

North East 400kV Upgrade Engineering Justification Paper





North East 400kV Upgrade Engineering Justification Paper

Title Section		
Name of Scheme/Programme	North East 400kV Upgrade	
Primary Investment Driver	Load	
Scheme reference/mechanism or category	SHT2001, SHT2002, SHT2003, SHT2004 & SHT2005	
Output references/type	LRT2SH2001, LRT2SH2002, LRT2SH2003, LRT2SH2004, LRT2SH2005	
Cost	£212.38m	
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
	£21.77m	£190.61m



North East 400kV Upgrade Engineering Justification Paper

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 to accommodate new renewable generators.

This paper provides justification to establish the North East 400kV Upgrade which has a completion date of October 2023. This transmission reinforcement is required to accommodate local connections, namely, the 800MW Moray West Offshore Windfarm at Blackhillock, Clashindarroch 77MW windfarm at Cairnford and the NorthConnect 1400MW interconnector between Peterhead and Norway.

The North East network comprises the transmission overhead lines, cables and substations connecting existing sites at Blackhillock, Kintore and Peterhead. The network south of Kintore is referred to as the East Coast. The North East 400kV Upgrade includes works that form a subset of the Network Option Assessment (NOA) recommended Main Interconnected Transmission System (MITS) works that are required to achieve wider system constraints relief. The North East works are being developed in line with the local customer connection timescales.

The cost benefit analysis has identified the capital cost and cumulative construction outage benefits of bringing forward future asset condition-based intervention works and coordinating these with the load works. These condition-based works comprise of 83km of phase reconductoring. This paper is for the North East 400kV Upgrade, further detail on how the East Coast and North East onshore reinforcement projects are being developed and referenced is available in Appendix A and the RIIO-T2 East Coast Onshore Transmission Investment Case.

Following a process of optioneering and detailed analysis, the proposed scope of work for the North East 400kV Upgrade involves; re-insulation and re-conductoring the existing 275kV overhead line (OHL) circuits between Peterhead, New Deer, Rothienorman, Blackhillock and Kintore to 400kV operation, the construction of a new 400kV double busbar at Peterhead and associated works at New Deer, Rothienorman, Kintore and Blackhillock substations to enable 400kV connectivity.

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.
- Accommodate the local connection of the 800MW Moray West Offshore Windfarm, Clashindarroch 77MW windfarm and the 1400MW HVDC interconnector between Scotland and Norway.

¹ Planning for Net Zero: Scenarios, Certain View and Likely Outturn



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- The output measure for the North East 400kV reinforcement is 720MVA per circuit based on the increase in overhead line Summer Pre-fault Rating. Of the 720MVA, 350MVA is attributed to the voltage uprating from 275kV to 400kV (based on twin zebra operating at 65°C), the remaining 370MVA uplift is attributed to the replacement of the phase conductors with twin Titora operating at 90°C.
- Facilitate effective competition in the generation and supply of electricity through the timely delivery of local works to accommodate connections. This is 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 £212.38m, the T1 spend is £21.77m, the cost of works undertaken during the RIIO-T2 period is £190.61m. The North East 400kV Upgrade will be complete by October 2023.

The North East 400kV Upgrade is above Ofgem's early and late threshold at £212m. The £212m 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. It is therefore 'unflagged'.

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 North East of our network 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

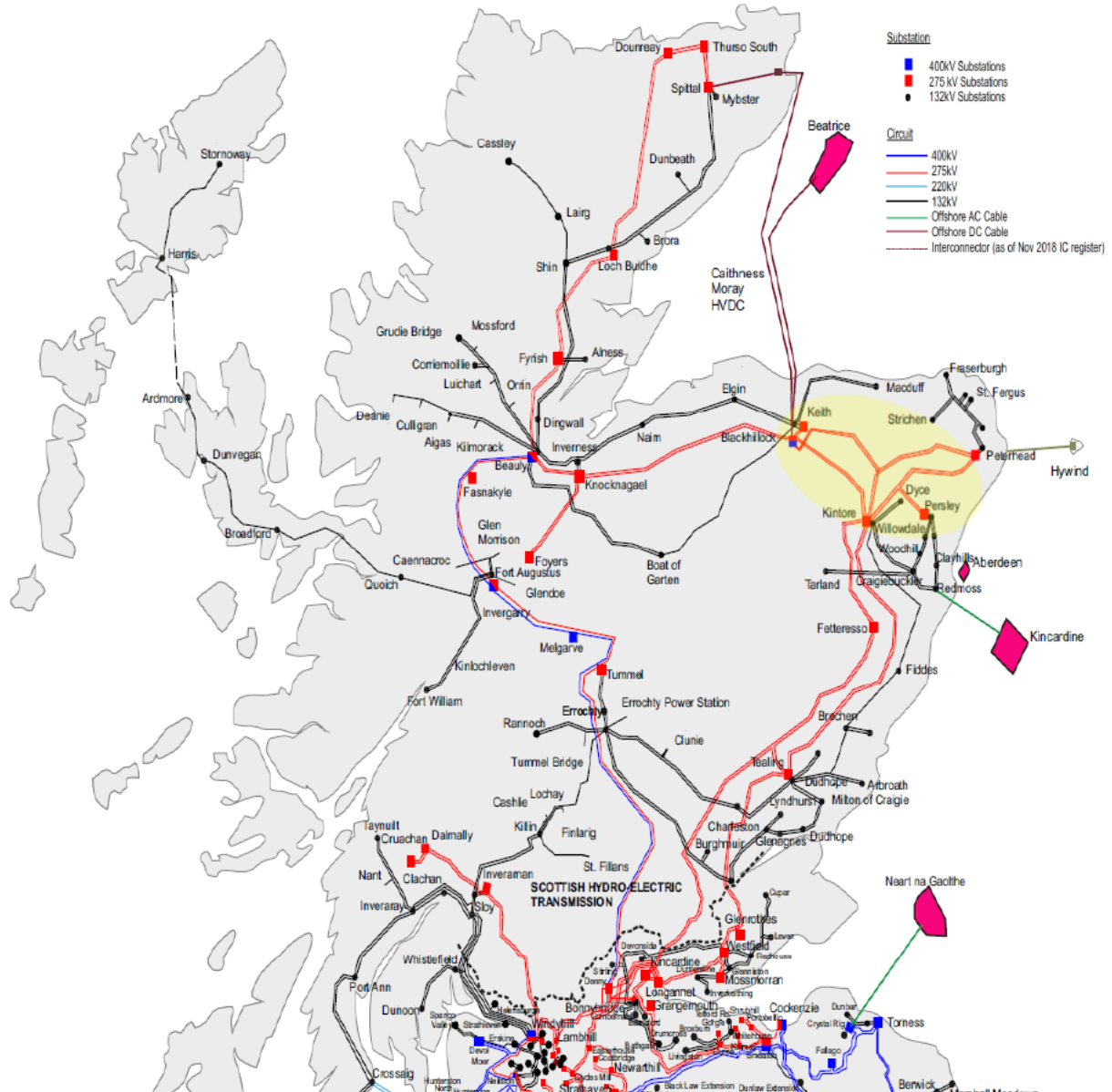
This section provides a view of whether the proposed scheme should be ring-fenced or subject to other funding mechanisms.

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.

North East 400kV Upgrade Engineering Justification Paper

Figure 1: Existing SHE Transmission Network Map

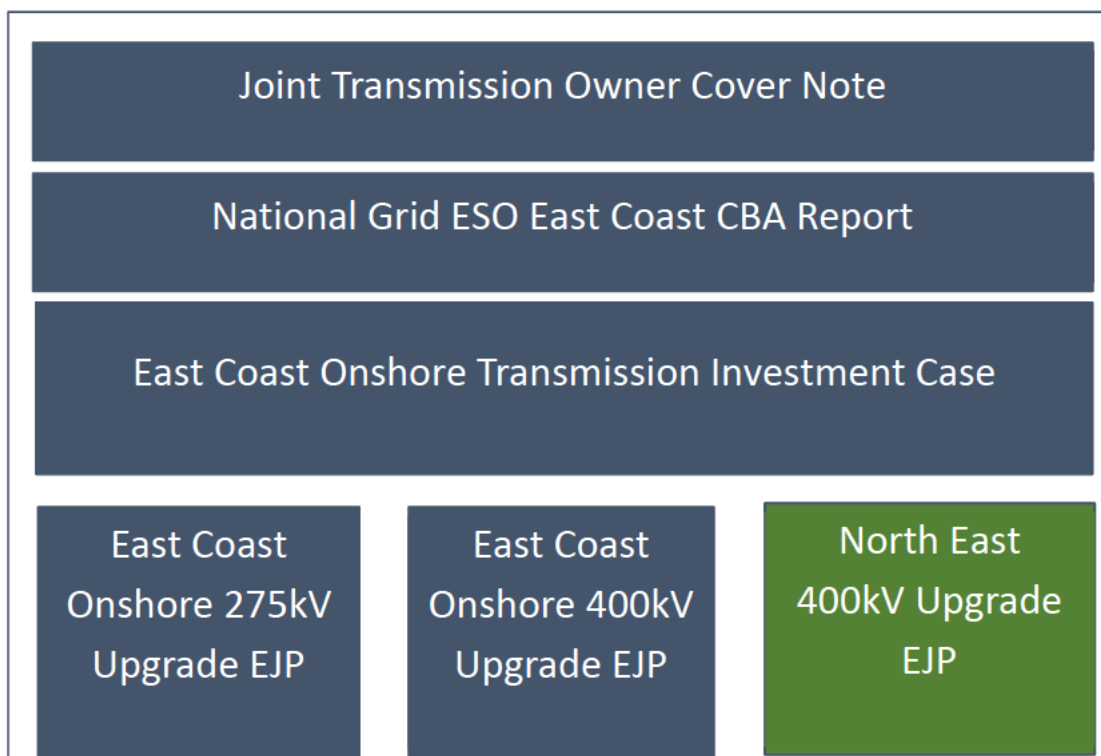


This paper is for the North East 400kV Upgrade and is one of a suite of documents setting out our RIIO T2 East and North East Transmission Reinforcement Plans. The hierarchy of the East and North East suite of documents is shown in Figure 2 and the purpose of each document is as follows;

North East 400kV Upgrade Engineering Justification Paper

- **Joint Transmission Owner Cover Note:** A one-page note detailing the coordinated, TO led Eastern Cost Benefit Analysis (CBA) undertaken by the National Grid 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



North East 400kV Upgrade Engineering Justification Paper**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 Growth Need

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 transmission network in the north east of Scotland is due to see a significant increase in the generation capacity in the period leading up to 2024. The contracted generator connections in the north east include both onshore, island and offshore windfarms totalling 2.3GW. Also contracted to connect in the area by October 2023 is NorthConnect, a 1.4GW High Voltage Direct Current (HVDC) interconnector link to Norway.

We are required at all times to plan and develop our transmission system in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (SQSS), and, the System Operator Transmission Owner Code (STC). Furthermore, we are obliged to ensure that we can provide adequate transmission capacity to facilitate connections to customers in the north of Scotland who wish to connect to, and use, the transmission system in order to participate in the national wholesale electricity market.

The North East network comprises the transmission overhead lines, cables and substations connecting existing sites at Blackhillock, Kintore and Peterhead. Kintore south will be referred to as the East Coast. Kintore is the interface point between the North East and East Coast as it requires enduring transformation of voltage to tie the future 400kV infrastructure to the existing 275kV network.

The north east transmission network forms part of the wider system reinforcement plans that are required to facilitate increased north to south power transfers and reduce network constraint costs. Together, the North East 400kV Upgrade and the East Coast 400kV Incremental Upgrade² increase the north to south transfer capability of our network. It has been demonstrated through the ESO’s NOA 2017/18 & 2018/19 and Lifetime CBA that the savings in constraint costs are greater than the total cost of the reinforcement works and that these works lead to the lowest regret.

The connection of Moray West Offshore Windfarm was subject to the Connection and Infrastructure Options Note (CION) process³. The CION records the output of the work between the Developers, TOs and ESO to identify the overall economic, efficient and coordinated connection option. The CION least

² RIIO T2 Core Load, Engineering Justification Paper – East Coast 400kV Incremental Upgrade

³ [National Grid ESO - Connection Infrastructure Options Note Guidance Note](#)

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worst regret analysis concluded that connecting Moray West into Blackhillock resulted in the lowest overall regret. Full details on the CBA and Sole Use works at Blackhillock 400kV are described in the Moray West Offshore Windfarm Engineering Justification Paper⁴.

The Connect & Manage arrangements allow generators to connect to the transmission system in advance of the completion of the wider transmission reinforcement works. Under Connect & Manage the works that are required to be completed prior to a generator connecting are classed as 'Enabling Works'. Enabling Works are required in the north east for the connection of the 800MW Moray West offshore windfarm in the Moray Firth.

In 2016, the ESO, at the request of the developer, carried out a feasibility study that determined Peterhead to be the most economic and efficient landing point for the connection of the NorthConnect 1400MW interconnector.

This paper will focus on the need for coordinated transmission reinforcement in the North East to accommodate local connections as it is their contracted dates that are driving the delivery for October 2023. Should the North East 400kV Upgrade not be delivered in 2023 to accommodate local connections, the works would need to complete in 2026 to achieve wider system capability outputs as set out in the East Coast 400kV Incremental Upgrade Engineering Justification Paper.

3.1.1 North East Growth in RIIO T1



Following the establishment of the Rothienorman and New Deer substations completing in April 2021, the 275kV network in the north east comprises two double circuit OHLs running south from Peterhead 275/132kV substation; one is routed inland and connects to New Deer and then Rothienorman. The other follows the coastline south deviating on one side of the line to tee into Persley substation before connecting into Kintore with the adjacent circuit. Furthermore, the north east 275kV network comprises of a double circuit OHL running east from Blackhillock (further inland) to Rothienorman and a double circuit OHL running south of Rothienorman to Kintore. The 2021 north east network single line diagram is shown in Appendix B.

Rothienorman substation and the reconductoring and reinsulating of 23km of double circuit overhead line between Rothienorman and Kintore is currently being constructed for April 2021 to accommodate the contracted capacity increase of Peterhead Power Station. In addition, a new grid supply point will

⁴ RIIO T2 Core Load, Engineering Justification Paper – Moray West Offshore Windfarm

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be established at the new Rothienorman substation as requested by Scottish Hydro Electric Power Distribution. By April 2021, the Rothienorman substation and the overhead line between Rothienorman and Kintore will be of 400kV construction but operated initially at 275kV.

New Deer substation is being established for the connection of Moray East Offshore Windfarm (Moray East) in April 2021 and built to 400kV construction but initially operated at 275kV.

The 400/275/132kV substation at Blackhillock completed in 2018/19 was established as part of the works for the Caithness – Moray HVDC link and additionally to accommodate the connections of Beatrice and Dorenell windfarms.



3.1.2 Local Contracted Connections Background

Transmission projects completed in RIIO T1 include the construction of the new Blackhillock 400/275/132kV substation. This substation was established to accommodate the connection of the Caithness-Moray HVDC link (800MW), Beatrice offshore windfarm (588MW) and Dorenell windfarm (177MW).

In addition to these completed schemes, the connection of large contracted generators in the north east include; Moray East offshore windfarm (900MW) in April 2021 and the Moray West offshore windfarm in April 2024 (800MW).

Also contracted to connect in the area for October 2023 is NorthConnect, a 1400MW bi-directional High Voltage Direct Current (HVDC) interconnector to Norway.

The large local connection schemes influencing the requirement for the North East 400kV upgrade are listed in Table 1.

North East 400kV Upgrade Engineering Justification Paper
Table 1: Large Connected/Contracted schemes in the North East

Name	Connection Location	Type	TEC (MW)	Connected/Contracted Date
Caithness-Moray (C-M) HVDC link	Blackhillock	NA	800	Connected
Dorenell Windfarm	Blackhillock	Onshore Wind	177	Connected
Peterhead Power Station	Peterhead	CCGT	1180	Connected
Beatrice Offshore Windfarm	Blackhillock	Offshore Wind	588	Connected
Moray East	New Deer	Offshore Wind	900	April 2021
Elchies	Blackhillock	Onshore wind	99	June 2023
Clashindarroch II	Cairnford	Onshore Wind	77	October 2023
North Connect	Peterhead	Interconnector	1400	October 2023
Moray West	Blackhillock	Offshore Wind	800	March 2024
Viking (Shetland & C-M HVDC Link)	Blackhillock	Island Windfarm	457	March 2024
Total			6478	

The NETS SQSS, Section 2 Generation Connection Assessment for the Moray West Offshore Windfarm and Clashindarroch II identified an exceedance of the summer pre-fault rating of the Cairnford to Kintore 275kV circuit during the single circuit planned outage of the adjacent Blackhillock to Kintore 275kV circuit. Transmission reinforcement works are therefore required to achieve NETS SQSS, Section 2 Pre-fault compliance and accommodate the local generation in Table 2.

Table 2: Generation Schemes accommodated by The North East 400kV

Name	Connection Location	Generation Type	TEC (MW)	Contracted Date
Moray West	Blackhillock	Offshore Wind	800	March 2024
Clashindarroch II	Cairnford	Onshore Wind	77	October 2023
Total			877	

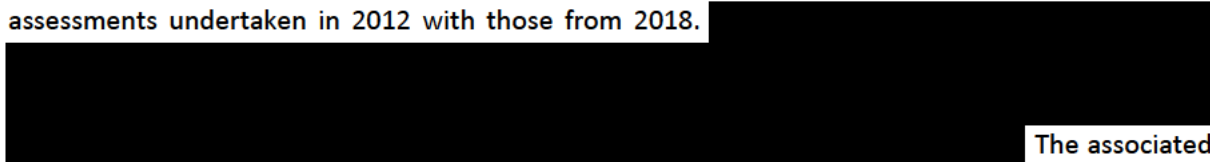
3.2 Asset Need

The existing double circuit OHL between Blackhillock, Rothienorman and Peterhead are steel lattice towers of L8 construction strung with Twin Zebra ACSR conductor operated at 65°C. These circuits have a summer pre-fault rating of 780MVA. Seasonal thermal ratings are shown in Appendix C. These structures were built in 1975/76 and it is proposed that the existing steel lattice towers will be retained and reinforced as required.



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An asset condition assessment carried out in 2018 identified that the phase conductors on the double circuit OHL between Blackhillock, Rothienorman and Peterhead have an estimated remaining life of 8-13 years (2026-2031). This was determined by extrapolating a corrosion rate by comparing condition assessments undertaken in 2012 with those from 2018.



The associated report therefore notes that based on condition alone, the replacement of these conductors should be planned as soon as possible in line with the remaining lifespan of the conductor.

The assessment has shown that intervention to replace the existing conductor will be required at a similar time to the load related reinforcement intervention. Consideration of network access, interface design between the existing and new parts of the transmission network and project execution efficiencies all contribute towards a coordinated delivery strategy.

North East 400kV Upgrade Engineering Justification Paper**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.

The north east network has overlapping wider boundary capability uplift and local customer connection drivers. Therefore, the proposed works must be planned and coordinated such that they are suitably designed to achieve both objectives. The timing of contracted connections is driving the need to deliver a subset of the proposed wider system works that have been economically assessed through NOA 2017/18 & 2018/19 and the ESO’s lifetime CBA.

The proposed works under the North East 400kV Upgrade are the minimum works required to meet the local connection requirements. Any works over and above these within the East coast 400kV project will not be progressed before the NOA recommended date of 2026 as this would be uneconomical.

The North East 400kV upgrade involves; re-insulation the existing 275kV overhead line (OHL) circuits between Peterhead, New Deer, Rothienorman, Blackhillock and Kintore to 400kV operation, the construction of a new 400kV double busbar at Peterhead and associated works at New Deer, Rothienorman, Kintore and Blackhillock substations to enable 400kV connectivity.

The North East 400kV Upgrade single line diagram is shown in Appendix D.

4.1 NorthConnect Interconnector, 1400MW, Oct 2023

In 2016 the ESO, at the request of the developer, carried out a feasibility study (with the help of the onshore Transmission Owners – including SHE Transmission) to determine the most economic and efficient landing point for the connection of the NorthConnect interconnector to the GB transmission system. Several landing points were examined across the north of Scotland, southern Scotland and the north of England. Following a Cost Benefit Analysis (CBA) carried out by the ESO, Peterhead was identified as the most economic and preferred landing point.

A new 400kV double busbar is required at Peterhead to accommodate the 1400MW connection of NorthConnect. The 400kV busbar is also required for the future connection of the Eastern HVDC link. The Eastern HVDC link is part of the wider GB system optimal development path.

4.2 Clashindarroch II, 77MW Windfarm, Oct 2023 and Moray West Offshore Windfarm, 800MW, March 2024

System Studies concluded that the North East 400kV subset satisfies the NETS SQSS Section 2 Pre-fault criteria and is therefore classed as Enabling Works for Moray West Offshore Windfarm and Clashindarroch II windfarm.



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The limiting Cairnford to Kintore 275kV circuit is not directly reinforced by the works associated with the North East 400kV reinforcement, however the transition from 275kV to 400kV in the north east encourages more power to flow through the uprated 400kV Blackhillock to Rothienorman circuits and alleviates the power flow on the Blackhillock to Kintore 275kV double circuit OHL. As such, the North East 400kV reinforcement enables the connection of over 800MW of generation at Blackhillock.

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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 Sequencing of Works

The North East 400kV Upgrade interfaces with the East Coast 400kV Incremental Upgrade² at Kintore substation. The Enabling Works for the connection of Moray West at Blackhillock and Clashindarroch at Cairnford do not extend beyond Kintore. The proposed 400kV upgrade works south of Kintore are classed as Wider Works, allowing Moray West to connect in advance of the completion of the 400kV upgrade south of Kintore. For these connections, Kintore substation is considered the notional point on the network that is sufficiently deep into the MITS at which the system operator has diverse constraint options to manage the system.

Figure 3 shows the timing and sequencing of the recommended wider system reinforcements without consideration of local works required to accommodate contracted connections. Also shown in Figure 3 are the opportunities to coordinate asset intervention need with the load driven wider system projects.

Figure 3: East Coast Timing and Sequencing uninfluenced by Contracted Connections

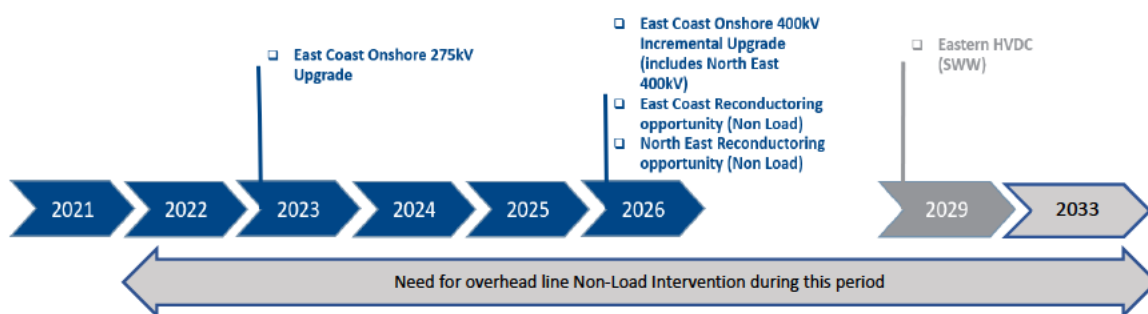
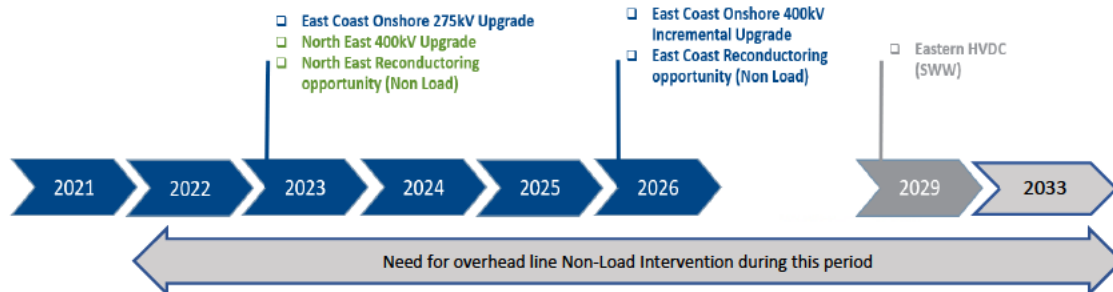


Figure 4 shows the timing and sequence of the recommended wider system reinforcements with consideration of local works. A subset of the East Coast Onshore 400kV Incremental reinforcement scope (as detailed in Section 4) is required to accommodate contracted connections in the North East; namely the NorthConnect, 1400MW interconnector from Peterhead to Norway and the Moray West Offshore Windfarm, 800MW connecting into Blackhillock. This subset comprises the scope of works required to deliver the North East 400kV Upgrade by 2023, aligning with the contracted connection dates. The opportunity to coordinate load and non-load works in the North East is therefore also advanced to 2023.

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Figure 4: East Coast Timing and Sequencing influenced by Contracted Connections



The scope of the East Coast 275kV⁵, East Coast 400kV Incremental² and North East 400kV Upgrades is provided in table format in Appendix E.

5.2 Optimal Delivery Strategy

In addition to the consideration of the local and wider system load drivers, condition assessment of the existing conductors between Blackhillock, Rothienorman and Peterhead have established that the conductors should be replaced between 2026 and 2031. The advancement of the reconductoring of the double circuit OHL has been assessed to determine the potential benefits of concurrently delivering both load (reinsulating) and asset condition (reconductoring) based drivers in the north east.

The concurrent delivery strategy considers the overall duration and frequency of construction outages and the potential to minimise constraint costs against a growing generation background. An additional benefit which, whilst difficult to quantify, can be realised through the coordination of the load and asset condition-based drivers is the reduction in the exposure of operatives to the live network environment during construction works.

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 outages on the network through 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 impact and disruption. This is through the reduction of the timescales over which the works are to be undertaken.

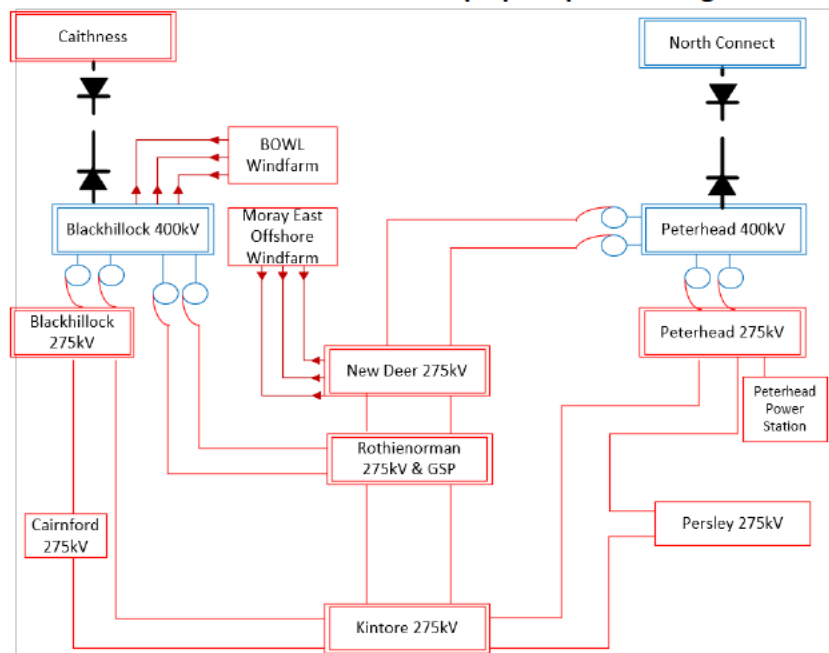
⁵ RIIO T2 Core Load, Engineering Justification Paper - East Coast 275kV Upgrade

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Peterhead 400kV Busbar

The new Peterhead 400kV double busbar is required for the connection of the NorthConnect Interconnector in 2023. The new 400kV substation is to be established close to the existing 275kV substation at Peterhead. A review of the existing substation options for Peterhead has been undertaken, which included the following options:

- i) A step up-step down configuration requiring four 1200MVA 400/275kV Super Grid Transformers (SGTs) for the connection of the 400kV double busbar to the 275kV north east network for the contracted date of NorthConnect – Two SGTs are required for the connection of the 400kV busbar to the existing 275kV busbar and the other two SGTs are required for the connection of the 400kV busbar to the existing 275kV double circuit OHL to New Deer. This option would then require the removal of two of the four 1200MVA 400/275kV SGTs for direct connection to the 400kV OHL from Peterhead to New Deer as part of the North East 400kV Reinforcement in 2024 (delivered for the connection of Moray West offshore windfarm) or later (for wider system need under East Coast Onshore 400kV Incremental Reinforcement (ECUP)). See single line diagram in Figure 5, blue is 400kV and red is 275kV.

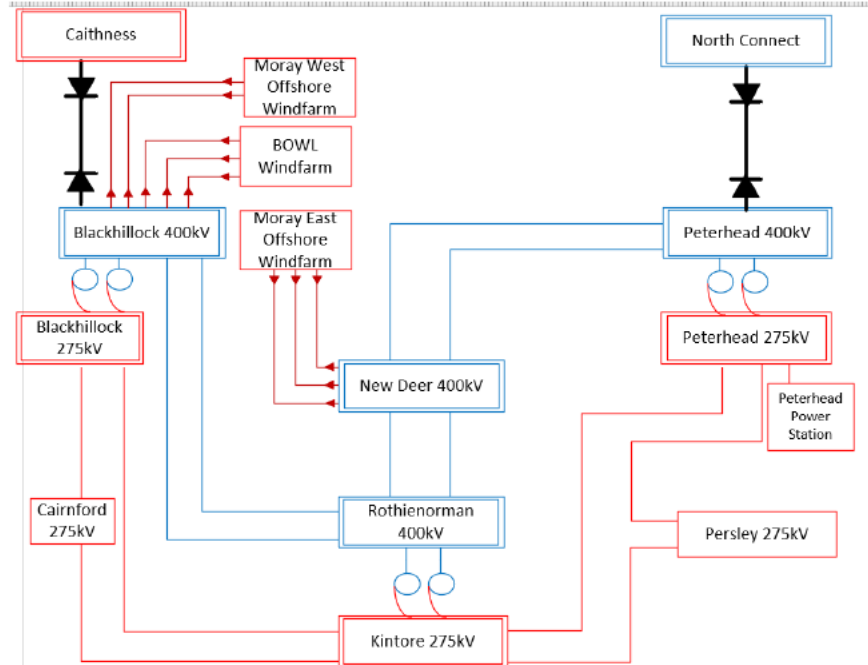
Figure 5: North East with Peterhead 400kV Busbar Step up-Step down Single Line Diagram



- ii) Direct connection of the 400kV double busbar to the 400kV OHL from Peterhead to Rothienorman requiring only two 1200MVA 400/275kV SGTs for connection to the existing 275kV Peterhead substation. This option therefore assumes the advancement of the North East 400kV reinforcement aligning with the contracted date for NorthConnect. See single line diagram in Figure 6, blue is 400kV and red is 275kV.

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Figure 6: North East 400kV Upgrade Single Line Diagram



North East 400kV Delivery Strategies

In addition to the substation options for Peterhead 400kV busbar, a number of delivery strategies based around the upgrade of the existing OHL in the north east between Peterhead, New Deer, Rothienorman, Blackhillock and Kintore have been considered. These strategies take into account the condition based requirements and the load requirement for 400kV operation.

The strategies and the corresponding components and delivery dates are summarised in Table 3. The detailed description for each strategy is detailed in Appendix F and all were taken forward to a CBA as detailed in Section 4 of this paper.

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Table 3: Delivery strategies for the North East 400kV reinforcement

Strategy		North East 400kV Upgrade components		
		Peterhead busbar	North East 400kV OHL re-insulation	North East OHL reconductoring
1	Contracted Position with OHL reconductoring post RIIO-T2: Project components tracking local drivers independently	2023 (4 SGTs)	2024	Beyond T2
2	Contracted Position with OHL reconductoring in RIIO-T2: Concurrent delivery of the Peterhead busbar with step up-step down configuration, and North East 400kV OHL re-insulation and reconductoring	2023 (4 SGTs)	2024	
3	Wider System Need: Concurrent delivery of the Peterhead busbar with step up-step down configuration, and North East 400kV OHL re-insulation and reconductoring	2023 (4 SGTs)	2026	
4	North East 400kV Opportunity with OHL reconductoring post T2: Concurrent delivery of the Peterhead busbar and the North East 400kV (re-insulation only)	2023 (2 SGTs)		Beyond T2
5	North East 400kV Opportunity with OHL reconductoring in T2: Concurrent delivery of all project components	2023 (2 SGTs)		

5.3 Cost Benefit Analysis

Each of the delivery strategies set out above were subject to the development of costs, programmes and outage profiles required to deliver each option.

5.3.1 Net Present Values

SHE Transmission has carried out a CBA using counterfactual Net Present Value (NPV) analysis to demonstrate the potential benefits of concurrently delivering all project components by 2023⁶.

⁶ See SHE Transmission's Cost Benefit Analysis Methodology for more information on the calculation methodology for counterfactual NPV analysis.

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These undiscounted costs have been developed based on recent comparable projects within the SHE Transmission portfolio to provide an accurate representation of project costs at this stage.

Strategy 1 has been considered the baseline position in the CBA as it delivers the project elements independently as and when the need arises rather than applying any synchronisation. The Spend profile for each strategy is shown in Appendix G. The NPV of the other four strategies were compared to Strategy 1 to determine the NPV gain from employing different variations of a synchronised approach. Table 4 shows the results of the NPV analysis.

Table 4: NPV analysis results

Option	Preferred Option	Forecast Capital Expenditure (£m)	Total NPV (£m)*	Benefit (Option to baseline)
Strategy 1	N			-
Strategy 2	N			
Strategy 3	N			
Strategy 4	N			
Strategy 5	Y			

*Excludes carbon displacement and Gross Value Add (GVA)

The NPVs conclude that strategy 5 is deemed to be the best value option for consumers, delivering a [REDACTED] NPV gain compared to the baseline position. The difference between Strategy 5, delivering the North East Upgrade in advance of the wider system capability uplift need in 2026 as demonstrated through NOA (Strategy 3) is [REDACTED]. The [REDACTED] saving is attributed to not delivering a step up-step down arrangement at Peterhead.

5.3.2 Construction Outages

Advancing the delivery of the North East 400kV reinforcement to align with the completion of the Peterhead 400kV busbar reduces the number of outages from 131 weeks to 105 weeks, eliminating 26 weeks (see Table 5). This removes the need for up to 70 weeks of outages that would be required to undertake non-concurrent reconductoring (Strategies 1 & 4) following the connections of NorthConnect and Moray West Offshore Windfarm. The constraints assessment undertaken by the ESO identified that the monetary value of advancing outages in the North East is negligible. This is due to the actions being taken in the balancing mechanism to relieve constraints further south (across B4 & B6), also relieve the local north east network.

⁷ The costs used in the CBA for Strategy 5 differ from the £212.38m in section 4.2 of this report. This is due to the CBA been carried out on class one cost estimates from November 2018. As the preferred option Strategy 5 has been further developed its costs have been refined. Comparing this refined cost to the less refined costs of the other strategies considered in the CBA would not provide a fair comparison and would not accurately represent the data that the decision was based on when costs were less refined.

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Table 5: North East 400kV Construction Outage Weeks

Strategy Reference	Total Network Outages (weeks)
Strategy 1: Contracted Position with OHL reconductoring post RIIO-T2	175
Strategy 2: Contracted Position with OHL reconductoring in RIIO-T2	131
Strategy 3: Wider System Need	131
Strategy 4: North East 400kV Opportunity with OHL reconductoring post T2	149
Strategy 5: North East 400kV Opportunity with OHL reconductoring in T2	105

As part of the review of the strategies the potential for a driver to terminate was considered and whether this could result in asset stranding. With consideration to the requirement for the Peterhead 400kV Busbar, this is currently driven by the NorthConnect however should this be terminated or delayed, the construction of this asset remains required for the delivery of the East Coast Onshore 400kV Incremental Reinforcement and the Eastern HVDC Link required under NOA for 2026 and 2029 respectively. The delivery of 400kV operation required for Moray Offshore West and Clashindarroch 2 windfarm requires assets capable to facilitate a 400kV connection at Peterhead to be in place by 2023.

Therefore, in terms of the selection of the preferred strategy, it can be seen there are multiple drivers in place for the key infrastructure required under this scheme. It is likely that even with the termination of a driver the worst-case scenario is that an element of the works is constructed in advance of a later date where it is required. Thus, it is considered the advancement of elements of these works do not introduce the risk of asset stranding.

When the above NPVs and planned network outages are considered it is evident that Strategy 5 provides the most benefit. This represents the most economic, efficient and coordinated option to deliver these works. This approach is in line with the stakeholders' feedback presented in Net Zero – A Risk Based Approach to Asset Management. Bringing forward future works to align with the T2 works where it is economic to do so brings value to stakeholders and consumers.

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 6).



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Table 6: 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). Whole life costs have been incorporated into the CBA calculations.	Annual opex is estimated to be £0.6m per year, totalling £28m across 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 at around £3.5m 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 all options considered enable the contracted generation, carbon abatement is the same across all scenarios. Current contracted generation (Western Development Area (800MW), Clashindarroch II (77MW) and North Connect (1400MW)) could equate to average annual discounted carbon displacement benefits in the region of £183m, according to the Scottish Governments Renewable Electricity Output Calculator ⁸ .

⁸ <https://www2.gov.scot/Topics/Statistics/Browse/Business/Energy/onlinetools/ElecCalc>



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Benefit category	Details	CBA value impact
<p>Regional Gross Value Add (GVA)</p>	<p>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:</p> <ol style="list-style-type: none"> 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 direct and indirect impact. 	<p>The total direct regional GVA to the Scottish economy associated with the contracted generation projects enabled is estimated at £100m (discounted over estimated asset life). Indirect and induced GVA totals £90m (discounted).</p> <p>The direct regional GVA associated with the SHE Transmission expenditure is estimated at £36m (discounted), indirect and direct GVA totals £39m.</p>

5.4 Cost risk and contingency

The cost of the North East 400kV works is detailed in the Project Cost & Efficiency Paper (T2BP-EST-0042). A summary of scope and cost breakdown is shown in Table 7.

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Table 7: Table of Costs

Component	Cost
<p>Peterhead - Construct an eight bay (includes bus section and two bus couplers) 400kV GIS Substation with two 400/275kV, 1200MVA Super Grid Transformers. All equipment will be housed in bespoke weather protected buildings due to Peterhead substations proximity to the coast.</p> <p>Install 275kV cable and associated sealing ends interconnecting the existing 275kV substation and the new 400kV substation.</p> <p>Underground cable and associated sealing ends for the Peterhead and Invergie Tee 132kV double circuit OHL entry into the existing Peterhead 132kV busbar to allow realignment of 400kV circuits from New Deer into the new substation.</p>	[REDACTED]
<p>OHL – Reinsulate and Reconductor the OHL between Peterhead to Rothienorman to Blackhillock for 400kV operation</p>	[REDACTED]
<p>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.</p> <p>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.</p> <p>The new SGTs will have enclosures to mitigate noise and a new substation control building for the 400kV operation. The Control room will be partially fitted out and completed under East Coast 400kV Incremental Upgrade works.</p>	[REDACTED]
<p>Rothienorman - 400kV upgrade works at Rothienorman Substation to include the installation of two 400/132kV, 240MVA Super Grid Transformers and two 132/33kV, 120MVA Grid Transformers. Includes the replacement of Surge Arrestors and CVTs suitable for 400kV operation.</p>	[REDACTED]
<p>New Deer - Upgrade works at New Deer Substation to include the replacement of Surge Arrestors and CVTs suitable for 400kV operation.</p>	[REDACTED]
<p>Total</p>	<p>£212.38</p>

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 cost of the North East 400kV Upgrade works

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has been estimated as £212.38m including £21.77m of pre-construction spend in RIIO-T1, the remaining £190.61m of this total is forecasted to be spent within the RIIO-T2 period (see Table 8).

Table 8: Spend Apportionment

T1	T2
£21.77m	£190.61m

5.5 Stakeholder Engagement

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 compiled 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.

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Table9: 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	<p>Sensitivity considered in Section 3 (Need) already.</p> <p>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.</p>
Asset utilisation	<p>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.</p>
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 (2045 in Scotland), SQSS and ESQCR.



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5.7 North East 400kV Upgrade Scope

The North East 400kV reinforcement involves; upgrading the existing 275kV overhead line (OHL) circuits between Peterhead, New Deer, Rothienorman, Blackhillock and Kintore to 400kV operation through re-insulation and re-conductoring, the construction of a new 400kV busbar at Peterhead and associated works at New Deer, Rothienorman, Kintore and Blackhillock substations to enable 400kV connectivity.

Overhead Lines

- Re-conductor and Reinsulate 83km of double circuit OHL between Peterhead, New Deer, Rothienorman and Blackhillock for 400kV operation. This is in addition to works undertaken under separate scope in RIIO-T1 to re-conductor and reinsulate 23km of OHL between Rothienorman and Kintore Substations, resulting in 106km of OHL operating at 400kV in the north east.

The existing steel lattice towers are L8 construction strung with Twin Zebra ACSR conductor operated at 65°C and have a summer pre-fault rating of 780MVA. Re-conductoring the Peterhead, New Deer, Rothienorman and Blackhillock circuits with Twin Totara AAAC conductor at 90°C operation at 400kV provides a summer pre-fault rating of 1500MVA, giving an incremental summer pre-fault capacity of 720MVA per circuit. Seasonal OHL conductor ratings are shown in Appendix C.

Alternative overhead line conductors have been considered and assessed in the Overhead Line Conductor Optioneering Report and Scoring Matrix during the project development stage to determine the optimum engineering solution. The Conductor Scoring Report concluded that Twin Totara was the optimal conductor technology considering steel strengthening, thermal capacity, project programme and operability.

Substations

- **Peterhead:** Construct an eight bay (includes bus section and two bus couplers) 400kV GIS Substation at Peterhead with two 400/275kV, 1200MVA Super Grid Transformers. All equipment will be housed in building due to Peterhead proximity to the coast.

Space provision for an additional 5 bay, one of which will connect the proposed East Coast HVDC link from Peterhead to the north of England.

Install 275kV cable and associated sealing ends interconnecting the existing 275kV substation and the new 400kV substation.

Install cable and associated sealing ends for the diversion of the Peterhead and Inverugie Tee 132kV double circuit OHL entry into the existing Peterhead 132kV busbar. This is to allow realignment of the upgraded 400kV circuits from New Deer into the new substation.

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- **New Deer:** 400kV upgrade works at New Deer Substation to include the replacement of Surge Arrestors and CVTs. The 275kV Surge Arrestors and CVTs replaced as part of the North East 400kV works will be utilised for strategic spares across the SHE Transmission Network.
- **Rothienorman:** 400kV upgrade works at Rothienorman Substation to include the replacement of Surge Arrestors, Capacitive Voltage Transformers (CVTs) and installation of two 400/132kV, 240MVA Super Grid Transformers and two 132/33kV, 120MVA Grid Transformers. The 275/33kV grid transformers and 275kV Surge Arrestors and CVTs installed in 2021 will be removed as part of the North East 400kV scope. These will be utilised for strategic spares across the SHE Transmission Network.
- **Kintore:** Install four 400kV Bays and partially construct the 400kV busbar to accommodate two 400/275kV, 1200MVA Super Grid Transformers connecting the updated 400kV circuits from Rothienorman to the existing Kintore 275kV busbar
- **Blackhillock:** 400kV upgrade works at Blackhillock Substation to amend the existing Gas Insulated Busbar layout and disconnect two 400/275kV 1200MVA Super Grid Transformers. These Super Grid Transformers will be utilised at Alyth Substation in its future upgrading to 400kV operation.

5.8 Output Measure

The North East 400kV reinforcement increases the capability of the circuits between Peterhead, Rothienorman and Blackhillock through the concurrent reconductoring and reinsulating of the overhead lines and the associated substation works. This enables the connection of over 800MW of generation at (or near to) Blackhillock (namely Moray West offshore windfarm and Clashindarroch II onshore windfarm) by addressing the load sharing across the Blackhillock-Rothienorman and the Blackhillock-Cairnford-Kintore double circuit overhead lines. In addition to this load driver, the benefits of coordinating the North East 400kV upgrade with the delivery of the Peterhead 400kV busbar and the connection of NorthConnect (1400MW) are demonstrated through CBA and anticipated to be enhanced through the proposed outage constraints analysis.

The output measure for the North East 400kV reinforcement is 720MVA per circuit based on the increase in overhead line Summer Pre-fault Rating. Of the 720MVA, 350MVA is attributed to the voltage upgrading from 275kV to 400kV (based on twin zebra operating at 65°C), the remaining 370MVA uplift is attributed to the replacement of the phase conductors with twin Totora operating at 90°C. The conductors summer pre-fault rating is used for the output measure as it is this that is the system constraint based on the NETS SQSSS, Section 2 assessment criteria and the Connect and Manage guidelines for identifying Enabling works.

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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;
- Accommodate the local connection of the 800MW Moray West Offshore Windfarm, Clashindarroch 77MW windfarm and the 1400MW HVDC interconnector between Scotland and Norway;
- The output measure for the North East 400kV reinforcement is 720MVA per circuit based on the increase in overhead line Summer Pre-fault Rating. Of the 720MVA, 350MVA is attributed to the voltage uprating from 275kV to 400kV (based on twin zebra operating at 65°C), the remaining 370MVA uplift is attributed to the replacement of the phase conductors with twin Totora operating at 90°C; and,
- Facilitate effective competition in the generation and supply of electricity through the timely delivery of local works to accommodate connections. This is 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 North East 400kV Upgrade is above Ofgem's early and late threshold at £212m. The £212m 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. It is therefore unflagged.

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 decision assessment can be made on the application of any new competition model to these projects.



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6 Conclusion

The North East 400kV reinforcement is to proceed with the works to reconductor and re-insulate the existing 275kV OHL between Peterhead, New Deer, Rothienorman and Blackhillock to 400kV, along with associated substation upgrade works, in line with delivery of the Peterhead 400kV busbar for the connection of NorthConnect in 2023 (Strategy 5). This coordinated approach facilitates the load and asset condition based drivers resulting in a potential saving of [REDACTED] when compared to the counterfactual. The difference between Strategy 5, delivering the North East Upgrade in advance of the wider system capability uplift need in 2026 as demonstrated through NOA (Strategy 3) is [REDACTED]. Further efficiencies and system access benefits are anticipated through the reduction in the duration and frequency of construction outages.

The North East 400kV reinforcement is a subset of the East Coast Onshore 400kV Incremental Reinforcement option included in NOA. The East Coast 400kV Incremental and North East 400kV Upgrades are both required to deliver the wider system capability uplift by 2026. Thus, if the works to accelerate the North East 400kV upgrade for 2023 delivery, as proposed in this paper, are delayed then the North East 400kV Upgrade will be aligned with the East Coast 400kV Incremental Upgrade boundary uplift output measure.

The total costs for these works is £212.38m with the execution to be completed within RIIO-T2. The current forecast completion date is October 2023. The output measure for the North East 400kV reinforcement is 720MVA per circuit based on the increase in overhead line Summer Pre-fault Rating.

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 RII0-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 North East 400kV Upgrade should be ring-fenced and if it does not go ahead, we will return the allowances of £212.38m in full (minus any justified preconstruction expenditure).

It also means that we commit to delivering 720MVA increase in overhead line Summer Pre-fault Rating for the costs of £212.38m. If we do not deliver that 720MVA increase in overhead line Summer Pre-fault Rating, 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 Outputs included in RIIO T1 Plans

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

North East 400kV Upgrade Engineering Justification Paper**Appendices****Appendix A: Background to the East and 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

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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 Incremental

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

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NorthConnect in October 2023 and to concurrently reinsulate and reconductor the overhead lines between Blackhillock, Rothienorman and Peterhead.



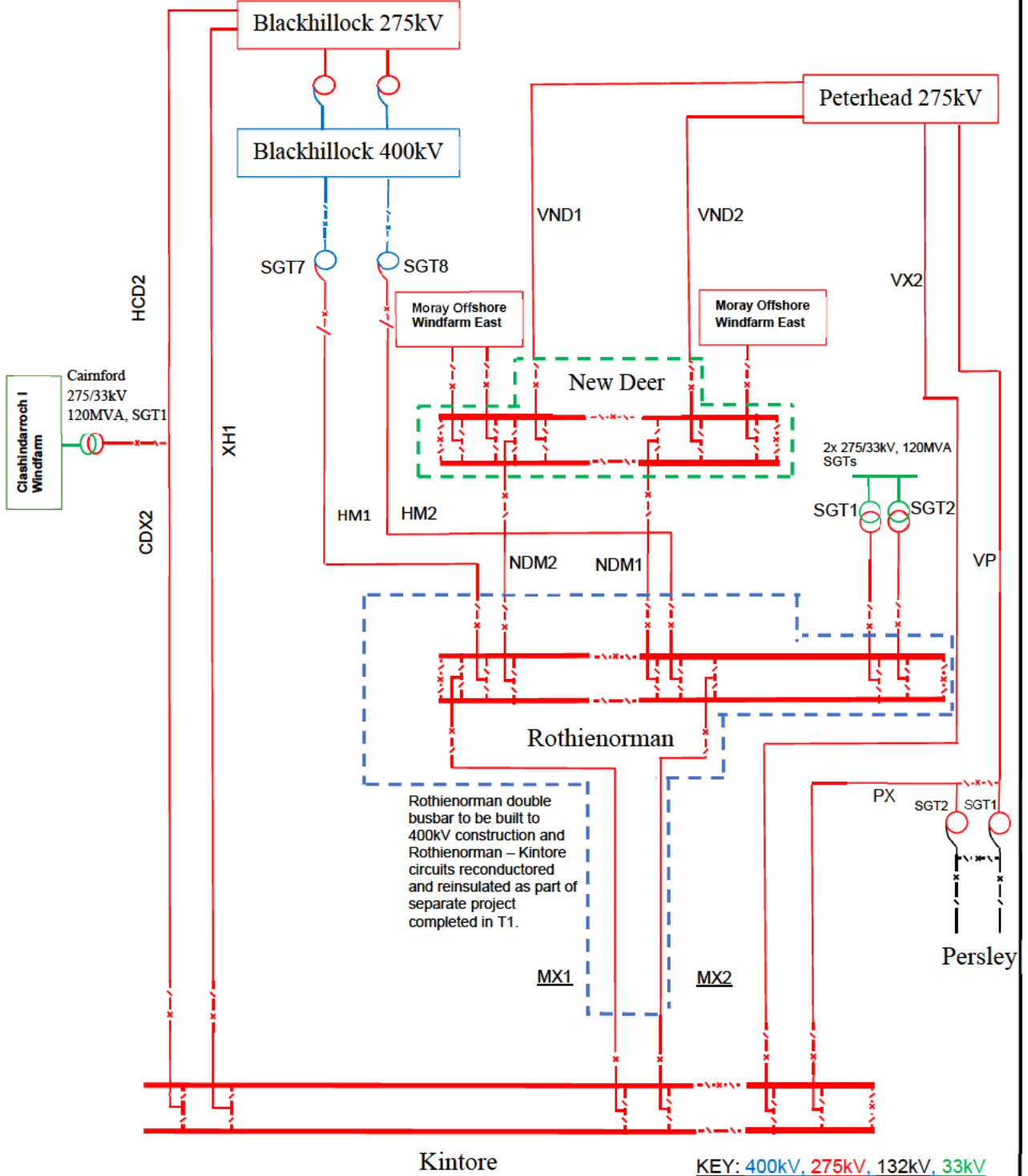
North East 400kV

- 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

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Appendix B: North East 275kV Network (2021)





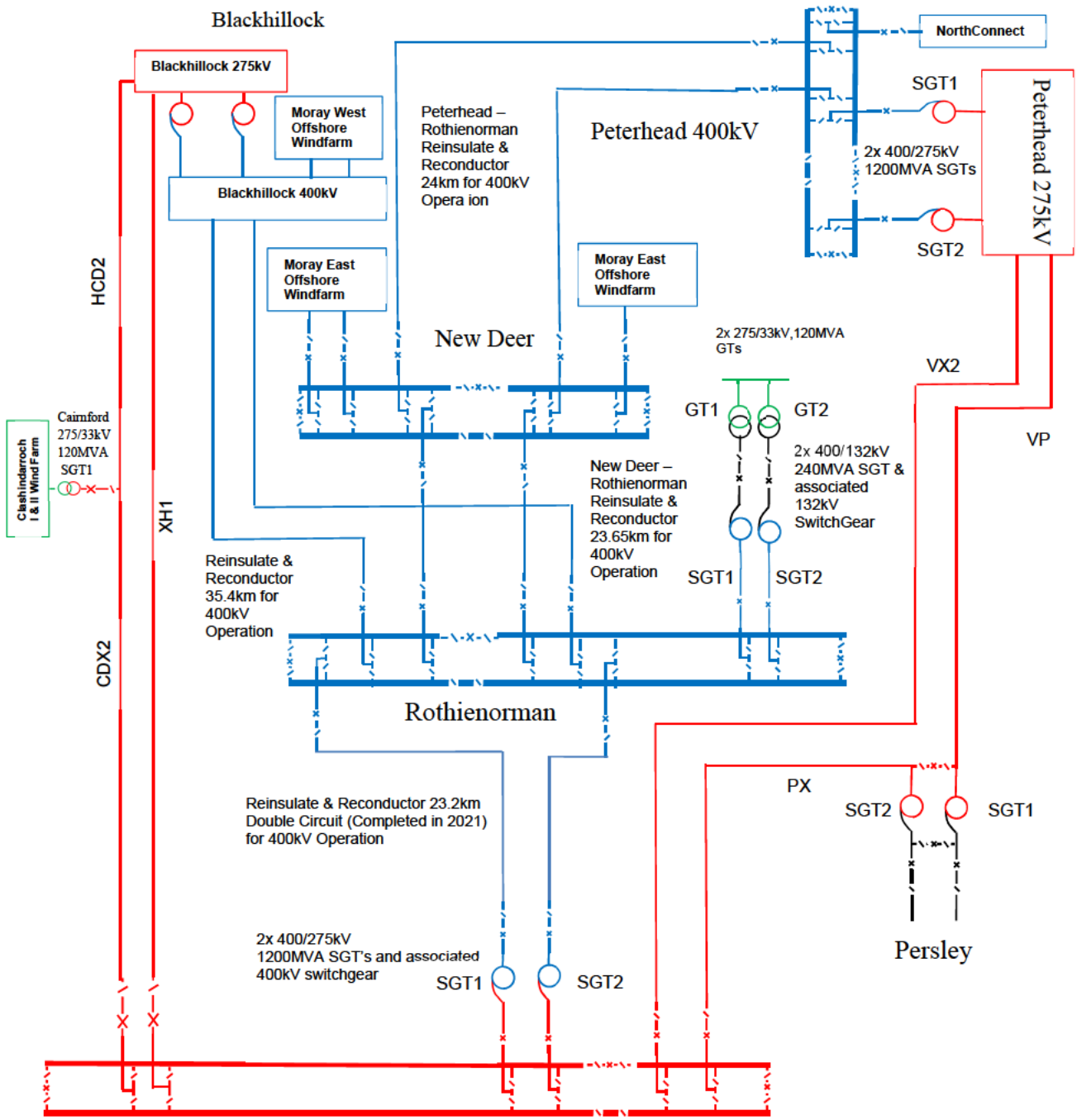
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Appendix C: Overhead Line Ratings

	Current 275kV Operation	Re-insulate 400kV Operation	Re-insulate & Re- conductor 400kV Operation
Conductor	Zebra	Zebra	Twin Totara
mm ²	400	400	425
Conductor Type	ACSR	ACSR	AAAC
Bundle	Twin	Twin	Twin
kV	275	400	400
Operating Temp (°C)	65°C	65°C	90°C
Winter Pre-fault rating (MVA)	920	1340	1680
Spring / Autumn Pre-fault rating (MVA)	865	1260	1610
Summer Pre-fault rating (MVA)	780	1130	1500
Winter Post-fault rating (MVA)	1090	1590	2000
Spring / Autumn Post-fault rating (MVA)	1030	1500	1920
Summer Post- fault rating (MVA)	925	1350	1790

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Appendix D: North East 400kV Network (2023)



Kintore

KEY: 400kV, 275kV, 132kV, 33kV

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Appendix E: 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.



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



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



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Appendix F: Delivery Strategy Options

The delivery strategy options which have been explored are:

- **Strategy 1: Contracted position with OHL reconductoring carried out after RIIO-T2 period:**

This option follows network requirement, delivering each project as and when the need is identified. Works included are as follows:

- Deliver step up-step down Peterhead 400kV busbar configuration by October 2023.
- Transition to 400kV OHL operation (re-insulation only) completing the minimum enabling works for the connection of Moray West offshore windfarm (at Blackhillock) by March 2024.
- Reconductor the north east 400kV circuits after the RIIO-T2 period (2026-2031).
- Noted from a Safety and Stakeholder perspective this Strategy does not offer any reductions in the identified areas which affect these aspects.

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- **Strategy 2:** Contracted position with OHL reconductoring carried out in the RIIO-T2 period:
 - Same as strategy 1 but with the advancement of the OHL reconductoring in the north east for completion by March 2024. This option combines OHL re-insulation and reconductoring for 400kV operation but will see Peterhead 400kV busbar and NorthConnect connect ahead of full system upgrade.
- **Strategy 3:** Wider system need for ECUP:
 - Same as strategy 2 but with the combined delivery of OHL re-insulation and reconductoring for 400kV operation in the north east by 2026 to complete works in line with East Coast 400kV Incremental Upgrade and ahead of the Eastern HVDC link.
- **Strategy 4:** North East 400kV opportunity with OHL reconductoring carried out after RIIO-T2 period:
 - Deliver reduced scope Peterhead 400kV busbar (two SGTs only) and North East 400kV reinforcement (re-insulation only) by October 2023. This option therefore avoids the need for two additional SGTs at Peterhead through delivery of the 400kV network on the same timescales as the busbar.
 - Reconductor the north east 400kV circuits after the RIIO-T2 period (2026-2031).
 - Noted from a Safety and Stakeholder perspective this Strategy does not offer any reductions in the identified areas which affect these aspects.
- **Strategy 5:** North East 400kV opportunity with OHL reconductoring carried out in the RIIO-T2 period:
 - Same as strategy 4 but with the combined delivery of OHL re-insulation and reconductoring for 400kV operation in the north east by October 2023. This option therefore also avoids the need for two additional SGTs at Peterhead.
 - Noted this Strategy could provide potential benefits to the Safety and Stakeholder elements through the coordination of the proposed works.



Appendix G: Strategy Spend Profiles

