Scottish & Southern Electricity Networks

Tealing Substation Works

Engineering Justification Paper

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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 SGT3 and its associated reactor R3 at Tealing 275/132kV substation. The primary driver for the scheme is the asset condition of the existing transformer and reactor.

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

- Removal of the existing SGT3, R3, the associated Earthing Transformer (ET) and Neutral Earthing Resistor (NER), Reactor circuit breaker (3R0) and the bund and concrete structures,
- Installation of a new SGT3, R3, associated ET and NER3, and 3R0 in the same location,
- Replacement of Protection and control panels.
- New disconnectors including structures and bases in the 275kV bay will be installed to provide full independent busbar selection.

This scheme will cost £9.3m and will deliver the following outputs and benefits during the RIIO T2 period;

- A long-term monetised risk benefit of R£56.0m,
- A reduction of total network risk calculated as R£3.6m,
- Improved operational flexibility and resilience in line with our goal to aim for 100% transmission network reliability for homes and businesses.

The Tealing Substation Works project is not flagged as eligible for early or late competition due to it being under Ofgem's £50m and £100m thresholds respectively.

[1] A Risk Based Approach to Asset Management

Name of Scheme/Programme	Tealing Substation Works
Primary Investment Driver	Asset Health (Non-Load)
Scheme reference/ mechanism or category	SHNLT2019
Output references/type	NLRT2SH2019
Cost	£9.34m
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 at Tealing Substation as shown on the map on the next page.

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.

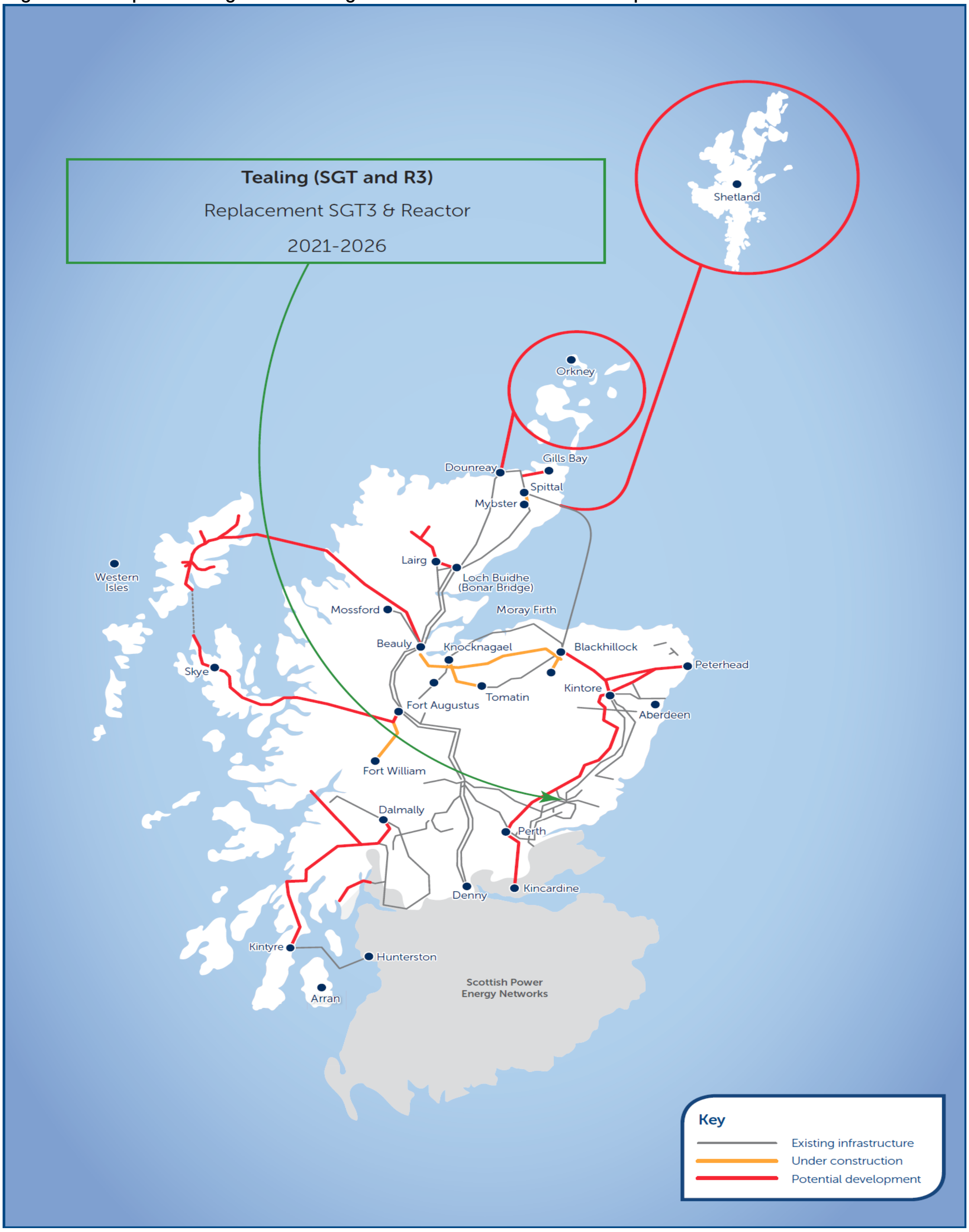
Section.7 Price Control Deliverables and Ring Fencing

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 Tealing Substation Works on a map of SHET network.



3 Need

3.1 Background

Tealing 275/132kV substation is located to the north of Dundee city, on the east coast of the SHE Transmission network. It is the largest substation in the Dundee area.

Tealing substation was constructed in the 1960s. It forms part of the GB Main Interconnected Transmission System (MITS). The substation is an integral part of the SHE Transmission 275kV network. It is connected to Kintore 275kV substation to the north, and Kincardine 275kV substation and Glenrothes 275kV substation to the south (both Scottish Power substations). The Tealing 132kV busbar is part of an interconnected network that feeds the Dundee city ring circuit, along with Arbroath, Lunanhead and Coupar Angus GSPs.

There are three 275/132kV 180MVA SGTs; SGT1, SGT2 and SGT3. SGT1 and its tertiary connected reactor were replaced in RIIO T1 on an asset condition basis. SGT2 was replaced in 1993 and has no tertiary connected reactor. SGT3 was installed in 1968. Its tertiary connected reactor was originally installed at Beauly in 1970, before being moved to Tealing in 1977. It is SGT3 and its associated reactor that are the subject of this project. At the end of the T2 period the transformer and reactor will be 58 years old and 49 years old respectively.

3.2 Asset Need

An Asset Condition Report[2] (ACR) has been prepared for this substation which identified a need for intervention. The ACR draws upon information from a variety of sources with the key points summarised below.

The available oil history of SGT3 shows that hydrogen and acetylene values have widely fluctuated in the main and selector tanks over the last 18 years. The gas patterns are consistent with a D1 (discharges of low energy) electrical fault. There is suspected oil communication between the main and selector tanks is due to their similar gas concentrations and trends being observed. This has not yet been confirmed. Another suspected cause is partial discharge, though again this has not been confirmed.

The sister unit of SGT3 (SGT1) was replaced within the RIIO T1 period due to condition. Prior to its failure, investigations into SGT1 revealed that there is a known manufacturing defect with this design of transformer though it is not suspected to be the cause of the gas in SGT3.

The external condition of SGT3 was visibly inspected. Oil stains were found on the HV side of the main tank and around the base of the unit. The suspected oil leak is at the top of the transformer. Numerous oil stains were also located around the bases and hatches of the selector tanks of all three phases.

[2] Tealing Substation Works Asset Condition Report T2BP-ACR-0023

An appreciable hum and the sound of corona could be heard coming from the transformer, with the sound of corona more apparent around the red phase.

Reactor R3 is showing advanced signs of a solid insulation ageing issue. This is confirmed from furan analysis results which show that furan levels are high and have been increasing at a steady rate for the last 18 years. The 2-furufal (2-FAL) trends provide estimated Degree of Polymerisation (DP) values in the range 291-316. End-of-life is widely considered to be a DP value of 200, therefore the furan data indicates that R3 will imminently reach its end of life.

Like SGT3, reactor R3 was visibly inspected. The base of the tank appeared to be deteriorating. Oil stains were observed on the pipework connecting the tank to the radiator. The conservator appears to be covered in some form of contamination and there are signs of corrosion at the bottom of the vessel.

It is the condition assessments undertaken on the plant, along with the calculated network asset risk of the plant, that were considered in combination to determine the need for including this refurbishment project on our list of core non-load schemes for RIIO T2.

From the assessments undertaken it can be concluded that SGT3 is beyond its design life and will continue to degrade if we are unable to successfully diagnose and resolve the root cause of the fault.

Attempts to diagnose SGT3's problems through conventional non-intrusive methods have been unsuccessful to date. Any further investigation is likely to be intrusive which carries additional risk and has no guarantee of success. As the nature of the problem is unknown, the benefits of refurbishment are limited, therefore, replacement is required.

Reactor R3 will imminently reach end-of-life and requires replacement.

The SGT3 and Reactor R3 protection will be 25+ years old by the end of RIIO-T2 putting it in the higher risk age group. Upgrading of the protection system will bring it up to modern standards and will provide full functionality including remote monitoring. When SGT3 and R3 are replaced in RIIO T2, a full protection replacement will be undertaken with relocation of the current 132kV protection panel to the 132kV control room.

3.3 Growth Need

Recent power system studies that have been undertaken in the area local to Tealing for prospective generator connections have shown no requirement to increase rating of the SGTs at Tealing. When considering the connection criteria from Section 2 of the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS), an increase in the rating of SGT3 only would not provide any additional firm network capacity at Tealing. The rating of SGT1 and SGT2 would also need to be increased in order to realise the firm capacity benefit. As a result, there is no load driver to install a larger capacity transformer as part of the non-load replacement project.

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 1 lists each option and a brief summary.

Table 1. Option summary table

Option	Option Detail	Taken Forward to Detailed Analysis
Do Nothing Option	Undertake no refurbishment work on the assets.	No
1	Rebuild SGT3 bay and R3 in the same location	Yes
2	Build SGT3 bay semi offline in adjacent bay to the west of existing bay.	No
3	Build SGT3 bay semi offline in adjacent bay to the east of existing bay.	No

Do Nothing Option

The do nothing option does not undertake any intervention on the transformer and reactor. 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.

NOT PROGRESSED TO DETAILED ANALYSIS

Option 1

This option considers;

- Replacement of SGT3 and R3 in the same location as the existing transformer. New SGT3, R3, associated ET and NER3, and 3R0 would be installed. The existing 132kV CVT will be replaced with a modern equivalent. As part of the bay rebuild new structures to carry 132kV busbar over the road would be required.
- The existing SGT3, R3, the associated Earthing Transformer (ET) and Neutral Earthing Resistor (NER), Reactor circuit breaker (3R0) and the bund and concrete structures are to be removed.
- New single-phase disconnectors including structures and bases in 275kV bay will be installed to create full independent busbar selection for the new SGT3.

- New Protection & Control relays panels will be installed for SGT3 to replace the existing scheme.

This option will result in the replacement of SGT3, R3 and associated equipment which meets the asset condition requirements. This option has the least amount of interface works with regards to the 275kV busbar and the 132kV busbar.

There might be a requirement to replace 132kV equipment if the bund requires extension, which needs to be investigated in detailed design. There are works proposed to replace the 275kV busbar for a load related reinforcement, therefore the two sets of works will need to be interfaced.

PROGRESSED TO DETAILED ANALYSIS

Option 2

This option considers;

- Replacement of SGT3 and R3 in an adjacent bay to the west of the existing transformer. New SGT3, R3, associated ET and NER3, and 3R0 would be installed. The existing 132kV CVT will be replaced with a modern equivalent. As part of the bay rebuild new structures to carry 132kV busbar over the road would be required.
- The existing SGT3, R3, the associated Earthing Transformer (ET) and Neutral Earthing Resistor (NER), Reactor circuit breaker (3R0) and the bund and concrete structures are to be removed.
- New single-phase disconnectors including structures and bases in 275kV bay will be installed to create full independent busbar selection for the new SGT3.
- New Protection & Control relays panels will be installed for SGT3 to replace the existing scheme.

This option will result in the replacement of SGT3, R3 and associated equipment which meets the asset condition requirements.

The existing SGT3 275kV switchgear would need to be moved to the new bay location and a new 132kV busbar arrangement would be needed to allow relocation of the SGT. There might also be a requirement to replace 132kV equipment if the bund requires extension, which needs to be investigated in detailed design. There are works proposed to replace the 275kV busbar for a load related reinforcement, therefore the two sets of works will need to be interfaced.

A design review undertaken concluded that there are significant spacing and access issues associated with Option 2. This is regarding the new SGT3 and the existing MSCDN 2, following the proposed semi offline build of SGT3 to the west of the current bay. As a result Option 2 has been ruled out, and is not progressed to detailed analysis.

NOT PROGRESSED TO DETAILED ANALYSIS

Option 3

This option considers;

- Replacement of SGT3 and R3 in an adjacent bay to the east of the existing transformer. New SGT3, R3, associated ET and NER3, and 3R0 would be installed. The existing 132kV CVT will be replaced with a modern equivalent. As part of the bay rebuild new structures to carry 132kV busbar over the road would be required.
- The existing SGT3, R3, the associated Earthing Transformer (ET) and Neutral Earthing Resistor (NER), Reactor circuit breaker (3R0) and the bund and concrete structures are to be removed.
- New single-phase disconnectors including structures and bases in 275kV bay will be installed to create full independent busbar selection for the new SGT3.
- New protection & control relay panels will be installed for SGT3 to replace the existing scheme.

This option will result in the replacement of SGT3, R3 and associated equipment which meets the asset condition requirements.

The existing SGT3 275kV switchgear would need to be moved to the new bay location and a new 132kV busbar arrangement would be needed to allow relocation of the SGT. There might also be a requirement to replace 132kV equipment if the bund requires extension, which needs to be investigated in detailed design. There are significant spacing and access issues between the new SGT3 and R1 as part of the move of the bay to the east of the existing bay. There are works proposed to replace the 275kV busbar for a load related reinforcement, therefore the two sets of works will need to be interfaced.

A design review undertaken concluded that there are significant spacing and access issues associated with Option 3. This is regarding the new SGT3 and R1, following the proposed semi offline build of SGT3 to the east of the current bay. As a result Option 3 has been ruled out, and is not progressed to detailed analysis.

NOT PROGRESSED TO DETAILED ANALYSIS

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

Of the three options that were discussed in section 4 Optioneering, only Option 1 has been considered for taking forward as a proposed solution to meet the existing asset condition requirements. Therefore, no CBA has been undertaken.

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 2. 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 this is a non-load project and the need is driven by the asset condition, the work would be required regardless of any changes to the energy scenarios.
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 optioneering exercise, the proposed solution we propose to proceed with in RIIO-T2 is Option 1 as detailed in the section 4 Optioneering of this justification report.

This option is the replacement of SGT3 and R3 in the same location as the existing transformer. SGT3, R3, the associated Earthing Transformer (ET) and Neutral Earthing Resistor (NER), Reactor circuit breaker (3R0) and the bund and concrete structures will be removed. New SGT3, R3, associated ET and NER3, and 3R0 will be installed. As part of the bay rebuild new structures to carry 132kV busbar over the road will be required, and the existing 132kV CVT will be replaced with a modern equivalent. New single-phase disconnectors including structures and bases in 275kV bay will be installed to create full independent busbar selection. New Protection & Control relays panels will be installed for SGT3 to replace the existing scheme. SGT3 and R3 will be on outage for the duration of the works.

Table 3: Outputs of Proposed Solution

Plant	Size of new plant	Replacement for
275/132kV transformer and ancillary plant	1 x 180MVA 275/132kV transformer 1 x 33kV reactor 1 x suit transformer protection 2 x 275kV disconnectors	1 x 180MVA 275/132kV transformer 1 x 33kV reactor 1 x suit transformer protection 1 x 275kV disconnector

5.4 Competition

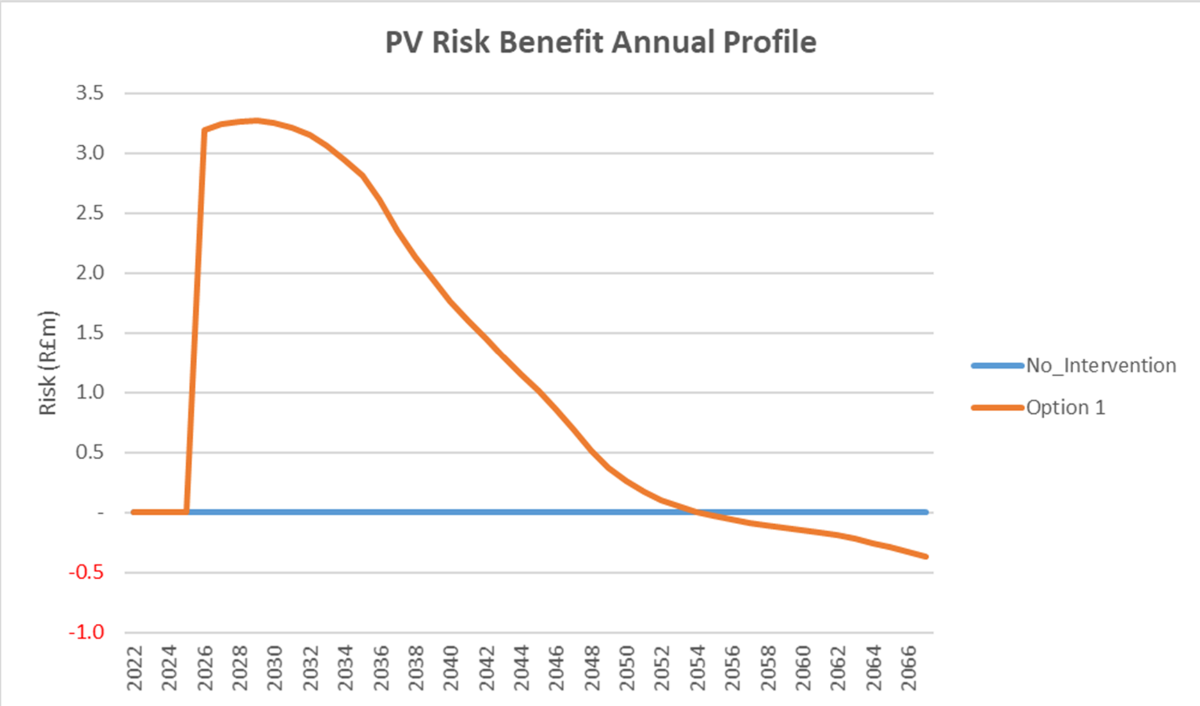
The Tealing Substation Works project is not flagged as eligible for early or late competition due to it being under Ofgem's £50m and £100m thresholds respectively.

5.5 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£56.0m. 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 intervention" scenario. The "no intervention" scenario assumes that when the asset experiences a catastrophic failure the asset is replaced.

Figure 2: Long Term Benefit of Proposed Intervention – rebuild the SGT bay and Reactor in the same location.



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£3.6m.

5.6 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 3. Carbon Footprint Modelling for the Tealing Substation Works.

	Project Information	Baseline (Option 3)
Project info	Project Name/number	
	Construction Start Year	2026
	Construction End Year	2028
Cost estimate £GBP	Embedded carbon	£ 229,572
	Construction	£ 4,226
	Operations	£ -
	Decommissioning	£ 1,935
	Total Project Carbon Cost Estimate	**£ 235,732**
Carbon footprint tCO2e	Embedded carbon	3,065
	Construction	56
	Operations	-
	Decommissioning	6
	Total Project Carbon (tCO2e)	**3,127**
Project Carbon Footprint by Emission Category	Total Scope 1 (tCO2e)	-
	Total Scope 2 (tCO2e)	-
	Total Scope 3 (tCO2e)	3,127
SF• Emissions	Total SF• Emissions 3 (tCO2e)	-

5.7 Cost Estimate

The cost of the preferred option for works at Tealing has been developed using rates from existing substation framework contracts and benchmarks delivered RIIO-T1 projects. The total cost for delivering the scope of works for the preferred solution is £9.3m. The works are planned to be completed within the RIIO T2 period.

6 Conclusion

This paper identifies the need for intervention on SGT3 and its associated R3 at Tealing 275/132kV substation. The primary driver for the scheme is the asset condition of the existing transformer and reactor.

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

- Removal of the existing SGT3, R3, the associated Earthing Transformer (ET) and Neutral Earthing Resistor (NER), Reactor circuit breaker (3R0) and the bund and concrete structures,
- Installation of a new SGT3, R3, associated ET and NER3, and 3R0 in the same location,
- Replacement of Protection and control panels. New disconnectors including structures and bases in the 275kV bay will be installed to create full independent busbar selection.

This scheme will cost £9.3m to deliver the following outputs and benefits during the RIIO T2 period;

- A long-term monetised risk benefit of R£56.0m,
- A reduction of total network risk calculated as R£3.6m,
- Improved operational flexibility and resilience in line with our goal to aim for 100% network reliability for homes and businesses.

The Tealing Substation Works project is not flagged as eligible for early or late competition due to it being under Ofgem's £50m and £100m thresholds respectively.

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

CONTENT DELETED