Scottish & Southern Electricity Networks

SSEN Transmission

RIIO-T2 Business Plan – T2BP-EJP-0031

Willowdale Substation 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 assets at Willowdale substation. The primary driver for intervention is the condition of the existing transformers and associated equipment.

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

- Replacement of GT1 and GT2; and,
- Replacement of the existing 132kV switchgear with GIS circuit breakers on six 132kV feeder bays and two GIS 132kV transformer bays, all within a new GIS hall. We propose to use an alternative to SF_6.

This scheme will cost £45.43m and will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetised risk benefit of -R£80.3m;
- A reduction of network risk calculated as R£7.7m;
- Improved operational flexibility and resilience in line with our goal to aim for 100% network reliability for homes and businesses; and,
- 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 Willowdale 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	Willowdale Substation Works
Primary Investment Driver	Asset Health (Non-Load)
Scheme reference/ mechanism or category	SHNLT2023
Output references/type	NLRT2SH2023
Cost	£45.43m
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 Willowdale 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.

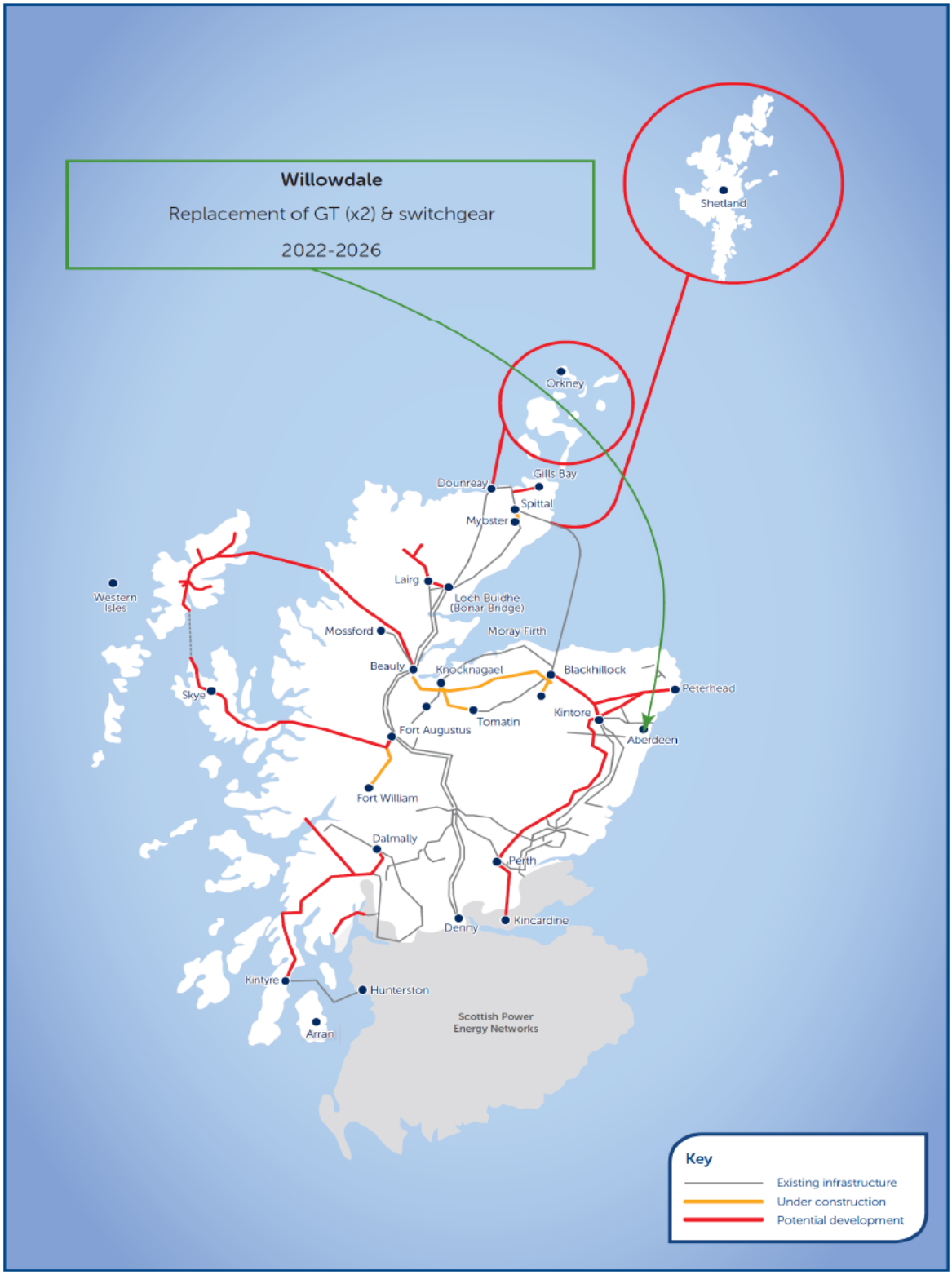
Section 7: Price Control Deliverables and Ring Fencing

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 - Map showing the Willowdale substation works on the SHET network



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

Willowdale 132/33kV substation is in the city of Aberdeen and is located less than 1 mile from the coast in the north east of Scotland. A mixture of residential and commercial properties surround the site and a railway line is located to the north east of the substation site.

Willowdale substation was constructed in 1963 and [redacted]. Willowdale substation has two 132/33kV 30/60MVA (ONAN/OFAF) Grid Transformers, connected to the distribution owned 33kV busbar via two SHE Transmission owned 33kV circuit breakers (1T0 and 2T0). [redacted] The transformers were manufactured in 1967 and at the end of the RIIO-T2 period they will be 59 years old. [redacted]

See Appendix A for a diagram showing the network connection of Willowdale substation.

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. Willowdale GT1 and GT2 are approaching their end-of-life due to multiple issues including; corrosion of the cooler banks, a reduction in cooling capability, tapchanger issues and concerns about paper insulation ageing.

The proximity of the site to the coast has led to severe corrosion of GT1 and GT2 cooler banks which has necessitated the removal of corroded radiator pipes. A site visit conducted in July 2018 confirmed the poor external condition of the transformers with severe corrosion and oil leaks noted.

Oil analysis shows that GT1 and GT2 have been experiencing oil quality issues for several years (acidity and dielectric dissipation factor). Of primary concern is the presence of acidity which accelerates the rate of paper insulation ageing and can lead to the formation of sludge which can impair cooling efficiency and further accelerate paper ageing. This is further compounded by the already reduced

[2] Willowdale Substation Works Asset Condition Report T2BP-ACR-0007

cooling capability of these units (due to the removal of radiator pipes) and poses a risk to the remaining life of the insulation.

An operational restriction is in place on the tapchangers of GT1 and GT2. In addition, following the tapchanger runaway incident in February 2018, both tapchangers now operate on fixed tap.

Kiosks have been fitted with an outer cover, however the inside of the kiosks are badly corroded and pose a risk to the integrity of the protection.

The grid transformers are situated in noncompliant bunds that contain defects and have no oil separators or bund guards. In addition, the associated earthing transformers don't have any bunds.

Circuit breakers 405 and 905 are generally weathered in appearance. There is evidence of seal failure and issues with moisture ingress which have previously led to micro switch failure and false gas alarms. Temporary measures have been taken on circuit breaker 405 in an attempt to weatherproof the plant. The structures of both circuit breakers are showing signs of corrosion. Circuit breakers 405 and 905 are unsuitable for the operating environment and require intervention to prevent their temporary or permanent loss.

Condition assessment reports have indicated that temporary repairs to trunking have taken place on the 33 kV circuit breakers 1T0 and 2T0. 1T0 and 2T0 scored an iSIM condition rating score of two which indicates apparent normal wear with intervention to be done in the next refurbishment, although the 33kV circuit breakers spares availability scored an iSIM condition rating score of four, which means that spares are difficult to source.

[redacted]

The Willowdale upgrade works and concurrent works at Persley 132kV substation give an opportunity to improve the circuit and protection arrangements for the Aberdeen ring. Therefore, protection on all the circuits passing through Willowdale should be considered for replacement with protection solutions which meet current standards. This would involve protection works at Persley, Clayhills, Redmoss and Craigiebuckler substations.

No system monitoring or fault recording is currently present at Willowdale and [redacted] this should be installed in RIIO-T2.

The recommendation from the condition assessment report for the RIIO-T2 period is to:

- Replace GT1 and GT2 plus associated equipment to prevent the temporary and/or permanent loss of these units.
- Replace 132kV circuit breakers 405 and 905 with ones suitable for the coastal environment.
- Add additional 132kV circuit breakers at Willowdale substation to the GT1 and GT2 circuits.
- Provide blackstart capability with upgrade LVAC and LVDC systems to address condition issues with the batteries and bring the site in line with the requirement for a minimum period of 120-hours substation resilience.
- Replace the full protection and control suite of GT1 and GT2, including auxiliary devices upon replacement of the transformers.
- [redacted]
- Install system monitoring to improve fault finding capabilities and the ability to perform any post-fault investigation.
- Replace the protection arrangements for JFW/JPW & JFE/JPE with a new standard 132kV protection solution as part of the wider Willowdale works, and concurrent works at Persley 132kV. This would involve remote end works at Persley, Clayhills, Redmoss and Craigiebuckler. Consider replacing the protection arrangements for WJ3 & WJ1 with a fully new standard 132kV protection solution as part of the wider Aberdeen strategy and wider Willowdale works.
- [redacted]

It is the condition assessments undertaken on the substation, along with the calculated network asset risk of the substation, 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.

3.3 Growth Need

Load profiles for GT1 and GT2 for the period of 2015 to 2018 have been downloaded from SHE Transmission Pi Historian database. The loading for GT1 and GT2 has rarely exceeded the 30MVA ONAN rating of the units and operates below the 60MVA OFAF rating. The Future Energy Scenarios (FES) out to 2050 have shown very limited growth in embedded generation on SHEPDs network at Willowdale, and there has been little to no generation activity at this GSP. The FES out to 2050 have shown that the winter peak demand at Willowdale GSP is expected to increase. However, the 60MVA transformers would maintain compliance with Section 3 Demand Connection Criteria of the National

Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) even with the FES forecasted demand increase. As a result, there is no load driver to install larger capacity transformer units 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	Like for like in situ AIS replacement of GTs and switchgear.	No
2	Build a new 132kV AIS/GIS solution on the current site footprint. Use 132kV GIS switchgear.	Yes
3	Offline build of a new 132kV AIS/GIS solution on a new site. Relocate cables to new site.	Yes

Do Nothing Option

The do nothing option does not undertake any intervention on the transformers or switchgear. 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.

Beyond the do nothing option three options are considered. All options consider replacement of the entire 132kV system with an improved busbar arrangement to improve network resilience and operability at Willowdale 132/33kV Substation.

Options 2, and 3 propose that the transformers are housed in buildings to meet current specification due to the location in proximity to the coast and the local residential and commercial environment.

Option 1

In situ replacement of GT1 and GT2, and associated equipment. Replace the existing 132kV circuit breakers and install AIS circuit breakers on six 132kV feeder bays and two 132kV transformer bays. Upgrade the existing battery system, and install system monitoring at the substation.

This option will result in the entire 132kV system at Willowdale being replaced which meets the asset condition requirements. The site layout will be reconfigured to provide a more resilient system.

This option would result in significant outages at the site in order to undertake the in situ replacement. A double circuit outage (outage of both GTs) would be required for one year. This would place a large number of customers at risk from a local distribution fault for an extended period of time. The constraints of the existing site mean that the layout would not meet engineering standards for fire safety and having indoor plant when in coastal environments. It also means that AIS circuit breakers could not be installed within the existing layout. As a result, this option is not to be taken forward for detailed analysis.

NOT PROGRESSED TO DETAILED ANALYSIS

Option 2

Construction of a new GIS solution on the footprint of the current site. Replace GT1 and GT2. Remove the existing 132kV circuit breakers and install GIS circuit breakers on six 132kV feeder bays and two 132kV transformer bays within a new GIS hall. Upgrade the existing battery system, and install system monitoring at the substation.

This option will result in the entire 132kV system at Willowdale being replaced which meets the asset condition requirements. The option to use GIS switchgear mitigates against the constraints imposed by the existing site as the land uptake is less than that required for AIS switchgear. We propose to use SF_6 free switchgear. This option also allows for one transformer to be taken out at a time, avoiding the requirement for double transformer outages.

PROGRESSED TO DETAILED ANALYSIS

Option 3

Offline build of a new GIS solution in a new location. Two new GTs and associated equipment would be installed at the new site, along with a new GIS busbar and a new 33kV GIS switchboard. The 132kV busbar would have six feeder bays and two transformer bays. The 33kV switchboard would include the two Transmission owned 33kV circuit breakers, along with distribution feeder circuit breakers. The equipment at the existing site would be decommissioned and removed.

This option will result in the entire 132kV system at Willowdale being replaced which meets the asset condition requirements. The option to use GIS switchgear would reduce the size of site required as the land uptake is less than that required for AIS switchgear. We propose to use SF_6 free switchgear.

This option would have reduced transformer outages compared to the other options as the build would be undertaken offline.

Significant Transmission and Distribution cable works would be required to relocate to the new site, which would require outages. There is also a lack of alternative sites available within the centre of Aberdeen, and the cost of the new site in the centre of Aberdeen would be significant.

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.

Option 2 meets the requirements of the condition assessment report recommendations. The works can be installed within the existing site boundaries.

Option 3 is similar to Option 2 but located at a new site. This option would meet the requirements of the condition assessment report recommendations. It would remove the Transformer outage requirements due to being an offline build, however it would have increased cable outages to move connections to the new site. Within Aberdeen city centre there are limited sites available, with only one potential site identified. The cost of land within the city centre is also a factor that needs to be considered.

5.1 Cost Benefit Analysis

Options 2 and 3 have been included in the Cost Benefit Analysis (CBA). The non-load requirement for the RIIO-T2 period is addressed through the baseline option – Option 2. The CBA is being undertaken to help inform which of the options is preferred from a cost benefit perspective.

NPV's for the two options were calculated and compared against each other. The output from the CBA is shown in Table 2.

Table 2. CBA results for the Willowdale Substation Works.

CBA Reference	Total Forecast Expenditure *(£m)*	Total NPV	Delta *(Option to baseline)*	Total NPV *(Incl. Monetised Risk £m)*
Baseline (Option 2)	-£45.83	-£42.71		-£9.98
Option 3	-£70.46	-£65.72	-£23.01	-£32.99

The CBA has shown that in the analysis of the two options, the Baseline Option 2 has a higher comparative NPV than Option 3. The difference between the total NPV for the Baseline Option 2 and Option 3 is £23.01m. When taking account of the monetised risk benefit provided by each option, Baseline Option 2 still has higher comparative NPV compared to Option 3. The preferred option is Baseline Option 2.

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 3. 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 CBA, Option 3 can be ruled out on the basis of the significantly higher NPV associated with it compared to Option 2. As a result of this Option 2 is the preferred solution.

Option 2 is the construction of a new GIS solution on the footprint of the current site. The 132/33kV GTs are replaced, and placed in new buildings to protect against the coastal environment the substation is located in. The 132kV switchgear is replaced with GIS switchgear in a GIS hall. 132kV circuit breakers are installed on each feeder.

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

5.4 Competition

The Willowdale Substation Works project is not flagged as eligible for early or late competition due to the cost of the scheme 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]).

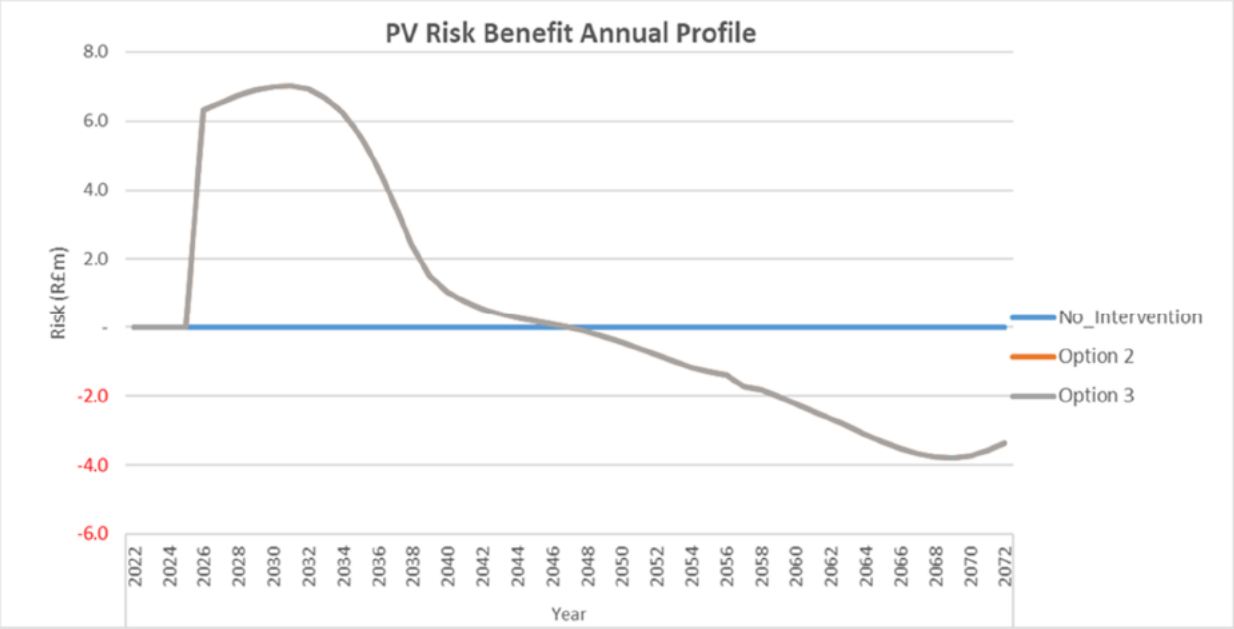
The long-term risk benefit which would be realised through the completion of this project is -£80.3m. The long-term benefit is derived by consideration of the risk of the asset experiencing a catastrophic

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.

The CBRM function which projects the 50-year view cannot currently model future interventions beyond T2. Therefore, some projects show a negative Long-Term Risk Benefit, particularly where additional assets are added, existing assets are refurbished or where the life of an asset is substantially less than the 50-year view.

The reason that the Long-Term Risk Benefit of this project is negative is due to additional assets that did not exist before. Although this provides better system security and selectability, the LTRB template does not take this into account, and projects the risk of all assets at the site in 50 years' time.

Figure 2: Long Term Benefit of Proposed Intervention – Rebuild in current footprint (Option 2) and Rebuild in a new compound (Option 3)



The long-term risk benefit for both options shown in Figure 2 follow identical profiles throughout their lifetime and as such, the graph displays only one line. 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£7.7m.

5.6 Innovation & Sustainability

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

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.

In terms of the results of analysis for this project, which are captured in the carbon footprint results table, Baseline Option 2 is the option that delivers the lowest comparative carbon footprint, which does align with our option selection in the CBA.

Table 4. Carbon Footprint Modelling for the Willowdale Substation Works.

	Project Information	Baseline (Option 2)	Option3
Project info	Project Name/number	Baseline (Option 2)	Option 3
	Construction Start Year	2026	2026
	Construction End Year	2028	2028
Cost estimate £GBP	Embodied carbon	£ 207,808	£ 323,654
	Construction	£ 99,774	£ 268,362
	Operations	£ 596,644	£ 596,651

	Decommissioning	£ 45,679	£ 122,863
	Total Project Carbon Cost Estimate	**£ 949,906**	**£ 1,311,530**
Carbon footprint tCO2e	Embodied carbon	2,775	4,322
	Construction	1,312	3,530
	Operations	2,609	2,609
	Decommissioning	131	353
	Total Project Carbon (tCO2e)	**6,827**	**10,813**
Project Carbon Footprint by Emission Category	Total Scope 1 (tCO2e)	2,452	2,452
	Total Scope 2 (tCO2e)	156	156
	Total Scope 3 (tCO2e)	4,218	8,204
SF_6 Emissions	Total SF_6 Emissions 3 (tCO2e)	2,410	2,410

5.7. Cost Estimate

The cost of the preferred option for works at Willowdale 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 £45.43m. The works are planned to be completed within the RIIO-T2 period.

6 Conclusion

This paper identifies the need for intervention on the assets at Willowdale substation. The primary driver for intervention is the condition of the existing transformers and associated equipment.

Three intervention options were identified for this scheme. Of these, two options were taken forward and considered for detailed analysis.

The CBA concluded that Option 2 is deemed the best value option, delivering a higher NPV compared against Option 3.

The proposed scope of works is:

- Replacement of GT1 and GT2; and,
- Replacement of the existing 132kV switchgear with GIS circuit breakers on six 132kV feeder bays and two GIS 132kV transformer bays, all within a new GIS hall. We propose to use an alternative to SF_6.

This scheme will cost £45.43m and will deliver the following outputs and benefits during the RIIO-T2 period:

- A long-term monetised risk benefit of -R£80.3m;
- A reduction of network risk calculated as R£7.7m;
- Improved operational flexibility and resilience in line with our goal to aim for 100% transmission network reliability for homes and businesses; and,
- To reduce the volumes of SF_6 on the network by using innovative non-SF_6 solutions.

The Willowdale 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 can 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 are no outputs associated with this scheme included in our RIIO-T1 plans.

Appendix A: Willowdale network connection diagram