Scottish & Southern Electricity Networks

SSEN Transmission

RIIO-T2 Business Plan - T2BP-EJP-0017

East Coast 400kV Incremental Upgrade

Engineering Justification Paper

Title Section			
Name of Scheme/Programme	East Coast 400kV Incremental Upgrade		
Primary Investment Driver	Load		
Scheme reference/ mechanism or category	SHT2010, SHT2011		
Output references/type	LRT2SH2010, LRT2SH2011		
Cost	£257.18m		
Delivery Year	2026		
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**	**T3**
	£6.40m	£214.95m	£35.83m

1 Executive Summary

Our paper 'Planning for Net Zero: Scenarios, Certain View and Likely Outturn' 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 400kV Incremental Upgrade which has a completion date of 2026. 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 400kV Incremental Upgrade is the second part of the phased onshore reinforcement on the east coast – the first part is the East Coast 275kV Upgrade which has a completion date of 2023. These onshore reinforcements comprise works on existing infrastructure in both our area and the Scottish Power 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, ScottishPower Transmission (SPT) and National Grid Electricity Transmission (NGET). The ESOs CBA report concludes that based on strong economic benefit and robustness of sensitivity analysis, ESO recommends that SHE Transmission and SPT progress eastern onshore projects. There is no regret in delivering these projects as early as practicable.

This paper is for the East Coast Onshore 400kV Incremental Upgrade, further detail on how the east coast onshore reinforcement projects are being developed and referenced is available in Appendix A and in the RIIO-T2 East Coast Onshore Transmission Investment Case.

In addition to the primary load driver, an asset condition assessment carried out in 2018 recommends re-conductoring the OHL between Kintore the SHE Transmission/SPT border during the period 2022-2033. This delivery of non-load reconductoring along with the line uprating works for 400kV operation offers an NPV gain of £15.82m compared to the counterfactual option of separately undertaking the non-load works towards 2033.

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 Onshore 400kV Incremental Upgrade follows on from the East Coast 275kV Onshore Upgrade. The scope establishes 400kV connectivity between Kintore in the North East to Kincardine by reinsulating the existing 170km of overhead line for 400kV operation. Substation works are also required at Kintore, Fetteresso, Alyth and Kincardine to uprate for 400kV operation and power flow control devices at Blackhillock to balance flows on the system and alleviate limitations observed for north to south power transfer.

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 480MW, which corresponds to a lifetime Net Present Value range of [redacted] (includes the East Coast 275kV Upgrade).
- Improved operational resilience through timey asset condition-based intervention in line with our goal to aim for 100% transmission network reliability.
- 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 East Coast 400kV Incremental Upgrade is flagged as above Ofgem's early and late competition criteria value threshold at £257m. The combined cost of £257m includes separable elements, however, the cost of the separable works is less than the late competition threshold of £100m. Combined, we do not consider that the scheme is separable from the wider system and does not meet Ofgem's late competition criteria.

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'.

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 within the existing Blackhillock substation 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.

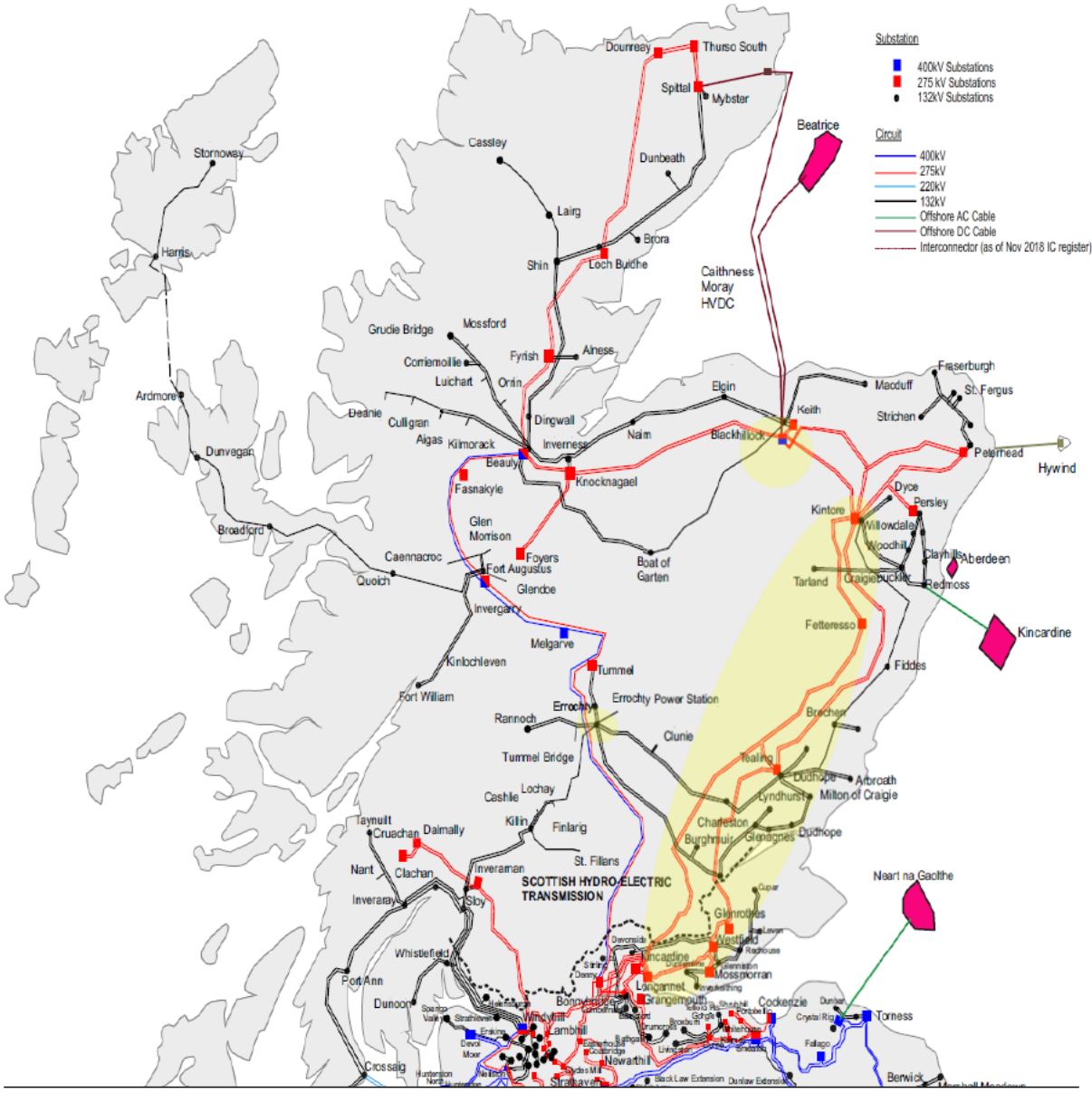
Section 7: Price Control Deliverables and Ring Fencing

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[1]

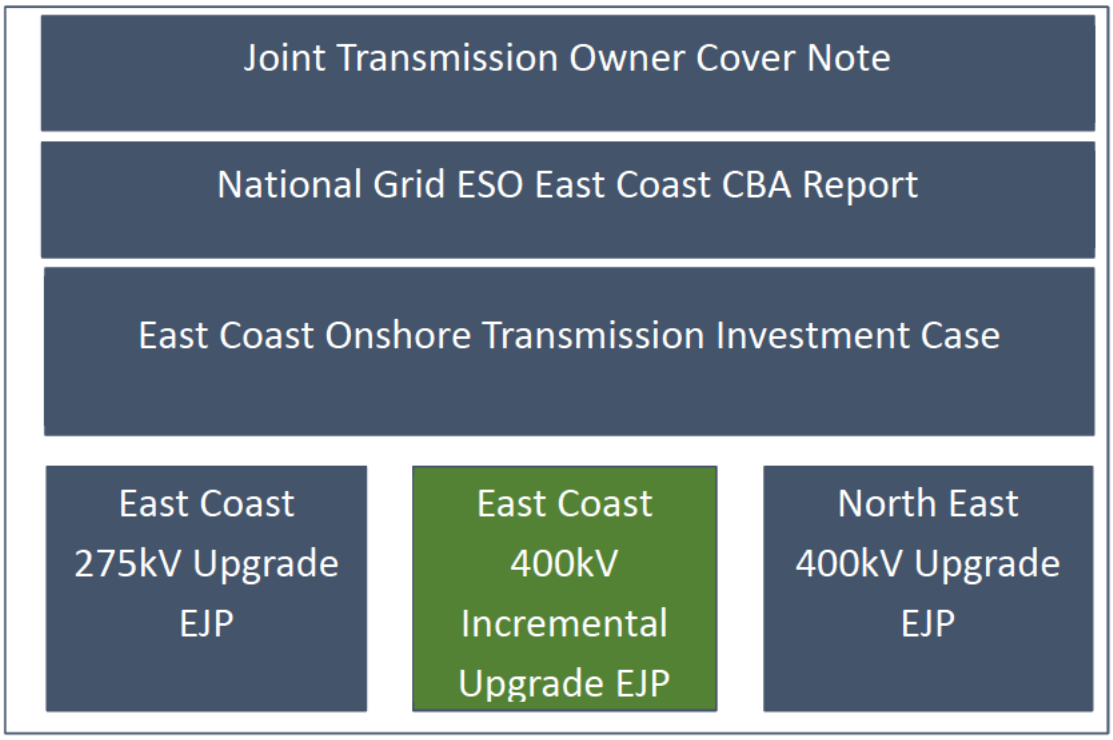


[1] Electricity Ten Year Statement 2018, Appendix A, Figure A2

This paper is for the East Coast Onshore 400kV Incremental 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;

- **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

3.1 Background

As set out in our Planning for Net Zero: Scenarios, Certain View and Likely Outturn Paper, 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 detail 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 life time economic regret assessment 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 is energy is replaced with generation on the importing side. Balancing the network by switching generation on and off costs money, and if the ESO are 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 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 Beauly – Denny 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

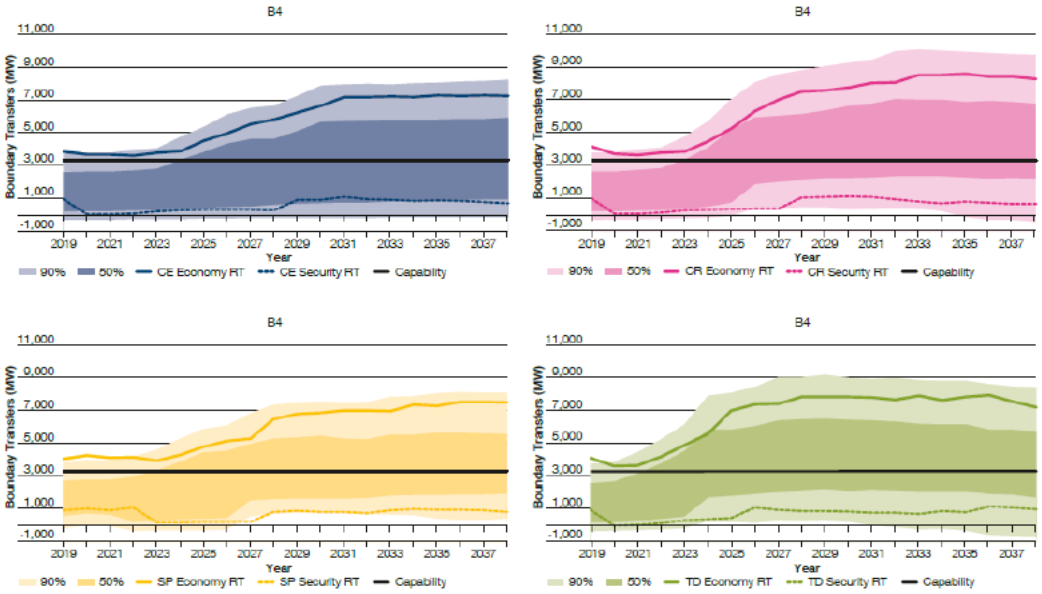
In June 2019 we published our draft Business Plan for the RIIO-T2 price control period from 1 April 2021 to 31 March 2026. Our Plan is what we call the Certain View where all of the activities and investments we propose have a strong, evidence-based need to be done. Our Planning for Net Zero: Scenarios, Certain View and Likely Outturn Paper 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 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[2]



3.3 Asset Condition

The existing double circuit OHL between Kintore, Fetteresso 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. 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. Following completion of the East Coast Onshore 275kV Upgrade in 2023, these circuits will be operated at 65°C with a winter post-fault rating of 1090MVA.

Assessment of the phase conductor mechanical properties and grease-drop point were completed on the Kintore, Fetteresso, Tealing and Kincardine OHL circuits in 2012 and 2013. During testing the grease condition, corrosion presence, turns to fracture and breaking load were all recorded. Each of these results were analysed to determine a remaining service-life estimation at each of the conductor sample locations. The results of the assessment are summarised in Table 1. The asset condition assessments identified that the phase conductors on the double circuit OHL between Kintore, Fetteresso, Tealing and Kincardine have an estimated service life range between 2022-2033.

The asset condition assessments also look at the condition of the towers, tower foundations, fixtures and fittings. A programme of aerial condition inspections on the east coast 275kV circuits throughout summer 2018 was conducted. This identified several instances of significant conductor damage. [redacted]

[2] Electricity Ten Year Statement 2018

[redacted]

[redacted]

Table 1: Overhead line Conductor Condition Assessment Summary

Circuit Reference	Circuit ID*	Circuit Length (km)	Year of Conductor Sample	Number of Samples	Estimated remaining conductor service Life (years)	Estimated service life range
Kintore - Fetteresso	XS1	32	2012	2	10-15	2022 - 2027
			2013	5	15-20	2028 - 2033
Fetteresso – Alyth	SY1	67	2013	2	15 – 20	2028 - 2033
Alyth - Kincardine	YZ1	70	2013	3	10 – 15	2023 - 2028
				3	15 – 20	2028 - 2033

*Reference circuit IDs on Single line diagram in Appendix C

In the event that the load driven East Coast onshore reinforcement projects were deferred or stopped, we would propose to carry out all works identified in the East Coast 275kV OHL Asset Condition Assessment Report_Rev2.00[3] within the timescales in Table 1 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

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

4 Optioneering

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 2 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 2: 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	2023	Progressed
2	East Coast Onshore 400kV Reinforcement	2025	Progressed
3	East Coast Onshore Incremental 400kV Reinforcement (SLD Appendix E)	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 (Reference Figure 2).

5 Detailed Analysis

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, 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.

The benefit of the incremental approach is that early boundary constraint relief can be achieved by delivering Option 1 in 2023 as opposed 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 East Coast Onshore 400kV Incremental Upgrade follows on from the East Coast 275kV Onshore Upgrade. The scope establishes 400kV connectivity between Kintore in the North East to Kincardine by reinsulating the existing 170km of overhead line for 400kV operation. Substation works are also required at Kintore, Fetteresso, Alyth and Kincardine to uprate for 400kV operation and power flow control devices at Blackhillock to balance flows on the system and alleviate limitations observed for north to south power transfer.

The ESO's Cost benefit analysis report[4] 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.

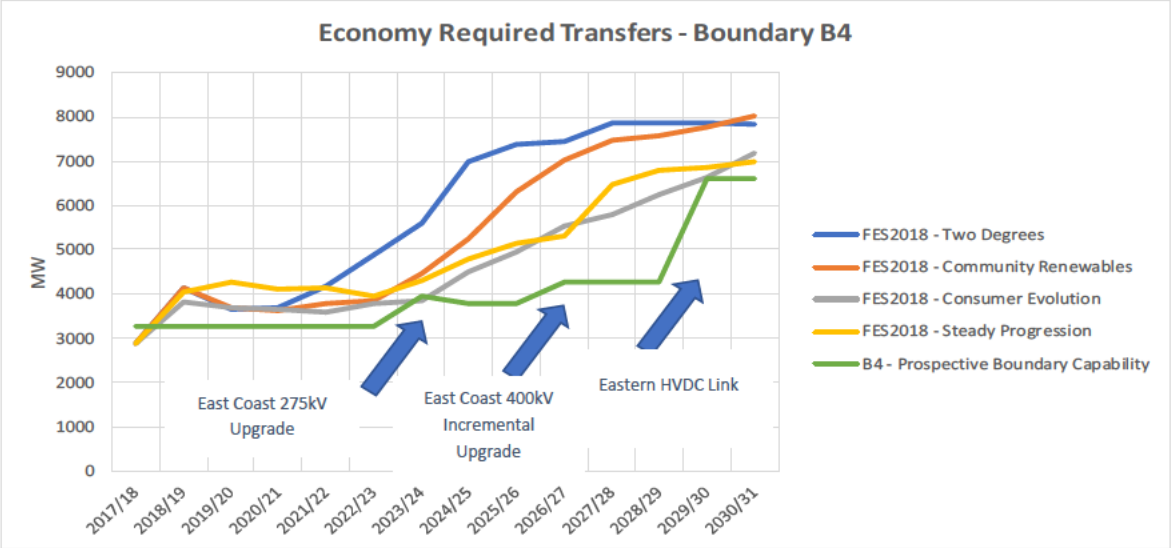
As set out in our East Coast Onshore Transmission Investment Case, the need for wider system reinforcement is based on the economic benefit associated with increasing the north to south capability of our network. In addition to this objective, we must also coordinate the local works required to accommodate regional connections in line with Section 2 of the NETS SQSS and; our asset intervention plans as set out in our paper A Risk Based Approach to Asset Management[5].

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 G.

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) 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 – awaiting results January 2020. The plot in Figure 4Figure 4 shows the strength of the need to progress with these onshore and offshore reinforcement works in the north of Scotland.

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

Figure 4: Economy Required Transfers and B4 Capability Uplift



The B4 boundary capability in 2026 without the East Coast 400kV upgrade is 3780MW, following completion of the East Coast 400kV Incremental Upgrade in 2026 the B4 boundary is thermally limited to 4260MW (based on the FES 2018 background). This constitutes a B4 boundary uplift of 480MW. All capability values stated are based on the import of 1400MW from NorthConnect, the HVDC interconnector to Norway. 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 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 net present value (NPV). The NPVs for the East Coast 400kV Upgrade (including North East 400kV[6] subset scope) following the East Coast Onshore 275kV Upgrade, range from [redacted] across the scenarios and sensitivities assessed. The NPV and lifetime least worst regret analysis from the ESO are included in East Coast Onshore Transmission Investment Case.

5.2 Coordination of Load and Non-load Works

The East Coast 400kV Incremental Upgrade scope includes the re-insulation of 170km of the OHL between Kintore, Fetteresso, Alyth and Kincardine for 400kV operation. This will result in the accumulation of construction outages and associated network constraints. This would in turn be followed by further outage requirements to reconductor the circuits in line with the non-load driver, if this is on a different timescale to the load driver. This has driven consideration of a concurrent

[6] North East 400kV Business Plan Justification Paper

reconductor and re-insulate approach to reduce the requirement for significant future construction outages against a growing generation background.

The assessment of non-load intervention is out with the scope of the NOA due to the CBA being based on boundary capability. SHE Transmission has thus identified the benefits of a concurrent reconductoring and reinsulating approach by a Net Present Value (NPV) assessment detailed in this report.

Condition assessment of the Alyth to Kincardine and Alyth to Kintore OHLs detailed in the Asset Condition section of this paper have shown that the current conductor will exceed its lifespan between 2022 and 2033.

The concurrent approach proposed enables the load driven boundary capability uplift to be achieved in 2026 through the 400kV uprating whilst coordinating the non-load asset replacement of the phase conductors.

Furthermore, the concurrent delivery of the reinsulating and reconductoring works presents a number of benefits to stakeholders, including generators, statutory consultees and the wider public. The coordination of the works will reduce construction outages on the network through the avoidance of multiple mobilisations, each requiring outages to complete their specific set of works. This has the potential to enable improved network availability when compared with an alternative delivery strategy.

From a Statutory Consultee and general public perspective, the coordination of the works and the reduction in the number of mobilisations will result in reduced impacts and disruption to their activities and concerns. This is through the reduction of the timescales over which the works are to be undertaken.

5.3 Load and Non-load Cost Benefit Analysis

SHE Transmission has carried out CBA using counterfactual NPV analysis to demonstrate the benefit of concurrently delivering load and non-load works.

The two options considered in the CBA are;

i. **Counterfactual** - Re-insulation of 170km of OHL between Kintore, Fetteresso, Alyth and Kincardine (in SPT's area) by 2026 and later reconductoring of these circuits in 2030.

ii. **Concurrent** - Reconductoring and re-insulation 170km of OHL between Kintore, Fetteresso, Alyth and Kincardine (in SPT's area) by 2026.

Table 3: NPV Analysis results

Option	Preferred Option	Forecast Capital Expenditure *(£m)*	Total NPV (£m)*	Benefit *(Option to baseline)*
Counterfactual	N	[redacted]	[redacted]	-
Concurrent	Y			[redacted]

The concurrent approach offers an undiscounted capex saving of [redacted]. This can be attributed to project re-mobilisation costs mainly related to site management and the avoidance of duplication of resources. Taking account of depreciation and discounting, the concurrent option offers an NPV gain of [redacted] compared to the counterfactual option over a 45-year asset life.

In line with our sustainability strategy commitments, whole life costs, losses, regional gross value add and the carbon impact of each of the options have also been assessed as part of our CBA (See Table 4.

Table 4: CBA Impact Table

Benefit category	Details	CBA value impact
Whole life costs	The CBA has been carried out based on TOTEX (i.e. includes both capex and opex). Unit costs for opex are still being worked through so numbers are indicative	As it's an existing OHL that is being reconductored and reinsulated, there would be no change in the OHL opex therefore only the additional opex from the new circuit breakers and transformers has been included in the CBA, totaling £2.2m over the 45-year asset life (undiscounted).
Reduced losses	Losses have not been included in this draft as the methodology for quantifying losses has not been finalised.	
Carbon impact – embedded carbon	Embedded carbon relates to carbon emissions associated with the manufacturing and production of the materials procured and installed as part of the project.	The discounted value of embedded carbon is estimated around £15m over the lifetime of the assets.
Carbon impact – carbon displacement	Carbon displacement is determined through allocating a value to the displacement of fossil fuels from connecting new renewable generation.	Since every option considered enables the same boundary uplift, carbon abatement is the same across all scenarios and as we are comparing the value add of each option against the baseline, including it would not change the results. However,

		following the delivery of the project, a further 480MW (of mainly low carbon generation from onshore wind, offshore wind and hydro) can be securely transferred out of the SHE Transmission area, which could equate to average annual discounted carbon displacement benefits in the region of £31million, according to the Scottish Governments Renewable Electricity Output Calculator[7].
Regional Gross Value Add (GVA)	GVA is a measure of the value generated in an economy by any unit engaged in the production of goods and services. SHE Transmission has developed a tool to quantify the estimated regional GVA on the Scottish economy resulting from expenditure associated with the new generation connections enabled, and the work associated with SHE Transmission investments. Total GVA is calculated by measurements at three levels: 1. Direct GVA: value generated from direct project expenditure 2. Indirect GVA: value generated from employment of sub-contractors and demand for goods and services from suppliers down the supply-chain 3. Induced GVA: value generated from greater demand and spending on goods and services such as accommodation, food, fuel and retail by employees who are employed as a result of the	The total direct regional GVA to the Scottish economy associated with the potential further 480MW capacity, which for the purpose of this CBA is assumed to be onshore wind connections, is estimated at £117m (discounted over estimated asset life of generation connections). Indirect and induced GVA totals £162m (discounted). The direct regional GVA associated with the SHE Transmission expenditure is estimated at £40m (discounted), indirect and direct GVA totals £44m.

[7] https://www2.gov.scot/Topics/Statistics/Browse/Business/Energy/onlinetools/ElecCalc

5.4 Network Study Overview

The B4 boundary capability in 2026 without the East Coast 400kV upgrade is 3780MW with the limiting contingency being the outage of the Melgarve – Denny North 400kV and Tummel – Braco West 275kV double circuit overhead line. The thermal constraint is present on both the 275kV circuit between Kintore and Tealing and the 132kV East Coast circuit between Craigiebuckler and Tealing. This is in line with the NETS SQSS, Section 4.6.3; The minimum transmission capacity of the MITS also be planned such that for the Economy Background condition and for the secured event of a double circuit overhead line fault outage on the supergrid.

The reduction in B4 capability from 4000MW in 2023 following the East Coast 275kV Upgrade is attributed to the 1400MW connection of NorthConnect in the North East resulting a change to the network dispatch characteristic.

Following the East Coast Onshore 275kV Upgrade, the north to south power flows remain limited by the thermal capacity of the east coast OHLs and the steady state voltage profile. Uprating the east coast overhead lines between Kintore, Fetteresso, Alyth and Kincardine circuits to operate at 400kV increases the thermal capacity of these circuits whilst also encouraging power flow away from the lower capacity parallel circuits.

Under increased north to south transfers at 275kV, there is an inability to achieve steady state voltages above the 248kV (90%) limits specified in the NETS SQSS, Section 6 across multiple east coast 275kV sites, therefore no longer being a localised issue at Alyth. The uprate to 400kV addresses these distributed steady state voltage issues and enables the network to achieve steady state voltage compliance under increased north to south power flows.

The proposed East Coast 400kV Incremental Upgrade (Single Line Diagram in Appendix E) utilises the existing OHL tower structures and includes new substation assets at Blackhillock, Kintore, Fetteresso and Alyth to facilitate 400kV operation and alleviate limitations observed for north to south power transfer.

The scope of East Coast 400kV Upgrade also includes the installation of two Phase Shifting Transformers (PSTs) at Blackhillock on the 275kV double circuit overhead line between Knocknagael and Blackhillock. The Blackhillock site was developed with space provision allowed for these units. The PSTs on these circuits provide an element of control of the east and west power flows, optimising sharing and enhancing power transfer across the B4 boundary.

The SHE Transmission network south of Beauly, for bulk power transfer out of our area, essentially consists of the Beauly to Denny 400/275kV double circuit OHL on the west, two 275kV double circuit OHLs on the east running south of Kintore, and a 275kV double circuit from Beauly towards Blackhillock/Kintore (i.e. from west to east). Following the establishment of a lower impedance 400kV network on the east coast, more power flows west to east and down the east coast, and therefore less power flows on the Beauly to Denny line. The PSTs at Blackhillock, situated on the west to east

275kV double circuit from Beauly to Blackhillock, are optimally located to aid in balancing power flow down the west and east coast, maximising the utilisation of the aforementioned circuits and therefore increasing the capability of the SHE Transmission system.

Following a single circuit fault outage on the west on the Beauly to Denny line, the PST tap position at Blackhillock can be set to pull more power down the east from Beauly, alleviating a potential thermal limitation on the remaining Beauly to Denny circuit. Vice-versa, following a double circuit fault outage on the east, the PST tap position at Blackhillock can be set to push more power west and down the Beauly to Denny line.

The PSTs at Blackhillock are therefore critical to achieve the B4 capability quoted post the East Coast 400kV incremental upgrade and provide further operational flexibility to the SHE Transmission network. The PSTs will also be of further benefit following completion of the Eastern HVDC link from Peterhead. To maximise the utilisation of the Eastern HVDC link, the PSTs at Blackhillock are needed to push power west and off of the west-east 275kV double circuit from Beauly to Blackhillock, to prevent overloading this west to east 275kV corridor when the Eastern HVDC link is drawing significant power from the onshore system. Without these PSTs, significant reinforcement would be required on the Beauly to Blackhillock OHL to maximise the utilisation of the HVDC link.

There are several project interdependencies between the 275kV and 400kV onshore upgrades as they largely concern common OHL assets. Exploration of the overlaps in their scope will continue to be reviewed through project development.

5.5 Cost, risk and contingency

The cost of the SHE Transmission part of the East Coast 400kV Upgrade works are detailed in the East Coast 400kV Incremental Upgrade Project Cost & Efficiency Paper (T2BP-EST-0051). A summary of scope and cost breakdown is shown in Table 5:

Table 5: Table of Costs

Component	Cost
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. Include space provision only for six future bays. Connect the overhead line circuits from Rothienorman and Fetteresso on to the new Kintore 400kV busbar. Completion of substation control room fit out (partially completed under North East 400kV Upgrade) and completion of final landscaping and mitigation works.	[redacted]
Fetteresso – Remove the existing 240MVA 275/132kV SGT (and store as strategic spare) 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. Fire walls will be installed to mitigate to achieve a four hour fire protection rating between the 400/132kV SGTs and other network assets based on site.	[redacted]
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. Enclosures will be constructed for each of the two new 1200MVA SGTs to mitigate noise. Rebuild/reconfigure the Alyth MSCDN for 400kV operation.	[redacted]
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.	[redacted]
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.	[redacted]
Total	**£257.18m**

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 cost for delivering the scope of works for the proposed solution is £257.18m. Each Investment Decision Pack will contain a Project Cost & Efficiency Paper that sets out how this total cost has been derived at both a scheme level and cost breakdown structure level. The distribution of this spend across price control periods is shown in Table 6.

Table 6: Spend Apportionment

T1	T2	T3
£6.40m	£214.95m	£35.83m

5.6 Stakeholder Engagement

In line with the Stakeholders feedback presented in Net Zero – A Risk Based Approach to Asset Management, bringing forward the phase conductor replacement works to align with the T2 load upgrade to 400kV is demonstrated to be a cost-effective solution that brings value to stakeholders and consumers.

SHE Transmission will carry out the public and consenting stakeholder engagement for the East Coast 400kV Upgrade in the future to align with the consenting and permitting requirements of SHE Transmission substations at Blackhillock, Kintore, Fetteresso and Alyth. Environmental and Technical data validity has also influenced timing of consultation to ensure efficient development and delivery of the project.

These public engagements will involve public exhibitions, information days and community council meetings. The outputs of these consultations will help inform the site design of the projects at each of the substation locations. Our stakeholder's input will be gathered via a number of means, included verbal and written responses and recorded in a stakeholder engagement register.

Ongoing consultation with the regulator, national grid and SPT will be undertaken as the project continues.

5.7 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.

Table 7: 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 target, SQSS and ESQCR.

5.8 East Coast 400kV Incremental Upgrade Scope

The scope of the East Coast 400kV Incremental Upgrade (SLD in Appendix E) is:

Works to be completed by SHE Transmission

Substation

- **At 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. Include space provision only for six future bays.

  SHE Transmission have made a commitment to reduce the use of new GIS containing SF_6 and will, where technically feasible, encompass this within the design. Exploration for SF_6 alternative gases for 400kV switchgear shall be explored with contractors as well as innovations to reduce gas leakage.

  It should be noted that if the works to accelerate delivery of 400kV operation in the north east are approved (via the North East 400kV reinforcement – to be complete by 2023), then the SGTs would already be in situ at Kintore with associate 275kV and 400kV bays. The 400kV OHLs from Rothienorman and Fetteresso are to be connected to the 400kV busbar via dedicated circuit breaker bays.

- **At 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. These works are required to operate the existing substation and the OHLs from Kintore and Alyth at 400kV.

- **At 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 to connect the existing 275kV OHL from Tealing Substation. Enclosures will be constructed for each of the two new 1200MVA SGTs to mitigate noise.

  The 400kV OHLs from Fetteresso and Kincardine (in SPT's area) are to be connected to the 400kV busbar via dedicated circuit breaker bays. Uprate the reactive compensation established at Alyth via the East Coast Onshore 275kV Upgrade for 400kV operation.

- **At Blackhillock:** Installation of two Phase Shifting Transformers (PSTs) at Blackhillock Substation on the 275kV double circuit OHL to Knocknagael. The PSTs will have a minimum rating of 920MVA and a nominal on-load angle range of +15/-15 degrees.

Overhead Line (OHL)

- Upgrade 170km of the re-profiled 275kV circuits (following the East Coast Onshore 275kV Upgrade) to 400kV operation between Kintore, Fetteresso and Alyth (established in the East Coast Onshore 275kV Upgrade) as far as the SHE Transmission/SPT border.

  The existing steel lattice towers are L8 construction strung with Twin Zebra ACSR conductor and following the East Coast 275kV Upgrade are operated at 65°C and have a winter post-fault rating of 1090MVA. Re-conductoring the Kintore, Fetteresso, Alyth and Kincardine circuits with Twin Totara AAAC conductor at 90°C operation at 400kV provides a winter post-fault rating of 2000MVA, giving an incremental capacity of 910MVA per circuit. Seasonal OHL conductor ratings are shown in Appendix H.

Works to be completed by SPT

Substation

- Installation of four 400/275kV Super Grid Transformers (SGTs) at Kincardine.

Overhead Line (OHL)

- Upgrade of the re-profiled 275kV circuits (following the East Coast Onshore 275kV Upgrade) to 400kV operation between the SHE Transmission/SPT border and Kincardine.

5.9 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 FES 2018 background Two Degrees scenario for the purposes of setting/measuring the output.

The B4 boundary capability in 2026 without the East Coast 400kV upgrade is 3780MW, following completion of the East Coast 400kV Upgrade in 2026 the B4 boundary is thermally limited to 4260MW (based on the FES 2018 background). This constitutes a B4 boundary uplift of 480MW. All capability values stated are based on NorthConnect, the HVDC interconnector to Norway importing. 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 400kV Upgrade is a B4 boundary uplift of 480MW (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

- Improved operational resilience through timey asset condition-based intervention in line with our goal to aim for 100% network reliability

- 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.

5.10 Competition

The East Coast 400kV Incremental Upgrade is above Ofgem's early and late competition criteria value threshold at £257m. The combined cost of £257m includes separable elements, however, the cost of the separable works is less than the late competition threshold of £100m. The OHL works are to be completed on existing towers and are therefore not considered separable.

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 to the above, and as highlighted within our Competition Strategy, 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 assessment can be made on the application of any new competition model to these projects.

6 Conclusion

The East Coast 400kV Incremental Upgrade scope addresses thermal and voltage network constraints that limit the north to south transfer of power across B4. The East Coast 400kV Incremental Upgrade is to proceed with the concurrent reinsulating and reconductoring of 170km of OHL between Kintore, Fetteresso, Alyth and Kincardine and undertaking the necessary 400kV substation upgrade works at Kintore, Fetteresso, and Alyth substations. Additionally, PSTs will be installed at Blackhillock to provide control of west to east power flows.

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 400kV Upgrade completion date is 2026. The NPVs for the East Coast 400kV Upgrade (including the North East 400kV subset), following the East Coast Onshore 275kV Upgrade, range 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.

If the works to accelerate delivery of the North East 400kV are delayed by changes in the generation background, then the North East 400kV works would need to be included in this option as part of the wider east coast strategy for delivery by 2026.

The estimated cost of the East Coast 400kV Upgrade is £257.18m with £214.95m forecast to be spent during the RIIO-T2 period. The output measure for the East Coast 400kV Upgrade is a B4 boundary uplift of 480MW (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 400kV Upgrade should be ring-fenced and if it does not go ahead, we will return the allowances of £257.18m in full (minus any justified preconstruction expenditure).

It also means that we commit to delivering 480MW[8] boundary uplift for the costs of £257.18m. If we do not deliver that 480MW[8] 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.

[8] 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

9 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 ESO lifetime CBA. 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 local connections ahead of the 2026 completion date. There is therefore an overlap of NOA reinforcements and works necessary to facilitate local 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

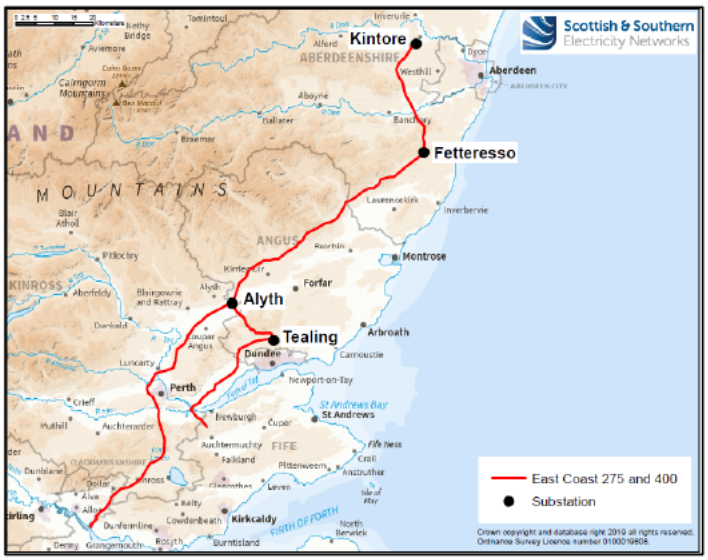


Figure A1: East Coast 400kV

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

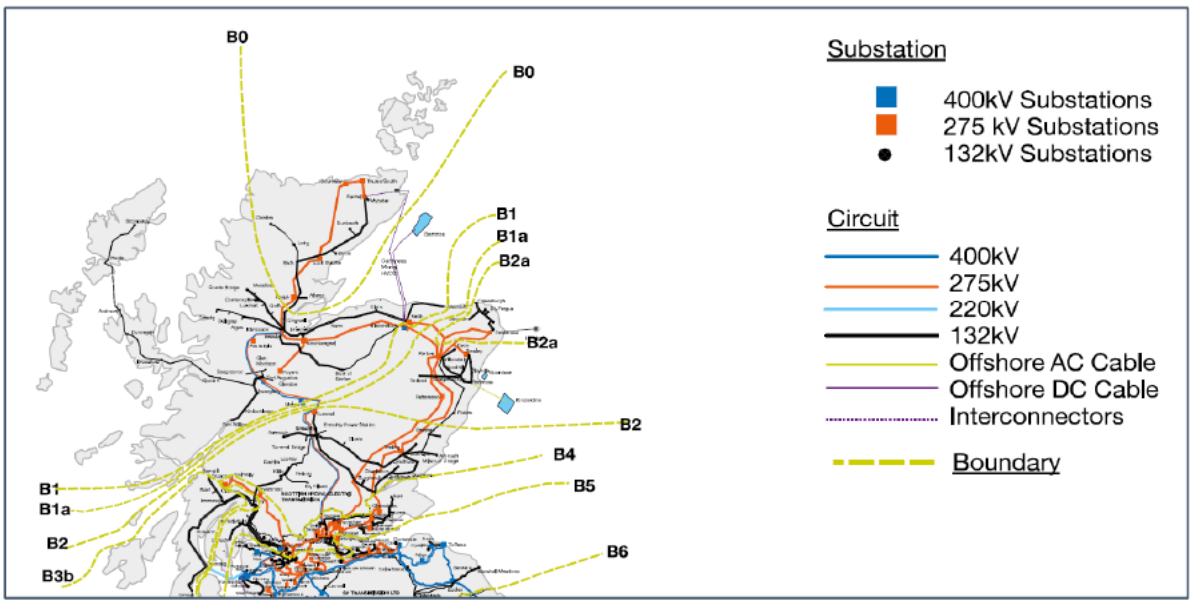


Figure B1: SHE Transmission Boundary Map 2018/19[9]

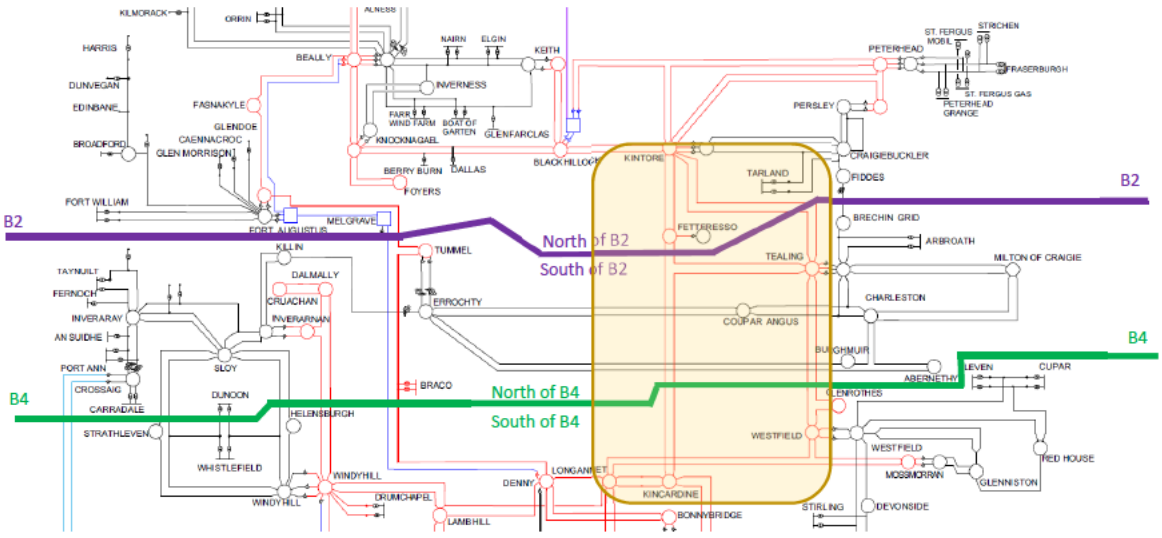
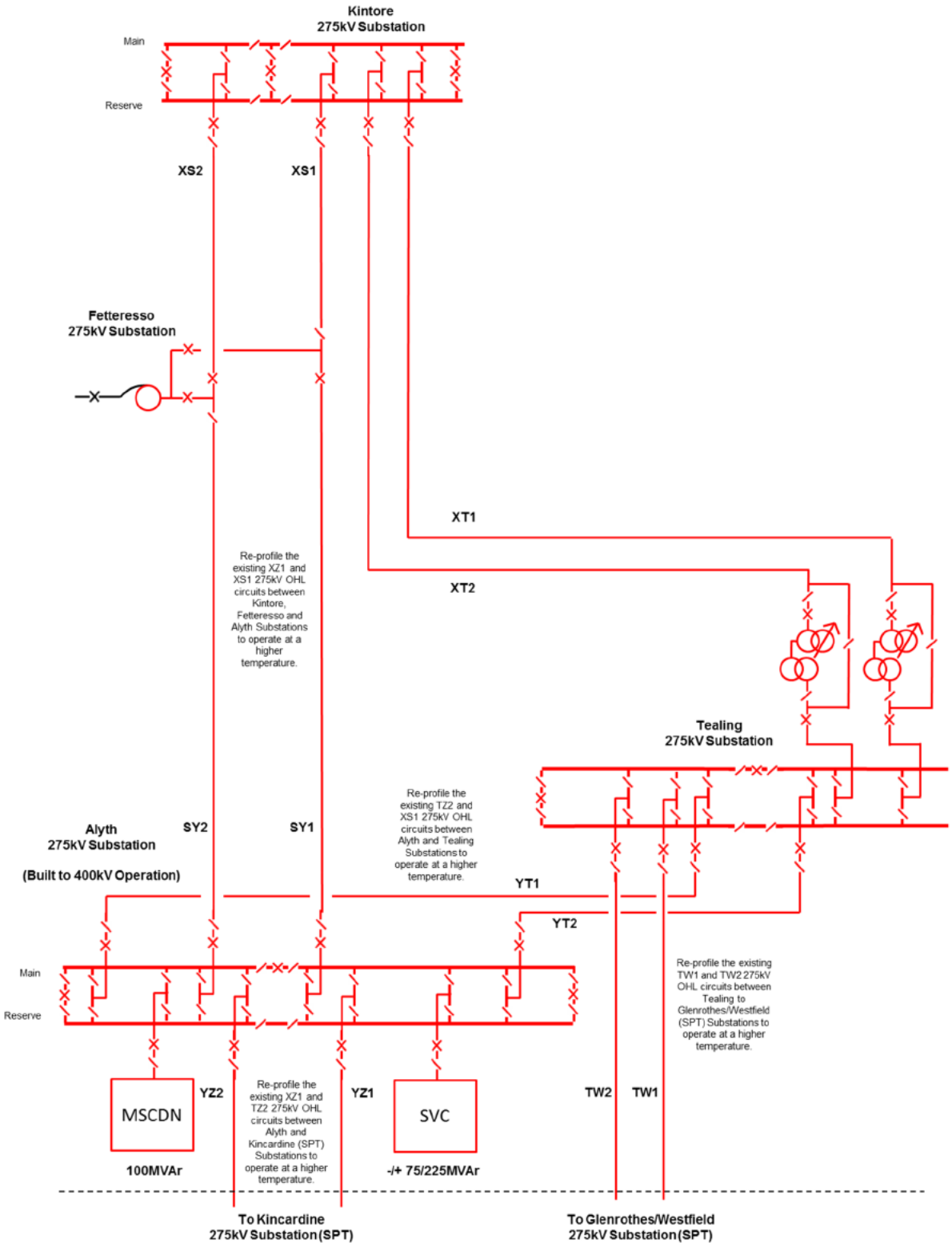


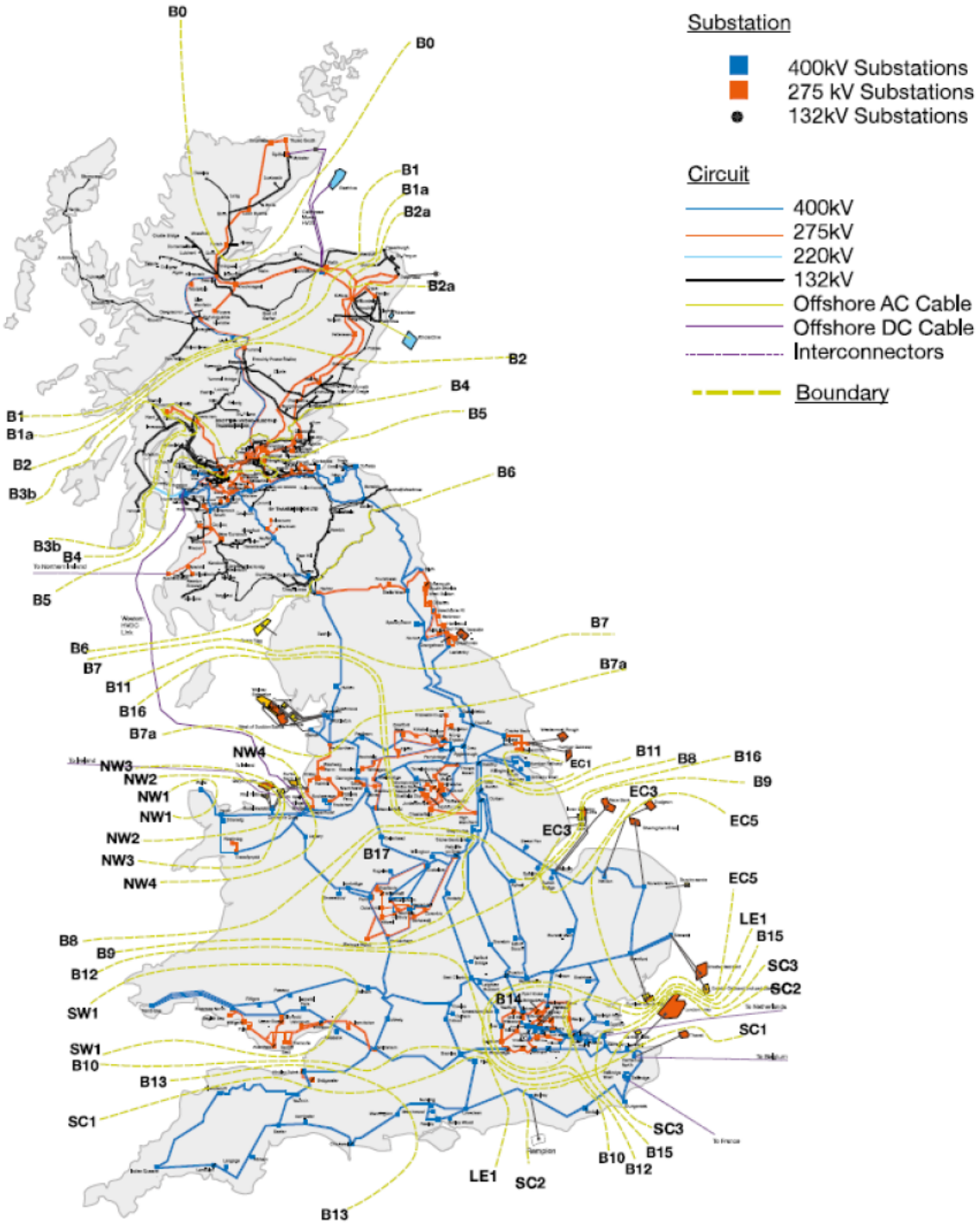
Figure B2: SHE Transmission B2 & B4 SLD 2018/19[10]

[9] Electricity Ten Year Statement 2018, Appendix A, Figure A3
[10] Electricity Ten Year Statement 2018, Appendix A, Figure A4

Appendix C – East Coast Onshore 275kV Upgrade

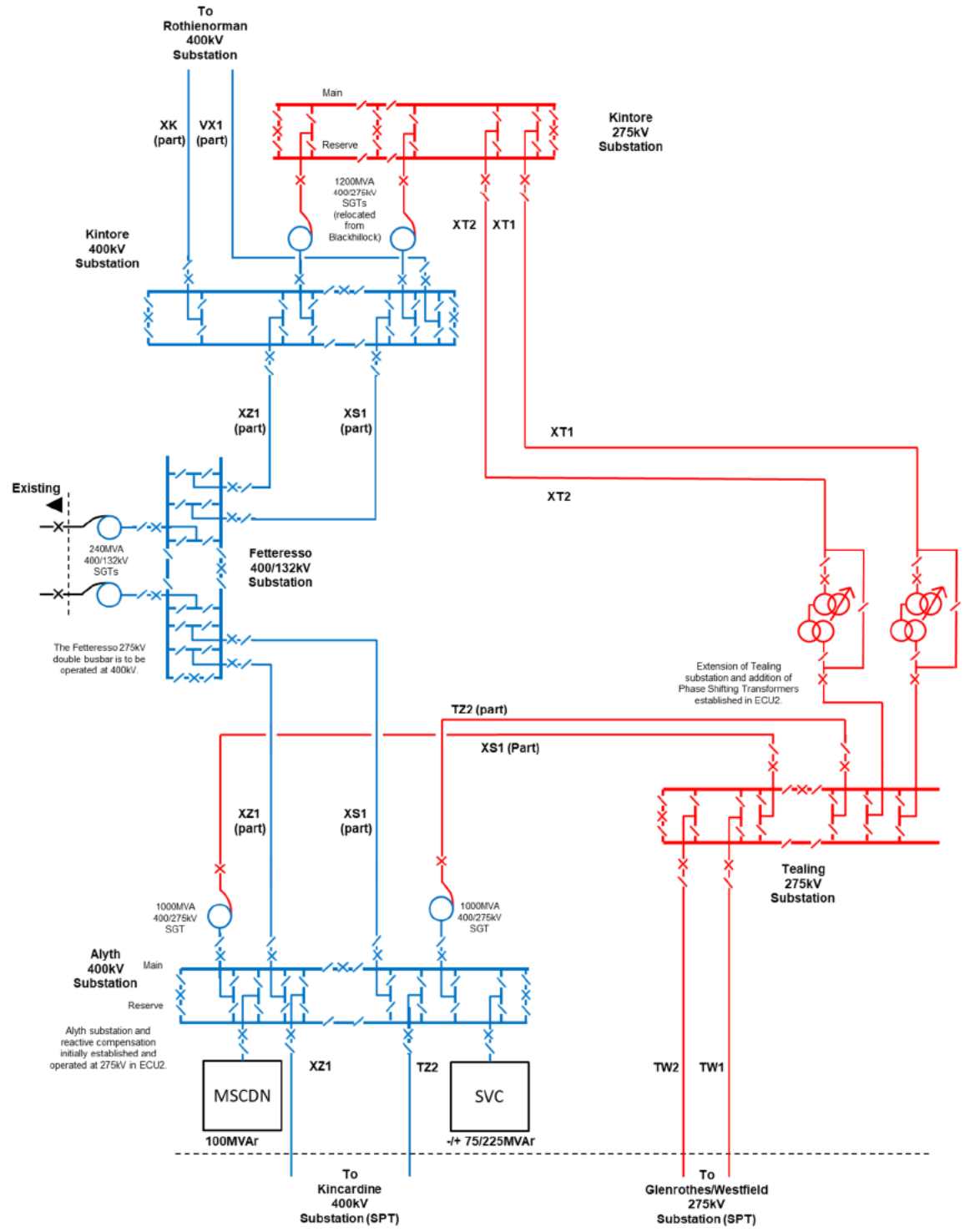


Appendix D: ETYS 2018, GB Boundary Map9



Appendix E: East Coast 400kV Upgrade

East Coast 400kV Incremental Upgrade



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.
		✓	**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.
		✓	**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.

East Coast 275kV Upgrade	North East 400kV & Peterhead 400kV Busbar	East Coast 400kV Incremental Upgrade	Description of works:
2023	2023	2026	Dates
		✓	**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

Appendix H – Overhead Line Ratings

	Re-profile at 275kV for operation at 65°C	Re-conductor 400kV Operation
Conductor	Zebra	Twin Totara
mm^2	400	425
Conductor Type	ACSR	AAAC
Bundle	Twin	Twin
kV	275	400
Operating Temp (°C)	65 °C	90°C
Winter Pre-fault rating (MVA)	920	1680
Spring / Autumn Pre-fault rating (MVA)	865	1610
Summer Pre-fault rating (MVA)	780	1500
Winter Post-fault rating (MVA)	1090	2000
Spring / Autumn Post-fault rating (MVA)	1030	1920
Summer Post- fault rating (MVA)	925	1790