Scottish & Southern Electricity Networks

Beauly Substation Works

Core Non-Load

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 replacement of the three Supergrid Transformers (SGTs) and the 132kV busbar at Beauly substation. The primary driver for the scheme is the asset condition.

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

- Offline replacement of the 132kV AIS double busbar with a fully selectable 132kV GIS double busbar switchboard
- Online replacement of three 120MVA 275/132kV SGTs with 360MVA units

This scheme will cost £89.8m and will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetized risk benefit of R£363.7m;
- A reduction of network risk calculated at R£81.7m;
- Improved operational flexibility and resilience in line with our goal to aim for 100% transmission network reliability for homes and businesses;
- Improved safety on the site due to earthing improvements;
- A reduction in the volume of SF_6 on the network from the use of innovative non SF_6 equipment contributing to our goal of a one third reduction in greenhouse gas emissions.

The Beauly SGT and 132kV Busbar Upgrade scheme is above Ofgem's early competition threshold at £89.8m. However, the intervention driven by the asset condition need cannot be delivered by non-network means and the secondary load driver has a time critical delivery date which cannot accommodate an anticipated 18-24 month delay as a result of running a competitive tendering process. Furthermore, this project cannot be separated from the existing substation due to the inline replacement works and therefore competition is not appropriate.

[1] A Risk Based Approach to Asset Management

Name of Scheme/Programme	Beauly Substation Works
Primary Investment Driver	Asset Health (Non-Load)
Scheme reference/ mechanism or category	SHNLT2010
Output references/type	NLRT2SH2010
Cost	£89.8m
Delivery Year	RIIO-T2
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 condition-related work during the RIIO-T2 period (April 2021 to March 2026). The planned work is at Beauly substation, the location of which is shown in Figure 1 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.

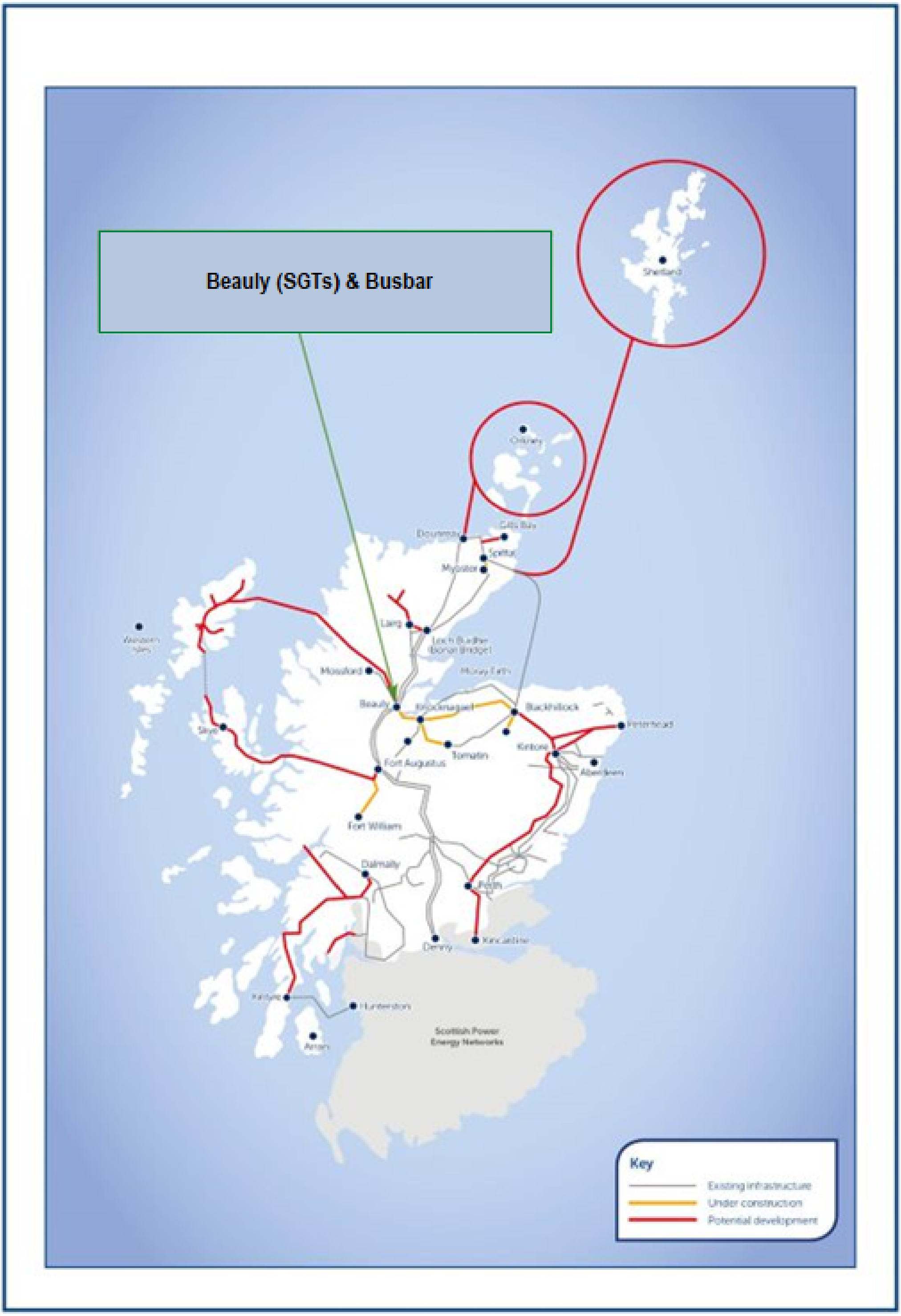
Section 7: Price Control Deliverables and Ring Fencing

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

Section 8: Outputs included in RIIO-T1 Business Plan

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

Figure 1: Geographical Representation



3 Need

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

3.1 Background

Beauly Substation is located approximately 17km west of Inverness. The substation is a key marshalling substation for 132kV, 275kV and 400kV circuits on the SHE Transmission Main Interconnected Transmission System (MITS).

The 132kV substation consists of an AIS 132kV double busbar with four 132kV double circuits connecting demand and generation, comprising:

- Two double circuits connecting approximately 200MW of hydro generation from the Affric/Beauly and Conon cascaded hydro schemes, as well as approximately 160MW of wind generation.
- A double circuit which connects the 132kV network heading north into the Caithness area via two Phase Shifting Transformers.
- One double circuit connecting the 132kV network along the Moray Coast to Keith, including Nairn and Elgin Grid Supply Points (GSPs).

Beauly Grid Supply Point (GSP) supplies the local network and is connected to the 132kV double busbar via two 45MVA 132/33kV Grid Transformers (GTs).

The 132kV double busbar is connected to a 275kV double busbar and onto the wider 275kV network via three 120MVA 275/132kV Supergrid Transformers (SGTs).

3.2 Asset Need

3.2.1 132kV Air Insulated Switchboard

The 132kV AIS double busbar switchboard (18 bays) requires replacement due to the deteriorating lead asset health as well as deterioration of the 132kV plant concrete support structures. [redacted], consideration has been given to network resilience and operability as well as the asset condition.

The substation was originally constructed in 1970 as a 132/33kV site. The busbar was constructed using concrete support structures all of which are now deteriorating with rebar exposed in numerous locations as well as crumbling concrete. Only one bay is selectable to the main and reserve bar. The circuit breakers which were replaced in 1997 using ABB LTB145 circuit breakers have become an operational and environmental hazard due to leaking SF_6 (this is a problem common to many other transmission network owners with circuit breakers of this make and model). The gas leakage presents a significant operability issue as the outages required to top the gas up are very labour intensive due to the non-selectable configuration. This leaves outgoing circuits on single circuit risk, in some cases constraining generation, and presents a significant impact on system security. While the main drivers for the replacement of the 132kV busbar is due to the asset health condition of the concrete structures and circuit breakers, the disconnectors also present operational issues since the majority are only operable manually.

The replacement of the 132kV busbar with a fully selectable double busbar configuration, as recommended by Appendix A of the NETS SQSS, provides the level of resilience, operability and security required of a key site such as Beauly. The recommendation from the Asset Condition Report[2] supports the decision to replace the 132kV AIS board with a GIS indoor alternative on the grounds of space constraint as well as the outage safety and resource constraints of an inline bay by bay replacement. Without intervention the assets will experience progressively greater leakage of the greenhouse gas sulphur hexafluoride (SF_6) which will lead to safety risk to staff / third parties if not mitigated. There are step potential issues for operatives working in and around the 132kV busbar, this safety issue needs to be addressed.

The 132/33kV Grid Transformers (GT) are non-selectable at Beauly therefore a busbar fault will trip a GT (plus multiple circuits) leaving Beauly customers supplied via a single GT. This would also result in the loss of approximately half the available circuits at Beauly for a busbar fault: the constraint costs to NG ESO would be significant. Beauly 132/33kV substation is our most inflexible 132kV substation and does not meet the current recommendations of Appendix A of the NETS SQSS. [redacted]

3.2.2 275kV Supergrid Transformers

The Supergrid Transformers at the Beauly site are all displaying increasing furan levels in their oil samples. This trend is indicative of insulation deterioration. In the case of SGT4 the oil analysis also shows acetylene levels indicative of an electrical fault having occurred.

There is an in increasing load being seen at this site and all three transformers have seen an increase in maximum duty from circa 70% to 90% between 2012 and 2018 based on PI data obtained by the Operations Team. This increased loading of the transformers will exacerbate the decline in the asset health as they are regularly operating within their forced cooling capabilities.

[2] Beauly 132 and SGT2,4,6 Asset Condition Report (Rev 1.20) [T2BP-ACR-0002]

Externally the SGTs are showing signs of leaking and rusting, again SGT4 is showing the most deteriorated condition.

3.3 Growth Need

Increased transformer loadings are being observed at this site and all three transformers have seen an increase in maximum duty from around 70% to 90% between 2012 and 2018, based on PI data. This data demonstrates that the concurrent occurrence of high levels of hydro and wind generation around Beauly and the wider Caithness area is significantly greater than the typical wider generation scaling used for SQSS Section 2 studies.

In February 2019, a generation connection offer was accepted which has triggered the reinforcement of Beauly substation as enabling works for the connection. This reinforcement requires an increase in capacity of the SGTs to 360MVA. The required capacity of the SGTs was calculated from system studies using generation scaling factors determined by the output from the PI data exercise described above.

The associated 275kV circuit breakers all require upgrading to allow for the installation of Point On Wave switching under this reinforcement.

3.4 Other Considerations

Beauly is a sensitive location with a long history of project work. Stakeholder engagement will be critical to a satisfactory delivery of these works and other closely linked projects proposed for the RIIO-T2 period.

The load and non-load elements required at Beauly will be delivered together to maximise efficiency. Other schemes proposed for RIIO-T2 include:

- Reconductoring of Beauly to Deanie 132kV overhead line circuits
- Kilmorack substation replacement
- Aigas substation replacement
- Culligran substation replacement
- Deanie substation replacement

In the interest of coordinated stakeholder engagement and efficient construction and commissioning the work discussed in this paper as well as the five noted above should be developed and delivered as a composite programme of works.

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 recommendation from the need, outlined in Section 3, means that intervention is required in the RIIO-T2 price control period so the “do nothing” option is not valid.

The new 132kV switchboard will result in all circuits being fully selectable providing full operational flexibility and compliance with the NETS SQSS.

Following on from the adoption of recent industry developments in the use of non-SF_6 insulating mediums the new GIS switchboard will be a non-SF_6 variant.

Table 1 – Options Summary

Option	Option Detail	Cost (£m)	Taken forward to Detailed Analysis?
1a	In-situ replacement of SGT 2, 4 & 6 and offline GIS 132kV board build to west of existing	89.8	Yes
1b	In-situ replacement of SGT2, 4 & 6 and offline GIS 132kV board build relocating telecoms building		No
2a	Offline replacement of SGT2, 4 & 6 and offline GIS 132kV board build to west of existing		No
2b	Offline replacement of SGT2, 4 & 6 and offline GIS 132kV board build relocating telecoms building		No

Option 1a

Remove and replace SGT2, SGT4 and SGT6 in turn at their current location. SGT2 and SGT4 are to be moved slightly to the west in order to ensure that SGT4’s fire damage zone does not encroach on the near-by overhead line. The existing Diesel generator is to be moved and its associated cables re-terminated in order to make space for SGT4 movement. The associated 275kV bays structures associated with each SGT will need reconfiguration. All three SGT bunds are to be removed and replaced with new spec compliant bunds. Additional noise enclosures are also to be included. The existing transformers are rated at 60/120MVA. In line with contracted generation connection agreements these transformers should be increased to 180/360MVA.

A new 132kV GIS building is to be built west of the existing 132kV AIS outside the existing substation fence line. The new GIS building will house a new double busbar 132kV GIS, new batteries and P&C panels. All 132kV connections are taken into the new 132kV GIS by either cable or GIB. All existing 132kV AIS structures are to be removed. The existing 132kV compound is to be levelled and covered in spec compliant chipping. Consideration should be given to the possible presence of PCB contamination when material is removed. Thought will be given to modifying the S/S boundary to improve screening if possible. Any tree felled to make way for the new GIS building will need to be compensated for with a planting regime elsewhere.

This option is compliant with all current specifications. The continued use of noise enclosures as well as the clearance of the 132kV AIS arrangement and creation of a GIS build presents an opportunity to improve the visual and noise impact of this substation.

PROGRESSED TO DETAILED ANALYSIS

Option 1b

Remove and replace SGT2, SGT4 and SGT6 in turn at their current location. SGT2 and SGT4 are to be moved slightly to the west in order to reduce the impact of the SGT4's fire damage zone on the near-by overhead line. The existing Diesel generator is to be moved and its associated cables re-terminated in order to make space for SGT4 movement. The associated 275kV bays structures associated with each SGT will need reconfiguration. All three SGT bunds are to be removed and replaced with new spec compliant bunds. Additional noise enclosures are also to be included. A new 132kV GIS building is to be built in place of the current telecoms building. This will require the telecoms building to be moved and all the associated plant and connections. The new GIS building will house a new double busbar 132kV GIS, new batteries and P&C panels. All 132kV connections are taken into the new 132kV GIS by either cable or Gas Insulated Busbar. All existing 132kV AIS structures are to be removed. The existing 132kV compound is to be levelled and covered in spec compliant chipping. Consideration should be given to the possible presence of PCB contamination when material is removed. Any tree felled to make way for the new GIS building will need to be compensated for with a planting regime elsewhere.

This option does not comply with current specifications on the treatment of fire damage zones, since the location of 132kV GIS building will encroach the fire damage zones of SGT2 and 4. As per Option 1a the continued use of noise enclosures as well as the clearance of the 132kV AIS arrangement and creation of a GIS build presents an opportunity to improve the visual and noise impact of this substation.

NOT PROGRESSED TO DETAILED ANALYSIS

Option 2a and 2b

These options are similar to options 1a and b, however these propose locating the new SGTs adjacent to the 400kV equipment on the western most edge of the exiting substation site. Both the HV and LV sides of the transformers would require long cable sections to make the connections back to the transformer HV and LV bays at the new and existing bay locations respectively.

These options are compliant with all current specifications. The SGT offline build presents the best emergency return to service response of the options considered. The clearance of the 132kV AIS arrangement and creation of a GIS build presents an opportunity to improve the visual and noise impact of this substation.

These options were not taken forward for further consideration due to the limitations that the cable installations would place on any future substation development. The cable routes would sterilise the grounds for future development of the 275kV and 400kV parts of the substation.

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

From the previous section there is only one option which is technically compliant with current engineering standards and which does not sterilise the substation for future development. Cost Benefit Analysis has therefore not been carried out.

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, only one option was taken forward to detailed analysis and therefore there is no impact on the preferred solution.

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. As there is only a marginal increase in capex to deliver the works at a higher capacity to accommodate the forecasted generation. The recently contracted generation triggers the need to install larger capacity transformers.
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

The scope of the proposed solution is the in-situ replacement of the SGTs and the offline replacement of the 132kV double busbar. The work is likely to require three outage periods to complete due to outage complexity. The project will be energised within the RIIO-T2 period. Table 2 below details the outputs.

Table 3 – Outputs from Preferred Solution

Plant	Size of new plant	Replacement for
132kV fully selectable double busbar GIS	20 x 132kV GIS bays	18 x 132kV AIS bays
132/275kV SGTs	3 x 180/360MVA	3 x 60/120MVA
275kV Circuit Breakers	3 x 275kV CB with POW	3 x 275kV CB

The load driven SGT upgrade can be accommodated with the in-situ replacement option and therefore does not contribute much to the decision-making process to the preferred solution. If the load driver persists during the development of the project, the design of 180/360MVA 275/132kV units can accommodate as the non-load driven 120/240MVA 275/132kV if required.

The works at Beauly 275/132kV substation is one project in a cluster of schemes in this part of the network. The timing and stakeholder engagement for the works should be considered alongside the following:

- Beauly – Deanie (BDN/BDS) 132kV OHL upgrade
- Aigas substation upgrade
- Kilmorack substation upgrade
- Culligran substation upgrade
- Deanie substation upgrade

The protection schemes on the 132kV circuit BDN/BDS and the inter-tripping to the four hydro generation connected sites at Aigas, Kilmorack, Culligran and Deanie is dependent on ageing pilot wire and Power Line Carrier (PLC) communications. In the interest of efficient and coordinated working this cluster of works in the Beauly area should be programmed such that the overhead line works are complete in advance of all substations works to allow the protection commissioning to be integrated via the new fibre on the BDN/BDS circuits.

5.4 Competition

All options for the intervention on the declining assets at Beauly are estimated to cost more than the £50m threshold for early competition. Addressing the condition and operational inflexibility of the 132kV switchboard can only be addressed by replacement with a fully selectable double busbar. The condition of the SGTs can only be addressed by replacement of these assets. There is therefore no contestable solution for the intervention at Beauly. The load driver at Beauly means that the delivery of the works is time critical and the 18 - 24 month estimate to run a competitive tendering process cannot be accommodated.

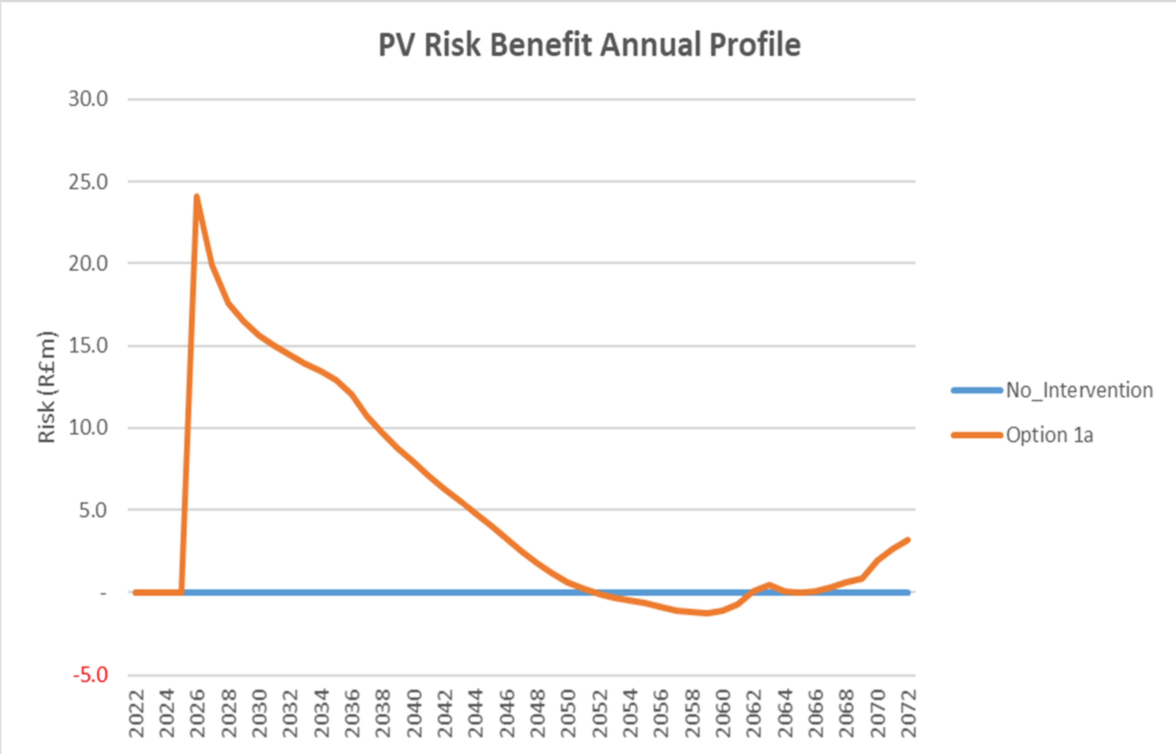
5.5 Risk Benefit

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 risk monetised benefit which would be realised through the completion of this project is R£363.7m. 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.

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£81.7m.

Figure 2: Long Term Benefit of Proposed Intervention – In situ replacement of GTs and offline GIS 132kV board west of site



5.5 Innovation & Sustainability

The installation of a GIS board at Beauly will employ a non-SF_6 filled solution in support of our Sustainability and Environmental policies.

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.

The results of analysis for this project are captured in the carbon footprint result in Table 4.

Table 3 – Carbon Calculation Summary

	Project Information	Baseline
Project info	Project Name/number	0
	Construction Start Year	2026
	Construction End Year	2028
Cost estimate £GBP	Embodied carbon	£ 849,999
	Construction	£ 363,838
	Operations	£ 1,237,703
	Decommissioning	£ 166,575
	Total Project Carbon Cost Estimate	**£ 2,618,116**
Carbon footprint tCO2e	Embodied carbon	11,350
	Construction	4,786
	Operations	5,412
	Decommissioning	479
	Total Project Carbon (tCO2e)	**22,026**
Project Carbon Footprint by Emission Category	Total Scope 1 (tCO2e)	4,985
	Total Scope 2 (tCO2e)	427
	Total Scope 3 (tCO2e)	16,614
SF_6 Emissions	Total SF_6 Emissions 3 (tCO2e)	4,773

5.8 Cost Estimate

The cost of the preferred option for works at Beauly has been developed using rates from existing substation framework contracts and benchmarks from delivered RIIO-T1 projects. The total cost for delivering the scope of works for the proposed solution is £89.8m.

6 Conclusion

This paper identifies the need for intervention on the 132kV busbar and the 132/275kV SGTs at Beauly substation. The primary driver for the scheme is the asset condition.

The proposed scope of work selected is:

- Offline replacement of the 132kV AIS double busbar with a fully selectable 132kV GIS double busbar switchboard
- Online replacement of three 120MVA 275/132kV SGTs with 360MVA units

This scheme will cost £89.8m and will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetized risk benefit of R£363.7m;
- A reduction of network risk calculated at R£81.7m;
- Improved operational flexibility and resilience in line with our goal to aim for 100% transmission network reliability for homes and businesses;
- Improved safety on the site due to earthing improvements;
- A reduction in the volume of SF_6 on the network from the use of innovative non SF_6 equipment contributing to our goal of a one third reduction in greenhouse gas emissions.

The Beauly scheme is over the £50m Ofgem threshold for early competition. However, the need cannot be delivered by non-network means and the secondary load driver has a time critical delivery date which cannot accommodate an 18-24 month period to undertake a competitive tendering exercise. Furthermore, this project cannot be separated from the existing substation due to the inline replacement works and therefore competition is not appropriate.

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 Plans

There were no outputs associated with this scheme included in the RIIO-T1 plans.