national gas transmission

ENGINEERING JUSTIFICATION PAPER (EJP)

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Site Assets - Preheating, Filters & Contents Pipework

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RIIO-GT3 NGT_EJP02

Contents

1 Summary Table

Table 1: Summary table for Preheating, Filters and Pipework Site Assets EJP

Name of Project	Site Assets		
Scheme Reference	NGT_EJP02_Site Assets - Preheating, Filters & Pipework_RIIO-GT3		
Primary Investment Driver	Asset Health		
Project Initiation Year	FY2027		
Project Close out Year	FY2031		
Total Installed Cost Estimate (£, 2023/24)	108,547,737.16		
Cost Estimate Accuracy (%)	+/- 30%		
Project spend to date (£, 2023/24)	0		
Current Project Stage Gate	ND500 4.0		
Reporting Table Ref	6.4		
Outputs included in RIIO-T2 plan	No		
Spend Apportionment	RIIO-T2	RIIO-GT3	RIIO-GT4
	£1.59	£106.22	£0.74

2 Executive Summary

2.1.1 This paper requests £108.55m (2023/24) baseline funding in RIIO-GT3 for asset health investments on our **preheating, filters** and **pipework** assets. It represents 90% of our Site Assets investment in RIIO-GT3. Asbestos, Stabbings and Redundant Assets are covered in a separate but linked EJP. Overall, across our Site Assets we are intervening on 275 sites which represents 53% of National Transmission System (NTS) sites based on known and forecast defects. Table 2 summarises the split of funding requested between this EJP and the associated EJP.

Table 2: Funding requested £m (2023/24)

EJP	Funding Request
This EJP (Preheating, Filters and Pipework)	108.55
Associated EJP (Asbestos, Stabbings and Redundant Assets)	41.04
Total for Site Assets	**149.59**

2.1.2 The primary driver for this investment is to maintain compliance with various legislation including Pressure System Safety Regulation (PSSR) and Pipeline Safety Regulations (PSR). This investment is also impacted by Asset Deterioration, Defects, Health & Safety and Operational drivers. If we do not progress these investments, it could lead to a need to isolate assets which would lead to loss of supply.

2.1.3 2004 interventions across the Preheat, Filters and Pipework site assets are required to ensure stable network risk is maintained during RIIO-GT3. This represents 92% of Site Assets interventions. This delivers £1.14m of NARMS benefit. The remaining 8% is covered in the associated NGT_EJP01_Site Assets - Asbestos, Stabbings and Redundant Assets_RIIO-GT3 EJP.

2.1.4 Our Site Assets covered in this EJP include modular boiler packages, heat exchangers, water bath heaters, mainline filters, coalescing filters, above ground pipework & cladding, pits and pipe supports, and below ground pipework and above ground installation (AGI) inspection tool. We considered different types of interventions to establish an optimal programme that would deliver desired regulatory outputs. In summary, we are proposing the interventions mix summarised in Table 3.

Table 3: RIIO-GT3 intervention mix - Sites Assets: Preheating, Filters and Pipework

	Preheating	Filters	Pipework	Total
RIIO-GT3 volumes	[redacted]	[redacted]	[redacted]	**2004**

2.1.5 In RIIO-T2 we have delivered [redacted] across our **Preheat, Filters** and **Pipework** assets than our original allowance of 734.7 interventions as shown in Table 4, this was due to efficiencies realised during the period. The percentage cost increase between the business plan and forecast delivery is higher than the corresponding percentage volume increase. The reason for this is due to the work mix site specific interventions scopes resulting in higher unit costs than the generic scopes used to establish baseline allowances. The further growth in RIIO-GT3 proposed intervention volumes is a consequence of the continued deterioration of these assets shown through actual, surveyed, and forecast defects. Additionally, RIIO-T2 interventions are providing us with greater clarity of remedial works required. This is reflected in the increase in costs.

Table 4: RIIO-T2 vs RIIO-GT3 (£m, 2023/24)

	RIIO-T2 Business Plan	RIIO-T2 Forecast Delivery	RIIO-GT3 Business Plan
Interventions	[redacted]	[redacted]	2004
Investment	[redacted]	[redacted]	£108.55m

2.1.6 We need to deliver a stepped increase in Preheat, Filters and Pipework defect rectification during RIIO-GT3 to ensure future network risk levels are not compromised.

2.1.7 The deliverability of this work has been assessed and we have high confidence that this can be delivered during RIIO-GT3 because we have taken into account interactions between outage requirements and other investments. The profile of Site Infrastructure investment, covering Preheat, Filters and Pipework site assets for RIIO-GT3 is shown in Table 5. The cost profile represents only the Preheating, Filters and Pipework interventions which are part of the wider asset health interventions on the NTS.

Table 5: RIIO-GT3 funding request for Preheat, Filter and Pipework Site Assets (£m, 2023/24)

Asset Sub-Group	2026	2027	2028	2029	2030	2031	2032	Total	Funding Mechanism
Preheating	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	19.32	Baseline
Filters	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	2.80	Baseline
Site Pipework	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	86.42	Baseline
Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	**108.55**	

3 Introduction

3.1.1 This Sites Assets paper covers the following range of assets:

- **Preheating** – assets used to regulate the temperature of gas: these include modular boiler packages, heat exchangers, and water bath heaters.
- **Filters** – assets that remove dust and debris from the gas flow to protect plant and ensure gas meets gas quality specifications in accordance with Gas Safety (Management) Regulations (GS(M)R)
- **Site Pipework** – comprising pipe supports, pits, lagging and cladding, and our AGI Inspection Tool used to support our gas transmission assets.

3.1.2 In line with our approach for our RIIO-T2 Uncertainty Mechanism (UM) for Plant and Equipment, we have followed where possible a quantitative approach. All asset programmes are bottom-up plans built using defect, redundancy, and obsolescence information (verified by stakeholders across the business) combined with investments recommended by Predictive Analytics (PA).

3.1.3 This EJP is linked to, and cognisant of the NGT_EJP01_Site Assets - Asbestos, Stabbings and Redundant Assets_RIIO-GT3 EJP, NGT_EJP024_Valves: PCVs and FCVs_RIIO-GT3 EJP, NGT_EJP023_Valves: Actuators_RIIO-GT3 EJP, NGT_EJP022_Valves: Valves_RIIO-GT3 EJP and NGT_EJP06_Gas Quality, Metering and Telemetry_RIIO-GT3 EJP.

3.1.4 The scope of this document is aligned with our Asset Management System (AMS) and relates to our *Meeting our critical obligations every hour of every day* and *Delivering a resilient network fit for the future* Business Plan Commitments (BPCs). More information on our AMS and a description of our commitments is provided in our NGT_A08_Network Asset Management Strategy_RIIO_GT3 annex and our BPCs are detailed within our NGT_Main_Business_Plan_RIIO_GT3

3.1.5 This EJP has been structured as shown in Figure 1 to cover three sub-themes of site assets, each with their independent drivers. There are sections in this EJP that are common to both Site Assets EJPs and these are summarised in Figure 1, too.

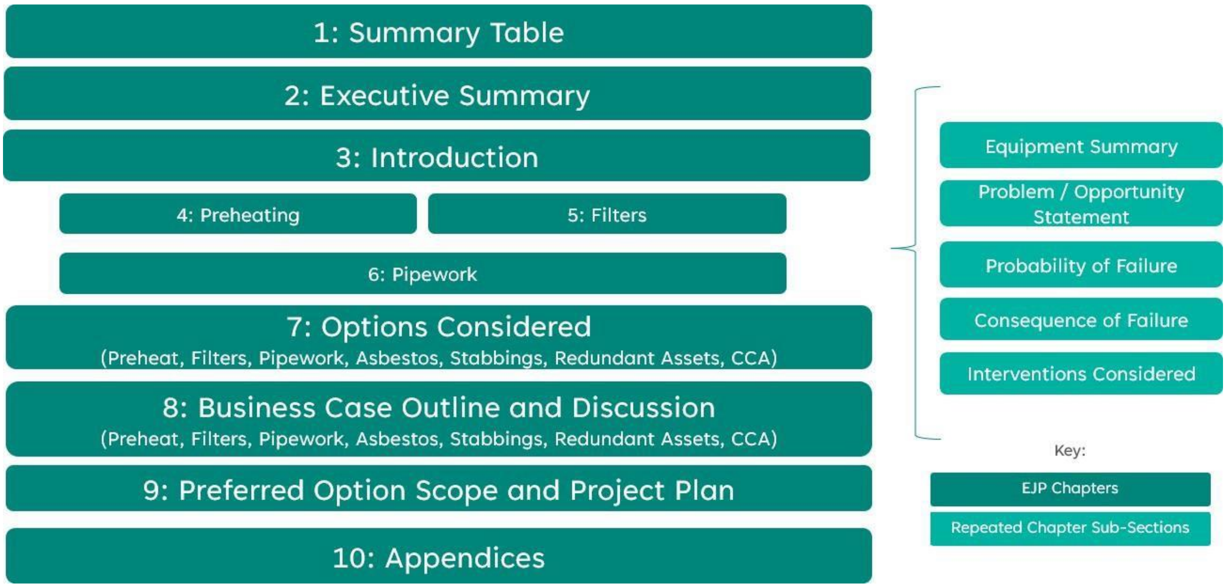

Figure 1: Document Structure of Preheating, Filters and Pipework Site Assets EJP

4 Preheating – £19.3m (2023/24)

4.1 Equipment Summary

4.1.1 Preheating assets regulate temperature of gas prior to the pressure reduction processes. When natural gas is reduced in pressure, it also reduces in temperature. To counteract this Joules Thompson effect, preheating assets compensate for temperature losses to ensure system temperature parameters are met. The main assets within preheating include the following as illustrated in Figure 2. Additional information on this equipment group such as the health score at the beginning and end of the price control and monetised risk are provided in the accompanying NGT_IDP01_Portfolio EJP Site Assets_RIIO-GT3.

- Modular boiler packages.
- Heat exchangers.
- Water bath heaters.

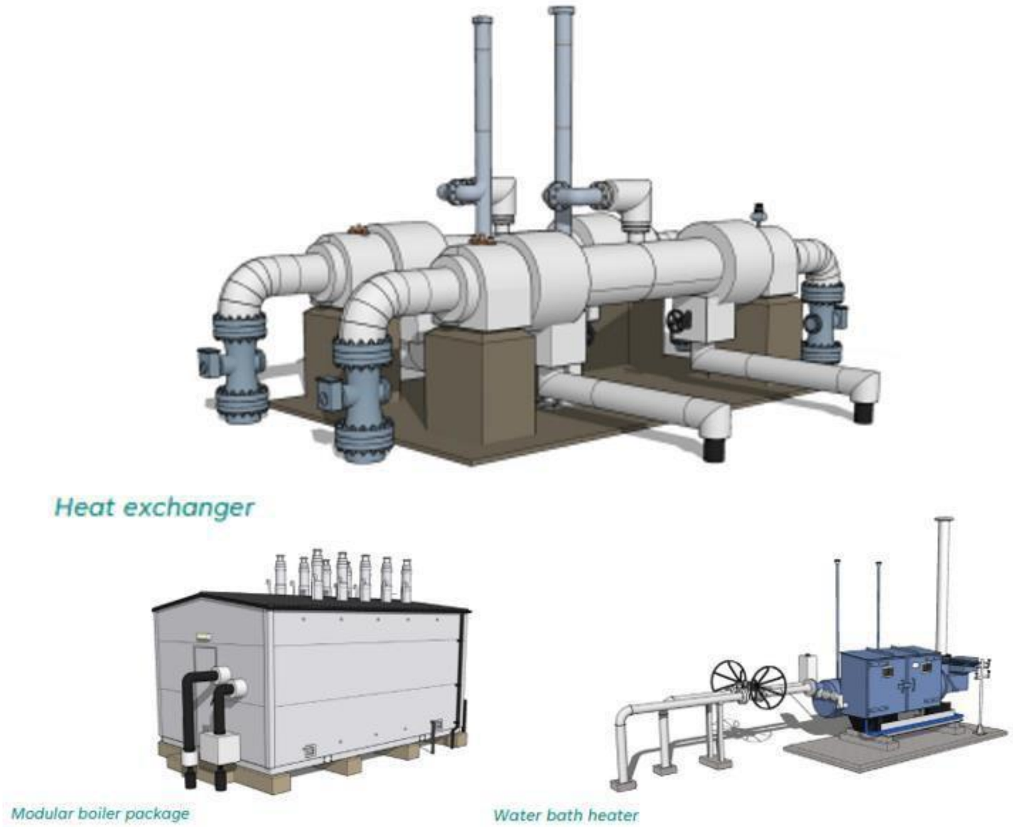

Figure 2: Preheating assets

Modular Boiler Packages

4.1.2 Modular boiler packages comprise a group of boilers arranged in a systematic way to heat water in a closed-circuit loop. The system also contains pumps and pipework to route heated fluid via a heat exchanger. They are usually housed within a standalone building. Modular boiler systems with heat exchangers or systems with water bath heaters are installed in an N+1 configuration. Where "N" equals the number of boiler modules or water bath heaters required to meet duty, giving the system redundancy and to facilitate maintenance.

4.1.3 Boiler houses vary across the NTS, with more recent installations being completely self-contained as a skid based modular building pre-assembled offsite allowing for quicker installation and commissioning. The hot water is pumped from the boiler house to the heat exchanger where heat is transferred from the system fluid to the process gas.

Heat Exchangers

4.1.4 Warm water from the boilers is passed through the heat exchanger which heats the gas flowing through the system. Within the heat exchanger, gas flows through small diameter tubes that are housed within the shell. The outer shell circulates the heated water.

4.1.5 To be efficient, shell and tube heat exchangers utilise round small tubes creating a large surface. As pressure vessels, heat exchangers are subject to Pressure Systems Safety Regulations (PSSR) legislation which drives inspection and validation of the assets and associated remediation of any defects found.

4.1.6 An integral component of the heat exchangers is bursting discs. They are used as pressure relief devices equipped with burst sensors which trigger an alarm once the disc bursts.

Water Bath Heaters (WBH)

4.1.7 An alternative to modular boilers, water bath heaters are indirect heaters which comprise carbon steel firetubes which lie below either one gas coil, or a series of seamless steel gas coils. These are immersed in a bath of water within a shell constructed from thin-walled carbon steel.

4.1.8 Firing a burner into the firetube enables heat to be transferred to the surrounding water. Since the gas coils are immersed in the water, the heat absorbed by the water is then passed directly onto the gas in the coils. The gas is therefore heated indirectly by the burner/firetube.

4.1.9 Table 6 summarises the Preheating assets on the NTS. There are more interventions associated with preheating assets than the number of assets summarised in Table 6. The reason there are more interventions than assets is some of these interventions are on different parts/components of the preheating systems and there are also 44 new interventions around gas detection. This is further elaborated in Section 4.5.

Table 6: Preheating assets

Preheat Asset	Quantity	Notes
Modular boiler package	21	N/A
Water bath heater	2	Excludes compressor stations
Heat exchangers	75	N/A

4.2 Problem / Opportunity Statement

Why are we doing the work and what happens if we do nothing?

4.2.1 Lack of investment in preheating assets will result in being non-compliant with legislation and being unable to effectively regulate the temperature of gas on the NTS which would lead to asset failures with the potential to disrupt connected customers operations. It can also lead to negative financial repercussions.

4.2.2 Modular boiler packages and associated controls range from new installations to older ones, in some cases containing obsolete parts. Some packages are towards the end of their expected life (15 to 20 years) and will start to encounter Programmable Logic Controller (PLC) issues along with material degradation of internal components. Numerous historical issues encountered have been due to boilers coming to end of their life. Failures were associated with breakdown of boilers and inability to repair due to obsolescence, once one boiler in the package fails the others tend to follow shortly afterwards.

4.2.3 WBHs are aging assets which are unreliable, inefficient, difficult to maintain, beyond design life and suffer from corrosion. Significant corrosion and loss of wall thickness on WBH gas coils have been found during inspections leading to assets being isolated. WBH control systems are obsolete and WBHs are prone to reliability issues especially when normal operation is required, usually during the winter period. Without intervention, WBHs will be unable to provide suitable preheating which could impact consumers.

4.2.4 Corrosion related failure is also applicable to heat exchangers which similarly operate with constant contact with water. Without intervention to address these known and forecast issues, modular boilers may become inoperable or need to be isolated due to integrity concerns.

4.2.5 An additional risk posed by gas heating assets is the potential for gas leaks within a confined space. Whereas compressor cabs always include gas detection, our older boiler houses do not consistently include this precaution. Operators of Major Accident Hazard (MAH) gas processing plant generally regard installation of gas detection as being recognised good practice in the buildings that can be occupied or also line of sight gas detection around site perimeter, where the site has proximity to other occupied facilities.

4.2.6 The key drivers for investment in preheating assets are summarised in Table 7.

Table 7: Categories of drivers for Preheating

Driver Category	Description
Legislation	Compliance with PSSR through appropriate inspections to identify defects and take remedial actions.
Safety	Ensuring that we take all necessary measures in the vicinity of MAH facilities or commercial and industrial premises to prevent release of substance, fire or explosion that causes serious danger to human health or the environment.
Asset Deterioration	The performance of preheating assets deteriorates with age. Factors such as fatigue (pressure and temperature cycling, contamination, over pressure, vibration, erosion and abrasion can all affect the integrity of the assets.

What is the outcome that we want to achieve?

4.2.7 We are seeking funding through this submission to ensure that the following outcomes are achieved:

- Meet legal requirements, including compliance with PSSR to prevent serious injury from the hazards of stored energy.
- Manage deterioration of the assets such that they do not limit availability, performance or cause damage to other assets on the NTS or those of consumers.

- Provide benefit to consumers through optimised investment to ensure the preheating assets meet their performance duty requirements, whilst balancing cost and risk.

How will we understand if the spend has been successful?

4.2.8 The investment plans will be considered to be successful when:

- We demonstrate continued compliance with PSSR and PSR and other legislative requirements.
- We have stabilised, and where required remediated, preheating asset deterioration and specific defect issues.
- We have ensured that preheat assets do not result in a loss of gas temperature regulation, present a safety risk, and are not a limiting factor on availability or performance of the NTS.

Narrative Real Life Example of Problem

4.2.9 Two examples will be provided in this section.

4.2.10 In 2020, there was a significant, HSE notifiable, Loss of Containment (LOC) within a Pressure Reduction Stream (PRS) house at the [redacted]. Without gas detection, it was fortunate that a passing operator noticed the noise of escaping gas. The leak lasted several hours before action could be taken to safely isolate and depressurise the PRS. It was also fortunate that there was no injury, fatality, major equipment damage or loss associated with this incident. Had there been gas detection installed within the PRS building or around the site perimeter the loss of containment would have been minimised.

4.2.11 In 2022 and 2023 surveys were conducted, by [redacted], a third party who specialises in industrial boilers, primarily targeted at older sites and those with older modular boiler packages to identify design issues, highlight current obsolete items and review maintenance records. The service life forecast in the reports broadly aligned to what is experienced on the NTS as well as Chartered Institution of Building Service Engineers (CIBSE) guidance. The consistent outcome of all the reports was that the boiler packages were suffering from performance, age and obsolescence issues. Without intervention to address these known and forecast issues, the modular boilers may become inoperable or need to be isolated due to integrity concerns. This has a detrimental impact on the necessary heating of gas which would impact consumers.

Project Boundaries

4.2.12 The boundary of spend covers preheating assets across the NTS. Intervention options consider Heat Exchanger, Modular Boiler or Water Bath Heater systems and the interconnecting pipework.

4.3 Probability of Failure

Failure Modes

4.3.1 Probability of failure (PoF) has been assessed utilising historical defects, results from surveys and utilising our Network Asset Risk Metric (NARMs) model. This model is built within our copperleaf asset management decision support tool to assess the forward-looking probability of failure. This provides a different lens to consider in addition to looking at historically captured defects.

4.3.2 Likely failure modes for preheating assets with an average proportion of failures of 0.5 or above are provided in Table 8, the full list of failure modes is available in the NARMS methodology.

Table 8: Preheating failure modes

Failure Mode	Average Proportion of Failures
Corrosion no leak	0.59
Loss of gas quality information	0.87

4.3.3 When applied to the asset count with an assumption that no investment is made, a forecast of failures across the RIIO-GT3 period is produced, shown in Table 9. The average failure rate represents the proportion of that asset type with an unresolved failure. The forecast failures per year shows the quantity of new failures modelled to occur each year.

Table 9: Forecasted failures

Asset Type	No. of Assets	Cumulative Average Defect Rates					Forecast Failures per Year				
		2027	2028	2029	2030	2031	2027	2028	2029	2030	2031
Mechanical (A.2.3)-Heat Exchangers	[redacted]	0.61	0.63	0.64	0.66	0.68	16.78	16.35	16.36	15.86	15.50
Mechanical (A.2.3)-Heat Exchangers-Plate Fin	[redacted]	0.96	0.96	0.96	0.96	0.96	0.04	0.02	0.02	0.02	0.02
Mechanical (A.2.3)-Heaters and Boilers	[redacted]	0.79	0.81	0.82	0.84	0.86	15.23	16.69	16.65	17.70	18.13
Mechanical (A.2.3)-Heaters and Boilers-Electric Heater	[redacted]	0.76	0.79	0.83	0.87	0.90	4.85	5.16	5.62	5.85	5.09

Asset Type	No. of Assets	Cumulative Average Defect Rates					Forecast Failures per Year				
		2027	2028	2029	2030	2031	2027	2028	2029	2030	2031
Mechanical (A.2.3)-Heaters and Boilers-Modular Boiler	[redacted]	0.59	0.61	0.64	0.67	0.70	5.53	5.63	6.02	6.07	6.32

Historic Defects

4.3.4 Analysis of historic data, highlighted in Figure 3 shows the majority of defects being raised against heaters and heat exchangers. Common attributes include corrosion and metal loss. This is the number of defects raised and not the date the defect manifested – we might not have found the defect for a while. The 2024 data represents what has been captured to date in our defects database and does not represent the entire year.

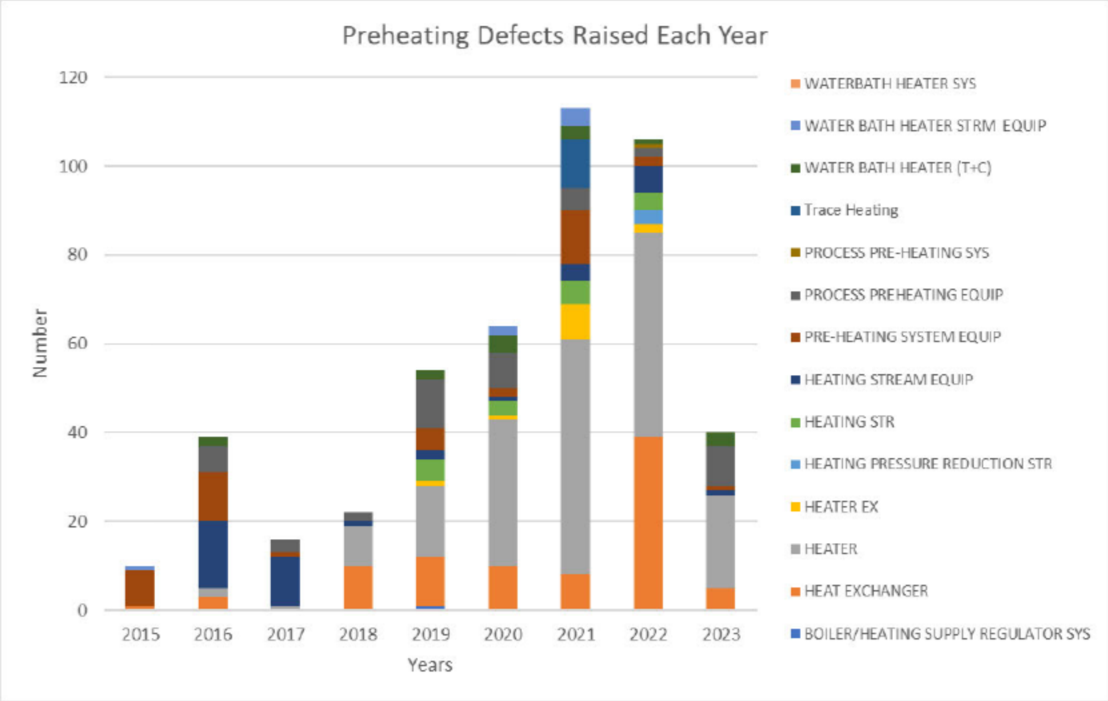

Figure 3: Historic defects raised each year

Probability of Failure Data Assurance

4.3.5 The NARMS Probability of Failure data was sourced from a Power BI dashboard, with data supplied from our Copperleaf asset management decision support system. This data was used in predicting future defects and failures of the preheating assets if no investment was made and also for conducting Predictive Analytics (PA) assessment described in further detail in Chapter 7 and Chapter 8.

4.3.6 An extract from our defect management system was undertaken on [redacted], with data analysis undertaken based on the columns of data exported from the system.

4.3.7 Probability of failure data has also been determined based on surveys conducted by our external partners, Armstrong Fluid Technology. The extract from our defect management system and outputs from our surveys was used to prioritise derivation of the bottom up volumes of investments in our plan.

4.4 Consequence of Failure

4.4.1 Table 10 presents the consequence of failure should the Preheating assets fail.

Table 10: Preheating consequence of failure

Impact / Consequence			
Availability	**Environmental**	**Financial**	**Safety**
If heat exchangers do not pass PSSR inspection satisfactorily, they cannot return to service until remediation work is completed and the PSSR inspection is repeated, therefore impacting the ability to heat gas to provide energy to consumers.	N/A Poorly performing and older boiler packages are likely to emit more GHGs than modern packages. Gas detection systems will help highlight gross leaks at sites and minimise methane losses in the system.	As part of complying with PSSR, any action taken by HSE arising from an issue could result in significant financial penalties. If preheating assets do not operate as intended, there is a risk that gas would not be suitable for supplying customers. If out of specification gas was to leave the NTS to customers, commercial actions may be taken leading to financial impacts and disruption to supply. Financial impacts would also arise from leaking assets due to emissions. Loss of containment would have significant safety, environmental and financial consequences.	PSSR exists to prevent serious injury from the hazard of stored energy. Failure to comply with these regulations could lead to serious injury and actions by the Health & Safety Executive (HSE). PSSR are appliable to heat exchangers. Leaks arising from asset deterioration also pose health and safety risks. Loss of containment could be catastrophic to plant, equipment, and people. Any gas escape within boiler houses poses a risk to personnel entering the buildings where build-up of gas could occur.

4.4.2 In cases where preheating is required for other functions of the NTS (e.g., pressure reduction at compressor stations) there may be an impact to the availability of these functions. However, specific interventions related to compressor fuel gas is covered in the NGT_EJP27_St Fergus: Rotating Machinery_RIIO-GT3 EJP.

4.5 Interventions Considered

4.5.1 Replacement, refurbishment/repair and deferral of intervention options were considered. However, deferral of interventions has been discounted due to the severity of defects and the need to remain legislatively compliant.

Counterfactual (Do nothing)

4.5.2 The counterfactual intervention considers no specific preheating assets intervention to be undertaken in RIIO-GT3. We will continue to conduct PSSR inspections to meet legislative requirements but would not progress any remediation. This would not address defects, would result in further degradation leading to isolation of assets. The resultant impact would be reduced preheat capability and reduced NTS resilience. This intervention is therefore not being progressed.

Heat Exchanger PSSR Inspection

4.5.3 This intervention involves conducting major (12 yearly) PSSR inspections, and progress all required defect remediation, to meet legislation which includes removing internal gas tubes for Non Destructive Testing / Magnetic Particle Inspection (NDT/MPI) examinations on both tubes and shell. The benefit of this intervention is that it provides investment certainty. In addition to meeting statutory requirements, it ensures availability of assets. If the Heat Exchanger is a twin-stream version and the stream isolation valves are in good condition an outage should not be required as typically, one exchanger is removed, inspected and then refitted followed by the other one.

Exchanger PSSR Bursting Disk Replacement

4.5.4 This involves replacing heat exchanger bursting discs either due to disc splitting, after a set period due to degradation or as part of preventative investment in addition to conducting PSSR inspections on the pressure containing elements of the Heat Exchanger. The benefit of this intervention is that it provides investment certainty as actual defects discovered are immediately remediated.

4.5.5 If the Heat Exchanger is a twin-stream version and the stream isolation valves are in good condition an outage should not be required as typically, one exchanger is replaced followed by the other one.

Refurbish Water Bath Heater

4.5.6 This intervention restores the WBH to original functionality and capability through welding repairs NDT inspection, pressure testing and recoating. Burner control system and regulators are also overhauled with all soft parts replaced. The benefit is that this intervention utilises existing infrastructure and provides six to ten years operational life. Depending on the redundancy built into a site, this intervention could require an outage.

Replace Modular Boiler Package

4.5.7 This intervention results in the installation of a new boiler package within existing boiler house/enclosure. The benefit of this intervention is that the new package can be adequately sized for its intended task and restores the original design intent of the boiler. Where the boiler packages are installed in an N+1 configuration one boiler package can be replaced while the other one provides redundancy.

Replace Modular Boiler Package Including Building

4.5.8 This intervention involves installation of a boiler package including the enclosure for the boiler package. The benefit of this intervention is that both the building and new package can be adequately sized for their intended task restoring the original design intent of the boiler. Where the boiler packages are installed in an N+1 configuration one boiler package can be replaced while the other one provides redundancy.

Refurbish Modular Boiler

4.5.9 This intervention involves replacement of sub assets within preheating system such as, but not limited to, Human Machine Interface (HMI) screens, Heat Exchangers (HEX), Local Monitoring Unit (LMUs), including fans and burner doors. The benefit of this intervention is that it does not require the whole modular boiler to be replaced. This intervention is unlikely to result in the requirement for an outage.

Installation of Building Gas Detection on AGIs

4.5.10 This intervention is the installation of Gas Detection equipment within process buildings (e.g., Boiler houses and regulator buildings) to comply with industry best practice. The benefit is that any unexpected release of gas is quickly detected minimising LOC and the associated operational and safety implications.

Installation of Line-of-Sight Gas Detection

4.5.11 This involves installation of line-of-sight gas detection equipment on the boundary fence of terminals and certain AGIs (Industrial and Power Station sites) due to the risk of the proximity of gas entering occupied buildings/sites with operatives. The benefit is that any unexpected release of gas is quickly detected minimising LOC and the associated operational and safety implications.

Interventions Summary

4.5.12 Table 11 shows a summary of the interventions assessed across our Preheating assets across RIIO-GT3.

Table 11: Interventions Technical Summary Table

Intervention	Design Life	Positives	Negatives	Taken Forward
Counterfactual	N/A	Lowest cost option.	Does not address defects. Assets would be isolated. Reduced preheat capability. Impact to resilience.	No
Heat Exchanger PSSR Inspection	N/A	Meets PSSR requirements. Provides investment certainty.	N/A	Yes
Heat Exchanger PSSR Bursting Disk Replacement	10	Ensures availability of assets.	N/A	Yes
Refurbish Water Bath Heater	10	Meets PSSR requirements. Addresses system component defects to return the asset to its original design intent.	Provides only 6 to 10 years operational life. Does not address all inefficiencies or operational problems.	Yes
Replace Modular Boiler Package	15	Utilises existing asset infrastructure. Ensures availability of assets. Boiler package can be suitably sized or ability to modulate for task.	Does not benefit building/enclosure	Yes
Replace Modular Boiler Package Including Building	15	Maximum age benefit Benefits building/enclosure including modular boiler package. Boiler package and building can be suitably sized or ability to modulate for task.	Most expensive option.	Yes
Refurbish Modular Boiler	10	Meets PSSR requirements. Addresses system component defects to return the asset to its original design intent.	N/A	Yes
Installation of Building Gas Detection on AGIs	15	Allows for timely detection of gas leaks to prevent LOC and its associated consequences. Addresses known safety risk by allowing rapid identification of gas leaks.	N/A	Yes
Installation of Line-of-Sight Gas Detection	15		N/A	Yes

Volume derivation

4.5.13 The volumes of preheating interventions were derived based on known defects, historical run rates and the legislative requirement for PSSR compliance including a view of the criticality of assets. Table 12 summarises the bottom-up intervention volumes across RIIO-GT3.

4.5.14 Open defects not proposed to be addressed during RIIO-T2 have also been used to develop the intervention volumes which our investment seeks to mitigate.

Table 12: Development of bottom-up volumes for RIIO-GT3

Intervention	Volume	Unit of Measure	How this volume has been developed
Heat Exchanger PSSR Inspection - Bacton	[redacted]	Per Asset	Derived based on known defects the legislative requirement for PSSR compliance
Heat Exchanger PSSR Inspection - NTS	[redacted]	Per Asset	Derived based on known defects the legislative requirement for PSSR compliance
Heat Exchanger PSSR Bursting Disk Replacement	[redacted]	Per Asset	Derived based on known defects, and historical run rates.
Refurbish Water bath Heater	[redacted]	Per Asset	Derived based on known defects
Replace Modular Boiler Package	[redacted]	Per Asset	Derived based on known defects
Replace Modular Boiler Package Including Building	[redacted]	Per Site	Derived based on known defects
Refurbish Modular Boiler	[redacted]	Per Asset	Derived based on known defects
Installation of Building Gas Detection on AGIs	[redacted]	Per Building	Derived based on asset information on buildings with, and without, this equipment.
Installation of Line-of-Sight Gas Detection	[redacted]	Per Site	Derived from the criticality of the installation and its proximity to adjacent sites.
Total	**157**		

Cost derivation

4.5.15 Costs for interventions have been built up from first principles and data records from our centralised system by our costing team. Table 13 summarises the cost sources and data points used to inform the unit costs in this EJP. A breakdown of the unit costs is also provided Appendix 10.1.

4.5.16 Our cost accuracies are determined based on the type of cost data available, the quantity of this data (i.e., the number of data points) and the similarity of the scope of these historical data points against our RIIO-GT3 investment programme.

4.5.17 Interventions in our site assets investment theme with a +/-50% accuracy are where they have been derived from RIIO-T2 unit costs, acknowledging the time since these interventions have been delivered.

Table 13: Preheating Intervention Unit Cost Summary Table (£m, 2023/24)

Intervention	Unit Cost (£m)	Unit of Measure	Cost Accuracy	Data Points	Source Data
Heat Exchanger PSSR Inspection - Bacton	[redacted]	Per Asset	+/- 50%	[redacted]	[redacted]
Heat Exchanger PSSR Inspection - NTS	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Heat Exchanger PSSR Bursting Disk Replacement	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Refurbish Water bath Heater	[redacted]	Per Asset	+/- 50%	[redacted]	[redacted]
Replace Modular Boiler Package	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Replace Modular Boiler Package Including Building	[redacted]	Per Site	+/- 10%	[redacted]	[redacted].
Refurbish Modular Boiler	[redacted]	Per Asset	+/- 50%	[redacted]	[redacted]
Installation of Building Gas Detection on AGIs	[redacted]	Per Building	+/- 50%	[redacted]	[redacted].
Installation of Line-of-Sight Gas Detection	[redacted]	Per Site	+/- 50%	[redacted]	[redacted].

4.5.18 Our cost accuracies are determined based on the type of cost data available, the quantity of this data (i.e., the number of datapoints), the similarity of the scope of these historical data points against our RIIO-GT3 investment programme and is in line with government cost estimating guidance and IPI standard. This also applies to Filters (5) and Pipework (6) investments.

4.5.19 Cost accuracies of +/-10% are defined where the scope of historical data points directly align to the investment proposed, or estimates have been derived from 4.0 level scopes with costs derived from supplier quotations. Where we have this level of accuracy (+/- 10%) we assessed as Green through our SVC confidence standard. Costs between +/-11% and +/-20% are allocated medium (Amber) rating, while costs with an accuracy of +/-50% are defined as Red. This also applies to Filters (5) and Pipework (6) investments.

Cost derivation example

4.5.20 A recent construction estimation exercise for a scope of "Replace Modular Boiler Package". This intervention was calculated utilising 9 [redacted]; one for each site anticipated as part of our future works plan. An average cost was then generated across the [redacted] to give our final unit cost. The scope across the sites varied in scale with costs ranging from [redacted] up to £2.1m per intervention. This range of estimates provided a full breadth of interventions and site types, providing us with a true representation of future works.

4.5.21 Each estimate was approached with a specific scope per site and with consideration of site restrictions and logistics. This approach was necessary in order to capture the significant variation in cost that can be apparent with this type of intervention. The estimates utilised quotations from our supply chain with additional considerations applied for project management, supervision and design requirements. Risk/contingency for both National Gas and the contractor has been applied at [redacted].

5 Filters – £2.8m (2023/24)

5.1 Equipment Summary

5.1.1 Due to the inherent risk of dust caused by corrosion of the carbon steel pipe from transporting methane, filters are located across the NTS at sites including terminals, compressor stations and exit points.

5.1.2 Mainline filters capture solid debris in the filter baskets which are installed within the filter vessel behind a sealed door. Solid debris captured by filters can contain Naturally Occurring Radioactive Material (NORM) and pyrophoric dust. These must be appropriately managed whilst undertaking any maintenance tasks. Coalescing filters are installed at some compressor stations and terminals to capture liquids, primarily arising from wet seal gas compressors. Filters on the NTS range in size depending on specific purpose and location. Filters installed at terminals are often 16" or 18". Smaller filters are installed on offtake sites as shown in Figure 4.

Bank of Class 600 Horizontal Filter Vessels installed on [redacted]

[redacted]

Figure 4: Filter Assets

5.1.3 Most sites have duty and standby filtration streams to facilitate flow swap between filter assets which enables maintenance to be conducted. Depending on flows, multiple filters may be operational in parallel. Banks of filters are installed at terminals to facilitate filtration of the large volumes of gas at these sites. For example, Figure 4 shows the bank of filters on one of the incomers at Bacton, of which there are six, each with up to five filter vessels. In total, there are 297 filter assets installed on the NTS.

5.1.4 Filter vessels operate at [redacted] and are subject to Pressure Systems Safety Regulations (PSSR). We need to comply with PSSR for safety and legal reasons. Major PSSR inspections are carried out every 12 years in accordance with ES/94/15 – Filter (Major). PSSR inspections include examining all closures, performing magnetic particle inspection (MPI) and hydrotests.

5.2 Problem / Opportunity Statement

Why are we doing the work and what happens if we do nothing?

5.2.1 Defective, damaged, or obsolete filters result in asset deterioration, corrosion, including failure of seals that result in leaks. Blockages in gas filters could disrupt gas supplies to consumers.

5.2.2 Failing to comply with PSSR would be a direct breach of legislative obligations. If unable to demonstrate compliance, the Health and Safety Executive (HSE) could conduct investigations and impose legal actions. Depending on the findings, and whether any incidents had occurred resulting from not complying, this could range from notices through to unlimited fines and prosecution.

5.2.3 Failure or reduction in performance of filtration assets could lead to contamination of critical downstream equipment. For example, failure of a filter on a Pressure Reduction AGI could lead to damage of a pressure regulator leading to security of supply issues.

5.2.4 Lack of investment in filter assets will result in being non-compliant with legislation and being unable to effectively capture and manage debris on the NTS. This would lead to damage to our assets and also customer assets resulting in negative financial repercussions. Leaks from filtration assets have potential health and safety, environmental and financial consequences.

What is the outcome that we want to achieve?

5.2.5 We are seeking funding through this submission to ensure that the following outcomes are achieved:

- Meet legal requirements, primarily compliance with PSSR to prevent serious injury from the hazards of stored energy.
- Provide benefit to consumers through optimised investment to ensure the filter assets last as long as compression is needed, balancing cost, risk and performance.
- Manage deterioration of the assets such that they do not limit availability, performance or cause damage to other assets on the NTS or those of consumers.

How will we understand if the spend has been successful?

5.2.6 The investment plans will be considered to be successful when:

- We continue to maintain legislative compliance and are effectively capturing and managing debris on the NTS that has the potential to damage assets and disrupt gas flow.
- We have stabilised, and where required remediated filter asset deterioration and specific defect issues.
- We have ensured that filters do not present a safety risk and are not a limiting factor on availability or performance of the NTS.

Narrative Real Life Example of Problem

5.2.7 In 2021, we had difficulty in obtaining a leak free seal on the closure on [redacted] This is one in a bank of three filters on one of the incoming feeds to the [redacted]. Analysis of the problematic closure identified that the reason we couldn't obtain a leak free seal on the closure was due to wear of the seal groove and pitting of the sealing surface. The design utilises two opposing yokes to secure the head to vessel. It is known that excessive gap between the yokes, (typically caused by wear) can result in catastrophic failure, including the door blowing off the vessel under full line pressure leading to massive loss of containment. In light of this knowledge, the filter was removed from service, deemed irreparable. In the intervening period we were reliant on another filter in the bank reducing our resilience until the issue was resolved. Subsequent inspection of the other filters in the bank revealed similar wear pattern. The filters were replaced in August 2022.

Project Boundaries

5.2.8 Within the spend boundary are all filter related assets, including the ones subject to 12 yearly PSSR inspections and remediations in accordance with ES/94/15 – Filter (Major).

5.2.9 To conduct PSSR inspections and remedial work, suitable isolation must be in place. This is facilitated by fully functioning valves which is covered in the NGT_EJP22_Valves: Valves_RIIO-GT3 EJP. Inlet strainers for compressors are covered in the NGT_EJP27_St Fergus: Rotating Machinery_RIIO-GT3EJP while the NGT_EJP31_St Fergus: Site Assets_RIIO-GT3 EJP covers the filters at that site.

5.3 Probability of Failure

Failure Modes

5.3.1 The summary provided in Section 4.3.6 on how PoF has been assessed applies to Filters as well.

5.3.2 Likely failure modes for Filter assets with an average proportion of failures of 0.5 or above are provided in Table 14, the full list of failure modes is available in the NARMS methodology (https://www.nationalgas.com/our-businesses/network-asset-risk-metric-narm)

Table 14: Filter Failure Modes

Failure Mode	Average Proportion of Failures
Vessel failure significant gas release	0.50
Loss of power - gas supply instrument trip	0.53
Loss of stream regulator slam shut - trip	0.53
Corrosion no leak	0.57
Vessel corrosion	0.70

5.3.3 When applied to the asset count with an assumption that no investment is made, a forecast of failures across the RIIO-GT3 period is produced, shown in Table 15. The average failure rate represents the proportion of that asset type with an unresolved failure. The forecast failures per year shows the quantity of new failures modelled to occur each year.

Table 15: Forecasted failures

Asset Type	No. of Assets	Cumulative Average Failure Rates					Forecast Failures per Year				
		2027	2028	2029	2030	2031	2027	2028	2029	2030	2031
Mechanical (A.2.3)-Filters	[redacted]	0.06	0.07	0.07	0.07	0.08	0.60	0.68	0.77	0.86	0.97
Mechanical (A.2.3)-Filters-Coalescing	[redacted]	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Mechanical (A.2.3)-Strainers	[redacted]	0.03	0.03	0.03	0.04	0.04	0.06	0.06	0.07	0.08	0.09

Historic Defects

5.3.4 Analysis of historic data, highlighted in Figure 5 shows the majority of defects being raised against filters. Common attributes include corrosion and gas leaks. This is the number of defects raised and not the date the defect manifested – we might not have found the defect for a while. The 2024 data represents what has been captured to date in our defects database and does not represent the entire year.

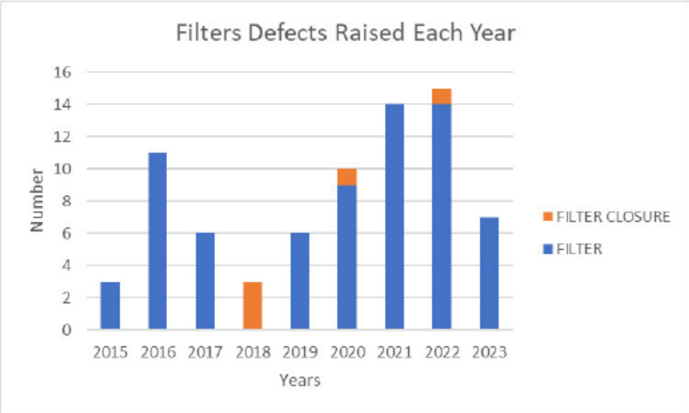

Figure 5: Historic defects raised each year

Probability of Failure Data Assurance

5.3.5 An extract from our defect management system was taken on the [redacted] with data analysis undertaken based on the columns of data exported from the system.

5.3.6 The NARMS Probability of Failure data was sourced from a Power BI dashboard, with data supplied from our Copperleaf asset management decision support system.

5.4 Consequence of Failure

5.4.1 Table 16 presents the consequence of failure should the Filter assets fail.

Table 16: Filters consequence of failure

Impact / Consequence			
Availability	**Environmental**	**Financial**	**Safety**
If filters do not pass PSSR inspection satisfactorily, they cannot return to service until remediation work is completed and the PSSR inspection is repeated, therefore impacting the availability of the asset.	Filters remove debris from gas flows. Environmental impacts, including leaks and hazardous material, are associated with the integrity of filter assets. This could have negative impacts to the environment with Methane being 28 times more harmful than Carbon Dioxide to the contribution of climate change.	As part of complying with PSSR, any action taken by HSE arising from an issue could result in significant financial penalties. If filters do not operate as intended, there is a risk that gas would not be suitable for supplying customers. If out of specification gas was to leave the NTS to customers, commercial actions may be taken leading to financial impacts. Financial impacts would also arise from leaking filters due to emissions. Loss of containment would have far-reaching financial consequences.	PSSR exists to prevent serious injury from the hazard of stored energy. Failure to comply with these regulations could lead to serious injury and actions by the Health & Safety Executive (HSE). Failure of assets presents health and safety risks to operatives required to work on filters which contain hazardous materials (e.g., NORM, pyrophoric dust). Leaks from filters arising from asset deterioration also pose health and safety risks due to the high pressure which the assets operate at. Loss of containment could be catastrophic to plant, equipment, and people.

5.5 Interventions Considered

5.5.1 This section summarises the interventions available to manage Filters.

Counterfactual

5.5.2 This counterfactual intervention considers legislatively governed PSSR inspections without undertaking any remedial actions for defects found. This is the lowest cost option in the short term, but it does not address defects. Assets would need to be isolated, impacting availability of downstream plant and equipment. This would result in reduced filtration capability and reduce the resilience of the NTS ultimately leading to the inability to meet service requirements of our customers. Therefore, the counterfactual investment is not being progressed.

Filter PSSR inspection and rectification

5.5.3 This intervention includes minor (every six year) and major (every 12 years) PSSR inspections and addressing defects found. The 12 year inspection includes intrusive examinations. These 12 yearly major PSSR examinations require the filter to be inspected and tested by specialist vendors.

5.5.4 Depending on the size, filter assets can be transported offsite to undergo the validation. If defects are found which result in the filter asset not meeting the PSSR standard, the specialist vendors will perform the necessary work to recover the asset. There are a combined 88 minor and major inspections/remediations due in RIIO-GT3.

5.5.5 This type of work typically includes replacing door seals and gaskets, refurbishing locking mechanisms, overhauling hinges, and addressing corrosion. As necessary, coatings may be removed using blasting techniques to resolve corrosion or welding defects prior being recoated.

5.5.6 This investment meets PSSR regulatory requirements and ensures availability of assets.

Alternative Gas Quality Solutions

5.5.7 In certain situations, alternative solutions for filtering gas may exist other than those installed and/or employed on the NTS. In order to conduct gas filtration, assets must be capable of operating at the necessary pressure of the gas flow. Therefore, even though different techniques could achieve filtration, the pressurised asset would fall under PSSR requirements.

5.5.8 Therefore, as this option would not reduce the 12 yearly major PSSR inspection and remediation programme it is not being progressed.

Intervention Summary

5.5.9 Table 17 summarises the investments assessed against our Filters Site Assets across RIIO-GT3.

Table 17: Intervention summary - Filters

Option	Option Class / Description	Positive	Negative	Taken forward
Counterfactual	Do Nothing	Lowest cost option in the short-term.	Does not address known AH issues that could compromise NTS operation.	No
Filter PSSR inspection and rectification	Repair of existing assets	Addresses known deterioration defect and operational issues. This option is applied where the site asset is beginning to show signs of deterioration which, if not addressed, will result in the asset degrading further compromising efficient operation of the NTS. The asset goes through comprehensive inspection, repair and testing to ensure it meets original design intent specifications. This provides better value for the consumer.	Nil	Yes
Alternative Gas Quality Solutions	Component and/or System Replacement	Addresses known deterioration defect and operational issues. This option is applied where system components have degraded to the point that replacement is the only viable option to ensure efficient operation.	More expensive than refurbishment.	No

Volume Derivation

5.5.10 Historical inspections have identified issues (driving the volumes in this paper) which required capital investments to remediate. Investment volumes have been built bottom-up based on legislation governing their minor (every six years) and major (every 12 years) inspection and remediation schedules. Table 18 summarises how the investments have been built for this this funding request.

Table 18: How Filters interventions have been developed

Option	Vol. of int.	Unit of measure	How this has been developed
Filter PSSR inspections and rectification	[redacted]	Per asset	This is a repeat of a RIIO-T2 scope to assess the quantity and severity of defects alongside re-evaluating those sites/assets where defect identification and resolution are not clear from the output of the initial surveys. In RIIO-T2 we have carried [redacted] filter refurbishment interventions. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys and review of our defects database.

Unit Cost Derivation

5.5.11 Our unit costs for the above intervention have been developed using historical outturn, from our centralised system. Table 19 summarises the cost sources and data points used to inform the unit costs in this EJP. A breakdown of the unit costs is also provided in Appendix 0.

Table 19: Site Assets cost sources and data points – Filters – costs in 2023/24

Intervention	Unit Cost (£m)	Unit of Measure	Cost Accuracy	Data Points	Source Data
Filter PSSR Inspection and Rectification - Bacton	[redacted]	Per Asset	+/- 50%	[redacted]	[redacted]
Filter PSSR Inspection and Rectification - NTS	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]

Cost derivation example

5.5.12 The cost for "Filter PSSR Inspection and Rectification" has been produced using 37 data points for historically delivered works over a 3 year period. These data points have been validated as a correct reflection of the scope and inflated to reflect a consistent cost base for future works. There were a number of exclusions in the calculation of this unit cost with some outliers demonstrating an abnormally low value in comparison with other data points. These were excluded as in some instances inspections can be abandoned, identify no further rectification, or include significantly fewer remedial works. In these instances, it was agreed with the Asset Management Plan team that these data points did not represent an accurate reflection of the future scope. As with all examples of historical data, no uplifts for additional risk have been applied to this figure.

6 Site Pipework - £86.4m (2023/24)

6.1 Equipment Summary

6.1.1 Our Site Pipework assets comprises a range of assets that are utilised for the safe transmission of gas through our operational above ground installations (AGIs), comprising terminals, offtakes, multijunction and block valves. These site pipework assets include pipe supports, pits, lagging and cladding, and the above and below ground process and small-bore pipework. A summary of these assets is illustrated in Figure 6. Additional information on this equipment group such as the health score at the beginning and end of the price control and monetised risk are provided in the accompanying NGT_IDP01_Portfolio EJP Site Assets_RIIO-GT3.

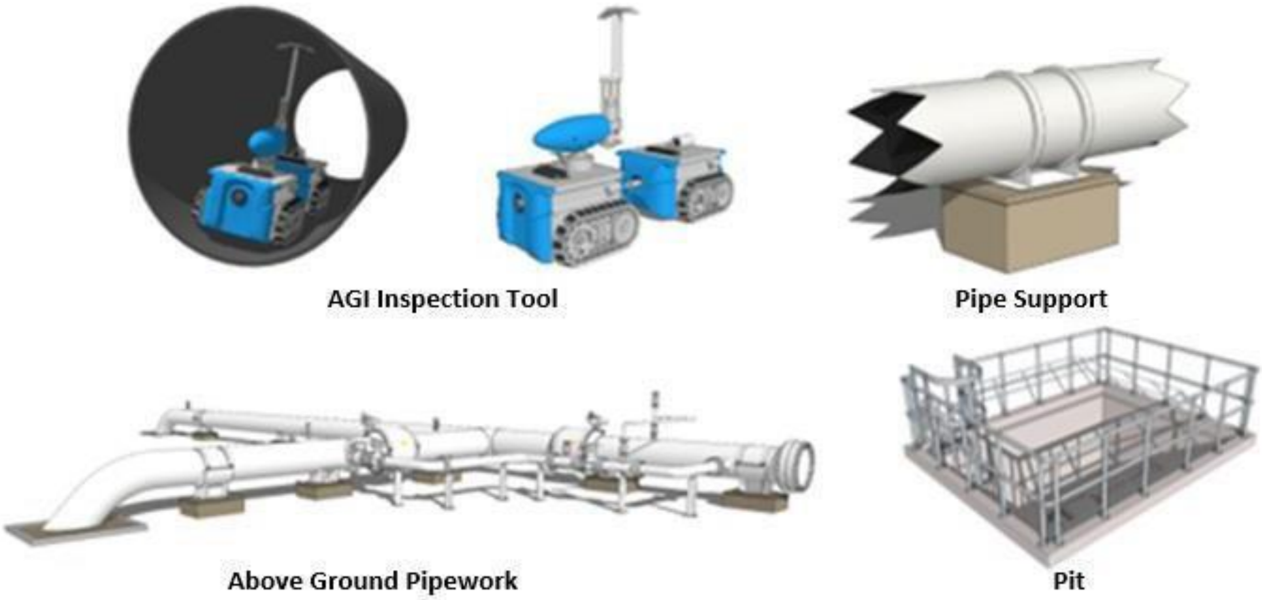

Figure 6: Site Pipework Equipment Summary

Above ground pipework, lagging and cladding:

6.1.2 Above ground pipework, within sites, contains and transports gas under pressure. Pipework can be large bore carrying process gas, or small bore (e.g., bridle pipework and fuel gas systems).

6.1.3 Above ground pipework consists of general pipework, risers and flanges. Coatings provide a barrier between these assets and the environment to protect against corrosion. These are subject to visual external inspection every six years, and T/PM/P/11 and T/PM/P/20 inspections to undertake an assessment on the severity of any identified damage and to undertake any necessary remediation. BAU Innovation

6.1.4 Pipe lagging and cladding is installed on pipework and within pits to mitigate noise and to provide thermal insulation to maintain the temperature of the gas in the pipework. It is also used to protect our staff from coming into contact with hot pipeline surfaces.

Pits and pipe supports:

6.1.5 Pits are designed to allow access to sections of pipework and valves on otherwise buried pipework runs and are required for operational, maintenance and inspection purposes. This asset category includes the pits themselves (generally constructed from brickwork or concrete), pit wall transitions, and pit covers.

6.1.6 Pipe supports are generally constructed from concrete or steel and provide structural support to above ground pipework. These can also incorporate vibration and noise control features. BAU Innovation

Below ground pipework and AGI Inspection Tool:

6.1.7 Our AGI Inspection tool is a small remotely controlled vehicle (robot) that can be utilised to inspect up to 100m of site pipework, from a launch vessel. This tool assesses pipework thickness, pipework coating and general pipework integrity to enable accurate fault detection reducing the need for unnecessary excavations and the risk of a high pressure gas release. In RIIO-T2 we have commenced the installation of these connection points to facilitate inspections, and our RIIO-GT3 investment seeks to use the robot to undertake inspections at these sites. BAU Innovation

Location and volume

6.1.8 Table 20 shows the asset count of these assets on the NTS.

Table 20: Site Pipework Asset Count

Asset	Count	Comments
Pipe Supports – Steel	3,658 (assets)	N/A
Pipe Supports - Concrete	N/A	Number unknown
Pipework	459 (sites)	This is the number of sites with the pipework assets. The majority of pipes at these locations are at diameters ranging from 50 mm to 1200 mm.
Lagging and Cladding	32 (sites)	N/A
Pits	1,172 (assets)	N/A

Pressure rating and Redundancy

6.1.9 Site pipework operates at a range of pressures up to and including the full pressure of the NTS, which is 70 to 94 bar. Within AGIs and Compressor stations, there is some further breakdown of pressures for other site equipment operations.

6.1.10 Where cladding is removed or becomes damaged it ceases to be able to fulfil its purpose, and there is no redundancy.

6.2 Problem / Opportunity Statement

Why are we doing the work and what happens if we do nothing?

6.2.1 Deterioration to assets such as pits and pipe supports can apply additional stress onto pipework which over time can damage pipework, leading to loss of integrity of these assets, unacceptable safety risks, and therefore limit the availability or performance of the NTS as a whole. Leaks through the pit wall transition inferred the build-up of moisture, which results in active corrosion on our pipework.

6.2.2 Lack of investment on site pipework assets will result in an increase in coating defects occurring, which will compound with time leading to active corrosion and potentially impact availability. Proactive application of coating mitigates deterioration and significant problems.

6.2.3 Lack of investment in remediating the defects on the cladding will result in increased corrosion. The existing defects will continue to get worse and new defects will arise. As further deterioration occurs there is a potential increase in corrosion on the associated pipework which could lead to loss of containment. BAU Innovation

6.2.4 Lack of investment in our AGI inspection tool inspection programme results in holding limited data on the condition of our below ground pipework assets. This could result in expensive reactive remediation should failure occur before it was identified through inspection.

6.2.5 The key drivers in Site Pipework management are summarised in Table 22.

Table 21: Categories of driver for site pipework

Driver Category	Description
Asset Deterioration	• Our pipework assets are subject to asset deterioration through corrosion mechanisms. Where the coating system fully breaks down, metal loss wall thickness losses may occur needing more significant interventions. This corrosion is accelerated by chloride contamination, crevice corrosion, dissimilar metal corrosion, stress corrosion cracking and erosion/fretting. • The key asset management challenge for lagging and cladding is Corrosion Under Insulation (CUI) facilitated by water ingress which creates ideal conditions for oxidation of the pipework. Inspection of the pipework beneath the lagging and cladding, promoting these conditions. By the nature of the cladding, the effects/extent of corrosion are difficult and expensive to inspect. • Above ground coating has varying design life dependant on environmental conditions. For example, existing coating systems typically have an effective design life of 10 to 15 years, subject to local environmental conditions, including soil resistivity. Corrosion defects are more prevalent in areas such as: underneath pipe supports, in congested areas subject to stagnant air or on specific elements (such as flanges or small-bore pipework), or pipework underneath lagging and cladding assets. • Significant deterioration issues can also occur at the pit wall transition, where the pipework enters and exists the pit through the sidewall, or at the wind/water lines. Remediation can be difficult and expensive due to requiring excavation and the complexity of the interaction to other operational assets, e.g., valves, pipework.
Legislation	• Lack of investment in the pipe supports and pits results in their deterioration to the point where they fail to fulfil their purpose and have the potential for impacting the integrity of the site pipework assets and therefore compliance with obligations under PSSR.
External Interference	• Assets such as site pipework, pipe supports and pits are subject to damage from external interference such as ground movement, which can lead to unacceptable stresses acting upon them. Climate change driven temperature extremes of both higher and lower nature will affect the rate of deterioration of coatings. We currently don't fully understand these properties due to the emerging nature of these issues.
Inspection methodologies	• On our below ground pipework where coating systems break down, carbon steel pipework will corrode, and this is the predominant life limiting factor. Coating provides primary corrosion prevention for all buried pipework with CP providing secondary protection. Whilst we have installed AGI inspection tool connection points, we currently have collected limited information to assess the condition and corrosion rates of our pipework on these sites.
Operational	• Operation of the assets comes with pressure and temperature cycling fatigue, vibration, erosion, and abrasion. All of these affect the integrity of pipework and coating and compound over time.

Driver Category	Description
Health and Safety	• Pits, especially on our oldest feeders, are often too small to get safe access to the assets located within them. These pits wouldn't pass modern safe design working standards and are also susceptible to flooding which can lead to corrosion defects on the pipework at the pit wall transition.

What is the outcome that we want to achieve?

6.2.6 We are seeking funding through this submission to ensure that the following outcomes are achieved:

- Meet legal requirements including compliance with PSSR to prevent serious injury from the hazards of stored energy.
- Ensure ongoing compliance with PSSR for both below and above ground pipework.
- Manage deterioration of the assets such as, pipe supports, lagging, cladding, and the AGI inspection tool, so that they do not limit availability, performance or cause damage to other assets on the NTS or those of consumers.
- Providing benefit to consumers through optimised investment to ensure the Site Pipework assets last as long as the flow of gas is needed, balancing cost, risk and performance.

How will we understand if the spend has been successful?

6.2.7 The investment plans will be considered to be successful when:

- We continue to meet legislative requirements and ensure ongoing compliance with PSSR.
- We have stabilised, and where required remediated Site Pipework asset deterioration and specific defect issues.
- We have ensured that Site Pipework assets do not present a safety risk and are not a limiting factor on availability or performance of the NTS.

Narrative Real Life Example of Problem

6.2.8 At [redacted], surveys were completed in June 2023 through the National AGI Renovation Campaign programme. A range of defects were identified including de-bonded paintwork on our above ground pipework and leaking pit wall transitions (Figure 7). Left as-is the rate of corrosion would be exacerbated leading to leaks resulting in network/consumer impact.

Figure [redacted] defects

6.2.9 At [redacted], a block valve site [redacted], there are eight pits at the site to access pipework and valve assets. Each pit provides access to an individual valve within the mainline and bridle block valve arrangement (Figure 8). These pits are confined spaces, too small for an operations technician to safely access the asset and don't pass modern safe design working standards. To resolve the issue, pits need to be broken out, enlarged including opened up, and valve stems brought above ground.

Figure 8: [redacted] covered pit denoted by red boundary. Second pit to the top left.

6.2.10 At [redacted] more aggressive environmental conditions are experienced due to the coastal location of the site, and levels of salinity in the air. Investment was completed in RIIO-T1 to recoat above ground assets. Based on the expected life of the coating and a range of coating defects data there is evidence that proactive overcoating may be required to keep on top of the defects. These [redacted] coating interventions are included in this EJP.

Project Boundaries

6.2.11 This EJP covers Site pipework as defined in the PSSR regulations. Excluded from this EJP is Pipelines which is covered under PSR regulations.

6.2.12 The Investment theme covers all investment on our above ground site pipework, including pipe supports, pits, and our AGI inspection tools. Included within this EJP are pipework risers, small and large bore pipework, our pits and pit wall transitions as well as pipework coatings [redacted] There is an overlap with the NGT_EJP022_Valves: Valves_RIIO-GT3 EJP where below ground valves and their ancillary assets are being brought above ground.

6.2.13 This paper excludes any pipework related investments at St Fergus.

6.3 Probability of Failure

Failure Modes

6.3.1 The summary provided in Section 4.3.6 on how PoF has been assessed applies to Pipework as well.

6.3.2 Likely failure modes for Pipework assets with an average proportion of failures of 0.5 or above are provided in Table 22, the full list of failure modes is available in the NARMS methodology.

Table 22: Pipework Failure Modes

Failure Mode	Average Proportion of Failures
Loss of power - gas supply instrument trip	0.53
Corrosion no leak	0.51
Corrosion no leak - pressure reduction	0.59
Structural damage leak affecting electrical control equipment loss of control / monitoring	0.64

6.3.3 When applied to the asset count with an assumption that no investment is made, a forecast of failures across the RIIO-GT3 period is produced, shown in Table 23. The average failure rate represents the proportion of that asset type with an unresolved failure. The forecast failures per year shows the quantity of new failures modelled to occur each year.

Table 23: Forecasted failures

Asset Type	No. of Assets	Cumulative Average Failure Rates					Forecast Failures per Year				
		2027	2028	2029	2030	2031	2027	2028	2029	2030	2031
Civils (GT.1.1)-Pits	[redacted]	0.14	0.15	0.15	0.16	0.17	9.40	9.79	10.20	10.63	11.06
Civils (GT.1.1)-Plinths	[redacted]	0.06	0.06	0.06	0.07	0.07	0.56	0.58	0.61	0.63	0.66

Asset Type	No. of Assets	Cumulative Average Failure Rates					Forecast Failures per Year				
		2027	2028	2029	2030	2031	2027	2028	2029	2030	2031
Civils (GT.1.1)-Plinths-Concrete	[redacted]	0.11	0.11	0.11	0.12	0.12	16.64	17.16	17.69	18.22	18.76
Mechanical (A.2.3)-Pipe Supports-Spring Hanger	[redacted]	0.03	0.03	0.04	0.04	0.04	0.02	0.02	0.02	0.02	0.03
Mechanical (A.2.3)-Pipe Supports-Steel	[redacted]	0.09	0.09	0.10	0.10	0.11	14.19	14.68	15.18	15.69	16.20
Mechanical (A.2.3)-Pipeline	[redacted]	0.14	0.14	0.15	0.16	0.16	1.35	1.42	1.48	1.55	1.62
Mechanical (A.2.3)-Pipework	[redacted]	0.86	0.89	0.92	0.94	0.96	0.70	0.59	0.51	0.32	0.24
Mechanical (A.2.3)-Pipework Protection-Cladding	[redacted]	0.49	0.51	0.53	0.55	0.57	0.80	0.78	0.70	0.61	0.59
Mechanical (A.2.3)-Pipework-Straight	[redacted]	0.37	0.38	0.39	0.40	0.41	3.78	3.91	4.05	4.19	4.33
Mechanical (A.2.3)-Pipework-Vent	[redacted]	0.70	0.72	0.73	0.74	0.75	1.02	0.98	0.73	0.76	0.82

Historic Defects

6.3.4 Defects, including CM/4 inspection defects, shown in Figure 9 have been analysed to assess the historical probability of failure (defect failure rate). Open defects not proposed to be addressed during RIIO-T2 have also been used to develop the intervention volumes which our investment seeks to mitigate.

Figure 9: Example of CM/4 Grade 6 defects

6.3.5 Through RIIO-T2 we have visited 312 of our NTS sites through our National AGI renovation campaign, surveyed the condition of the site, the open defects and addressed all known issues to maintain risk.

6.3.6 Of our remaining NTS sites, defects have been analysed and interventions considered based on the severity and type of defect present as summarised in Table 24 .

Table 24: Site pipework defect analysis

	Cat 3	Cat 4	Cat 5	Cat 6
Open Defects	118	382	449	144
Sites Count	58	164	174	95

6.3.7 At [redacted], there are 48 open CM/4 defects of category 3, 4 and 5 across the 6 CM/4 zones on the site. Category 3 and 4 defects can usually be remediated through coating related intervention, with category 5 and 6 defects assessed for more significant investment. All these defects need remediation during the RIIO-GT3 period. This is summarised in Table 25.

Table 25: [redacted]

Zone/Category	Cat 3	Cat 4	Cat 5	Cat 6	Total
Total	**11**	**34**	**3**	**0**	**48**

Probability of Failure Data Assurance

6.3.8 The NARMS Probability of Failure data was sourced from a Power BI dashboard, with data supplied from our Copperleaf asset management decision support system. This data was used in predicting future defects and failures of the preheating assets if no investment was made and also for conducting Predictive Analytics (PA) assessment described in further detail in Chapter 7 and Chapter 8.

6.3.9 An extract from our defect management system was taken on [redacted] with data analysis undertaken based on the columns of data exported from the system.

6.3.10 Probability of failure data has also been determined based on surveys conducted in RIIO-T2. The extract from our defect management system and outputs from our surveys was used to prioritise derivation of the bottom up volumes of investments in our plan.

6.4 Consequence of Failure

6.4.1 Table 26 presents the consequence of failure for all assets within our Site Pipework grouping.

Table 26: Site Pipework Consequence of failure

	Impact / Consequence			
	Availability	**Environment**	**Financial**	**Safety**
Above and Below Ground Pipework	Corrosion failures could lead to active corrosion leading to outages, pressure restriction, isolation of downstream customers and network constraints. Corrosion failures resulting in high pipework stresses impacting availability.	Loss of gas through corrosion and joint leaks including loss from pipework. Associated with the loss of gas through corrosion at the interface between Pipework and the pipe support. This could have negative impacts to the environment with Methane being 28 times more harmful than Carbon Dioxide to the contribution of climate change.	Pipework failures could lead to unplanned outages and restriction to downstream customers which could result in financial consequences.	The potential for corrosion failure, mechanical failure, ground movement or damage, causing a pipework to leak or rupture. Gas losses resulting from corrosion will vent to air. Self-ignition due to static energy is possible.
Pipe Supports and Pits	Corrosion failures resulting in high pipework stresses impacting availability. Failure of pit wall transitions, resulting in pipework corrosion could lead to outages and pressure restrictions	Associated with the loss of gas through corrosion at the interface between Pipework and the pipe support; and also, at the interface between exposed and buried pipework within the pits.	Network constraints resulting from corrosion failures bear a financial consequence. There is significant cost to remediate damaged pit wall transitions.	The potential for corrosion failure, mechanical failure, ground movement or damage, causing a pipework to leak or rupture. Gas losses resulting from corrosion will vent to air. Self-ignition due to static energy is possible. The potential for injury to personnel walking on damaged or weak pit covers.
Cladding	Damaged cladding can: affect temperature regulation affecting efficiencies. result in Corrosion Under Insulation (CUI) which could lead to outages, pressure restriction and leaks.	Noise nuisance caused by poor acoustic cladding.	Failure or removal of cladding can result in heat losses, resulting in running preheating packages more frequently to maintain system temperatures meaning more fuel gas being used resulting in additional spend.	The failure of cladding associated with personal protection could result in injury to site personnel.

6.5 Interventions Considered

6.5.1 Due to the large number of pipework interventions considered (18 against the three in Filters (Table 17) and the nine (Table 11) in Preheat), they have been presented in tabular form in Table 27. As a result, the table also contains the scope of each of the interventions considered. Technical optioneering has been undertaken on the AMP investments to identify credible interventions for the different types of site pipework assets. The positive and negative narrative for the two broad options taken forward, these being replacement and refurbishment are similar, hence the groupings of investment types in the table.

6.5.2 The interventions in have been considered to address the various issues articulated in the problem statement. We have split these into the four asset types within the scope of this theme; Pipework, Lagging and Cladding, Pits and Pipe Supports.

6.5.3 Deferral of interventions has been discounted due to the severity of defects and the need to remain legislatively compliant.

6.5.4 Our intervention in Remediation of Pit Wall Transition Defects shall utilise a combination of traditional link seal arrangements and removable Composite Transition Pieces (CTP). CTP was an innovation project in RIIO-T1 to create a removable piece for pipe to wall transitions, instead of the traditional cementing of the joint, which must be removed and resealed to conduct maintenance and inspections on the pipework in the joint. The CTP will be removable and allow for safer, easier inspection and maintenance.

6.6 Intervention Summary

6.6.1 Table 27 summarises the investments assessed against our Pipework Site Assets across RIIO-GT3.

Table 27: Intervention Summary – Pipework

Intervention	Intervention Type	Investment Design Life	Scope	Positives	Negatives	Taken forward
Counterfactual (Do Nothing)	**N/A**	N/A	Continuing with routine inspection and minimal maintenance activities to meet statutory obligations.	Lowest cost and short-term option	Does not address known AH issues that could compromise NTS operation.	**No**
Decommission	N/A	N/A	Disconnect and remove assets from the NTS.			
Lagging and Cladding - Replacement of Cladding/Lagging (Large Site)	Replacement	20	Replacement of existing pipework Lagging or Cladding due to deterioration with the existing lagging/cladding installation or age based deterioration. Before intervention into the Cladding/Lagging we should undertake a noise survey to validate the need for lagging/cladding.	Addresses known deterioration defect and operational issues. This option is applied where system components have degraded to the point that asset replacement is the only viable option to ensure efficient operation. This provides better value for the consumer.	Nil	Yes
Lagging and Cladding - Replacement of Cladding/Lagging (Small Site)	Replacement	20				Yes
Replacement of Steel Pipe Supports	Replacement	40	Pipe Support - Removal of the existing steel pipe support and clamp and installation of half clamp and new steel pipe support.			Yes
Replacement of Concrete Pipe Support with Steel Pipe Support	Replacement	40	Break out of existing concrete pipe support and replacement with a steel pipe support and pipe clamp.			Yes
Replacement of Concrete Pit Covers with GRP Composite Covers	Replacement	40	Replacement of Concrete Pit covers with lighter GRP Composite covers that enable Pit cover lifting operations to occur.			Yes
A/G Pipework - CM/4 Defect Resolution	Refurbishment	15	Resolving CM/4 defects post P11/P20 inspection. Could include pipework cut outs, use of flanges, clamps, sleeves over affected section of pipework or painting if corrosion is not as severe.	Addresses known deterioration defects and operational issues. This option is applied where the site asset is beginning to show signs of deterioration which if not addressed will result in the asset degrading further compromising efficient operation of the NTS.	Nil	Yes
A/G Pipework - AGI Partial site coating	Refurbishment	15	Partial grit blast and paint of all above ground pipework on site.			Yes
A/G Pipework - AGI Full site coating	Refurbishment	15	Full grit blast and paint of all above ground pipework on site.			Yes
Bacton A/G Pipework Biocide Coating Application	Refurbishment	5	Application of a biocide coating to prevent the formation of Algae. Proposed to be undertaken every 5 years across the zones at the site aligned to the schedule of CM/4 inspections, to aid the analysis of surface corrosion through the removal of foreign organic growth.			Yes
Bacton A/G Pipework - AGI Partial Zone coating	Refurbishment	15	Undertaking Grit blast and then re-coating of part of the above ground pipework within a CM/4 zone within the terminal.			Yes
Site Vibration Rectification 5 Volumes	Refurbishment	5	Rectification of any vibration related issues arising on site assets. Includes modifications to pipework/assets at sites e.g., Regulators, Valves, Preheating etc.			Yes
Concrete Plinth Repair	Refurbishment	20	Repair undertaken to a concrete plinth, either repairing cracks and damage to a concrete plinth pad or planing off the top 50mm.			Yes

Intervention	Intervention Type	Investment Design Life	Scope	Positives	Negatives	Taken forward
Remediation of Pit Wall Transition Defect	Refurbishment	20	Undertake remediation of Pit wall transition defects, through the installation of a Composite Transition Piece, or a traditional Link Seal arrangement.			Yes
Break out of Pit Infrastructure	Decommission	N/A	Break out existing pit infrastructure, removing all pit/chamber walls, pit covers, and access equipment. Backfill with soil and earth.	Gets rid of redundant assets thereby reducing the asset management cost. It enables maximum asset management efficiency. It meets HSE requirements.	Nil	Yes
AGI Inspection Tool Survey	Survey	N/A	Inspection and assessment of below ground pipework.	Provides investment certainty and better asset condition data to support decision making.		Yes
Pit Wall Transition Non-Destructive Testing	Survey	N/A	Undertake Non-Destructive testing survey, without causing any damage, of Pit Wall Transition defects to understand the extent of the corrosion around pit wall transitions.			Yes
Monitoring of Pipe Supports and Pits Assets	Survey	N/A	Visual or where appropriate by physical survey / Non-destructive Testing (NDT) and formal record / report, all conducted by an appropriate specialist and to include remnant life assessment on our Pipe Supports & Pits Assets.			Yes

Volume derivation

6.6.2 All the assessed intervention volumes have been determined from known defects or the requirement to improve gas detection methods. Table 28 summarises how the bottom-up interventions have been built for this funding request.

Table 28: How Pipework options have been developed

Intervention	Intervention Type	Volume	Unit of measure	How this volume has been developed
Counterfactual (Do Nothing)	[redacted]	[redacted]	N/A	N/A
Lagging & Cladding - Replacement of Cladding/Lagging (Large Site)	[redacted]	[redacted]	Per Site	In RIIO-T2 we have carried out three of these replacements. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Lagging and Cladding - Replacement of Cladding/Lagging (Small Site)	[redacted]	[redacted]	Per Site	In RIIO-T2 we have carried out three of these replacements. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Replacement of Steel Pipe Supports	[redacted]	[redacted]	Per Asset	In RIIO-T2 we have carried out 294 of these replacements. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Replacement of Concrete Pipe Support with Steel Pipe Support	[redacted]	[redacted]	Per Asset	The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Replacement of Concrete Pit Covers with GRP Composite Covers	[redacted]	[redacted]	Per Asset	The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
A/G Pipework - CM/4 Defect Resolution	[redacted]	[redacted]	Per Project	In RIIO-T2 we have carried 204 of these refurbishments. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of CM/4 defects,
A/G Pipework - AGI Partial site coating	[redacted]	[redacted]	Per Site	In RIIO-T2 we have carried five of these refurbishments. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
A/G Pipework - AGI Full site coating	[redacted]	[redacted]	Per Site	In RIIO-T2 we have carried 100 of these refurbishments. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Bacton A/G Pipework Biocide Coating Application	[redacted]	[redacted]	Per CM/4 Zone	The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Bacton A/G Pipework - AGI Partial Zone coating	[redacted]	[redacted]	Per CM/4 Zone	The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Site Vibration Rectification 5 Volumes	[redacted]	[redacted]	Per Project	The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Concrete Plinth Repair	[redacted]	[redacted]	Per Asset	The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Remediation of Pit Wall Transition Defect	[redacted]	[redacted]	Per Pit Wall Transition	In RIIO-T2 we have carried four of these refurbishments. The same approach has been used to scope similar RIIO-GT3 investments. The RIIO-GT3 investments were developed based on assessment of targeted surveys, review of our defects database and historic run rates.
Break out of Pit Infrastructure	[redacted]	[redacted]	Per Pit	This option was developed by identifying site assets that are surplus to requirements and require removal for operational, health and safety and asset health integrity reasons.
AGI Inspection Tool Survey	[redacted]	[redacted]	Per Site	Volumes were derived by forecasting a run rate based on similar historically delivered interventions.
Pit Wall Transition Non-Destructive Testing	[redacted]	[redacted]	Per Pit Wall Transition	
Monitoring of Pipe Supports and Pits Assets	[redacted]	[redacted]	Per Asset	
Total		**1820**		

Unit cost derivation

6.6.3 Costs have been derived using known data for activities which share the scope with the interventions within this EJP. We have mapped RIIO-GT3 interventions to RIIO-T2 Unique Identifiers (UIDs) and assessed the available historical outturn and/or forecasted completion costs.

6.6.4 Where historical outturn or tendered costs have not been available, we have undertaken estimating using first principles, including sourcing quotations from the supply chain to calculate the Estimated Cost of Completion (ECC). Table 29 summarises the cost sources and data points used to inform the unit costs in this EJP. A breakdown of the unit costs is also provided in Appendix 0.

6.6.5 Our cost accuracies are determined based on the type of cost data available, the quantity of this data (i.e., the number of data points) and the similarity of the scope of these historical data points against our RIIO-GT3 investment programme.

6.6.6 Interventions in our site assets investment theme with a +/-50% accuracy are where they have been derived from RIIO-T2 unit costs, acknowledging the time since these interventions have been delivered.

Table 29: Site Assets cost sources and data points – Pipework (£m, 2023/24)

Intervention	Unit Cost	Unit of Measure	Cost Accuracy	Data Points	Source Data
Lagging & Cladding - Replacement of Cladding/Lagging (Large Site)	[redacted]	Per Site	+/- 10%	[redacted]	[redacted]
Lagging & Cladding - Replacement of Cladding/Lagging (Small Site)	[redacted]	Per Site	+/- 10%	[redacted]	[redacted]
A/G Pipework - CM/4 Defect Resolution	[redacted]	Per Project	+/- 10%	[redacted]	[redacted]
A/G Pipework - AGI Partial site coating	[redacted]	Per Site	+/- 10%	[redacted]	[redacted]
A/G Pipework - AGI Full site coating	[redacted]	Per Site	+/- 10%	[redacted]	[redacted]
AGI Inspection Tool Survey	[redacted]	Per Site	+/- 10%	[redacted]	[redacted]
Pit Wall Transition Non-Destructive Testing	[redacted]	Per Pit Wall Transition	+/- 10%	[redacted]	[redacted]
Replacement of Steel Pipe Supports	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Replacement of Concrete Pipe Support with Steel Pipe Support	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Remediation of Pit Wall Transition Defect	[redacted]	Per Pit Wall Transition	+/- 30%	[redacted]	[redacted]
Break out of Pit Infrastructure	[redacted]	Per Pit	+/- 10%	[redacted]	[redacted]
Monitoring of Pipe Supports & Pits Assets	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Bacton A/G Pipework Biocide Coating Application	[redacted]	Per CM/4 Zone	+/- 50%	[redacted]	[redacted]
Bacton A/G Pipework - AGI Partial Zone coating	[redacted]	Per CM/4 Zone	+/- 30%	[redacted]	[redacted]
Site Vibration Rectification 5 Volumes	[redacted]	Per Project	+/- 50%	[redacted]	[redacted]
Concrete Plinth Repair	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]
Replacement of Concrete Pit Covers with GRP Composite Covers	[redacted]	Per Asset	+/- 10%	[redacted]	[redacted]

Cost derivation example

6.6.7 An example of how cost for these interventions have been derived is summarised in the following. The cost for "A/G Pipework - AGI Full site coating" has been produced using 58 data points for historically delivered works across 58 different sites and a total of 5,658m^2 of coating completed (an average of 97.56m^2 per site). These data points have been validated as a correct reflection of the scope. There were no outliers identified in the data available. The cost produced has been taken as an average of the 58 data points. As with all examples of historical data, no uplifts for additional risk have been applied to this figure.

7 Options Considered

7.1 Portfolio Approach

7.1.1 In developing our plans, we focused on value for money and deliverability, while managing the risks of aging assets. We evaluated the cost-effectiveness of our investment program through a full Cost Benefit Analysis (CBA) using the NARMs Methodology within the Copperleaf Decision support tool.

7.1.2 We have assessed the benefit from options across the entire Site Assets portfolio to meet investment drivers, business plan commitments, and consumer priorities. Therefore, a single CBA covers Asbestos, Stabbings, Redundant Assets, Climate Change Adaptation, Preheating, Filter and Pipework. Table 30 summarises the split of funding requested between this EJP and the associated EJP.

Table 30: Funding requested £m (2023/24)

EJP	Funding Request
This EJP (Preheating, Filters and Pipework)	108.55
Associated EJP (Asbestos, Stabbings and Redundant Assets)	41.04
Total for Site Assets	**149.59**

7.1.3 The options considered combine the interventions discussed previously (and those covered in the NGT_EJP01_Site Assets - Asbestos, Stabbings and Redundant Assets_RIIO-GT3 EJP) in varying combinations and volumes to identify the optimal investment for site assets.

7.1.4 In line with HM Treasury Green Book advice and Ofgem guidance, we assessed the value of investing in Site Assets across the RIIO-GT3 period by analysing the cost benefit over a 20-year horizon.

7.1.5 We derived bottom-up intervention volumes using the engineering assessments described in the previous chapters. Each investment was assessed via the Ofgem-approved NARMs Methodology embedded in Copperleaf, quantifying risk reduction and Long Term Risk Benefit (LTRB). Analysing this performance, Copperleaf Predictive Analytics (PA) is then able to select further NARM driven interventions to create further options to satisfy certain criteria, such as stable risk across the portfolio.

7.1.6 Only interventions assigned to a specific asset have been assessed in the CBA, as benefits cannot be applied to interventions that are assigned to various locations. Interventions which have been discounted (i.e., because they do not meet legislative requirements) have also not been modelled.

7.2 Options

7.2.1 Using the Predictive Analytics Optimisation module (PA) within Copperleaf, our Site Assets have been optimised against the NARMs Methodology to ensure the portfolio achieves a variety of outcome risk levels, to satisfy stakeholder needs.

7.2.2 All the options described have been assessed against our Option 0, Counterfactual (Do Nothing) option, which considers no investment over and above maintenance and corrective repairs.

7.2.3 In all options (except the counterfactual) we include the bottom-up intervention volumes to address known defects and obsolescence issues. A table of these intervention volumes is in Appendix 10.4.

Option 1: Total Monetised Risk Stable to RIIO-T2 Start

7.2.4 In this option we have utilised our Copperleaf Portfolio optimisation tool to constrain the overall level of NARMS risk at the end of the RIIO-GT3 period to remain consistent with the levels of risk at the start of the RIIO-T2 period. Individual NARMS service risk measures (SRMs) are not individually constrained, however overall risk outcome is.

7.2.5 The total spend of proposed interventions in this option is £157.24m (2023/24) which addresses known and forecast defects. Our Predictive analytics model has selected the most cost beneficial interventions to keep overall NARMs risk stable. The proposed intervention volumes and the associated spend for this option are shown in Table 31.

Table 31: Option 1 Summary (£m, 2023/24)

Intervention	Volumes	RIIO-GT3 Value
Bottom-Up Interventions	[redacted]	154.84
Predictive Analytics	[redacted]	2.40
Total	[redacted]	**157.24**

Option 1A: Post Deliverability Assessment of Total Monetised Risk Stable to RIIO-T2 Start

7.2.6 This is a variation of Option 1 that has been taken through a deliverability assessment which assesses the programme of works against outputs across our entire capital investment plan. It is therefore more constrained than Option 1.

7.2.7 The total spend of proposed interventions in this option is £149.59m (2023/24) which delivers less volumes and spend than Option1. The proposed intervention volumes and the associated spend for this option are shown in Table 32.

Table 32: Option 1A Summary (£m, 2023/24)

Intervention	Volumes	RIIO-GT3 Value
Constrained Interventions	[redacted]	149.58
Predictive Analytics	[redacted]	0.017
Total	[redacted]	**149.59**

Option 2: 10% Additional Risk Reduction

7.2.8 In this option, we applied optimisation to achieve a 10% additional monetised risk reduction by the end of the RIIO-GT3 period. Copperleaf has selected the most cost-effective investments to meet the lower risk constraint.

7.2.9 The total spend of proposed interventions in this option is £157.24m (2023/24). In this option we see similar spend to Option 1, as shown in Table 33. PA could not reduce risk further given the constraints; therefore, we have added additional options to show what cost and value would result from maximising risk benefit.

Table 33: Option 2 Summary (£m, 2023/24)

Intervention	Volumes	RIIO-GT3 Value
Bottom-Up Interventions	[redacted]	154.84
Predictive Analytics	[redacted]	2.40
Total	[redacted]	**157.24**

Option 3: Lowest WLC

7.2.10 In this option, we applied optimisation to select interventions with the lowest Whole Life Cost. Copperleaf identifies the most beneficial interventions, and no investment is selected if the cost exceeds the asset's lifetime benefit, as per the NARMS methodology.

7.2.11 The total spend of proposed interventions in this option is £157.24 (2023/24) as shown in Table 34. In this option we see similar spend to Option 1 and Option 2, as shown in Table 33. PA could not reduce risk further given the constraints; therefore, we have added additional options to show what cost and value would result from maximising risk benefit.

Table 34: Option 3 Summary (£m, 2023/24)

Intervention	Volumes	RIIO-GT3 Value
Bottom-Up Interventions	[redacted]	154.84
Predictive Analytics	[redacted]	2.40
Total	[redacted]	**157.24**

Option 4: Maximise Risk Benefit

7.2.12 In this option, the model was allowed to maximise risk benefit from all applicable interventions and available assets. This resulted in a high-value, high-cost option for comparison purposes.

7.2.13 The total spend of proposed interventions in this option is £469.55m (2023/24) as shown in Table 35. Generally, this option will undertake more work than option 1 in an attempt to control the rising risk of availability and reliability, Option 1 is running on overall monetised risk and therefore may make an economical decision to over reduce other SRMs like Financial & H&S due to the associated cost with maintaining.

Table 35: Option 4 Summary (£m, 2023/24)

Intervention	Volumes	RIIO-GT3 Value
Bottom-Up Interventions	[redacted]	154.84
Predictive Analytics	[redacted]	314.71
Total	[redacted]	**469.55**

Option 5: Remove Two Interventions and Maximise Risk Benefit

7.2.14 In this option, the model was allowed to maximise risk benefit from all applicable interventions and available assets. However, 2 interventions (*Replace Modular Boiler Package* including building and *Replace Modular Boiler Package*), were removed because they were asset replacement interventions. The intent was for the model to select refurbishment interventions instead of replacement.

7.2.15 The total spend of proposed interventions in this option is £227.20m (2023/24) as shown in Table 36. Generally, this option will undertake more work than option 1 in an attempt to control the rising risk of availability and reliability, Option 1 is running on overall monetised risk and therefore may make an economical decision to over reduce other SRMs like Financial & H&S due to the associated cost with maintaining supply.

Table 36: Option 5 Summary (£m, 2023/24)

Intervention	Volumes	RIIO-GT3 Value
Bottom-Up Interventions	[redacted]	154.84
Predictive Analytics	[redacted]	72.36
Total	[redacted]	**227.20**

7.3 Option Summary

7.3.1 Table 37 presents the technical summary table of all CBA options.

Table 37: Options Technical Summary Table (£m, 2023/24)

Option	First Year of Spend	Final Year of Spend	Total Volume of Interventions	Investment Design Life	% of Assets / Sites Intervened On	Total Spend Request
Option 0: Counterfactual (Do Nothing)	2026	2032	N/A	N/A	[redacted]	N/A
Option 1: Total Monetised Risk Stable to T2 Start	2026	2032	2715	5 to 40 years	[redacted]	157.24
Option 1A: Post Deliverability	2026	2032	2237	5 to 40 years	[redacted]	149.59
Option 2: Additional 10% Risk Reduction	2026	2032	2715	5 to 40 years	[redacted]	157.24
Option 3: Lowest WLC	2026	2032	2715	5 to 40 years	[redacted]	157.24
Option 4: Maximise Risk Benefit	2026	2032	5188	5 to 40 years	[redacted]	469.55
Option 5: Remove 2 Interventions and Maximise Risk Benefit	2026	2032	5188	5 to 40 years	[redacted]	227.20

8 Business Case Outline and Discussion

8.1 Key Business Case Drivers Description

8.1.1 The operating conditions seen across the NTS means that site assets deteriorate over time and with use, preventing them from performing their required function. Any failure or significant deterioration causes the associated asset to be unavailable and hence directly affects the availability of the network and compression assets. There is potential for inefficient operation of the NTS, increased operational cost and accelerated asset degradation due to site assets operating in sub-optimal conditions.

8.1.2 The key drivers for investment in Site Assets, are:

- Legislation requirements.
- Asset deterioration, linked to our ageing asset base and asset type.
- Change of operational requirement (redundancy)
- Health and safety, including decommissioning and removing assets that are no longer required to manage overall whole life cost and risk.

8.1.3 Managing the number of defects that are being raised on our assets, including the need to manage redundant assets and future-proof assets, is important in ensuring they continue to deliver the required network capability. We have been fully cognisant of the need to develop plans that are value for money, acceptable, affordable, and deliverable, whilst achieving a suitable level of risk of our aging assets.

8.2 Business Case Summary

8.2.1 A variety of technical interventions have been considered and combined to create a range of CBA options, the results of which are presented in Table 38.

8.2.2 Figure 10 shows a decrease in the Net Present Value (NPV) for all options, with no visible payback in the modelled period. Overall, the risk associated with Site Assets is much smaller than other asset health themes and so it takes a long time, beyond the modelled period, to accumulate the benefit needed to pay off the initial investment.

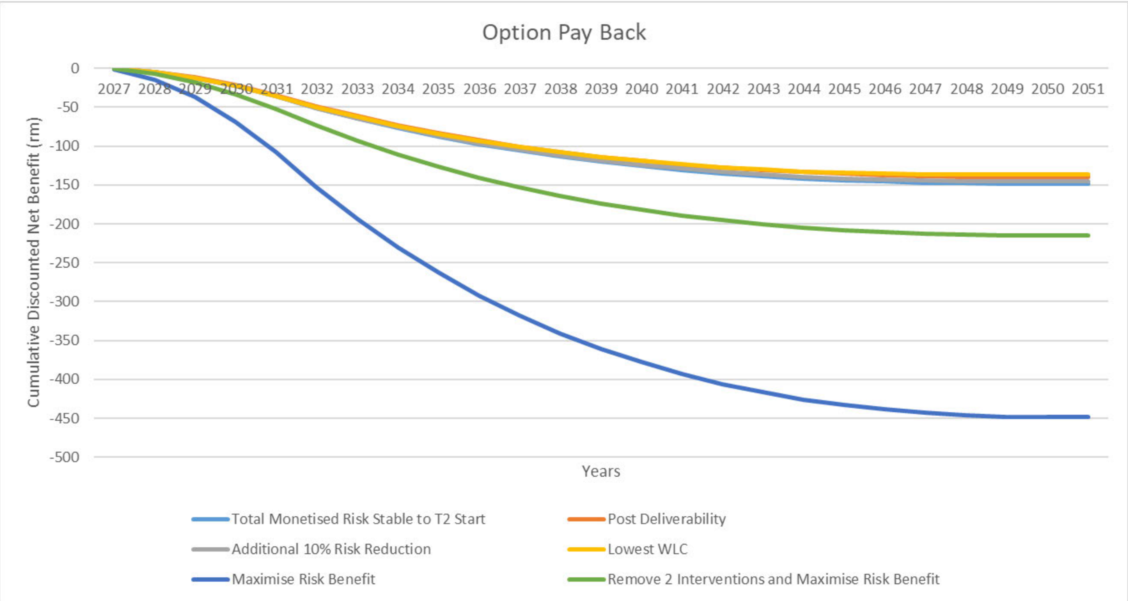

Figure 10: Payback period for different options

Table 38: Option summary of headline business case metrics (£m, 2023/24)

Option	Total Volume of Interventions	Total Spend Request	Outcome Risk End of RIIO-GT3	% change in comparison to start of RIIO-T2	NPV (£m)	Payback Period from 2031	% change in service risk measures compared to start of RIIO–T2				
							Financial	Health and safety	Environmental	Availability Reliability	Societal
Option 0: Counterfactual (Do Nothing)	N/A	0	£3.11m	112.89%	N/A	N/A	102.74%	164.72%	116.67%	215.46%	140.98%
Option 1: Total Monetised Risk Stable to T2 Start	2715	£157.24m	£2.94m	106.60%	(148.35)	Does not payback in the period	92.71%	142.87%	114.00%	214.67%	128.73%
Option 1A: Post Deliverability	2237	£149.59 m	£2.94m	106.62%	(207.33)	Does not payback in the period	95.88%	146.41%	111.85%	209.97%	129.06%
Option 2: Additional 10% Risk Reduction	2715	£157.24 m	£2.75m	99.87%	(145.48)	Does not payback in the period	88.93%	136.86%	105.00%	214.46%	127.55%
Option 3: Lowest WLC	2715	£157.24m	£2.11m	76.64%	(135.95)	Does not payback in the period	78.49%	134.09%	70.95%	214.67%	127.62%
Option 4: Maximise Risk Benefit	5188	£217.77m	£2.88m	104.58%	(210.35)	Does not payback in the period	90.00%	139.42%	112.64%	214.67%	102.96%
Option 5: Remove 2 Interventions and Maximise Risk Benefit	5188	£169.31m	£2.89m	104.71%	(160.39)	Does not payback in the period	90.33%	139.42%	112.64%	214.67%	102.96%

8.2.3 Based on the validated, defects driven package of investment and the volume of sites this is being undertaken at, the modelled benefit is more than risk stable. It is predominantly a bottom-up plan.

8.2.4 We need to invest in maintaining functioning Site Assets on the NTS to support and enable the safe and efficient operation of sites across the NTS. The investments presented in this paper aim at maintaining statutory compliance and the asset health of site assets while striking an appropriate balance between tolerable risk and value for money for consumers.

8.2.5 By selecting locations and defects highlighted through our targeted surveys and extracted from our defects system, across all Site Assets, we have presented the most pragmatic option while protecting our site assets from corrosion.

8.2.6 Our investment, across all Site Assets, seeks to address, stabilise and manage known defects from surveys and our defects database.

8.2.7 Failure of these assets has the potential of impairing the smooth flow of gas on the NTS which would have safety, environmental, financial, and reputational consequences. We therefore need to progress the interventions.

9 Preferred Option and Project Plan

9.1.1 The preferred option to manage our site assets is **CBA Option 1: Total Monetised Risk Stable to RIIO-T2 Start**. Our programme of investment on site assets has been taken through a deliverability assessment which assesses this programme of works against outputs across our entire capital investment plan. This results in a slightly adjusted **Option 1A** which includes the mixture of interventions for Preheating, Filters and Site Pipework listed in Table 39. Our proposed investment maintains statutory compliance whilst striking an appropriate balance between tolerable risk and value for money for consumers.

Table 39: Preferred intervention summary (£m, 2023/24)

Intervention	Primary Driver	Volume	Unit of Measure	% Assets / Sites Intervened upon	Total RIIO-GT3 Request	Funding Mechanism	PCD Measure
Replace Modular Boiler Package including building	AH Known Defects Secondary	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Replace Modular Boiler Package	AH Known Defects Secondary	[redacted]	Per Site	[redacted]	[redacted]	Baseline - NARMS	A1
Refurbish Modular Boiler	AH Risk Management	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Heat Exchanger PSSR Inspection - Bacton	AH Legislation	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Heat Exchanger PSSR Inspection - NTS	AH Legislation	[redacted]	Per Asset		[redacted]		
Lagging & Cladding - Replacement of Cladding/Lagging (Small Site)	AH Legislation	[redacted]	Per Site	[redacted]	[redacted]	Baseline - NARMS	A1
A/G Pipework - CM/4 Defect Resolution	AH Legislation	[redacted]	Per Project	[redacted]	[redacted]	Baseline - NARMS	A1
A/G Pipework - AGI Partial site coating	AH Legislation	[redacted]	Per Site	[redacted]	[redacted]	Baseline - NARMS	A1
A/G Pipework - AGI Full Site coating	AH Legislation	[redacted]	Per Site	[redacted]	[redacted]	Baseline - NARMS	A1
AGI Inspection Tool Survey	AH Legislation	[redacted]	Per Site	[redacted]	[redacted]	Baseline - NARMS	A1
Pit Wall Transition Non Destructive Testing	AH Risk Management	[redacted]	Per Pit Wall Transition	[redacted]	[redacted]	Baseline - NARMS	A1
Filter PSSR Inspection and Rectification - Bacton	AH Legislation	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Filter PSSR Inspection and Rectification - NTS	AH Legislation	[redacted]	Per Asset		[redacted]		
Replacement of Steel Pipe Supports	AH Policy	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Replacement of Concrete Pipe Support with Steel Pipe Support	AH Policy	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Remediation of Pit Wall Transition Defect	AH Policy	[redacted]	Per Pit Wall Transition	[redacted]	[redacted]	Baseline - NARMS	A1
Break out of Pit Infrastructure	AH Policy	[redacted]	Per Pit	[redacted]	[redacted]	Baseline - NARMS	A1
Heat Exchanger PSSR Bursting Disk Replacement	AH Legislation	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Monitoring of Pipe Supports & Pits Assets	AH Risk Management	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Refurbish Water bath Heater	AH Legislation	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Bacton A/G Pipework Biocide Coating Application	AH Legislation	[redacted]	Per CM/4 Zone	[redacted]	[redacted]	Baseline - NARMS	A1
Bacton A/G Pipework - AGI Partial Zone coating	AH Legislation	[redacted]	Per CM/4 Zone	[redacted]	[redacted]	Baseline - NARMS	A1
Site Vibration Rectification 5 Volumes	AH Policy	[redacted]	Per Project	[redacted]	[redacted]	Baseline - NARMS	A1
Concrete Plinth Repair	AH Known Defects Secondary	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Replacement of Concrete Pit Covers with GRP Composite Covers	AH Known Defects Secondary	[redacted]	Per Asset	[redacted]	[redacted]	Baseline - NARMS	A1
Installation of Building Gas Detection on AGIs	AH Policy	[redacted]	Per Building	[redacted]	[redacted]	Baseline - NARMS	A1
Installation of Line of Sight Gas Detection	AH Policy	[redacted]	Per Site	[redacted]	[redacted]	Baseline - NARMS	A1
Preheating, Filters and Pipework Total		**2004**	**92%**		**108.55**	**73%**	
Site Assets Total		**2237**	**100%**		**149.59**	**100%**	

9.2 Asset Health Spend Profile

9.2.1 The spend profile in Figure 11 provides an indicative view on when the EJP interventions are to be carried out. The cost profile represents only the Preheating, Filters and Pipework interventions which are part of the wider asset health interventions on the NTS.

[redacted]

9.3 Investment Risk Discussion

9.3.1 Our preferred option can be delivered effectively within outage constraints on our sites and ensures appropriate levels of site and asset availability to deliver effective and efficient network operations.

9.3.2 All Site Assets identified for intervention are in line with our Needs Case and future strategy of keeping gas flowing in the interests of consumers. Key risks and currently identified mitigations are summarised in Table 40.

Table 40: Site Assets key risks and identified mitigations.

No.	Risk	Mitigation (based on current view)
1	Additional buried services being identified.	Check data banks and internal desktop review but ensure GPR and underground surveys are completed in areas of the works as assurance to de-risk.
2	Initial site survey doesn't sufficiently capture required information resulting in additional site surveys which increase intervention cost and delivery time surveys.	Minimise number of surveys by optimising contractors site visits.
3	Additional scope requirements (including mechanical, design and civil) leading to scope change / creep.	Close engagement with contractor and site operations. Detailed surveys to ensure no additional works required.
4	Discovery of nesting birds, pests and additional environmental considerations could result in project delays.	Carryout intrusive surveys before commencing works.
5	Ground conditions are unsuitable for excavation.	Ground investigations and bore holes to be completed to assess ground conditions, weather monitoring around ground related activities. Unforeseen residual risk will always remain.

9.4 Project Plan

9.4.1 Project delivery has been split into three phases which align with our Network Development Process (ND500) as summarised in Table 41. Commissioning dates are not relevant to all intervention types but take place at the end of the delivery phase.

Table 41: Delivery phase alignment with ND500

Delivery Phase	ND500 Stage Gate(s)
Preparation	T0, T1, F1 (Scope establishment), T2, F2 (Option selection), T3, F3 (Conceptual Design Development and Long Lead Items Purchase), T4
Delivery	F4 (Execute Project), T5, Available for Commercial Load (ACL), T6
Close Out	F5 (Reconcile and Close)

9.4.2 Table 42 shows the summary plan and provisional delivery phases for site Preheating, Filters and Pipework sanctions within RIIO-GT3. Internal stakeholder engagement has identified when we can obtain network access, where required, to complete these works.

Table 42: Site Assets Portfolio Programme for RIIO-GT3 period

EJP	Sanctions	RIIO-T2		RIIO-GT3					RIIO-GT4
		FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32
Site Assets: Preheating, Filters and Pipework	T3_Bacton_Civils								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_Construction_FY29								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_Construction_FY28								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_Construction_FY30								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_Construction_FY31								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_NGS_FY29								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_NGS_FY31								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_Construction_FY27								
Site Assets: Preheating, Filters and Pipework	T3_Pipelines_PSSR								
Site Assets: Preheating, Filters and Pipework	T3_Bacton Site Asset FY29								
Site Assets: Preheating, Filters and Pipework	T3_Bacton Site Asset FY27								
Site Assets: Preheating, Filters and Pipework	T3_Bacton Site Asset FY30								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_NGS_FY28								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_NGS_FY30								
Site Assets: Preheating, Filters and Pipework	T3_Sites_AGI_NGS_FY27								

9.4.3 Preheating assets have long-lead times of circa six months. Filter interventions are guided by legislative PSSR requirements. Pipework investments are expected to be spread out through the RIIO-GT3 period.

9.4.4 The work has been profiled based on a deliverability assessment across our whole plan and align with outages associated with the in-line inspection programme and major projects.

9.5 Key Business Risks and Opportunities

9.5.1 The risk associated with our preferred option revolves around the difference in condition between the information utilised to build our investment proposals, defect information, condition surveys, and that identified through construction surveys at the time of delivery. This has the potential to increase the scope in excess of that identified through the development of the plan.

9.5.2 Our costs have been built through unit costs analysis and estimates from the market. However, there is a risk that costs of materials may increase due to macro-economic conditions. This shall partly be mitigated through the CPI-H inflation and real price effect mechanisms within our RIIO-GT3 regulatory framework.

9.5.3 Changes to system operation or supply and demand scenarios are unlikely to impact upon the proposal in this EJP.

9.5.4 Transitioning to hydrogen happening sooner than planned could impact these proposals due to the fact that hydrogen adversely alters the ductility, fracture resistance and fatigue properties of our preheating, filter and pipework infrastructure.

9.5.5 The interventions scopes identified within this EJP are clearly identified and understood. We have delivered similar scopes in RIIO-T2 with no change to these scopes proposed in RIIO-GT3.

9.5.6 Our programme of investment on our Site Assets has been taken through a deliverability assessment, including a network access/outage assessment, procurement assessment and contracting strategy development. These constraints enable the assessment of the delivery of this programme of works against our other outputs across our capital investment plan.

9.6 Outputs Included in RIIO-T2 Plans

9.6.1 There are no outputs from RIIO-T2 plans to be included within RIIO-GT3.

10Appendices

10.1 Appendix 1 - Preheating Unit Cost Breakdown

Intervention	External Cost	External %	NG Cost	NG %	Pre build Cost	Pre build %	Materials, Plant & Equipment cost	Materials, Plant & Equipment %	Risk & Contingency cost	Risk & Contingency (% of total cost)	Total Cost
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

10.2 Appendix 2 - Filters Unit Cost Breakdown

Intervention	External Cost	External %	NG Cost	NG %	Pre build Cost	Pre build %	Materials, Plant & Equipment cost	Materials, Plant & Equipment %	Risk & Constingency cost	Risk & Contingency (% of total cost)	Total Cost
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

10.3 Appendix – 3 Pipework Unit Cost Breakdown

Intervention	External Cost	External %	NG Cost	NG %	Pre build Cost	Pre build %	Materials, Plant & Equipment cost	Materials, Plant & Equipment %	Risk & Contingency cost	Risk & Contingency (% of total cost)	Total Cost
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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10.4 Appendix 4 - Intervention Volumes

Intervention / Location	Bottom Up Volumes	PA Volumes	Total Volumes
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
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