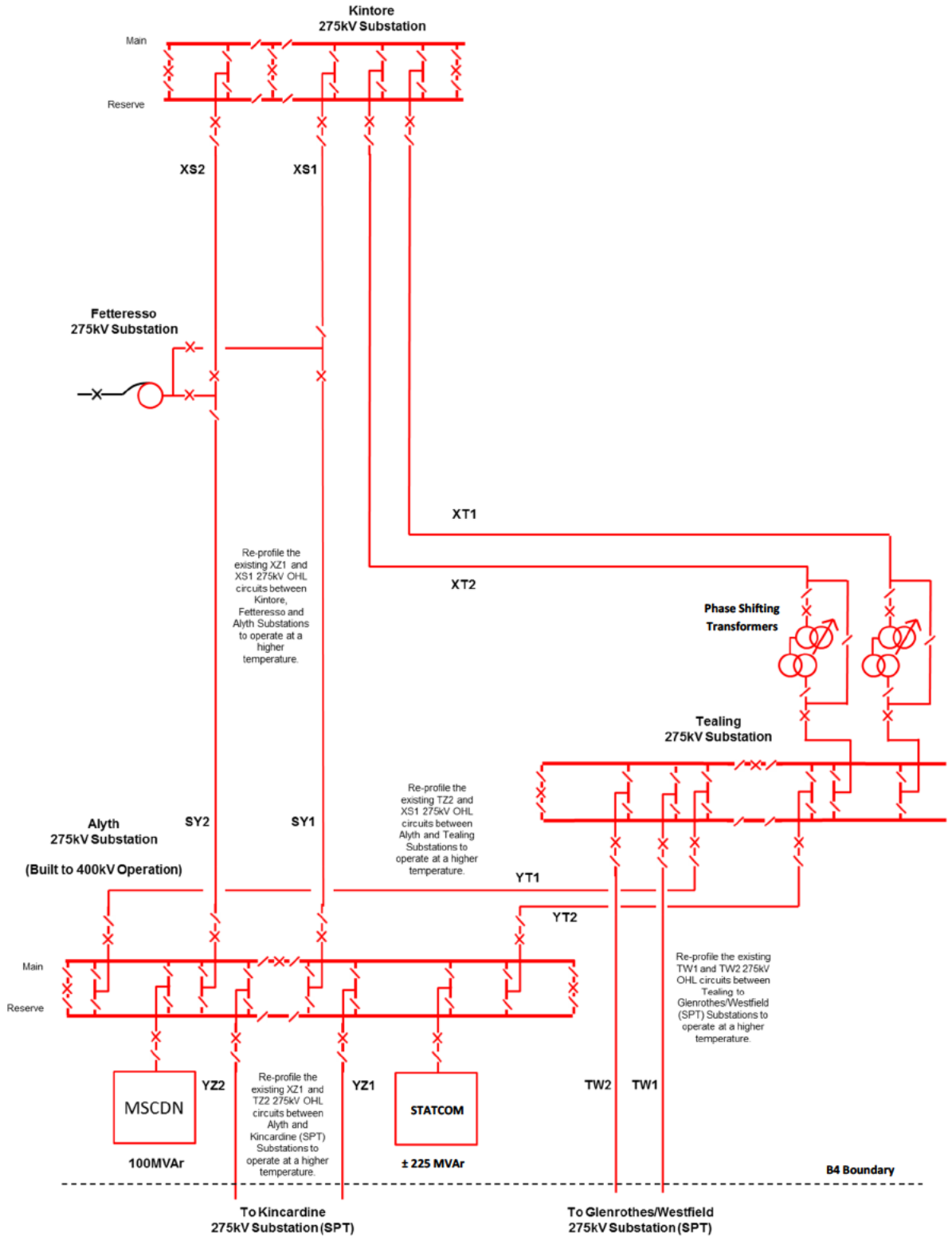
Appendix C – East Coast 275kV Network (2019)



Appendix D: ETYS 2018, GB Boundary Map[11]



Appendix E: East Coast 275kV Upgrade (2023)



Appendix F: Detailed Option Scope Descriptions

Option 1 - East Coast Onshore 275kV Upgrade - 2023

The proposed East Coast Onshore 275kV Upgrade (single line diagram in Appendix C) utilises predominantly the existing OHL assets between Kintore to Kincardine and Tealing to Glenrothes/Westfield, a new substation at Alyth and Power flow control devices at Tealing to balance flows on the system and alleviate limitations observed for north to south power transfer.

The asset condition assessment on the overhead line confirmed that all conductors are suitable for operation at 65°C.

PROGRESS TO DETAILED ANALYSIS

Option 2 - East Coast Onshore 400kV Reinforcement (includes North East 400kV scope) - 2025

The proposed East Coast Onshore 400kV Upgrade establishes 400kV connectivity between Peterhead, Blackhillock and Kintore in the North East to Kincardine by reinsulating the existing OHL circuits for 400kV operation, a new substation at Alyth and Power flow control devices at Tealing and Blackhillock to balance flows on the system and alleviate limitations observed for north to south power transfer. This option goes straight to 400kV on the East Coast with no precursory 275kV Upgrade.

PROGRESS TO DETAILED ANALYSIS

Option 3 - East Coast Onshore 400kV Incremental Reinforcement (includes North East 400kV scope) – 2026

The proposed East Coast Onshore 400kV Incremental Upgrade (single line diagram in Appendix F) follows on from the precursory East Coast 275kV Onshore Upgrade (Option 1). Similarly to Option 2, this option establishes 400kV connectivity between Peterhead, Blackhillock and Kintore in the North East to Kincardine by reinsulating the existing OHL circuits for 400kV operation, 400kV substation upgrades at Kintore, Fetteresso, Alyth and Kincardine and Power flow control devices at Tealing and Blackhillock to balance flows on the system and alleviate limitations observed for north to south power transfer.

PROGRESS TO DETAILED ANALYSIS

Option 4 - East Coast HVDC Link - 2029

The Eastern HVDC Link option between Peterhead and the North of England can be considered as both a standalone (no onshore reinforcement) option and as an incremental to the proposed onshore reinforcement options. In order to be assessed as a standalone option, this option must include the North East 400kV Upgrade scope. This is an important aspect to be considered in the cost benefit assessment as it needs to be demonstrated that the onshore reinforcement works are not regretted if we build the HVDC link following onshore reinforcement works.

PROGRESS TO DETAILED ANALYSIS

Options 5 – 8

Options 5-8 were ruled out at the desktop design stage due to environmental and consenting challenges, technical considerations and limited boundary capability uplift as a result of poor load sharing across parallel MITS circuits. The scope description for these options and further reasoning for not progressing these to detailed analysis will be included in our RIIO-T2 East Coast Onshore Transmission Investment Case.

NOT PROGRESSED

Appendix G: East and North East Table of Scope

East Coast 275kV Upgrade	North East 400kV & Peterhead 400kV Busbar	East Coast 400kV Incremental Upgrade	Description of works:
2023	2023	2026	Dates
✓			**Alyth:** Establish a eleven bay new double busbar substation at Alyth, constructed to 400kV but initially operated at 275kV. Reconfigure and terminate all overhead line circuits from Fetteresso, Tealing and Kincardine (SPT) on to the new Alyth busbar. Install a reactive compensation scheme at Alyth substation comprising a +225/-225MVar Dynamic and 100MVAr Static.
✓			**Tealing:** Extend the 275kV substation at Tealing, installing two feeder bays with full busbar selection to connect two PSTs on the Kintore to Tealing 275kV OHL circuits. The PSTs will have a minimum rating of 920MVA and a nominal on-load angle range of +10/-10 degrees.
✓			**Errochty:** Install an operational intertrip scheme that will trip the feeder breakers on the Errochty to Killin 132kV single circuit OHL in the event of a loss of the Beauly to Denny 400/275kV double circuit OHL south of Tummel (275kV)
✓			**OHL:** Re-profile the existing 275kV OHL between Kintore, Fetteresso, Tealing and Kincardine and between Tealing and Glenrothes/Westfield up to the SHE Transmission/SPT border, to operate at 65•C, increasing the winter post-fault rating to 1090MVA.

East Coast 275kV Upgrade	North East 400kV & Peterhead 400kV Busbar	East Coast 400kV Incremental Upgrade	Description of works:
2023	2023	2026	Dates
	✓		**Rothienorman:** Uprate the existing 275kV double busbar for 400kV operation. Install two new 240MVA 400/132kV SGTs and two new 120MVA 132/33kV GTs to replace the existing 120MVA 275/33kV GTs for the existing GSP connection.
	✓		**New Deer:** Uprate the existing 275kV New Deer double busbar for 400kV operation.
	✓		**Blackhillock:** Remove the 400/275kV line connected SGTs and use the existing 400kV circuit breakers to connect the re-insulated 400kV OHL from Rothienorman Substation.
	✓		**Kintore**: Install four 400kV Bays and partially construct the 400kV busbar to accommodate two 400/275kV, 1200MVA Super Grid Transformers connecting the uprated 400kV circuits from Rothienorman to the existing Kintore 275kV busbar. Install 8km of 275kV cable and associated sealing ends associated with the diversion of the existing double circuit overhead line from Blackhillock/Cairnford and interconnection between the 275kV SGT terminal and the 275kV busbar.
	✓		**OHL:** Reconductor and Reinsulate 170km to 400kV operation between Kintore, Fetteresso and Alyth (established in the East Coast Onshore 275kV Upgrade) as far as the SHE Transmission/SPT border.

East Coast 275kV Upgrade	North East 400kV & Peterhead 400kV Busbar	East Coast 400kV Incremental Upgrade	Description of works:
2023	2023	2026	Dates
	✓		**Kintore:** Establish an additional six bays (four bays installed under North East 400kV Upgrade) and complete the construction of the 10 bay (includes bus section and two bus couplers) 400kV AIS double busbar adjacent to the existing 275/132/33kV Kintore Substation.
		✓	**OHL:** Reconductor and Reinsulate 170km to 400kV operation between Kintore, Fetteresso and Alyth (established in the East Coast Onshore 275kV Upgrade) as far as the SHE Transmission/SPT border.
		✓	**Kintore:** Establish an additional six bays (four bays installed under North East 400kV Upgrade) and complete the construction of the 10 bay (includes bus section and two bus couplers) 400kV AIS double busbar adjacent to the existing 275/132/33kV Kintore Substation.
		✓	**Fetteresso:** Remove the existing 240MVA 275/132kV SGT and install two new 240MVA 400/132kV SGTs. Utilise existing 400kV equipment at Fetteresso substation to establish a 400kV double busbar. These works are required to operate the existing substation and the OHLs from Kintore and Alyth at 400kV
		✓	**Alyth:** Uprate the 275kV (built for 400kV operation) Gas Insulated Switchgear double busbar arrangement established at Alyth via the East Coast Onshore 275kV Upgrade for 400kV operation. Install two new 1200MVA 400/275kV SGTs with piled foundations to connect the existing 275kV OHL from Tealing Substation.

East Coast 275kV Upgrade	North East 400kV & Peterhead 400kV Busbar	East Coast 400kV Incremental Upgrade	Description of works:
2023	2023	2026	Dates
		✓	**Blackhillock:** Installation of two Phase Shifting Transformers (PSTs) at Blackhillock Substation on the 275kV double circuit OHL to Knocknagael including installation of associated civils & interconnecting electrical infrastructure. The PSTs will have a minimum rating of 920MVA and a nominal on-load angle range of +15/-15 degrees.

Appendix H – Overhead Line Ratings

	Current 275kV Operation at 55°C	Re-profile at 275kV for operation at 65°C
Conductor	Zebra	Zebra
mm^2	400	400
Conductor Type	ACSR	ACSR
Bundle	Twin	Twin
kV	275	275
Operating Temp (°C)	55°C	65°C
Winter Pre-fault rating (MVA)	805	920
Spring / Autumn Pre-fault rating (MVA)	740	865
Summer Pre-fault rating (MVA)	640	780
Winter Post-fault rating (MVA)	955	1090
Spring / Autumn Post-fault rating (MVA)	885	1030
Summer Post- fault rating (MVA)	760	925