Scottish & Southern Electricity Networks

Port Ann – Crossaig 132kV OHL Works

Engineering Justification Paper

1 Executive Summary

Our paper A Risk Based Approach to Asset Management[1] sets out our approach to network risk and how we subsequently identify assets that require intervention to limit the rise of risk over the RIIO-T2 period.

This paper identifies the need for intervention on the Port Ann – Crossaig OHL asset. The Port Ann – Crossaig Overhead Line Reinforcement relates to 132kV Transmission circuit located on the Kintyre peninsula in the south west region of the Scottish Hydro Electric Transmission (SHE Transmission) network. The overhead line was constructed in the 1960s.

The primary driver for the reinforcement works in this project is the asset condition and fault performance of the existing OHL.

There is a secondary load driver on this project. In addition to the asset health condition driver for refurbishment there are a number of contracted and scoping generation schemes in the Argyll and Kintyre area that impact on the power flow on the Inveraray – Crossaig circuits. The contracted generation requires an increase in the capacity rating of the overhead line to connect to the network in order for SHE Transmission to maintain compliance with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

Following optioneering and detailed analysis, as set out in this paper, the proposed scope of works is:

- Construction of a new steel tower double circuit 132kV overhead line from Port Ann to Crossaig, with the capability to operate at 275kV for future capacity increase.
- Demolish the existing overhead line between Inveraray – Port Ann – Crossaig, with the steel towers and conductors removed and reinstatement undertaken.

This scheme will cost £127.53m and will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetized risk benefit of R£1089.5m;
- a reduction of network risk calculated as R£14.9m; and,
- improved operational flexibility and resilience in line with our goal to aim for 100% network reliability for homes and businesses.

We are rebuilding the Inveraray – Port Ann circuit within the RIIO T1 period to meet the non-load requirement identified at the beginning of the RIIO T1 price control period. The dismantling works on this circuit will be undertaken in the RIIO T2 period following the completion of the rebuild. This

[1] A Risk Based Approach to Asset Management

work will be ex-ante funded as part of RIIO T2; the cost of the dismantling works for Inveraray – Port Ann OHL is £10.71m.

The Port Ann – Crossaig 132kV OHL Works project is above both Ofgem's early and late competition threshold at £127.53m. The project is not flagged as suitable for early or late competition, as detailed in Section 5 Detailed Analysis of the EJP.

Name of Scheme/Programme	Port Ann – Crossaig 132kV OHL Works
Primary Investment Driver	Asset Health (Non-Load)
Scheme reference/ mechanism or category	SHNLT200
Output references/type	NLRT2SH200
Cost	£127.53m (Port Ann – Crossaig Reinforcement) £10.71m (Inveraray – Port Ann Dismantling)
Delivery Year	RIIO T2 Period
Reporting Table	C0.7_Non_Load_Master_Data
Outputs included in RIIO T1 Business Plan	No

2 Introduction

This Engineering Justification Paper sets out our plans to undertake refurbishment works of existing assets during the RIIO-T2 period (April 2021 to March 2026). The planned work is replacement of the Port Ann – Crossaig OHL 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.

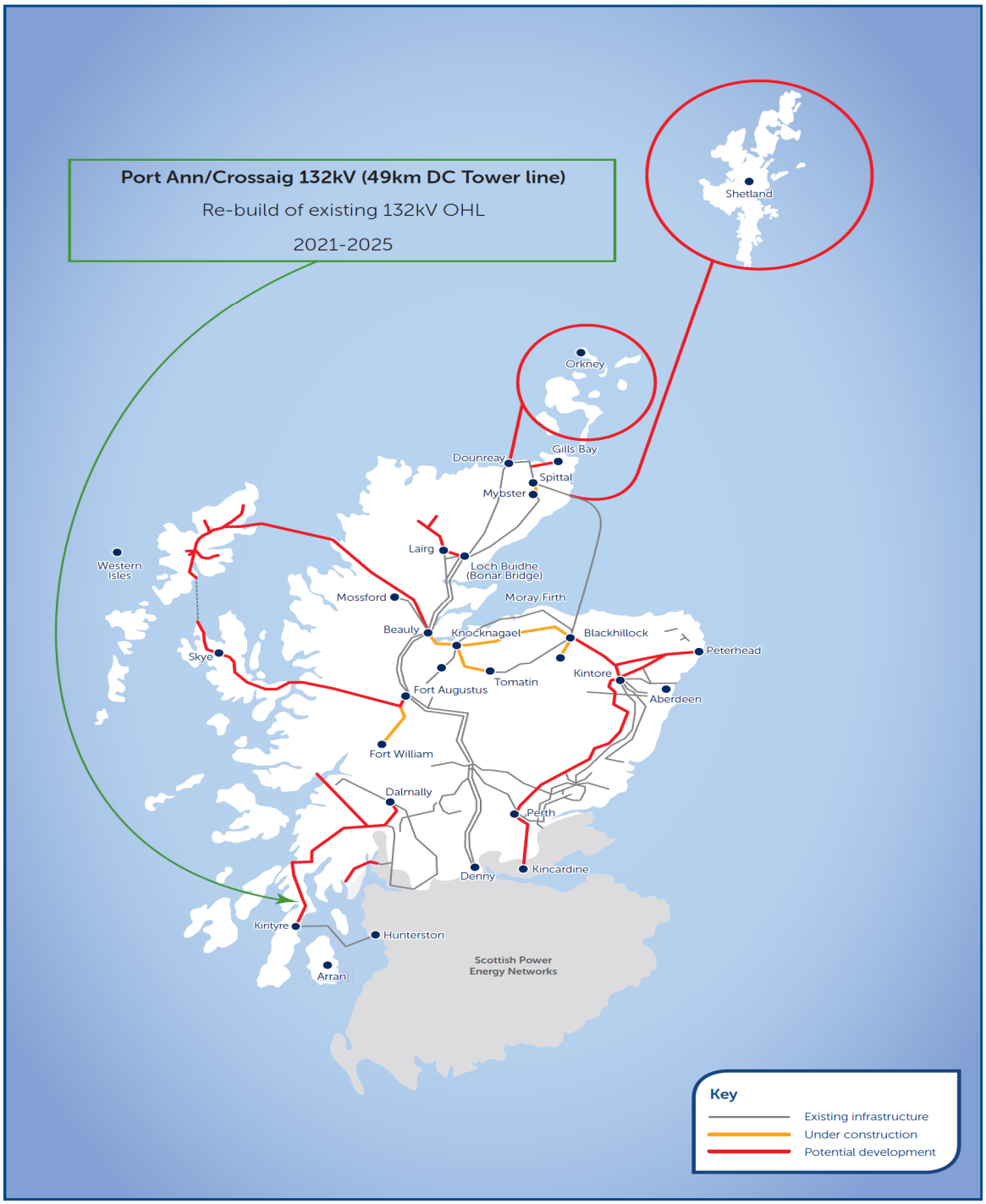
Section.7 Price Control Deliverables and Ring Fencing

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

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. Map showing the Port Ann – Crossaig 132kV OHL works on a map of SHE Transmission network.



3 Need

3.1 Background

The Port Ann to Crossaig reinforcement relates to the double circuit transmission overhead line (OHL) in Kintyre between the Port Ann Tee-off and Crossaig substation.

The primary driver for this reinforcement is the asset health of the OHL. The existing 132kV OHL between Inveraray and, originally Carradale, was constructed in 1960, and the towers and associated foundations have deteriorated considerably over time as discussed in the non-load section of this paper. The existing OHL between Inveraray and Carradale was constructed in 1960 and the section between Port Ann and Crossaig was reconductored in 1991/92.

In addition to the asset health condition driver for refurbishment, there are several contracted and scoping generation schemes in the Argyll and Kintyre area that impact on the power flow in the Inveraray – Crossaig circuits. This constitutes a secondary load driver for the project.

In 2013 an increase in the renewable generation seeking connection to the network in the Argyll and Kintyre area resulted in SHE Transmission submitting a Strategic Wider Works (SWW) Needs Case for the Kintyre – Hunterston project, which was subsequently approved by Ofgem. A new substation at Crossaig was constructed to the north of Carradale, two subsea cables installed between Crossaig substation and Hunterston substation (in ScottishPower Transmission's area), and the 132kV OHL between Crossaig and Carradale was rebuilt as part of this project. The project completed in 2015.

Between 2013 and 2015, a further increase in renewable generation seeking to connect to the Argyll and Kintyre network resulted in SHE Transmission developing a project to rebuild the Inveraray – Crossaig double circuit OHL. This reinforcement project formed part of an optioneering process in 2016 considering a range of long-term solutions for Argyll and Kintyre. Generation connections were the primary driver for the OHL rebuild, however the reinforcement also covered the RIIO T1 non-load output requirement for Inveraray – Port Ann section of the line.

There are now effectively two routes to export power out of the Argyll and Kintyre area. These are the three overhead line circuits from Inveraray to Sloy and the two subsea cables from Crossaig – Hunterston. These two routes are coupled together by the Inveraray – Crossaig 132kV double circuit. It is the Port Ann – Crossaig section of this OHL which is outlined in this justification paper. See Appendix A for a map of the existing transmission infrastructure in the Argyll and Kintyre area. In addition to the Port Ann to Crossaig OHL reinforcement, further reinforcements have been identified for the Argyll and Kintyre network as triggered previously by generation connection applications. These provide an outline of the longer-term strategy of the Argyll and Kintore area as follows:

- North Argyll Substation. Construction of a new 275/132kV substation in North Argyll area at Creag Dubh (along the existing Inveraray to Taynuilt 132kV double circuit OHL route). This new substation will be connected to the Dalmally substation in ScottishPower Transmission's area

via a new 275kV double circuit OHL connection. The Taynuilt – Inveraray 132kV double circuit OHL is turned into the North Argyll substation, with the circuits to Inveraray operated normally open.

- Inveraray – North Argyll Reinforcement. Rebuild of the double circuit OHL between Inveraray and the North Argyll substation with a new 275kV L8 tower construction with twin Rubus conductor, to be initially operate at 132kV. This will enable the radialisation of the Argyll and Kintyre network. Crossaig substation will be radially connected to Hunterston via the subsea cables while the Carradale and Port Ann substations will be radially connected to North Argyll substation. The circuits from Inveraray to Sloy will be operated with an open point, resulting in Clachan and Ardkinglas connecting to Sloy on radial circuits.

Between 2016 and 2017 there were a number of generator scheme terminations and Modification Applications following the withdrawal of subsidies for onshore wind. This resulted in a reduction of the amount of generation contracted to connect in the area. Following this, a review of the Inveraray – Crossaig OHL design was undertaken to look at alternative solutions that could meet both the non-load requirement and the reduced load driver. The alternatives included reconductoring of the line using existing towers. As part of this work, condition assessments of the existing towers were undertaken. These identified that the OHL asset health was in poor condition and identified significant deterioration of towers, foundations and fittings. The conductors on the Inveraray – Port Ann double circuit OHL were also assessed to be in a poor condition in 2018 with a limited remaining life of 5 years, while the conductors on the Port Ann – Crossaig section have an estimated remaining life of 15-20 years. As a result, the Inveraray – Crossaig OHL still requires to be rebuilt, however the primary driver changed from a load driver to a non-load driver.

This paper focuses on the Port Ann to Crossaig section of the line which will be delivered within the RIIO-T2 period (October 2023). Appendix A shows a map of the Argyll and Kintyre network with the existing transmission infrastructure, with the Inveraray – Port Ann and Port Ann – Crossaig sections of the OHL highlighted.

3.2 Project Drivers

SHE Transmission's RIIO-T1 business plan identified the need, from an asset health perspective, to reconductor the OHL between Inveraray and Port Ann. Condition assessments carried out subsequently identified additional replacement works across the full length of the line from Inveraray to Crossaig. There are also several load drivers, based on contracted and scoping generation upgrades which drive the need for additional circuit capacity.

The asset health and load drivers are summarised in Table 1.

Table1: Asset health and Load drivers

Asset Health driver considerations	Load driver considerations
• The existing 132kV double circuit OHL between Inveraray and Carradale was constructed in 1960 and the towers have deteriorated considerably over time. • Tower foundations have been constructed shallow at most towers tested in comparison to standard PL16 tower foundation designs with six foundations significantly shallower. Any structural loading increase is likely to drive foundation reconstruction/resizing works. • Recent condition assessments confirmed fixtures and fittings replacement works are required. • The existing double circuit OHL was constructed without an earth wire, resulting in poor performance and frequent unplanned outages, believed in part to be due to lightning strikes.	• The contracted generation requires an uprating of the existing circuits to be compliant with the Security Quality of Supply Standards (SQSS). Reconductoring of the existing line to provide this capacity uplift is not possible due to the light duty tower design. In addition, reconductoring would not address the performance issues due to the absence of an earth wire. • A significant volume of additional interest in renewable generation developments seeking connection in the Kintyre peninsula. This will be in addition to the existing generation connected to the Inveraray to Crossaig OHL.

3.3 Non-Load

An asset condition report[2] (ACR) has been prepared for this circuit which identified a need for intervention. The ACR draws up on information from a variety of sources with the key points summarised below.

The Port Ann to Crossaig OHL is a double circuit tower line commissioned in 1960 using a bespoke PL16 tower construction and consists of 219 towers over 48.3 km between Port Ann and Crossaig substations. The line was constructed post war, which resulted in a reduced design with smaller, lighter towers, shorter insulators which do not meet the current minimum insulation levels and without a continuous earth wire for the 48.3 km route. These design reductions have contributed to the overhead line being subject to frequent faults and unplanned outages.

In 2013 a Port Ann to Crossaig unplanned outage occurred as a result of the structural failure of multiple lattice support structures during a severe weather event in the Argyll and Bute region. The circuits were subsequently restored by installation of short sections of wood pole trident OHL within the impacted spans. The occurrence of this failure emphasises the higher 'risk of failure' present because of the inherent design limitations of the bespoke tower suite utilised in this construction.

[2] Port Ann Crossaig 132kV OHL Asset Condition Report T2BP-ACR-0001

Assessment of the asset health by analysis of visual assessment data captured in 2013 and 2017/18 has determined structural steelwork condition to be poor, displaying high levels of surface corrosion on most structures and with a presence of green algae noted in some instances. Refurbishment of the steelwork members would require significant surface preparation prior to commencing any painting works.

Insulator sets have been assessed to be in fair condition both mechanically and electrically with only minor rusting present on some sets. Fittings are displaying signs of wear and rusting on approximately a quarter of all U-bolts and shackles which will require to be addressed by a replacement programme of works.

Remedial works are required to address deterioration of the concrete in both foundation stubs and muffs in a small number of cases. A further programme of muff coating is required to rectify the age-related wear of the bitumastic protective layer. Further to these issues identified visually, a foundation evaluation study conducted in 2014 identified that the majority of towers tested were found to be shallow in comparison to standard PL16 tower foundation designs. Six foundations were identified to be significantly shallower than the design depth.

The condition of phase conductors has been determined by conductor sampling indicating an estimated remaining service life of 15-20 years from time of testing in 2018.

The circuit was built without an earthwire, consequently there are significant issues with the protection arrangements and the general fault performance. The circuits are some of the worst performing on the network; the continued long-term use of the current protection arrangements is inadvisable. Provision of a Category 1 communications link and earthwire on the circuit has been recommended to fully mitigate these issues.

3.4 Inveraray -Port Ann Dismantling

Reconductoring of the OHL from Inveraray – Port Ann was included within the proposed non-load works for the RIIO T1 period and SHE Transmission received ex-ante funding to undertake those works in RIIO T1. However, the detailed engineering design work identified that it was not feasible to reconductor the full circuit from Inveraray to Crossaig on the existing towers. As a result, SHE Transmission is now rebuilding the Inveraray – Port Ann circuit within the RIIO T1 period to meet the non-load requirement identified at the beginning of the price control period.

As a result of the decision to rebuild the OHL there is now a new requirement to remove the existing OHL and reinstate the old circuit route and accesses. This is additional work that was not envisaged at the time of proposing the original reconductoring project. The dismantling works will be undertaken in the RIIO T2 period following the completion of the rebuild of the complete circuit in RIIO T2. This work will be ex-ante funded as part of RIIO T2; the cost of the dismantling works for Inveraray – Port Ann OHL is £10.71m.

3.5 Load

The contracted level of generation in the Inveraray – Crossaig region was 342MW by the end of 2014 and the original connection dates associated with many of these schemes was in 2020 and 2021. This made the load related reinforcement timescales consistent with the existing asset health related refurbishment of the Inveraray – Port Ann section of the OHL. The withdrawal of subsidies for onshore windfarms from 1 April 2016 saw significant reduction in the volume of generation seeking near term connection and 150MW of generation schemes terminated their connection arrangements. This decrease in generation led to a project review to ensure that the most economic and appropriate design solution was taken forward.

Table 2 details the latest contracted position (November 2019) for generation at Carradale, Crossaig and Port Ann. This totals 276MW, of which 177MW has the Port Ann – Crossaig reinforcement as enabling works. There have been a number of recent generation connection applications in the south Kintyre peninsula. Four developers totalling 383MW have applied to connect to the network in the local area. The applications are currently in process and offers are due to be issued. All four of the generators will require the Port – Crossaig reinforcement as enabling works.

Table 2 Generation schemes contingent on the Port Ann – Crossaig line (all within RIIO-T2 period)

Generator	TEC (MW)	Connection	Contracted Date	Enabling Works
Willow Wind	45.0	Crossaig	October 2023	•
Clachaig Glen	48.0	Carradale	October 2023 (firm)	•
Sound of Islay	10.0	Port Ann	November 2021	•
Tangy 3	39.1	Carradale	April 2022	•
BAT 3	50.0	Carradale	October 2021	•
Sheirdrim	84.0	Crossaig	April 2025	•
[redacted]	165.0	Near Port Ann	October 2025	•
	117.6	Near Crossaig	October 2025	•
	50.4	Port Ann	October 2025	•
	50.0	Crossaig	October 2025	•

*Connection Offers being prepared for issue to the developers.

Table 3 shows generation developers with whom we have discussed potential connection applications through pre-application meetings in the last year. Despite the drop in the contracted generation, the scoping activity demonstrates a continuing volume of generation potentially seeking connection in the region south of Port Ann. This shows a range of additional generation from a minimum of 30MW to maximum potential of 370MW. The schemes highlighted in green are those that have submitted an application for planning consents as of June 2019, which are currently being reviewed by the Scottish Government.

Table 3 Scoping Generation Schemes in Argyll Area

Generator	Developer	Capacity (MW)	Location	Pre-app Date	Type
[redacted]	[redacted]	59	West Tarbert	Dec 2018	Wind
[redacted]	[redacted]	63	Crossaig	Dec 2018	Wind
[redacted]	[redacted]	38	Carradale	May 2018	Wind
[redacted]		45	Campbelltown	May 2018	Wind
[redacted]	[redacted]	35	Crossaig	May 2018	Wind
[redacted]	[redacted]	36-50	Port Ann	Aug 2018	Wind
[redacted]	[redacted]	50	Tarbert	Jun 2018	Wind
[redacted]	[redacted]	30	Crossaig	Mar 2019	Wind
Total		**356 – 370**			

Table 4 shows the current capacity of Port-Ann – Crossaig OHL and gives an indication of the headroom at the start of the RIIO-T2 period under summer pre-fault loading conditions with a single outage of a transmission circuit.

Table 4 Headroom at the beginning of RIIO-T2

Circuit	Current Capacity (MVA)	Headroom (MVA)
Port Ann - Crossaig 132kV OHL (PR1)	67	26
Port Ann - Crossaig 132kV (PR2)	67	32
Crossaig – Hunterston 220kV Subsea Cable (RH1)	240	90
Crossaig - Hunterston 220kV Subsea Cable (RH2)	240	90

The headroom will be impacted as more generators connect onto the network. System analysis has shown that the connection of three or more of the contracted generators from Table 2 will result in a requirement to reinforce the Port Ann- Crossaig circuits within the RIIO-T2 period.

The connection of the current contracted generators, along with those that have applied for a connection, would result in a requirement to radialise the Argyll and Kintyre network. Network studies undertaken on the radialised network have shown that the power flow arising from the connected, contracted and offered generation, would result in a minimum circuit rating requirement of 340MVA

per circuit on the Port Ann – Crossaig OHL. This does not consider any of the scoping generators listed in Table 3. In order to accommodate any further scoping generation onto the network this rating would require to be greater than this. A strategic view was considered in order to ensure that sufficient capacity can be provided to meet the current capacity needs while allowing efficient further capacity upgrades to meet future capacity requirements when the need arises. This removes potential barriers to the connection of currently known scoping generation interests highlighted in Table 3 and further future interests, potentially unlocking future renewable connections in this area.

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. Table 5 lists each option and gives a high level detail of each option.

Table 5 – Options Summary

Option	Option Detail	Taken forward to Detailed Analysis?
Option A – Do Nothing	Undertake no refurbishment works on the assets.	No
Option B – Refurbishment	Undertake tower strengthening works, fitting replacement and necessary foundation upgrades to refurbish the circuit.	No
Option C – Rebuild	Rebuild the OHL with a higher capacity circuit. Dismantle and remove the existing towers and conductor.	Yes

Do Nothing Option

The do nothing option does not undertake any intervention on the circuit. This option has been discounted at this stage as the network asset risk and asset condition assessments have concluded a need to intervene and replace the assets.

Refurbishment

Technical studies were carried out in 2017/2018 to assess the possibility of strengthening the existing structures to bring them up to current standards and reduce the risk of another failure similar to that experienced in 2013[3]. The outcome of these studies concluded that to strengthen the towers to an acceptable level, significant works (including strengthening of up to 40% of tower leg members) would be required resulting in a significant number of towers to be replaced.

Additionally, reusing the existing towers would not mitigate the reduced phase to earth (tower to conductor) infringement, due to an inherent design issue with the dimensions of the tower which do not meet minimum requirements set out in BS EN 50341. Also, the OHL would continue to operate without an earthwire and with reduced size insulator sets, resulting in continued poor fault performance of the line.

[3]132kV PR1/PR2 Port Ann to Crossaig Load and Strength Assessment Report, LSTC Reference 49_17053_05

The option of installing an extension to the existing earthwire peaks was investigated to accommodate an earthwire. However, it was found that this led to additional and increased overloads in the tower legs which would result in further tower replacements being required. Similarly, extended insulator sets were assessed to increase the insulation level however this leads to ground clearances which are non-compliant with Electricity Safety, Quality and Continuity Regulations (ESQCR).

The refurbishment of the existing line is excluded on the grounds of network performance and the significant amount of intervention required to improve the circuit.

Rebuild

The recommendation from the asset management investigations is to rebuild the Port Ann to Crossaig double circuit overhead line. The main drivers are the poor tower condition and performance. Tower phase to earth clearance infringements, the absence of an Earthwire and reduced insulation levels have resulted in an unacceptable number of unplanned outages between Port Ann and Crossaig.

The engineering factors described above led to a rebuild solution requirement for the Port Ann – Crossaig route in order to resolve the non-load condition drivers on the OHL. As there is a secondary load driver for this project, the capacity required on the circuit to accommodate the connected and contracted generation as well as the future scoping generation and requirements to meet net-zero capacity scenarios must be considered.

Several rebuild options were considered (Options 1 to 7). The options consider the selection of either a 132kV or 275kV construction with a standard tower design of L7 or L8 respectively and several different conductor types which reflected a range of capacities which were compatible with the selected towers. Table 6 outlines the options considered. The options and costing (May 2017, CAPEX only) shown in Table 6 consider both Inveraray – Port Ann and Port Ann – Crossaig sections of OHL. It should be noted that there is an increase in capacity (125MVA) between Option 1 and Option 2 but the cost associated with each option is the same. Therefore, Option 1 has not been progressed to detailed analysis and is not included within the Cost Benefit Analysis (CBA).

Table 6: Options considered for the Inveraray – Crossaig Line Rebuild

Option	Tower Geometry	Conductor (Operating Temperature)	Operating Voltage	Capacity (MVA)	Capital Cost (£m)*
O1	L7	Araucaria (50°C)	132kV	223	142.3
O2	L7	Araucaria (90°C)	132kV	348	142.3
O3	L7	HTLS	132kV	445	156.8
O4	L8	Araucaria (90°C)	132kV	348	159.7
O5	L8	Twin Rubus (90°C)	132kV	475	168.5
O6	L8	Araucaria (90°C)	275kV	715	206.2
O7	L8	Twin Rubus (90°C)	275kV	990	218.0

***Capital cost from May 2017, in 2017/18 cost base

5 Detailed Analysis

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

5.1 Cost Benefit Analysis

Cost Benefit Analysis (CBA) was carried out using a least worst regret (LWR) approach[4]. The Inveraray to Port Ann section and the Port Ann to Crossaig option are included in the CBA model to replace the full overhead line circuit between Inveraray and Crossaig. LWR has been chosen to conduct the CBA for the strategic load aspect of this project. This is reflected through different capacity scenarios.

The costs used in the CBA were for the rebuild of the line from Inveraray – Port Ann and Port Ann - Crossaig. Since the CBA was undertaken in 2018, further refinement of the costs for the preferred option have taken place to reflect work carried out in design, site investigation, land and wayleave agreements, access assessments and interface with stakeholders. Therefore, the costs for the Port Ann – Crossaig line rebuild differ from the costs for the preferred option within the CBA. The CBA is also undertaken on an older template and therefore monetised risk is not included. However the monetised risk would be the same for all options considered in the CBA and therefore would not change the outputs of the CBA.

The non-load requirement has been addressed through the baseline option – Option 2. The CBA considers a range of capacities and line designs to take account of the longer-term potential for radial circuit operation to maximise the additional connection capacity derived from the reinforced network. These are shown in Table 7.

To enable comparison across different line designs and conductor options, the additional cost to develop each option to provide increased capacity up to the maximum 990MVA was established. Table 7 outlines the details of the additional works required for each of the conductor options considered to deliver the capacity scenarios. Table 8 shows the base cost for each of the options (as seen in Table 6) plus the estimated cost of the additional works required to meet the different capacity scenarios.

[4] LWR is used in decision making whenever it is difficult or inappropriate to attach probabilities to possible future generation scenarios. The “regret” is the difference in value between the decision made and the optimal decision, given the realisation of a generation scenario. See SHE Transmission Cost Benefit Analysis Methodology for more information on this approach.

Table 7: Details of additional works required to deliver capacity scenarios considered

Description of additional works	No additional works needed

Option	Scope of additional works to meet Capacity Scenario				
	348 MVA	445 MVA	475 MVA	715 MVA	990 MVA
O2 (baseline)	-	Restring with HTLS	Rebuild with O5	Rebuild with O6	Rebuild with O7
O3	-	-	Rebuild with O5	Rebuild with O6	Rebuild with O7
O4	-	Operate at 275kV	Operate at 275kV	Operate at 275kV	Restring with Twin Rubus
O5	-	-	-	Operate at 275kV	Operate at 275kV
O6	-	-	-	-	Restring with twin Rubus
O7	-	-	-	-	-

Table 8: Additional costs required for each option to deliver capacity scenarios

Base cost + additional cost to deliver capacity	No additional works needed

Option	Additional costs to meet Capacity Scenario (£m)				
	348 MVA	445 MVA	475 MVA	715 MVA	990 MVA
O2 (baseline)	142.3	142.3 + 19.5	142.3 + 168.5	142.3 + 206.2	142.3 + 218
O3	156.8	156.8	156.8 + 168.5	156.8 + 206.2	156.8 + 218
O4	159.7	159.7 + 46.5	159.7 + 46.5	159.7 + 46.5	159.7 + 66.5
O5	168.5	168.5	168.5	168.5 + 49.5	168.5 + 49.5
O6	206.2	206.2	206.2	206.2	206.2 + 20.0
O7	218.0	218.0	218.0	218.0	218.0

NPVs for each option across the 6 capacity scenarios were calculated, and then compared to the baseline option. For each reinforcement and capacity option combination, the NPV is compared to the highest NPV across the different capacities to determine a regret NPV and from this the least worst

regret across all the options can be established. The calculation steps for carrying out LWR are explained in more detail in the CBA model[5].

Considering only the connected, contracted and soon to be offered generation, a minimum circuit capacity of 340MVA on the Port Ann – Crossaig circuits is required. However, additional developer activity indicates the required capacity in the long-term is greater than this and could potentially require 275kV capability. Therefore, a conventional 132kV tower and conductor design would not preserve optionality in the future in the event the capacity demand increases.

In Table 9, LWR shows that operating at 132kV initially has the least worst regret of £28M which is less than the worst regret of £81M if a 275kV design and operation is adopted straight away, or a regret of £165m in the event option 3 (132kV High temperature Low Sag composite conductor (HTLS)) is adopted as significant works would be needed to deliver higher capacities in the future.

Table 9: LWR analysis results

Option	Option Regrets for Capacity Scenario (£m)					
	348 MVA	445 MVA	475 MVA	715 MVA	990 MVA	Max regret
O2 (baseline)	-	5	150	150	150	**150**
O3	15	-	165	165	165	**165**
O4	19	53	40	-	9	**53**
O5	28	13	-	13	-	**28**
O6	68	52	40	-	8	**68**
O7	81	66	53	13	-	**81**

The option assessment uses a least worst regret calculation (LWR) to recommend proceeding with option O5 (L8 Twin Rubus initially operated at 132kV). The worst regrets, given in Table 9, show that this is the option of LWR. The table also indicates that the optimal option could be either O2 or O5 depending on the required capacity that transpires: O2 if less than 445MVA, or O5 if greater than 445MVA. A technique that can be used to help address and provide additional insight in this situation is the use of implied probabilities. This approach is used by the ESO in their assessment of Network Option Assessment (NOA)[6] option recommendations that may vary dependent upon scenario considered. Here we have used it to compare option O2 and option O5 for a capacity scenario of

[5]SHE Transmission Cost Benefit Analysis Methodology

[6] Network Options Assessment published annually by NGESO

445MVA and a capacity scenario of 475MVA to answer the question; How likely is the required capacity to be less than or greater than 445MVA?

Probabilities are not assigned to scenarios in the LWR but there is an implied probability in choosing one option over another. The approach compares expected costs of the options. The expected cost of an option is found from;

[Cost of option for Scenario A x probability of scenario A] + [(1- probability of Scenario A) x cost of option for Scenario B]

And the implied probability of a scenario can be found when the expected cost of two different options are equal. In this instance Scenario A is capacity less than 445MVA and Scenario B is capacity greater than 445MVA.

Figure 2 shows the expected cost of the options O2 and O5 vs the probability of required capacity being less than 445MVA. The implied probability where the two lines cross is 84.5%.

This leads to the conclusion that option O5 is optimal if:

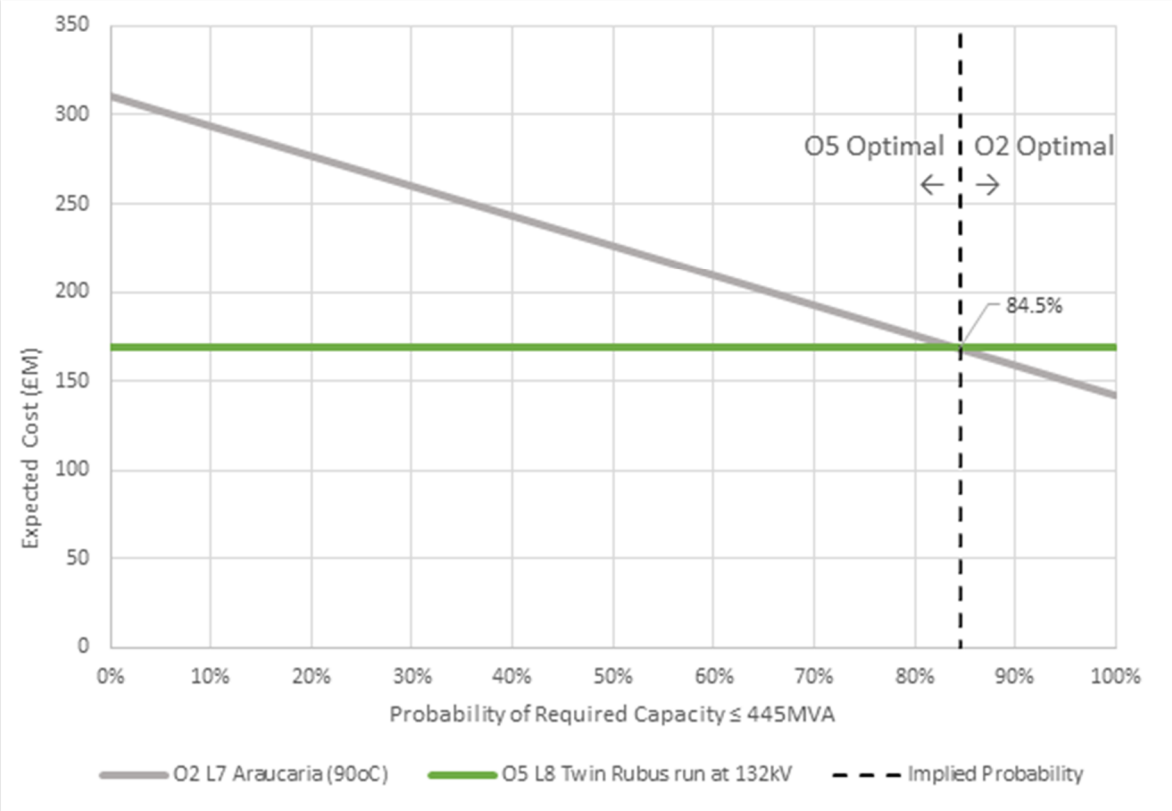
- It is believed the required capacity is more likely to be greater than 445MVA.
- It is believed the required capacity is equally likely to be greater than as less than 445MVA.
- It is believed that the required capacity is more likely to be less than 445MVA (but less than 84.5% probability).

Option O2 is optimal if:

- It is believed the required capacity is highly likely to be less than 445MVA (with at least 84.5% probability).

When considering the contracted generation, generation under offer and the scoping generation activity in the Argyll region, as shown in Table 2 and Table 3, then the likelihood of the required capacity being less than 445MVA is considered to be less than the 84.5% threshold. Consequently Option 5 is preferred and recommended.

Figure 2. The expected cost of O2 and O5 vs Probability



5.2 Project Sensitivity

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 "A Risk-Based Approach to Asset Management" outlines our approach to monitoring and assessing the condition of our assets to maintain the reliable and resilient network that is expected by our stakeholders. Where asset condition deteriorates, we undertake a programme of cost-effective, risk-based interventions to maintain the longevity and performance of the transmission network. Each of our non-load related projects for T2 is underpinned by Asset Condition Reports which clearly outline that the works are necessary and driven by reliability.

Table 10. Sensitivity Analysis table

Sensitivity	Test and impact observed – switching inputs
Asset Performance / deterioration rates	Switching deterioration assumption: The asset performance / deterioration rates can only improve or deteriorate. As the need for this project is driven by an asset condition report (as outlined in Section 3), the asset condition will not improve in the intervening period. The second option is for the asset performance to deteriorate and therefore the need remains, and the project would be considered for advancement within available outages.
Ongoing efficiency assumptions	Switching efficiency assumption: increased or decreased. Test would have no impact on (feasible) option selection, as the options move in parallel and have no impact on ordering within CBA.
Demand variations	No significant demand forecast.
Energy scenarios	Sensitivity considered in Section 3 (Need) already. As there is only a marginal increase in capex to deliver the works at a higher capacity to accommodate the forecasted "certain view" generation. Please see Section 3 of the EJP and our paper "A Network for Net Zero – Scenarios" for further details.
Asset utilisation	Our policy paper "A Risk-Based Approach to Asset Management" outlines our approach to monitoring and assessing the condition of our assets to maintain the reliable and resilient network that is expected by our stakeholders. Where asset condition deteriorates, we undertake a programme of cost-effective, risk-based interventions to maintain the longevity and performance of the transmission network. Each of our non-load related projects for T2 is underpinned by Asset Condition Reports which clearly outline that the works are necessary and driven for reliability.
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.

5.3 Proposed Solution

Based on the output of the CBA; taking consideration of the asset health condition, and a strategic position on the generation connection capacity requirements, the proposed reinforcement solution is: the rebuild of the Port Ann – Crossaig OHL with L8 towers and strung with Twin Rubus conductor. The OHL would initially operate at 132kV, with the capability to operate at 275kV in the future. The now redundant existing OHL will be dismantled and removed. Appendix B shows a single line diagram of the Port Ann – Crossaig reinforcement.

The proposed programme for this solution would see construction on site starting in June 2021, with an energisation completion date of October 2023.

The total cost for delivering the scope of works for the proposed rebuild of Port Ann - Crossaig is £127.53m. The costs for the dismantling works associated with Inveraray – Port Ann is £10.71m.

5.4 Competition

The Port Ann – Crossaig 132kV OHL Works project is above both Ofgem's early and late competition threshold at £127.53m. However, as outlined within Section 4 "Optioneering", SHE Transmission has completed an extensive optioneering exercise to determine all possible solutions and does not consider the scheme has the potential to be delivered via an alternative solution ('the contestability test'). The project is required to address the requirement to replace the existing asset based upon assessed asset condition. It is also required to meet the anticipated future load growth in the local Kintyre network area.

This project has been assessed against Ofgem's 'new' and 'separable' criteria ahead of any consideration of the applicability of a late competition model. The overhead line (OHL) project is a new and complete replacement and the scheme is also above Ofgem's value threshold. The existing OHL from Inveraray to Crossaig is a continuous OHL, of which the Inveraray to Port Ann tee point section is under construction and will complete before RIIO-T2. This project would replace the line section from the Port Ann Tee point to Crossaig. The new circuit will not turn into Port Ann substation. It is not efficient to construct a switching station solely for the purpose of making the project separable as this will result in additional cost to consumers. Therefore, the project is subsequently unflagged as being eligible for late competition.

5.5 Stakeholder Engagement

The project team has engaged with several organisations throughout the development of the Port Ann to Crossaig project including; Statutory Authorities, Community groups and land owners. Each of these agencies have had an influence over the development of the project to enable the submission of the Section 37 (S37) consent in July 2018. The project team has engaged with the Statutory Authorities in over 30 instances from 2014. Twelve community engagement events with local communities have been undertaken along the Inveraray to Crossaig route between 2014 and 2017 prior to the

submission of the S37. Community engagement will continue throughout the project's construction phase. Landowners along the alignment have been contacted individually and engaged during community events. Landowner engagement will continue throughout the construction of the project. Further information can be found within the consultation report[7].

SHE Transmission undertook an overhead line routing and alignment process to enable an Environmental Impact Assessment to be prepared and a S37 consent application to be submitted.

A route options study was undertaken to identify potential route corridors. This study considered the route options along a corridor adjacent to the existing line[8] as well as three potential route corridor options along the Inveraray to Crossaig route. Following meetings with Argyll and Bute Council and SNH in September 2014, and public consultations in October 2014, a preferred route corridor was chosen.

Following the route options appraisal, a technical alignment was created by designing the position of provisional angle points, ground lines and elevations, and this formed the "Baseline Alignment". The Baseline Alignment is considered to represent the shortest technically feasible alignment within the Preferred Route Corridor and the least cost option. Alternative alignments are compared against the Baseline Alignment. Six deviations to the Baseline alignment were identified. Five of these were driven by environmental aspects and resulted in a less economic alignment however balancing the environmental, technical and cost impacts these alternatives were chosen to ensure compliance with Environmental Impact Assessment (EIA) regulations and submission of the S37 consent application. Section 37 consent was granted in July 2019.

5.6 Risk Benefit

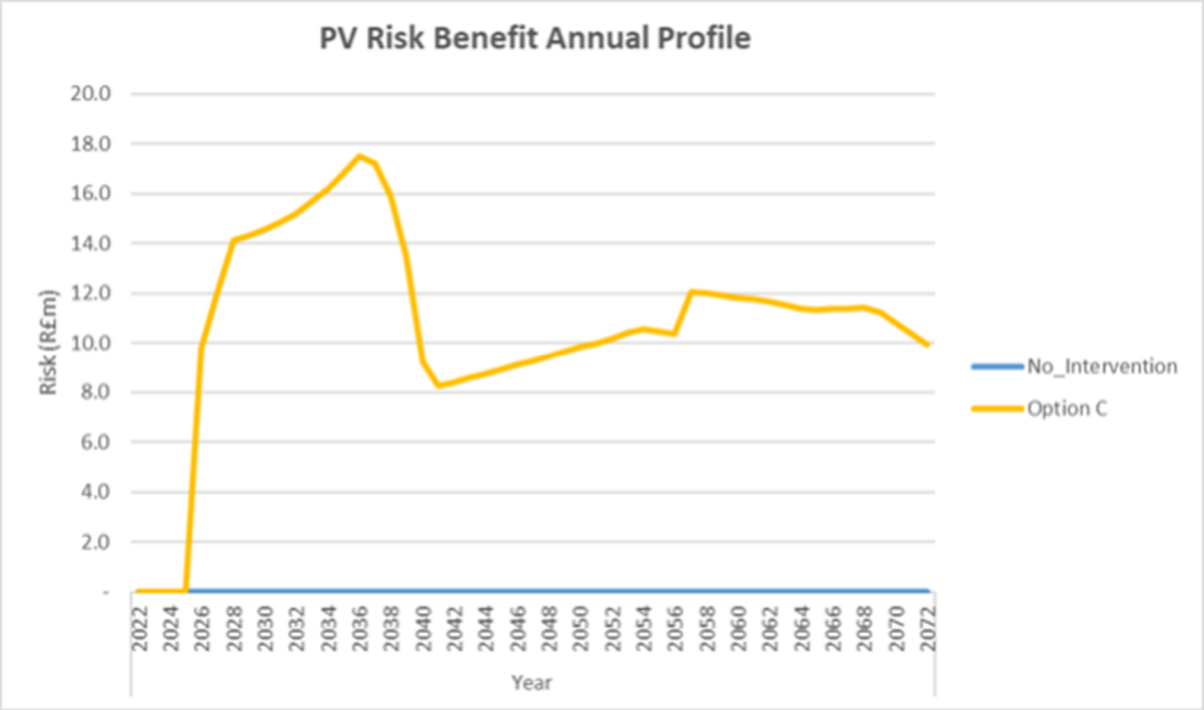
A Risk Benefit Analysis has been carried out in order to compare "no intervention" against the selected "with intervention" option. Please note that while monetised risk is denoted as a financial figure, it is important to note that it is not "real" money and does not correspond to the cost that SHE Transmission would incur if an asset was to fail and these values are thus identified with R£ prefix (for more details please refer to A Risk Based Approach to Asset Management[1]).

The long-term monetised risk benefit which would be realised through the completion of this project is R£1089.5m. The long-term benefit is derived by consideration of the risk of the asset experiencing a catastrophic failure weighted by the probability that the asset will survive for the Options and "no intervention" scenarios. The long-term benefit is an aggregation of the risk of all assets being considered within the option. The risk of each Option is then compared with the "no

[7]Report on Consultation- Alignment Selection and EIA Scoping, Inveraray to Crossaig 275 kV overhead line (June 2018)
[8]RIIO T2 LT40 Stakeholder Engagement Summary (April 2019)

intervention" scenario. The "no intervention" scenario assumes that when the asset experiences a catastrophic failure the asset is replaced.

Figure 3 - Long Term Benefit of Proposed Intervention – Option C Rebuild



In addition to assessing the long-term risk benefit, a monetised risk benefit has also been determined. The monetised risk benefit which would be realised through the completion of this project is R£14.9m.

5.7 Carbon Modelling

We are committed to managing resources over the whole asset lifecycle – i.e. including the manufacturing of assets, construction, operations and decommissioning activities – to reduce our greenhouse gas emissions in line with climate science and become a climate resilient business. It is our aspiration that the carbon lifecycle cost of investment options plays a key role within our project development and is considered in the selection of a preferred solution. We have therefore developed an internal carbon pricing model that estimates a carbon cost for each option considered in our CBA through deriving values for:

1. Embodied carbon, which relates to the carbon emissions associated with the manufacturing and production of the materials use in production of the lead assets (transformer, reactors, underground cables and overhead lines. Overhead line is made up of tower/wood pole/composite pole, conductor and fittings) procured and installed as part of the project.

2. The carbon emissions associated with the main stages of the project lifecycle (construction, operations and decommissioning).

It is our vision to embed carbon considerations within our strategic optioneering and project development processes, which will require us to determine a way of flagging high carbon options within our CBA outputs. We will continue to develop our thinking in this space, which will involve our model being validated by a third party, so the results included in this EJP are indicative and subject to change. Table 11 shows the carbon footprint modelling for Option 2 and Option 5. A complete table with all options from the CBA is included in Appendix 3.

Table 11. Carbon Footprint Modelling for the Port Ann – Crossaig 132kV OHL Works

	Project Information	Option2	Option5
Project info	Project Name/number	O2	O5
	Construction Start Year	2022	2022
	Construction End Year	2028	2028
Cost estimate £GBP	Embodied carbon	£420,548	£517,623
	Construction	£176,010	£352,019
	Operations	£136,443	£272,885
	Decommissioning	£836,733	£1,673,466
	Total Project Carbon Cost Estimate	**£1,569,733**	**£2,815,994**
Carbon footprint tCO2e	Embedded carbon	5926	7294
	Construction	2366	4732
	Operations	591	1183
	Decommissioning	2366	4732
	Total Project Carbon (tCO2e)	**11249**	**17940**
Project Carbon Footprint by Emission Category	Total Scope 1 (tCO2e)	591	1183
	Total Scope 2 (tCO2e)	0	0
	Total Scope 3 (tCO2e)	10658	16757

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. This is detailed in Table 12.

Table 12. Whole Life Costs, Carbon Impact and GVA table showing CBA value impact

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 £0.5m per year, totalling £23m 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 £1.8m 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.	The estimated annual discounted carbon abatement associated with the 177MW of contracted generation is the region of £9m, according to the Scottish Governments Renewable Electricity Output Calculator[1] . (177MW is the level of contracted generation for Willow Wind, Clachaig Glen and Sheirdrim; Table 2 refers.)
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 direct and indirect impact.	The total direct regional GVA to the Scottish economy associated with the onshore wind generation projects enabled is estimated at £23m (discounted over estimated asset life). Indirect and induced GVA totals £26m (discounted). The direct GVA associated with the SHE Transmission expenditure is estimated at £33m (discounted), indirect and direct GVA totals £35m.

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

6 Conclusion

The primary driver for this reinforcement is the asset health condition of the OHL. The existing 132kV double circuit OHL between Inveraray and, originally Carradale, was constructed in 1960. The towers and associated foundations have deteriorated considerably over time and have significant design limitations which impact performance.

In addition to the asset health condition driver for refurbishment there are contracted and scoping generation schemes in the Argyll and Kintyre area that impact on the power flow on the Inveraray – Crossaig circuits. This constitutes a secondary load driver for the project.

From this load perspective:

- There is a short-term requirement for a relatively modest increase in capacity of the Port Ann-Crossaig overhead line due to contracted generation in the area.
- This capacity cannot be achieved by reconductoring the existing overhead line due to its limited structural capabilities. The overhead line therefore needs to be rebuilt.
- The cheapest rebuild option is an overhead line with L7 towers for 132kV operation. However, this option will result in a large regret if a further increase in capacity is required in the future to realise the long-term strategy for the region.
- The regret seen with the minimum build option can be mitigated by building a larger L8 tower, initially operating at 132kV but giving the option to operate at 275kV in the future to unlock additional capacity. The CBA recommends proceeding with this option as it has the least worst regret.

A Section 37 consent application was submitted in July 2018 for a new steel tower double circuit 132kV overhead line from Inveraray to Crossaig, with the capability to operate at 275kV for future capacity increase. Consents were granted in July 2019. The section from Inveraray to Port Ann will be constructed and energised during RIIO T1 while the section from Port Ann to Crossaig substation is to be constructed and energised by October 2023, with demolition of the existing steel tower line and land reinstatements for this section being completed in the more seasonally appropriate period for mid-2024.

This scheme will cost £127.5m and will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetized risk benefit of R£1089.5m;
- a reduction of network risk calculated as R£14.9m; and,
- improved operational flexibility and resilience in line with our goal to aim for 100% network reliability for homes and businesses.

The costs for the dismantling works associated with Inveraray – Port Ann is £10.71m.

The Port Ann – Crossaig 132kV OHL Works project is above both Ofgem's early and late competition threshold at £127.53m. The project is not flagged as suitable for early or late competition, as detailed in Section 5 Detailed Analysis of the EJP.

7 Price Control Deliverables and Ring Fencing

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.

For our core non-load projects this means that we commit to delivering our overarching NARMs target. If we do not deliver the NARMS target, or a materially equivalent target, then we should be subject to a penalty. Equally, if we over-deliver against our target and are able to justify that the over-delivery is in the consumers interests and could not have been reasonably factored into our business plan at the time of target setting then we should be made cost neutral for this work.

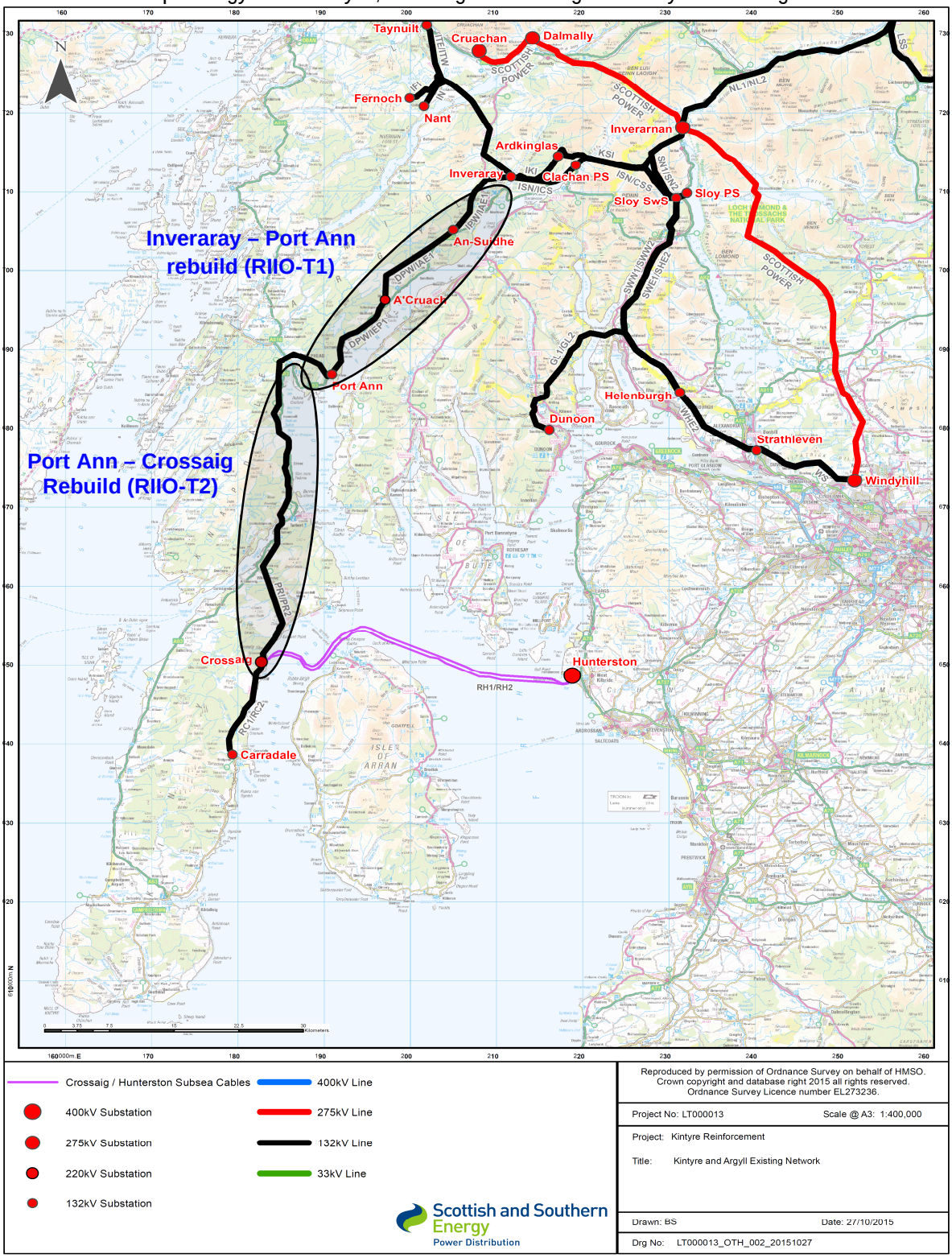
Core non load projects should not be ring fenced. This is to allow for substitution of projects in order to meet that NARMs target. We need flexibility to respond to up to date asset data information or external influences on our network during the price control; this information might drive us to substitute one project for another in order to ensure a reliable and resilient network. Ring fencing projects may result in sub-optimal decisions, having adverse consequences for the health of our network, which will ultimately be reflected in the NARMs target.

8 Outputs included in RIIO T1 Business Plan

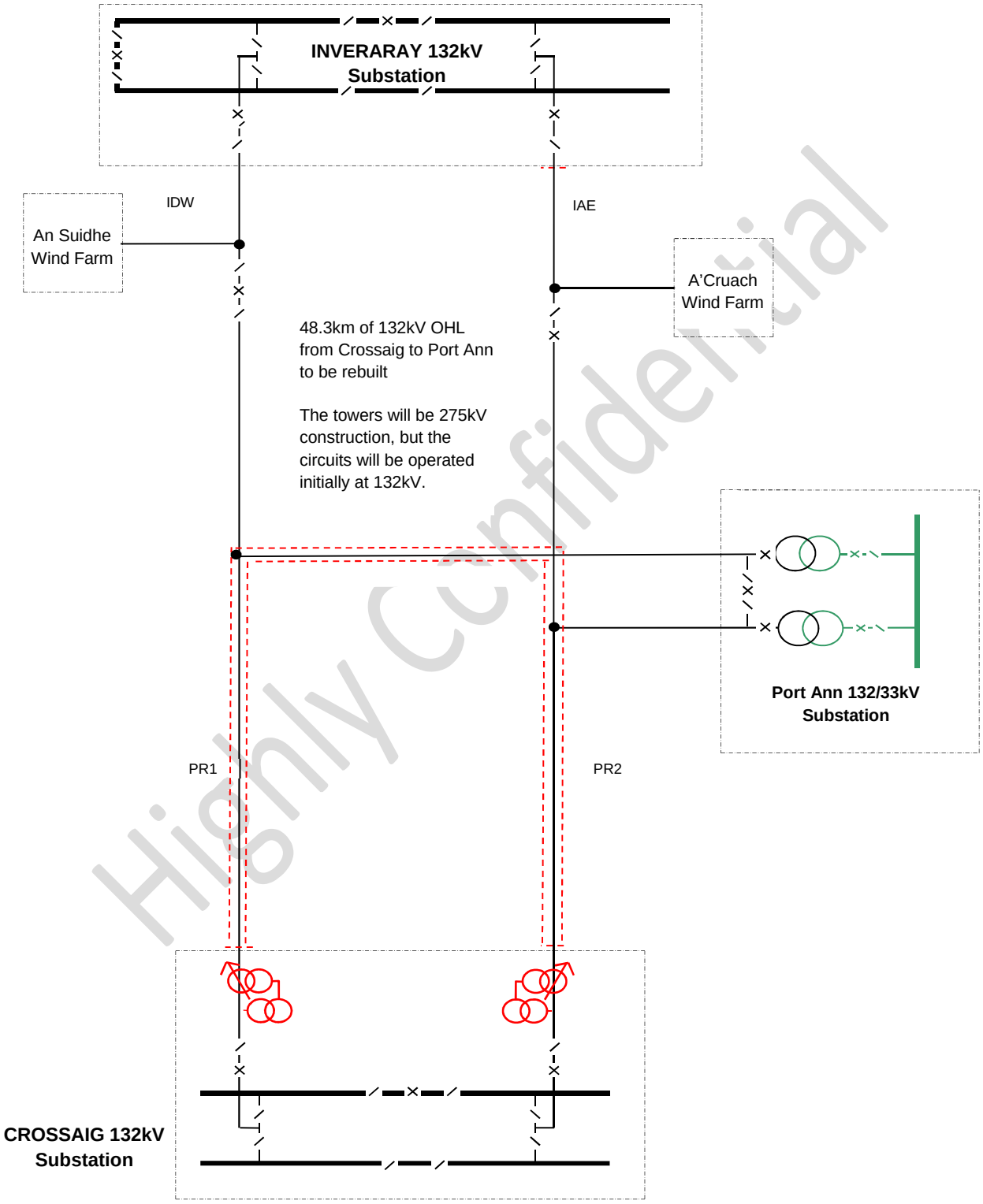
There are no outputs associated with this scheme included in our RIIO T1 plans.

Appendices

APPENDIX A: Map of Argyll and Kintyre, showing the existing Inveraray to Crossaig OHL route



APPENDIX B: Inveraray to Crossaig single line diagram at completion of the works.



Appendix C: Full Carbon Modelling Table for all Options in CBA

	Project Information	Option2	Option3	Option4	Option5	Option6	Option7
Project info	Project Name/number	O2	O3	O4	O5	O6	O7
	Construction Start Year	2022	2021	2022	2022	2022	2022
	Construction End Year	2028	2026	2028	2028	2028	2028
Cost estimate £GBP	Embedded carbon	£420,548	£413,765	£406,593	£517,623	£940,439	£1,266,973
	Construction	£176,010	£171,948	£176,010	£352,019	£187,809	£352,019
	Operations	£136,443	£129,290	£136,443	£272,885	£145,590	£272,885
	Decommissioning	£836,733	£830,500	£836,733	£1,673,466	£892,827	£1,673,466
	Total Project Carbon Cost Estimate	**£1,569,733**	**£1,545,503**	**£1,555,778**	**£2,815,994**	**£2,166,665**	**£3,565,344**
Carbon footprint tCO2e	Embedded carbon	5926	5926	5729	7294	13252	17853
	Construction	2366	2366	2366	4732	2524	4732
	Operations	591	591	591	1183	631	1183
	Decommissioning	2366	2366	2366	4732	2524	4732
	Total Project Carbon (tCO2e)	**11249**	**11249**	**11052**	**17940**	**18932**	**28499**
Project Carbon Footprint by Emission Category	Total Scope 1 (tCO2e)	591	591	591	1183	631	1183
	Total Scope 2 (tCO2e)	0	0	0	0	0	0
	Total Scope 3 (tCO2e)	10658	10658	10461	16757	18301	27316