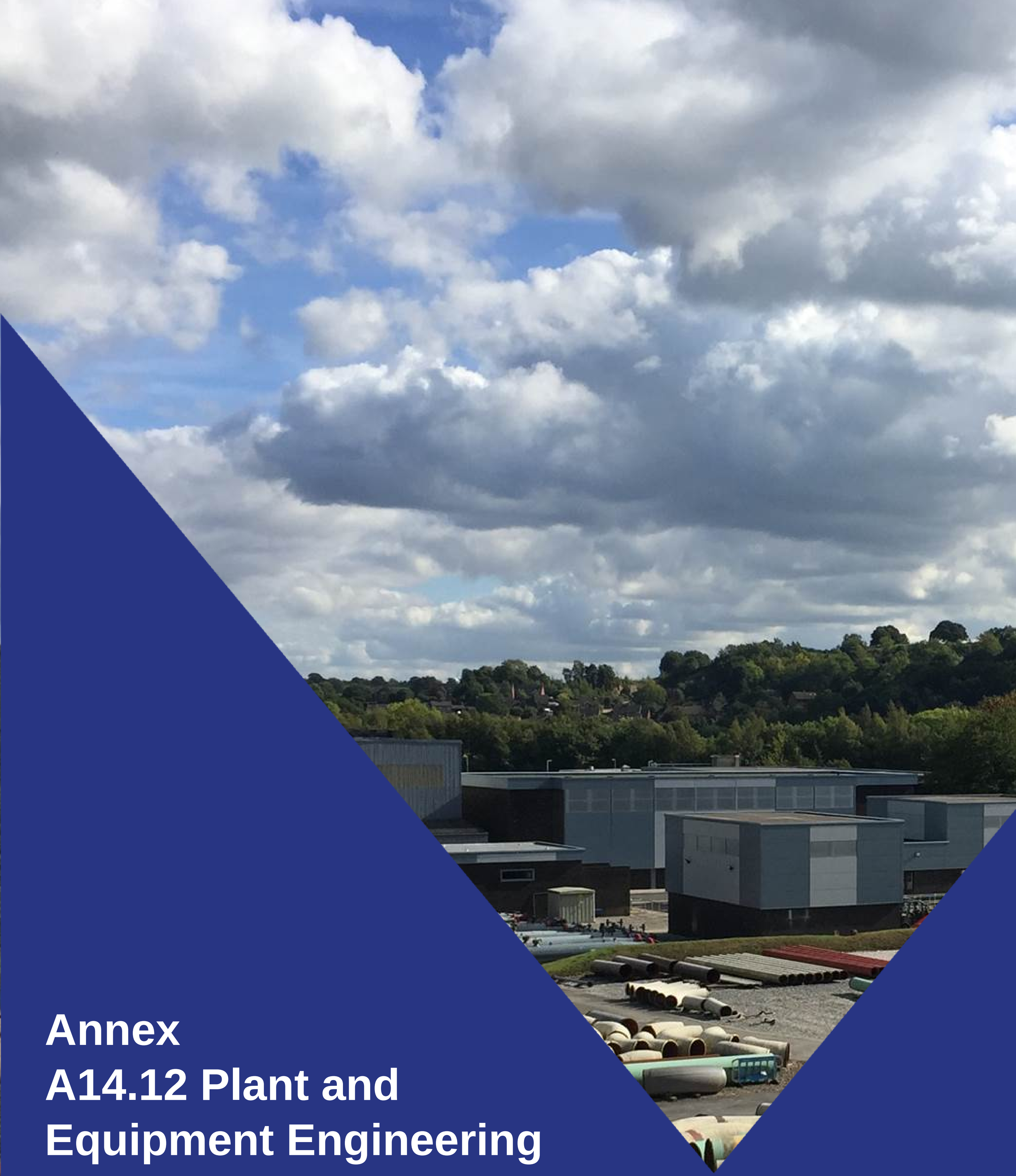


Annex
A14.12 Plant and Equipment Engineering Justification Paper

December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

Executive Summary

Introduction

To maintain the ongoing safe, secure and reliable operation of the UK Gas National Transmission System (NTS) it is imperative that the health of the assets that constitute the NTS is carefully managed.

Our Asset Health programme is an ongoing plan of works that assures this and consists of 7 core asset themes of work. This document outlines our approach to the management of our Plant and Equipment assets to meet desired regulatory, stakeholder and financial outcomes. A 10-year view has been taken, covering the RIIO-2 and RIIO-3 regulatory periods to ensure a balanced, lifecycle approach to asset management.

The Plant & Equipment investment theme covers a wide range of primary assets that make up the primary assets that contain and control the gas flows at the Above Ground Installations on the NTS. These assets are covered by safety legislation and in many cases have been in operation for over their original design life of 40 years.

The Plant & Equipment asset health programme is split across 3 sub-themes. In total, we propose £156.4m of investment (25.4% of the 7 themes that comprise the overall asset health plan) ensuring risk levels are maintained on our Pipeline assets during RIIO-2.

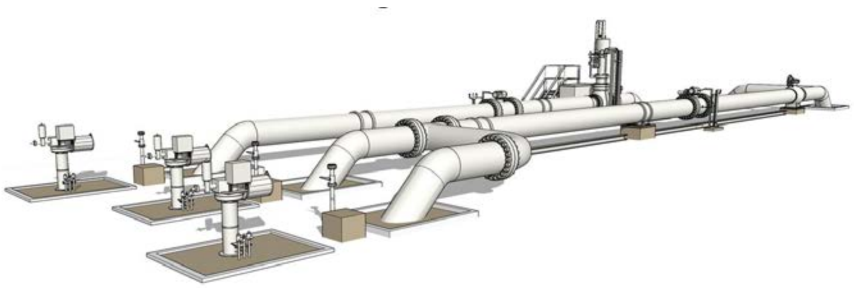
Sub-theme	Intervention Volumes	Cost
Above Ground Pipework, Cladding and CP Systems	832	£130,776,585
Filters, Scrubbers and Preheaters	221	£17,157,246
Pressure Reduction, Flow Control and Slamshut Systems	296	£8,506,360
Total	**1,349**	**£156,440,192**

The profile of Plant and Equipment asset health investment for the 10-year period, derived from the volumes of work and the unit costs, is shown in the table below:

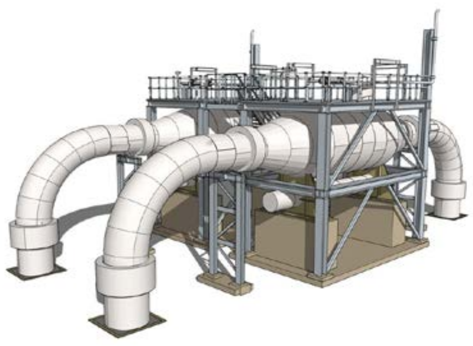
Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total	17,763	33,076	38,849	38,570	28,181	35,467	36,496	43,324	34,368	26,711
	156,440					**176,365**				

The Assets

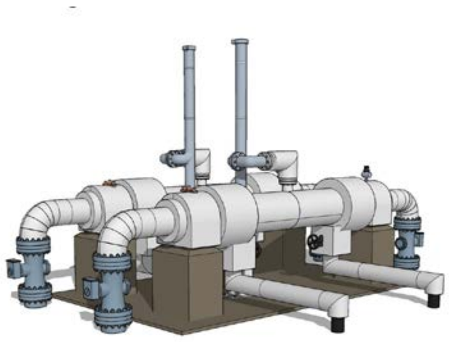
The Plant & Equipment assets comprise equipment on all of the 23 compressor stations and 504 above ground installations (AGIs) on the NTS. It includes **Pipework** which is **Coated** as a primary means of corrosion prevention and protected by **Cathodic Protection** as a secondary means where it is underground, **Pipe Cladding** to mitigate noise and thermally insulate the pipework, **Filters, Scrubbers and Strainers** to remove particulates and liquids from the gas flow, **Preheaters** to prevent condensate after **Pressure Reduction** points that meet customer requirements and **Slamshut** valves that close to protect plant and equipment from over pressurisation.



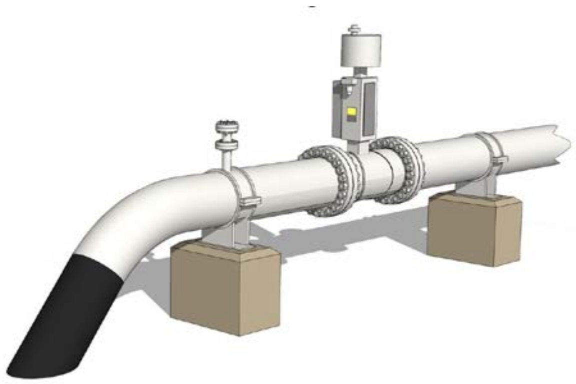
Above ground Pipework



Scrubber



Pre-heaters & Heat Exchangers



Flow and Pressure Control

The Plant and Equipment assets were installed at the same time as the sites were built. By the start of the RIIO-2 period, 70% of these sites will have been commissioned for over 40 years and have therefore reached or exceeded their original design lives.

Pipework is subject to the Pipeline Safety Regulations (PSR) and therefore needs to be designed, constructed and operated so that the risks are as low as is reasonably practicable. They are subject to a regular inspection regime with the associated resolution actions and repairs.

Whilst the equipment is varied in nature and purpose, except for cladding and cathodic protection, they operate at full NTS gas pressure and as such are subject to Pressure System Safety Regulations (PSSR). These regulations drive a regular regime of inspections (6 year and 12 year) and a managed resolution of any issues that are identified.

The [redacted] have recognised that managing the integrity of ageing plant and equipment is a key issue for the industry; in particular degradation due to corrosion, erosion and fatigue. Our external inspection and subsequent remediation of defects or "features" to industry standards, supplemented by internal policy and procedure, is accepted by the [redacted] as an appropriate way of operating safe plant and equipment, to comply with legislation.

The **above ground pipework** suffers age and mechanical degradation of the coating and corrosion from exposure to the atmosphere. The corrosion is more significant when the site is located in areas subject to air borne salts or other contaminates, such as in coastal or industrial locations. Corrosion is more prevalent in key areas such as underneath pipe supports, at the transition from above to below ground (either at a pit wall or the wind/water line), in congested areas subject to stagnant air or on specific elements (such as flanges or small-bore pipework).

Regular inspections indicate that defects on **filters, scrubbers and strainers** are increasing significantly and increased levels of refurbishment and replacement investment will be required for these assets.

Preheaters suffer from corrosion. In some cases, the original design has led to their sub optimal operation due to their distance from the compressor allowing the gas to cool and condense prior to reaching the compressor. This condensate can result in asset damage, inefficiency of the compressors and increasing overhaul frequency and cost.

Evidence from inspection demonstrates that numerous **Slamshut Valves** are at a point in their life cycle where their performance is sub-optimal, and they will not be able to perform their duty effectively. They will be refurbished when this is found to be the case and only replaced when overhaul is not possible or effective.

Corrosion also becomes a significant problem where water gets inside the **cladding**, soaking the insulation and creating ideal conditions for oxidation of the pipework. By the nature of the cladding, this corrosion is difficult and expensive to inspect.

Impacts of no investment

Lack of investment will result in an unsustainable situation where the volume of corrosion defects will grow to a level where the performance on the NTS cannot be maintained and any level of remediation would not keep pace with degradation. This would place the NTS in a state where only significant asset replacement would counter the corrosion issues, at significant cost to customers and consumers.

Proposal Development

In defining our proposed intervention approach, we have focused our effort on developing a least whole-life cost option that enables an optimised ongoing, rolling programme of work. Significant expert challenge and review has underpinned the levels of intervention and the proposed phasing ensures we meet the desired engineering and stakeholder outcomes whilst smoothing out the workload.

Whilst some interventions are cost beneficial over the investment period, the intervention required for Pipework, Coating, Cladding and Cathodic Protection is not. Coating, Cladding and Cathodic Protection all contribute to limiting degradation of the associated Pipework and so all must fail to a degree for degradation to happen. This means that although consequences can be high, cumulative probabilities, and associated risks, are often low. However, without effective protection, pipework will deteriorate rapidly requiring an expensive replacement programme to maintain performance and compliance. As such, these protective items are essential for meeting the desired outcomes.

In choosing the option to be carried forward into our plan we have considered the results of our CBA analysis amongst a range of other factors, examples set out below:

The need to achieve legislative compliance may not necessarily be reflected through the quantified benefits delivered through a cost beneficial investment option. For example, the [redacted] will not tolerate a planned increase in safety risk, regardless of the economics.

Where there is a backlog of known asset failures to be resolved, this will not always be reflected by the CBA as the risk valuation is calculated using an expected rate of future defects across the whole population of an asset type.

Our understanding of individual asset condition has improved during RIIO-1 but there are still gaps in our knowledge. Our plan reflects the need for a likely practical mix of intervention categories once specific assets are surveyed and their true condition and risk are understood. For example, a plan based upon 100% refurbishment may require a high number of replacements should a proportion of the assets be determined as non-serviceable

The need for a deliverable programme of work, both in terms of planning outages, resource availability and contract efficiency. For example, through "bundling" work it may be more cost-effective to undertake alternative interventions to achieve reductions in contract costs, minimise outage risks or avoid an early repeat intervention in future RIIO periods

The table below summarises the key considerations when developing this theme of work.

To deliver these outcomes….
• Ensure continued compliance with legislation in relation to PSSR and PSR inspections and resolution of any identified issues • Stabilise and improve the asset deterioration to prevent loss of containment of high-pressure gas, limit the safety risk, not limit availability or performance of the NTS and not cause damage to the compressors or other equipment • Ensure the filter, scrubber, strainer and preheater assets prevent accelerated deterioration of condition, availability and performance of the compressors and other assets on the NTS. • To ensure that flow control valves enable the flexibility, operation and line-pack of the NTS • To ensure Slamshut valves operate correctly and within the defined time to safely protect the downstream NG and customer assets • Review the need for individual assets and decommission where no longer required or refurbish or replace to maintain functionality or upgrade if justified • Meeting the expectations of our customers and stakeholders and keeping risk stable
…by intervening like this…
• Implementing painting programmes as appropriate to ensure suitable pipework protection • Remove cladding where possible and replace where it is damaged • Inspecting, maintaining, testing and, where excessively damaged or obsolete, replacing pressure containing equipment to ensure its continued performance can compliance • Decommissioning equipment that is no longer required such as strainers from construction works
…based on this knowledge:

- An asset-specific risk-based review of the results of routine inspections, maintenance and investigations already undertaken
- A forecast of the defects and associated risks following routine interventions
- Knowledge of the volumes of assets that are currently obsolete or forecast to be obsolete during the investment period
- Site-specific PSSR Written Schemes of Examination and the associated inspection history
- Operational performance requirements on flow-control and pressure reduction stations
- The safety performance requirements of Slamshut valve systems.

RIIO-2 Plant & Equipment Asset Health Investment Proposal Summary

Plant & Equipment Asset Health investment proposal headlines

- 99% of the Plant & Equipment Asset Health proposals deliver NARMs outputs with 74% of the proposal driven by Legislation/Safety Case requirements.
- 58% of our Plant & Equipment programme is based upon interventions to address known defects (30%) and high confidence work volumes based on historical trends (28%).
- Two of the three sub-themes are cost beneficial (The “Filters, Scrubbers & Preheaters” and the “Pressure Reduction, Flow Control and Slamshut Systems” Sub Theme). However, these only represent 16% of the total cost of this theme.
- All elements of the “Above Ground Pipework, Cladding and CP Systems” sub-theme is driven by safety legislation except for the patch, partial and full site painting element (£24.5m). This work delivers NARMS outputs and avoids significant future corrosion defect remediation costs.

A range of options has been considered for each sub-theme of the Plant & Equipment interventions:

Sub-theme	RIIO-2 Plan (£)	Percentage of Theme	Options considered	Option summary / considerations
Above Ground Pipework, Cladding and CP Systems	£130,776,585	83.6%	4	Range of options identified to balance cost/risk detailed within this justification report for this significant area of work. The selected option is the least cost option to meet outputs and legislative requirements
Filters, Scrubbers and Preheaters	£17,157,246	11.0%	3	Range of options identified to balance cost/risk detailed within this justification report for this significant area of work. The selected option is cost beneficial and the least cost option to meet outputs and legislative requirements
Pressure Reduction, Flow Control and Slamshut Systems	£8,506,360	5.4%	3	Range of options identified to balance cost/risk detailed within this justification report for this significant area of work. The selected option is cost beneficial and the least cost option to meet outputs and legislative requirements.

We have estimated unit costs across all our proposed Plant and Equipment interventions either from historical outturn data points, from supplier quotations or from other estimation methods (such as extrapolation to similar types of work or from reviewing industry benchmarking data). Our approach has been primarily based top down from final actual costs combined with bottom up from estimating procedures and supplier rates or quotations. We have challenged our costs through internal benchmarking review with current supply chain partners combined with use of benchmarking data where this exists.

All the unit costs include the efficiencies resulting from bundling delivery programmes across asset classes and within available outages and efficiencies resulting from our innovation projects where these are proven to deliver benefits and can be utilised in the planned investments.

While some aspects of the Plant and Equipment Asset Health plan are built on robust data that has been gathered over many years, only 52% overall can be justified through outturn costs. There are several cost differentiators (e.g. diameter, productive hours and length) and unique factors (e.g. repeatable activities, ground conditions, access requirements and work mix) that influence the degree of certainty, which are presented in this report.

The Plant and Equipment theme is the most diverse in terms of asset types and there are areas where there have been challenges to identify representative historic projects. For example, unit costs for AGI painting have been determined from our costs and experience from RIIO-1 and are a blend of patch, partial site and full site painting taken from final actual costs and weighted by the forecast work mix included in our plan. The internal challenge and review resulted in a further split into small, medium and large sites to reflect the economies of scale obtained whilst undertaking a greater volume of painting once mobilised on site.

The table below summarises the evidence used to produce the Plant and Equipment unit costs.

Investment sub-theme	Secondary Asset Class	RIIO-2 Business Plan	Evidence		
			Outturn	Quotations	Other
Above Ground Pipework, Cladding and CP Systems	Above Ground Pipe and Coating	£100.8m	78%		22%
	Cathodic Protection	£28.2m			100%
	Cladding	£1.7m		100%	
Filters, Scrubbers and Preheaters	Filters and Scrubbers (Including condensate tanks)	£11.7m	26%		74%
	Preheaters	£5.5m			100%
Pressure Reduction, Flow-Control and Slamshut Systems	Flow or pressure regulators	£7.1m			100%
	Slamshut valves	£1.4m			100%
Total		**£156.5m**	**52%**	**1%**	**47%**

We have set out full details of our process for estimating unit costs across our asset health proposals in our Asset Health Unit Cost Annex.

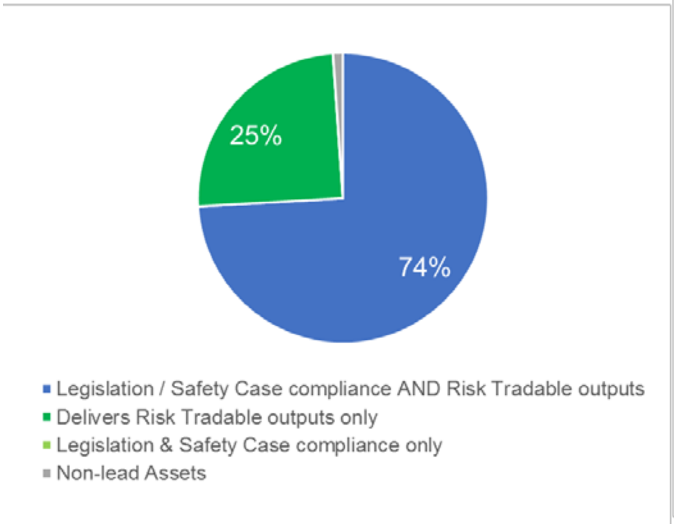
The RIIO-2 Asset Health Structural Integrity theme and intervention costs and volumes by output are provided below. All costs are in thousands (£000)

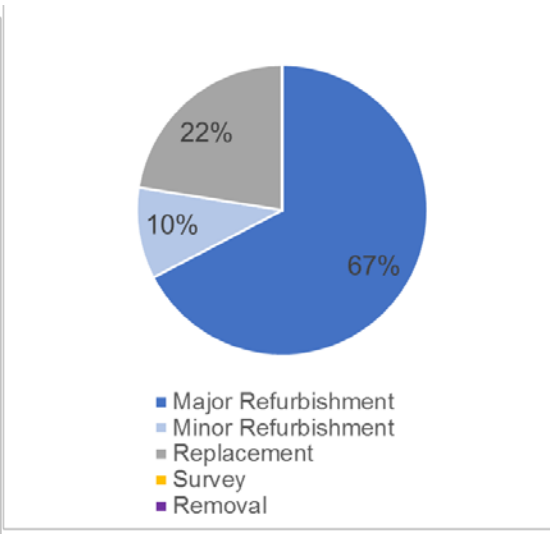
Sub-theme & Intervention	RIIO-2 Volumes[1]	Legislation/ Safety Case & Risk Tradable	Risk Tradable	Legislation & Safety Case	Non-lead Assets
Above Ground Pipework, Cladding and CP Systems					
Replacement of Failed IJs on AGIs	[redacted]	£1,922	£0	£0	£0
CP Investigations & Rectification	[redacted]	£1,914	£0	£0	£0
AGI Pipework Painting (Full, Partial or Patch)	[redacted]	£0	£505	£0	£0
AGI Pipework Painting (Full, Partial or Patch)	[redacted]	£0	£23,069	£0	£0
CM/4 Corrosion Defects Resolution	[redacted]	£43,429	£0	£0	£0
Replace Cladding on on AGIs	[redacted]	£0	£0	£0	£1,731
Replacement of Failed IJs on AGIs	[redacted]	£13,332	£0	£0	£0
Resolve Existing AGI CP Priority 1 Defects	[redacted]	£15,019	£0	£0	£0
Resolve Existing AGI CP Priority 2 Defects	[redacted]	£7,842	£0	£0	£0
Pipework modifications - compressor surge issues (St Fergus)	[redacted]	£0	£5,153	£0	£0
Resolve CAT4 CM/4 Defects on pipework (St Fergus)	[redacted]	£12,367	£0	£0	£0
Pipework modifications - Minor CAPEX (St Fergus)	[redacted]	£0	£103	£0	£0
Above Ground Pipework Patch Painting (St Fergus)	[redacted]	£0	£928	£0	£0
Replacement of CP system at St Fergus	[redacted]	£3,463	£0	£0	£0
Filters, Scrubbers and Preheaters					
Filters PSSR Inspection & Major Overhauls	[redacted]	£185	£0	£0	£0
Preheater PSSR Revalidation, WBH Inspection & Major Refurbs	[redacted]	£104	£0	£0	£0
Filters PSSR Inspection & Major Overhauls	[redacted]	£3,058	£0	£0	£0
Replace Strainers with Filters/Separators	[redacted]	£6,486	£0	£0	£0
Scrubber & Condensate Tank Internal Inspections & Estimated Major Refurbs	[redacted]	£1,958	£0	£0	£0
Preheater AGI Boiler Replacement	[redacted]	£0	£1,288	£0	£0
Preheater Minor Refurb	[redacted]	£93	£0	£0	£0
Preheater PSSR Revalidation, WBH Inspection & Major Refurbs	[redacted]	£3,469	£0	£0	£0
Preheater Upgrade - Compressor Fuel Gas @ Wooler	[redacted]	£0	£515	£0	£0
Pressure Reduction, Flow Control and Slamshut Systems					
Pressure Reduction - Flow Control Valve Upgrade	[redacted]	£0	£5,314	£0	£0
Pressure Reduction Offtakes - Regulator Replacement	[redacted]	£0	£1,134	£0	£0
Pressure Reduction Skid Replacement - Compressor Stations	[redacted]	£0	£386	£0	£0
Pressure Reduction Streams - Major Overhauls	[redacted]	£0	£277	£0	£0
Pressure Reduction - Flow Control Valve Upgrade	[redacted]	£1,211	£0	£0	£0
Pressure Reduction Offtakes - Regulator Replacement	[redacted]	£0	£0	£0	£0

[1] Where 'rounding' resulted in volumes being presented as a zero, we have included a decimal place to illustrate the proportion of the site (unit of measure is site) that is to be intervened upon.

Pressure Reduction Skid Replacement - Compressor Stations	[redacted]	£0	£129	£0	£0
Pressure Reduction Streams - Minor Overhauls	[redacted]	£56	£0	£0	£0
Total	[redacted]	**£115,909**	**£38,800**	**£0**	**£1,731**

Plant & Equipment Asset Health theme outputs and intervention categories:

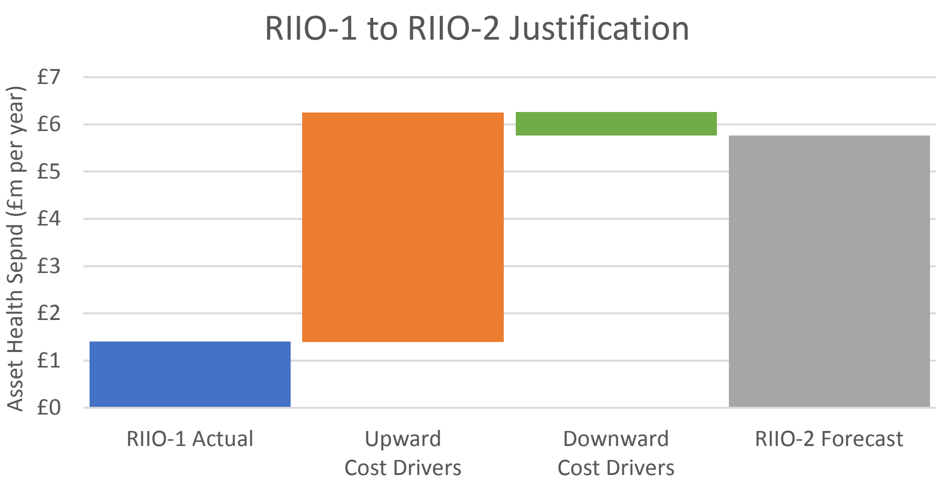




Comparing our RIIO-2 proposal to our RIIO-1 programme

The annualised RIIO-2 spend has increased when compared to RIIO-1 from £7.0m to £28.8m for the Plant & Equipment Asset Health theme.

Note that this cost information is annualised to provide a comparative cost per year and the total RIIO-2 forecast below also includes the application of our agreed efficiency target within the downward drivers.



The drivers for the increase in spend from RIIO-1 to RIIO-2 stem from increased volumes rather than increases in unit costs. Our proposed RIIO-2 unit costs are broadly in line with RIIO-1 unit costs (with further efficiencies also added) of which 45% of costs for Plant & Equipment are estimated from RIIO-1 historical outturn data.

The volume drivers, both upward and downward, affecting our proposed RIIO-2 spend are set out below.

Upward Drivers

There are several differences in our approach to managing our plant and equipment assets in RIIO-2 when compared to RIIO-1. It is of note that our forecast total spend for RIIO-1 in this area is double that was originally anticipated and we no longer classify above ground pipework and coating asset health work as OPEX.

Throughout RIIO-1 we have sought to significantly increase our understanding of the condition and deterioration rates of our assets. A new corrosion management process was implemented, producing more detailed assessments of corrosion defects on our AGIs – this is data that was not available ahead of RIIO-1 and now shows widespread corrosion issues that require resolution during RIIO-2 to ensure significant end of life asset risks do not materialise in the medium term.

Better information is now available on the condition and effectiveness of our cathodic protection assets at our AGIs. This information has shown many ineffective systems and widespread condition issues. These CP systems are the primary protection systems for our AGIs, failure to bring these systems back to a good working order will result in significant risks to these assets and in turn significantly higher costs in later years to replace AGI assets wholesale.

Downward Drivers

Project GRAID provides a novel robotic technique for inspecting non-piggable sections of pipeline, primarily associated with AGIs, which have been previously difficult to inspect. Investment is required to use this technique on AGIs, costs will vary depending on complexity of pipework unique to sites. Currently it is estimated to be used on 34 sites (5+5year period), with associated rollout costs of £28.45 million. It is estimated that 7-8 excavations per year will be avoided, at circa. £0.28 million each (total £20.7m). Further benefits of GRAID include the ability to validate the extended life of assets; it is estimated that one major project could be avoided in RIIO-2 at a cost of £10.9 million, generating an estimated saving of £31.7 million (5+5-year period).

Table of Contents

Executive Summary **1**

Table of Contents **10**

1. Summary Table 12

Plant and Equipment **13**

2. Introduction 13

Pipework, Coating, Cladding and Cathodic Protection (£130.8m) **15**

Above Ground Pipe and Coating **15**

3. Above Ground Pipework and Coating - Equipment Summary 15
4. Above Ground Pipework and Coating - Problem Statement 19
5. Above Ground Pipework and Coating - Probability of Failure 25
6. Above Ground Pipework and Coating - Consequence of Failure 27
7. Above Ground Pipework and Coating - Options Considered 28

Pipework Cladding **32**

8. Pipework Cladding - Equipment Summary 32
9. Pipework Cladding - Problem Statement 33
10. Pipework Cladding - Probability of Failure 35
11. Pipework Cladding - Consequence of Failure 37
12. Pipework Cladding - Options Considered 38

Buried Site Pipework, Coating and Cathodic Protection **40**

13. Buried Site Pipework - Equipment Summary 40
14. Buried Site Pipework - Problem Statement 42
15. Buried Site Pipework - Probability of Failure 45
16. Buried Site Pipework - Consequence of Failure 47
17. Buried Site Pipework - Options Considered 48

Business Case **51**

18. Business Case Outline and Discussion 51
19. Investment Decision – Above Ground Pipework and Coating 56
20. Investment Decision – Pipework Cladding 58
21. Investment Decision – Buried Site Pipework, Coating and Cathodic Protection 60
22. Business Case Summary 61

Preferred Option **64**

23. Preferred Option Scope and Project Plan 64

Filters, Scrubbers, Strainers and Preheaters (£17.2m) **66**

Filters, Scrubbers and Strainers **66**

24. Filters, Scrubbers and Strainers - Equipment Summary 66
25. Filters, Strainers and Scrubbers - Problem Statement 67
26. Filters, Scrubbers and Strainers - Probability of Failure 72
27. Filters Scrubbers and Strainers - Consequence of Failure 74

28. Filters Scrubbers and Strainers - Options Considered 75
Preheaters **78**
29. Preheaters - Equipment Summary 78
30. Preheaters - Problem Statement 80
31. Preheaters - Probability of Failure 84
32. Preheaters - Consequence of Failure 86
33. Preheaters - Options Considered 87
Business Case **91**
34. Business Case Outline and Discussion 91
35. Investment Decision – Filters, Scrubbers and Strainers 95
36. Investment Decision – Preheaters 97
37. Business Case Summary 99
Preferred Option **102**
38. Preferred Option Scope and Project Plan 102
Pressure Reduction, Flow Control and Slamshuts (£8.5m) **104**
Pressure Reduction and Flow Control **104**
39. Pressure Reduction and Flow Control - Equipment Summary 104
40. Pressure Reduction and Flow Control - Problem Statement 105
41. Pressure Reduction and Flow Control - Probability of Failure 109
42. Pressure Reduction and Flow Control - Consequence of Failure 111
43. Pressure Reduction and Flow Control - Options Considered 112
Slamshuts **114**
44. Slamshuts - Equipment Summary 114
45. Slamshuts - Problem Statement 115
46. Slamshuts - Probability of Failure 118
47. Slamshuts - Consequence of Failure 120
48. Slamshuts - Options Considered 121
Business Case **122**
49. Business Case Outline and Discussion 122
50. Investment Decision – Pressure Reduction and Flow Control 126
51. Investment Decision – Slamshut 128
52. Business Case Summary 130
Preferred Option **133**
53. Preferred Option Scope and Project Plan 133
Appendices **135**
Appendix A – Intervention Driver Categories 135

1. Summary Table

Name of Scheme/Programme	*Plant and Equipment*
Primary Investment Driver	*Asset Health*
Scheme reference/ mechanism or category	*A22.12*
Output references/type	-
Cost	*£156.4m*
Delivery Year	*2022-2026*
Reporting Table	*3.03b*
Outputs included in RIIO-1 Business Plan	-

Plant and Equipment

2. Introduction

Structure of the Case

2.1. This document summarises the justification for the required investment in the plant and equipment assets installed on the High-Pressure Gas National Transmission System (NTS). All assets have been assessed using a consistent overall risk and evidence based analytical framework.

2.2. The investment case for Plant and Equipment is organised into three groups.

- The pipework and associated assets on our sites:
  - Above Ground Pipework
  - Pipework Cladding
  - Below Ground Pipework, Coating and Cathodic Protection
- Those assets that condition the gas ready for use by ourselves, our customers or transmission on the NTS:
  - Filters, Scrubbers and Strainers
  - Preheaters
- Those that control the pressure and flow of gas and provide protection for over pressurisation:
  - Pressure Reduction and Flow Control
  - Slamshut Systems

2.3. The groups enable the assets with similar drivers, purpose and impacts to be discussed and assessed collectively. For each group of assets, the following structure has been followed:

2.4. The investment case for investment in the plant and equipment is set out in the following sections of this document:

- **Equipment summary** – which provides a summary and profile of the asset base
- **Problem statement** – the issues facing the asset base, drivers for investment and impact of no investment
- **Probability of failure and Probability of consequence** – sections which set out the way an asset may fail and the impact on consumers and/or environment
- **Options considered** – the potential mix of intervention options to be considered for each of the assets within a range of programmes
- **Business case outline and discussion** – our preferred option and reasons, given the cost benefit analyses and assessment of other drivers and business plan objectives
- **Preferred option and plan** – the final selected option restated, along with the five year spend profile

2.5. This structure is used for each of the elements of the plant and equipment assets:

Overview of Plant and Equipment

2.6. On compressor sites and other Above Ground Installations (AGIs) there are specific types of plant and equipment that enable the efficient and safe operation of the NTS. There are 23 compressor sites and 504 AGIs with a combination of the following items of plant:

Pipework and Coating – enables the flow of gas onto, around and away from the site. Pipework is protected by paint or other coating which provides the primary protection against corrosion.

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

Cathodic Protection – provides corrosion protection for any buried pipework or other buried steel structural site elements where the primary barrier coating has failed

Filters, Scrubbers and Strainers – placed within the gas flow at points on the site to remove dust, debris and liquid from the high-pressure gas flow and protect key items of operational plant

Preheaters – preheat the gas prior to pressure reduction to prevent condensation and the subsequent liquids entering items of plant or being transmitted through the NTS

Pressure Reduction – reduce the pressure of the gas from full NTS pressure to that required for use by customers, actuation of valves or to provide fuel gas to compressors

Flow Control Valves - allows Gas Network Control Centre (GNCC) to remotely control the flow of gas and pressure between two or more sections of pipeline

Slamshuts – automatic devices which protect the pipe work and other assets from over pressure failure

Pipework, Coating, Cladding and Cathodic Protection (£130.8m)

Above Ground Pipe and Coating

3. Above Ground Pipework and Coating - Equipment Summary

3.1. The purpose of above ground pipe is to contain natural gas flow and conduct it under pressure between process, flow-control, pressure control, gas quality, compression, metering, scrubbers and Pipework inspection equipment.

3.2. Above ground pipework consists of:

- General Pipework
- Risers
- Flanges
- Pipe Supports (Corrosion at interface with pipeline)
- Pit Wall Transitions (Corrosion at interface with pipeline)
- Cladding
- Vent and Sealant (Proposed investment captured within the valves justification report A22.14)

3.3. Pipework coating provides a barrier between the parent pipework and its environment to prevent corrosion from occurring. Corrosion has been highlighted as being the single biggest life limited mechanism affecting the NTS.

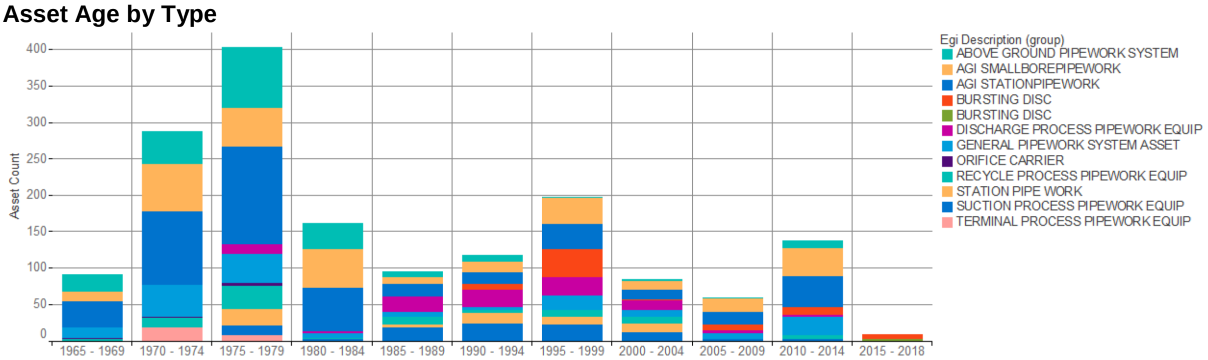
3.4. Pipework is also designed to allow access to associated assets (e.g. valves), for operation and maintenance.

Location and Volume

3.5. Above ground pipework is present on a total of 375 sites, 23 Compressor Stations, 42 Multi-Junctions, 15 Entry Points, 119 Exit Points and 253 Block Valves. The clear majority are at diameters ranging from 50 mm to 1,200 mm.

3.6. The chart below shows the age profile of above ground pipework and coating assets by asset type.

Asset Age by Type



Pressure Ratings

3.7. The above ground 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 Compressors there is some further breakdown of pressures for other site equipment operations.

Managing the Above Ground Pipework

3.8. The design, construction, operation and maintenance of the above ground pipeline is subject to both:

- Pressure System Safety Regulations 2000 (PSSR) – general legislation for all pressure vessels, defining the regime for setting inspection frequencies and subsequent remediation of defects.
- The Pipeline Safety Regulations 1996 (PSR) – specific legislation for operating pipelines, placing obligations to manage the safety risks that they present to members of public and NG staff.

3.9. The management of above ground steel pipework has been evolving over the last 50 years as their use has increased and issues with their lifecycle management become clear. We have been at the forefront of the evolution of these techniques alongside other pipeline owners, national bodies and technical experts. We are leading the development of the techniques and policies used due to the large scale, diversity, complexity and age of our pipework assets.

3.10. The industry standard for the design construction, operation and maintenance and decommissioning management of pipework in the UK is IGEM/TD/1. The is the recognised standard and is published by the Institute of Gas Engineers and Managers and developed by a panel of cross industry technical experts. National Grid and its predecessors have been involved with the evolution of this standard ever since the requirement to transport natural gas in an integrated way across the UK.

3.11. The NTS evolved from initial construction in the late 1960's and was built, operated and managed to the appropriate version of TD/1 in place at the time. Construction practices have developed hand in hand with the standards ultimately resulting in the evolution of TD/1.

3.12. Corrosion is unavoidable in the pipework and the management of corrosion issues has developed with time and this has been reflected in the evolving standard. Corrosion mechanisms are far better understood allowing the management of them to become more sophisticated. Paint types have changed over time as the understanding of the materials and their long-term performance is better understood.

3.13. The external inspection and subsequent remediation of pipework defects or "features" to industry standards (IGEM TD/1), supplemented by NG policies and procedures is accepted by the Health and Safety Executive as an appropriate way of operating a safe above ground pipework asset and complying with required legislation.

Inspection and Remediation Method

3.14. NG use a defined methodology and specification for the visual inspection of paint, coating, and cladding for above ground assets (CM/4). The CM/4 inspections are undertaken for all above ground pipework assets every six years.

3.15. The CM/4 inspections are undertaken, and results recorded for seven individual asset types:

- General Pipework
- Risers
- Flanges
- Pipe Supports
- Pit Wall Transitions
- Cladding
- Valve Vent and Sealant Lines

3.16. Each inspection result is categorised on a scale of 1 to 6 (examples of these are provided below)

3.17. Following an inspection those assets in category 4, 5 or 6 are subject to further investigation and assessment which will include non-destructive testing, removal of paint to assess the corrosion loss. Depending upon the asset concerned and the severity of the potential defect this may require pressure reduction.

3.18. Following the assessment, a decision is then made against defined NG policies to determine the intervention that is required which may include; cut out and replace, repair, recoat, composite wrap/ or clamps. These interventions are described in more detail in the relevant sections of the report. The NG policies used to make this decision are T/PM/P/11 Inspection and Damage Assessment for Pipelines the Nominal Diameter greater than 150mm or T/PM/P/20 which applies up to 150mm nominal diameter. These policies ensure the pipework is repaired and can be operated up to its maximum operating conditions.

3.19. The inspection regime, timing and defect categorisation is designed to ensure that a defect should not move more than one category between each inspection. This balances the effective monitoring of corrosion, the mitigation of risk of increasing corrosion and the costs of inspection.

Inspection Results and Records

3.20. Prior to the update of the CM/4 methodology in 2016 the results recorded from the CM/4 inspections were for the worst category of defect identified for each of the seven asset types on a site. This provided the information required to further investigate and assess the site and determine the actual number of defects requiring remediation.

3.21. The update of the CM/4 methodology in 2016 changed the inspection and recording policy in order undertake more effective and efficient management and planning of the corrosion defects. From 2017 onwards, all CM/4 inspections record the actual volume for the individual categories of 3[2], 4, 5 and 6 defects, together with an 'indication' of the number of category 2 and 3 defects. Therefore by 2024 all sites will have undergone a CM/4 inspection using the revised policy and individual counts of all significant defects for all seven asset types will be available.

[2] Vent & Sealant lines only

4. Above Ground Pipework and Coating - Problem Statement

4.1. Paint provides the corrosion protection for all above ground pipework. Above ground paint systems typically have an effective design life of 10 to 15 years. This can vary depending upon the environment that it is subjected to. Throughout the life of the paint coating it will start to break down. As paint systems break down the resulting defects require inspection and localised repair. This may include remediation of the corrosion of the underlying pipework. The paint coating needs to be reapplied every 10 to 15 years (varied by local environment) to relife it and ensure its continued effectiveness to protect the pipework asset.

4.2. Along with fatigue, due to thermal and pressure cycling, corrosion is the life limiting factor for the above ground pipework.

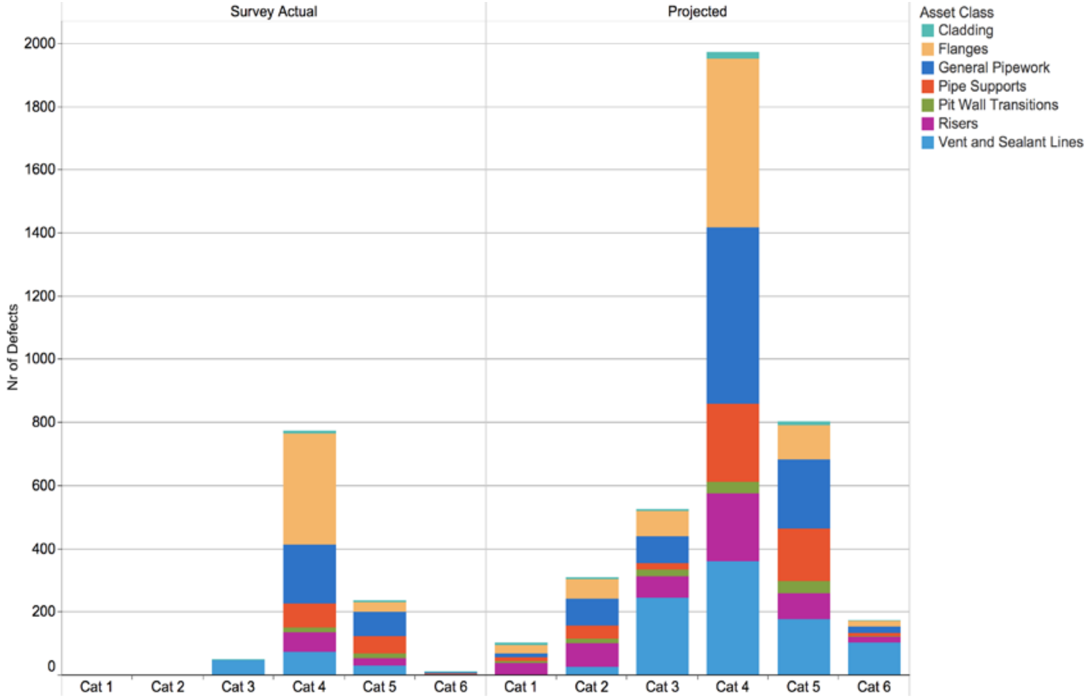
4.3. By the end of RIIO-3 over 77% of the above ground pipework will be over 50 years old with paint coatings being between 15 and 20 years old. NG are experiencing and will continue to experience pipework corrosion and other related defects that need investment to remediate and prevent the associated consequences.

4.4. As stated in the previous section, from 2017 onwards, all CM/4 inspections record the actual volume for the individual categories of 3, 4, 5 and 6 defects, together with an 'indication' of the number of category 2 and 3 defects. The first chart below shows the summary of the results of these surveys for the sites that have already been completed.

4.5. Extrapolating the results of the completed surveys across the sites that have yet to have a detailed survey undertaken indicates the level of CM/4 defects across the whole NTS is as shown in the second chart below.

Number of Corrosion Defects Identified from Detailed Surveys (exc St Fergus[3])

Potential Total Number of Corrosion Defects across the Whole NTS (exc St Fergus)

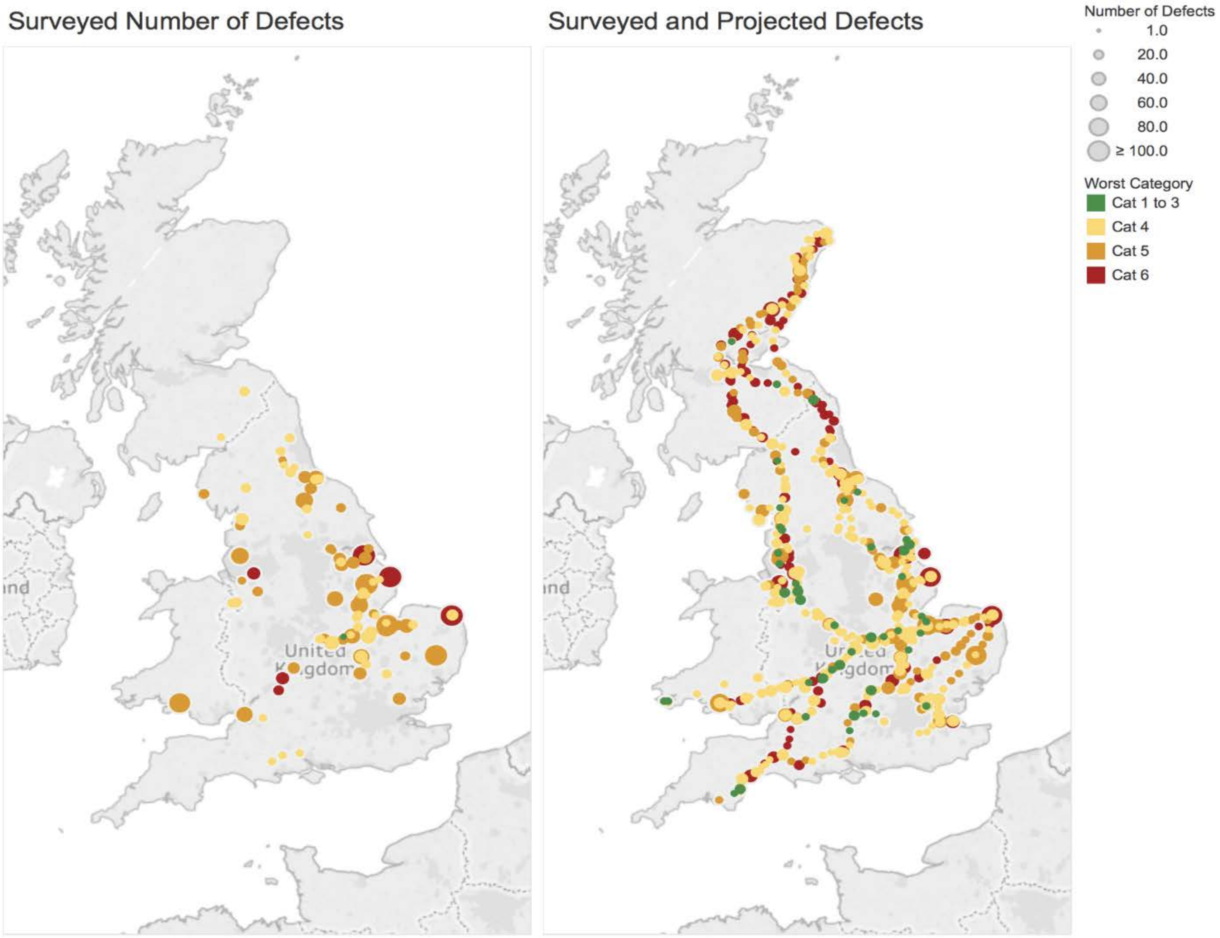


[3] For illustrative purposes we have excluded the St Fergus dataset as the volume of defects is so high.

4.6. The charts below show the number of corrosion defects for each of the sites on the NTS. The total number of CM/4 defects is shown together with the category of the worst defects. The first chart shows the results of the surveys for the sites that have already been completed. The second chart shows extrapolation of the results of the completed surveys across the remaining sites.

Number of Corrosion Defects by Site Identified from Detailed Surveys (exc St Fergus)

Potential Total of Corrosion Defects across the Whole NTS (exc St Fergus)

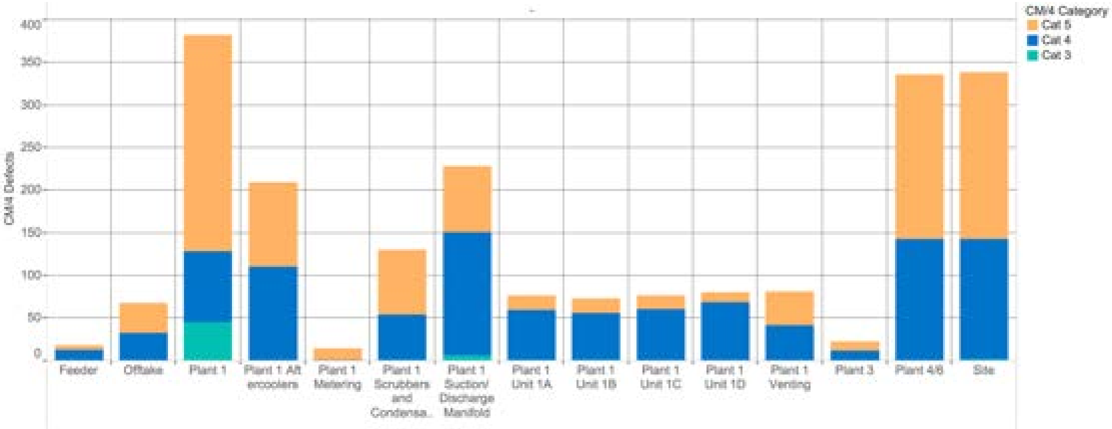


4.7. Due to its age, operating conditions and coastal location the above ground pipework at St Fergus is experiencing significant corrosion.

4.8. In order to understand the extent of the corrosion of the above ground assets as St Fergus a full survey of all of the above ground pipework against CM/4 was undertaken in 2015. The results of this indicated corrosion across the site. Significant investment has been made during T1 to remediate these issues, £59.3 m has already been invested and £42.1m will be invested by the end of T1 (18/19 price base). This will result in all Category 6 corrosion defects being removed from St Fergus by the end of T1. Other, less severe corrosion defects have also been removed where this can be achieved cost-efficiently.

4.9. There will still remain Category 3,4 and 5 defects that are spread across the site, the chart below shows the identified defects at St Fergus (excluding those on Plant 2[4]).

Total Number of Corrosion Defects at St Fergus (exc Plant 2)



Drivers for Investment

4.10. The key drivers for investment in the above ground pipework and coating are:

- Legislation
- Asset Deterioration
- Defects
- External Interference
- Operational

4.11. These assets deteriorate over time and with use, which in turn leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements such as PSSR and PSR.

4.12. The investment in above ground pipework and coating is driven by:

Deterioration – pipework and its paint coating are subject to several deterioration mechanisms:

- o the pipework coating deteriorates due to and fails to protect the pipework
- o where the paint coating breaks down and has failed, external corrosion and the associated metal loss reduces wall thickness. This corrosion is accelerated by chloride contamination, crevice corrosion, dissimilar metal corrosion, stress corrosion cracking and erosion/fretting.
- o internal corrosion and the associated metal loss and reduction in wall thickness

Defects - material, manufacturing or installation defects impacting the integrity of the pipework or its coating

External Interference - the pipework is subject to damage by external parties which reduces the structural integrity of the pipework resulting primarily from dents and

[4] No remedial works have been proposed within parts of the St Fergus site which solely support Plant 2 (See justification report: A14.16 for further details).

metal loss. Ground movement on site can also lead to unacceptable stresses within the pipework potentially compromising the structural integrity.

Operational and other factors such as; fatigue (pressure and temperature cycling, contamination, over pressure, vibration, erosion and abrasion can all affect the integrity of the pipework and paint.

Legislation – inspection, maintenance and associated remediation is essential to maintaining compliance with PSSR and PSR.

Impact of No Investment

4.13. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk

4.14. Lack of investment in remediating the defects on the above ground pipework paint will result in an increasing number of corrosion defects. The existing defects will continue to get worse and new defects will arise. Lack of investment in painting will further increase the amount of corrosion and the associated defects.

4.15. Unmanaged corrosion and unresolved defects will ultimately lead to loss of integrity of the above ground pipework, loss of containment of high-pressure gas, unacceptable safety risks, and therefore limit the availability or performance of the NTS as a whole.

4.16. Assessment and management of corrosion on above ground assets is challenging:

- The depth and extent of any corrosion defect cannot be fully understood and assessed until an investigation has been undertaken.
- Stresses on above ground pipework are more complex than pipelines which are predominately pressure loaded. Additional loads from associated equipment need to be considered and can result in a lower tolerance to corrosion on above ground pipework compared to pipelines.

Examples of the Problem

4.17. The photographs below show examples of each of the CM/4 defect categories 1 to 6.

CM/4 Grade 1



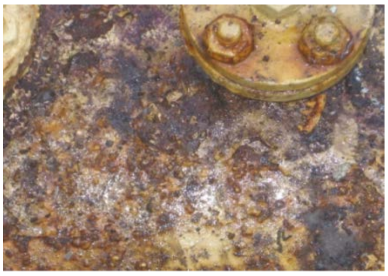
CM/4 Grade 2

CM/4 Grade 3

CM/4 Grade 4

CM/4 Grade 5

CM/4 Grade 6



Spend Boundaries

4.18. The proposed investment includes all above ground pipework and coating on the NTS, including any ‘no-regrets’ site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

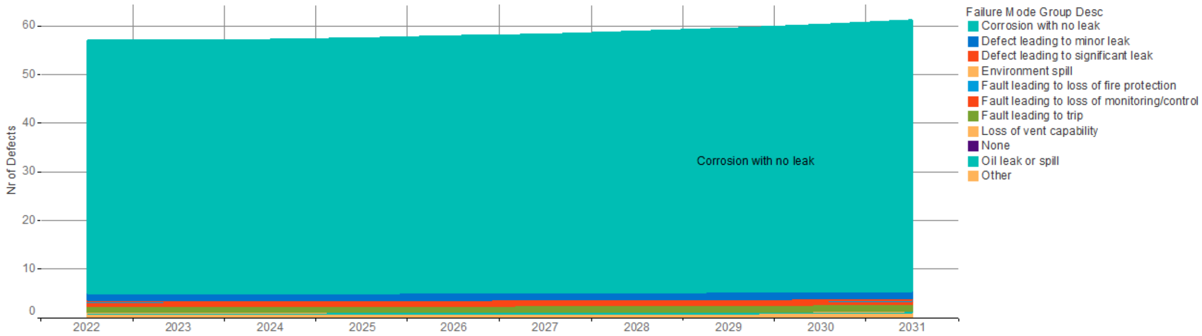
4.19. The proposed investment in cladding is covered later within this report; valve vent and sealant lines are included in the Valves justification report.

4.20. The investment for the pipework and coating at Kings Lynn is included in the Kings Lynn Subsidence paper (A22.04).

5. Above Ground Pipework and Coating - Probability of Failure

5.1. The probability of failure is modelled using our NOMs methodology. The chart below shows the predicted frequency of failures split by failure mode for above ground pipework and coating assets.

Predicted Defects by Failure Mode with No Investment



5.2. For above ground pipework and coating assets the chart indicates that the failure modes that contribute most to the probability of failure are:

- Corrosion with no leak
- Defect leading to minor leak.

Probability of Failure Interventions

5.3. The table below shows the drivers for Plant and Equipment investments that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

SACs Impacted by Plant & Equipment Investments, by NARMs Intervention Category

NARMs Asset Intervention Category	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Above Ground Pipe and Coating
Asset Refurbishment (PoF Driven) Included Major Refurbishments	Above Ground Pipe and Coating

5.4. These are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this justification report.

Above Ground Pipework and Coating Interventions

5.5. The table below shows the interventions for above ground pipe and coating split by the type.

Plant & Equipment Interventions by Category

Intervention	SAC	Intervention Category
A22.12.1.1 / AGI Pipework Painting (Full, Partial or Patch)	Above Ground Pipe and Coating	Major Refurbishment
A22.12.1.2 / CM/4 Corrosion Defects Resolution	Above Ground Pipe and Coating	Major Refurbishment
A22.03.3.1 / AGI Pipework Painting (Full, Partial or Patch) (Bacton)	Above Ground Pipe and Coating	Major Refurbishment
A22.22.5.1 / Pipework modifications - compressor surge issues (St. Fergus)	Above Ground Pipe and Coating	Minor Refurbishment
A22.22.5.2 / Resolve CAT4 CM/4 Defects on pipework (St. Fergus)	Above Ground Pipe and Coating	Major Refurbishment
A22.22.5.3 / Pipework modifications - Minor CAPEX (St. Fergus)	Above Ground Pipe and Coating	Minor Refurbishment
A22.22.5.4 / Above Ground Pipework Patch Painting (St. Fergus)	Above Ground Pipe and Coating	Minor Refurbishment

Data Assurance

5.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

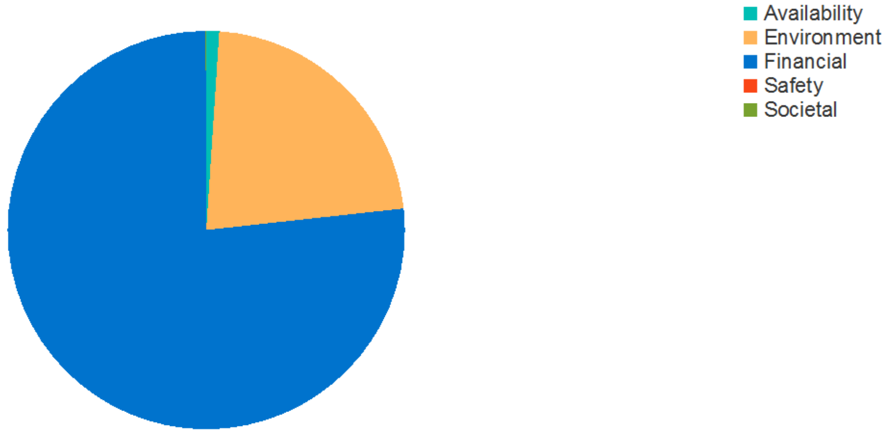
5.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

5.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

6. Above Ground Pipework and Coating - Consequence of Failure

6.1. The chart below shows the expected stakeholder impacts because of failures occurring on the above ground pipework and coating assets. The chart shows the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact



6.2. The contribution of individual service risk measures towards the overall risk for Above Ground Pipework and Coating can be explained as follows, in order of significance:

- **Financial risk** is mostly associated with the costs of operating and maintaining the network at the current level of risk.
- **Environmental risk** is caused by the loss of gas through corrosion and joint leaks
- **Availability risk** is negligible, but is due to possible outages associated with the loss of pipework to downstream assets

6.3. The risks associated with other service measures for Above Ground Pipe and Coating are negligible, based on the assigned failure modes. Gas losses resulting from corrosion will generally vent to air and ignition causing fires or explosions is unlikely.

7. Above Ground Pipework and Coating - Options Considered

7.1. The following intervention categories have been considered for the above ground pipework and coating assets.

Inspection and Investigation

7.2. **CM/4 Inspection and Investigation** - An above ground condition based visual inspection of the pipework, the purpose which is to determine the condition of the pipework and coating. The inspection is to determine whether the pipework is in an appropriate condition to meet the required duty and if there is a need for further intervention to assess the condition of the asset.

7.3. These inspections are primarily to determine the determine the extent of paint breakdown and any associated external corrosion, they will also record any visual mechanical interference or defects such as gouges and dents. For CM/4 categories 4, 5 and 6 remedial actions are required which could include:

- Additional or more frequent monitoring or intervention, for example, re-evaluate after 6 months to determine if further degradation has occurred
- Detailed assessment of the asset as in the case of cladding removal, P11/P20 inspections
- Physical interventions in the form of patch/partial painting or full repainting of the asset equipment or site
- Risk assessment or risk prioritisation as part of a deviation request

7.4. The results of these CM/4 investigations and assessments could result in any of the following interventions. The decision on the intervention to be undertaken is specific to the nature and location of the defect together with the type and volume of the adjacent defects and site.

Interventions

7.5. **Patch Paint** - removal of coating, pipework preparation and repainting of small individual sections of pipework. Defects of category 3 and above will require some level of coating repairs to prevent the defect from deteriorating to a level where physical intervention and non-destructive testing (NDT) will be required by the next inspection.

7.6. **Partial Site Repaint** - removal of coating, grit blasting of the pipework and repainting of whole sections of pipework.

7.7. **Full Site Repaint** - removal of coating, preparation of the pipework (including grit blasting) dressing and repainting of all the pipework on a site

7.8. **Pipework Repair** - for external corrosion of the pipework and external interference damage:

- minor redressing of the large diameter pipework and reinstatement of the coating.

- replacement of small sections of small diameter pipework

7.9. **Pipework Refurbishment** - for external corrosion of the pipework and external interference damage more significant issues can be resolved by:

- for large diameter pipework the installation of a shell or clamp over the pipework and the reinstatement of the coating.
- replacement of full sections of small diameter pipework
- the use of composite repair techniques

7.10. **Pipework Replacement -** for significant external corrosion, external interference damage or internal corrosion then a section of the pipework can be replaced which consists of pipework isolation and shutdown, vent inventory, purge, cut out affected section and weld in replacement, reinstate coating and recommission.

Intervention Unit Costs

7.11. The total RIIO-2 investment for Above Ground Pipe and Coating represents 55% of the Plant and Equipment investment theme. The unit costs that support the Above Ground Pipe and Coating investment have been developed using many historical outturn cost data points and where this has not been possible other estimation methods have been applied. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex.

7.12. 92% of costs for Above Ground Pipe and Coating are supported by historical outturn information, where we have been able to reference 38 data points gathered from 2 sanction papers, this is currently being verified. The remaining 8% of costs have been developed using other estimation methods.

7.13. Unit costs for AGI painting have been determined from our costs and experience from RIIO-1 and are a blend of patch, partial site and full site painting taken from final actual costs. The internal challenge and review resulted in a further split into small, medium and large sites to reflect the economies of scale obtained whilst undertaking a greater volume of painting once mobilised on site. Unit costs for rectifying defects stemming from CM/4 inspections have been obtained from actual costs and experience from RIIO-1. It is recognised that there exist a wide range of possible outcomes needed to rectify a CM/4 defect ranging from relatively low-level works to highly complex projects.

7.14. The CM/4 inspection results prior to 2017 only record the worst defect for each asset category on the site and is the only measure on which we can forecast. Therefore, in developing the unit costs for planning purposes, our experience of RIIO-1 delivery has been used to determine the actual number of defects that have been found and resolved on the sites where we have intervened. This has then been related to the original CM/4 inspection results. This has resulted in a per category per site defect remediation cost to allow us to forecast this across the remaining sites. This per site cost has been cross checked using a calculation of the per defect cost for remediation together with an understanding of the number of individual defects remediations undertaken.

7.15. The table below provides the unit costs for all the potential Above Ground Pipe and Coating interventions.

Intervention Unit Costs – Above Ground Pipework and Coating

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Above Ground Pipe and Coating					
A22.12.1.1 / AGI Pipework Painting (Full, Partial or Patch)	[redacted]	Per asset	Outturn	6	£ 23,068,648
A22.12.1.2 / CM/4 Corrosion Defects Resolution	[redacted]	Per CM/4 category	Outturn	32	£ 43,429,110
A22.03.3.1 / AGI Pipework Painting (Full, Partial or Patch) (Bacton)	[redacted]	Per asset	Estimated - Other	0	£ 505,022
A22.22.5.1 / Pipework modifications - compressor surge issues (St. Fergus)	[redacted]	Per asset	Estimated - Other	0	£ 5,152,778
A22.22.5.2 / Resolve CAT4 CM/4 Defects on pipework (St. Fergus)	[redacted]	Per site	Outturn	2	£ 12,366,668
A22.22.5.3 / Pipework modifications - Minor CAPEX (St. Fergus)	[redacted]	Per site	Estimated - Other	0	£ 103,056
A22.22.5.4 / Above Ground Pipework Patch Painting (St. Fergus)	[redacted]	Per site	Estimated - Other	0	£ 927,500

Innovation

7.16. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of innovation into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

7.17. In the above ground pipework and coating investment theme, we developed and implemented several projects in the RIIO-1 period which will be brought forward into this investment period:

Above Ground Installation Integrity Decision Support Tool - has provided a baseline from which we can make future maintenance and investment decisions regarding AGIs with site/risk prioritisation.

Building Information Modelling (BIM) - while some aspects of the project are in development, this technique was used four times in RIIO-1. The savings arouse from taking a more considered approach design to a project when more information was given, helping to refine the design. This is business implemented and would be expected to be used in any major project in RIIO-2.

Development of "AGI safe" - produced a multi module tool which address all the key area of safety. This tool now forms part of the ongoing maintenance of the National Grid's AGIs.

7.18. We are also looking to continue to develop the following projects and deliver benefit from them in this investment period:

3D Scanner Project - has developed and tested 3D scanners which gave information in line with management procedure, for assessing damage to the pipeline. This technique gives improved information as well as providing a time saving efficiency, while also removing the subjectivity from corrosion assessments. There may also be a benefit from use of the scanner on the below ground pipework where it has been exposed for other work.

Project GRAID - is an innovative piece which looks at using an internal robot to scan and inspect non-piggable sections of pipework that exist on AGIs. The results will then be fed into a model which will inform design decision. There is a cost to using GRAID, which will depend on the complexity of the site but includes using the model, the time for scanning the pipeline and any work associated with providing an entry point for the robot. The ART project which has yet to be started looks at improving the efficiency and accuracy of the scanning and Information which GRAID provides. It is anticipated that using GRAID will give a range of benefits to the business, from avoided excavations to validating the extended life of assets.

Sarco Stopper - a new project led by the St Fergus team which will develop a novel technique to repair 2" stabbing while the pipeline remains live, avoiding the need to vent.

Composite Repairs to Complex Shapes - is a joint industry programme looking at the possibility of using composites to repair pipelines, as well as allowing for the use of different morphologies.

7.19. There were several projects which were not asset health related but still yielded a benefit relevant to the pipework and coating:

Manual Phased Array - for small diameter offtake weld inspection, was a project which examined the potential for the manual phase array to examine subsurface defects, which will help to shape future maintenance procedures.

Non-Destructive Testing - NDT, several projects have been undertaken to test the viability of ultrasonic techniques for non-destructive testing of pipework assets. There is also potential that further development of these techniques could benefit below ground pipelines.

Pipework Cladding

8. Pipework Cladding - Equipment Summary

8.1. The purpose of cladding around pipework is to mitigate noise, to provide thermal insulation to maintain the temperature of the gas in the pipework and to provide protection to personnel. Compressor sites and offtakes to power stations or industrial customers have cladding for thermal efficiency on heaters or heat exchangers.

Location and Volume

8.2. There are 52 AGIs with acoustic cladding including 23 Compressor sites.

Pressure Ratings

8.3. Cladding covers above ground pipework which operates at a range of pressures up to and including the full pressure of the NTS, which is 70 to 94 bar.

9. Pipework Cladding - Problem Statement

9.1. Corrosion under acoustic cladding and thermal insulation, due to penetration of water into the cladding/insulation material, is a major problem for the oil and gas industry. Acoustic cladding and thermal insulation are both employed at AGIs and compressor sites, predominantly for sound reduction and/or personnel protection respectively.

9.2. Most of the lagged equipment on National Grid sites does not operate at elevated temperatures or have significant thermal cycling. As a result, the risk of corrosion under insulation is generally considered to be low and any associated corrosion rates will be low. Industry best practice indicates the inspection regime where the risk of corrosion under insulation is low should entail removal of insulation at "critical points with evidence of damage" and the re-evaluation of the risk based on the examination at these points.

9.3. Damage to cladding and subsequent water ingress can result in a significant risk of corrosion under installation. Corrosion can eventually lead to loss of containment.

9.4. Failure of acoustic barriers could lead to complaints from the public and possibly enforcement action from the environment agency.

Drivers for Investment

9.5. The investment in cladding is driven by:

Asset Deterioration – the pipeline asset deteriorates due to several mechanisms:

- deterioration of the cladding followed by deterioration of the protective paint system
- corrosion of the metal of the asset
- accelerated corrosion in the form of Corrosion Under Insulation.

Impact of No Investment

9.6. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk.

9.7. 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 the cladding continues to deteriorate there is a potential increase in corrosion on the associated pipework.

9.8. While cladding itself does degrade over time, a significant concern is with the pipework associated with the cladding. Where the cladding is damaged water ingress occurs and increases corrosion risks for pipework while also concealing the visual evidence of potential corrosion damage.

9.9. Failure of the cladding could result in:

- reduced noise mitigation leading to complaints and failure of environmental permits.
- reduced gas temperature leading to reduced efficiency and/or corrosion of downstream equipment

9.10. Lack of investment in the remediation of failures found during inspections will result in a rise in the number of cladding defects and associated pipe corrosion issues.

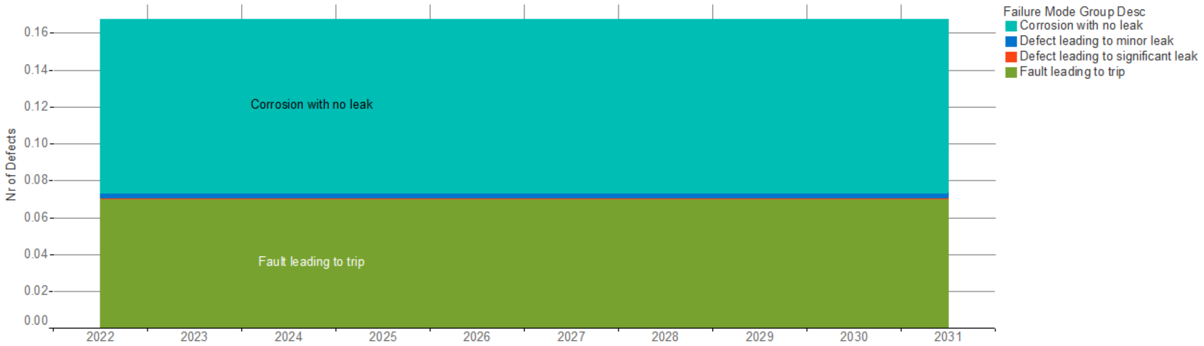
Spend Boundaries

9.11. The proposed investment includes all Cladding on the NTS, including any 'no-regrets' site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

10. Pipework Cladding - Probability of Failure

10.1. The probability of failure is modelled using our NOMs methodology. The chart below shows the predicted frequency of failures split by failure mode for cladding assets.

Predicted Defects by Failure Mode with No Investment



10.2. For the cladding assets the chart indicates that the failure modes that contribute most to the probability of failure are:

- Corrosion with no leak
- Fault leading to trip.

Failure Consequence

10.3. Cladding assets are defined as only delivering Consequential Interventions based upon the following definitions:

*"Any intervention on a network asset, or other infrastructure asset, that modifies the probability of failure, or consequence of failure of **another network asset**. A consequential asset can include, for example:*

- installation or removal of physical infrastructure designed to prevent damage to adjacent assets in the event of an asset failure (e.g. installation of a blast wall),

- addition or disposal that increases or decreases the resilience of a local or regional network and hence modifies the consequence of failure of other asset(s) in the locality or region."

10.4. The SACs that are considered to deliver Consequential Interventions are listed in the table below:

SACs Impacted by Plant and Equipment Investments (Consequential Interventions)

NARMs Asset Intervention Category	Secondary Asset Class
Consequential Interventions (Non-risk tradeable)	Cladding

Cladding Interventions

10.5. The table below shows the interventions for cladding split by the type.

Plant & Equipment Interventions by Type

Intervention	SAC	Intervention Category
A22.12.1.3 / Replace Cladding on AGIs	Cladding	Minor Refurbishment

Data Assurance

10.6. All PoF and CoF values are taken from the National Grid Gas Transmission ‘Methodology for Network Output Measures’ (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

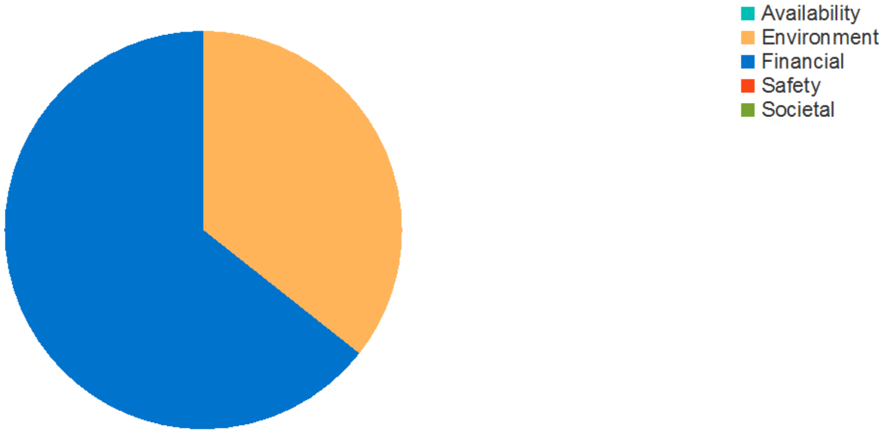
10.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

10.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally “not reject” the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

11. Pipework Cladding - Consequence of Failure

11.1. The chart below shows the expected stakeholder impacts because of failures occurring on the cladding assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact



11.2. The contribution of individual service risk measures towards the overall risk for Cladding can be explained as follows, in order of significance:

- **Financial risk** is mostly associated with the costs of operating and maintaining the network at the current level of risk.
- **Environmental risk** is caused by the loss of gas through corrosion and joint leaks (from the pipework protected by the cladding). Noise nuisance caused by poor acoustic cladding will also contribute

11.3. The risks associated with other service risk measures for Cladding are negligible, based on the assigned failure modes. Gas losses resulting from corrosion will generally vent to air and ignition causing fires or explosions is unlikely. Poor insulation of the cladding on pre-heater pipework would potentially cause a failure of the pressure reduction system, but this risk is low.

12. Pipework Cladding - Options Considered

Potential Intervention Options

12.1. The following intervention categories have been considered for the cladding.

CM/4 Inspection and Investigation

12.2. Cladding is inspected as part of the CM/4 inspections. If all cladding is removed for inspection then it should only be put back if it is demonstrated to be in good condition (AH1 or 2) and there is an ongoing requirement for Noise Prevention, Personnel protection or thermal efficiency.

12.3. CM/4 inspections are an above ground condition based visual inspection of the cladding, the purpose which is to determine its condition. The inspection is to determine whether the cladding is in an appropriate condition to meet the required duty and if there is a need for further intervention to assess the condition of the asset.

12.4. These inspections determine metal loss due to mechanical defects, external corrosion, mechanical interference (gouges and dents), and other mechanisms. The CM/4 inspection triggers follow up NDT Inspections and other Investigations.

12.5. The results of a CM/4 inspection and investigation could result in any of the following interventions. The decision on the intervention to be undertaken is specific to the nature and location of the defect.

Replacement

12.6. Replacement of individual sections of cladding including recoating the associated pipework as required. This is undertaken when there are only discrete damaged sections of cladding that require replacement and the general condition is sound.

12.7. Replacement requires expert technicians and equipment to ensure the desired level of water (rain) tightness.

Removal

12.8. Cladding will be removed when there is indication of cladding performance breakdown as specified in CM/4

12.9. Removal of the cladding; a case by case review of the continued requirement and suitability or need case for the presence of the cladding/insulation will be undertaken. As part of this assessment consideration is given but not limited to the current duty of the cladding i.e. acoustic, personnel protection, thermal e.g. to limit temperature loss etc. and the current and future operational constraints of the site. Where such cladding/insulation is found to no longer be required then it should be removed entirely and a further detailed visual assessment of the condition of the equipment below the insulation/cladding should be undertaken in accordance with the relevant sections within T/SP/CM/4.

Intervention Unit Costs

12.10. We have aimed to provide a high-quality submission based on efficient unit costs. Unit cost data has been obtained by NG from our existing supply chain. Quotation details have been retained and audit trails have been maintained.

12.11. The total RIIO-2 investment for Cladding represents 1% of the Plant and Equipment investment theme. The volume of cladding replacement works completed in RIIO-1 has been low and therefore cladding unit costs have been estimated using a bottom up approach based on an average of prices obtained from three supplier quotations. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex.

12.12. The unit costs for cladding are based on an NIA project which has the scope of investigating the potential technical options for the management / replacement of the cladding assets. As part of the project, quotations for the different cladding options have been sought from suppliers. These costs have then been applied to typical types of site to obtain a range of unit costs for each site type. The average for each site type has been used in the investment plan and is presented below.

12.13. The table below provides the unit costs for all cladding interventions.

Intervention Unit Costs - Cladding

Intervention	Cost (£)	Unit	Estimate	Data Points	Overall value in BP
Cladding					
A22.12.1.3 / Replace Cladding on AGIs	[redacted]	per site	Estimated – Quotation	3	£ 1,731,060

Innovation

12.14. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of innovation into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

12.15. We are looking to continue to develop the following project and deliver benefit from it in this investment period:

Pipeline Noise Mitigation Project - is developing a series of sustainable noise mitigation claddings solutions, which will mitigate corrosion as well as reduce cladding wastage.

12.16. There were other projects which were not asset health related but still yielded a benefit relevant to cladding:

Valve Pits Insulation - is in development, evaluating a more modern, low density solution for mitigating noise from closed valve pits, reducing the environmental noise impact, may have an asset health benefit, but the primary driver is reduction of noise.

Buried Site Pipework, Coating and Cathodic Protection

13. Buried Site Pipework - Equipment Summary

13.1. AGIs provide the connectivity between the high-pressure pipelines, enabling the control and management of the flow and pressure of the gas.

13.2. A typical AGI will have a proportion of buried site pipework, constructed from high strength steel with a wall thickness of between 5mm and 40mm depending on the diameter and design. High strength steel is presently the only material technically and economically viable to use for this pipework.

13.3. All buried steel pipework and structures will corrode in their environment. As a result, other assets are put in place to manage and mitigate this. Whilst there are situations where internal corrosion can occur most of the corrosion occurs externally. The primary corrosion protection for buried pipework is the application of high-quality homogeneous coatings which are applied both internally and externally to the pipe.

13.4. Cathodic Protection (CP) is applied by means of apparatus which is installed at electrically discrete sites or is provided from the incoming pipelines. The application of CP is secondary to the primary protection but is required to prevent corrosion where the primary coating is imperfect or has failed. The key elements of the impressed current CP systems are the transformer rectifier, ground bed and CP test posts.

13.5. Different CP are electrically isolated from each other using insulating/isolation joints (IJs). Separating CP systems enable them to be set up specifically for the specific asset(s) that requires protection. The characteristics of, and therefore management of a cathodic protection system on AGI pipework will be subtly different to that of a pipeline. The need/ability to keep these electrical systems separate is of key importance due to the complex current interactions that take place at complex sites with numerous buried plant or equipment.

13.6. Investment in the buried pipework cannot be considered in isolation. An integrated strategy across the pressure containing and protection asset types ensures the lowest whole life cost of the pipework.

Management of the Pipework

13.7. The design, construction, operation and maintenance of pipework is subject to both:

- Pressure System Safety Regulations 2000 (PSSR) – is general legislation for all pressure vessels and defines the regime for setting inspection frequencies and subsequent remediation of defects.
- The Pipeline Safety Regulations 1996 (PSR) – is specific legislation for those operating pipelines and places the obligation to manage the safety risks that they present to members of public and NG staff.

13.8. The management of steel pipework has been evolving over the last 50 years as their use has increased and issues with their lifecycle management become clear. We have been at the forefront of the evolution of these techniques alongside other pipeline owners/operators, National bodies and technical experts. We are uniquely placed in leading the development of the techniques and policies used due to the large scale, diversity, complexity and age of our pipework assets.

13.9. The industry accepted standard for the design construction, operation and maintenance and decommissioning management of above ground installations, including buried pipework in the UK is IGEM/TD/13. The standard is published by the Institute of Gas Engineers and Managers and developed by a panel of cross industry technical experts and learned individuals. National Grid and its predecessors have been involved with the evolution of this standard ever since the requirement to transport natural gas in an integrated way across the UK.

13.10. The corrosion of steel pipework either above or below ground is an unavoidable consequence of operation. The management of corrosion issues has improved with time and this is reflected in the evolving standard. Corrosion mechanisms are now better understood allowing the management of them to become more sophisticated. Coating/painting types and techniques have improved over time as the understanding of the materials and their long-term performance, safety and environmental impact is better understood.

13.11. The remediation of pipework defects or “features” to industry standards (IGEM TD/13), supplemented by NG policies and procedures is acknowledged by the Health and Safety Executive as an appropriate way of operating a safe above ground pipework asset and complying with required legislation.

Pressure Ratings

13.12. The pipework operates at a range of pressures up to and including the full pressure of the NTS, which is 70 to 94 bar.

14. Buried Site Pipework - Problem Statement

14.1. Where coating systems break down, carbon steel pipework will corrode, and this is the predominant life limiting factor for the buried site pipework across the NTS as a whole. Coating provides primary corrosion prevention for all buried pipework with CP providing secondary protection where the coating is imperfect or has failed.

14.2. Coatings deteriorate with age. As they do, they expose the buried steel to its environment providing a situation where corrosion processes can occur. Unlike NTS pipelines which can be internally inspected, presently there is no methods to provide the same level of integrity information for buried AGI pipework. Where coating defects occur, we are fully reliant on the CP system as the primary protection for buried steel pipework.

14.3. In parallel with the below ground pipelines the AGI CP systems are deteriorating. Many have reached the limits of their original life and design capacity and can no longer effectively protect the buried site pipework from the effects of coating degradation and the volume of defects present and occurring.

14.4. The effectiveness of the CP at sites is also complicated and impacted by the following issues:

- Other buried metallic structures and steelwork on the site
- Shielding of the pipework by surrounding soft fill materials installed to allow the pipework to ‘move’ to reduce physical stresses placed on it
- Shorting of the isolation joints that are in place to electrically separate the individual Pipeline CP systems from the site Pipework CP system where feeders enter a site
- Degradation of specific elements of the CP system such as ground beds

14.5. As with the CP systems on the pipeline, the protection of the CP system can, within limits, be balanced to compensate for some of these factors and in doing so maintain its protective capability. This is acceptable but has three limitations:

- Each CP system has a maximum capacity and range of influence in which it is effective.
- Increasing the CP output too much results in damage to the coatings systems increasing their rate of degradation and reducing their effectiveness.
- Increasing CP output can lead to interaction with other buried metallic services and structures which can lead to an accelerated rate of corrosion rather than reducing corrosion

14.6. A critical factor in the corrosion rate of the buried steel pipework and the condition of the coating is the performance of the CP system. The CP system is in place to prevent the corrosion at locations on the pipework where the coating has been compromised. To be effective, the CP system needs to maintain a defined polarised potential at the location which it needs to protect. The current attenuates with distance away from the CP source, the ground conditions and the number/size of the defects in the coating. The clear majority of CP systems were designed and installed when the buried structures were new with minimal coating defects. As the coating ages and degrades the current requirement for effective CP protection increases.

14.7. Most of the CP systems have been balanced as far as it is possible within their operating parameters. These systems need investment to ensure that they can provide effective protection without presenting a further risk to coating integrity and buried site pipework corrosion. There remain additional complexities in protecting an arrangement of buried pipework rather than buried site linear pipeline.

14.8. There is growing evidence that the performance of the CP systems is deteriorating. As with other electrical assets elements of the CP system will deteriorate over time and through operation. As part of the overall CP system other elements are sacrificial, such as the ground beds; their deterioration is dependent upon the duty performed since installation. These issues are specifically prevalent on impressed current CP systems but still apply to some extent on the sacrificial systems. From data obtained as part of CP maintenance, we are experiencing an overall decrease in the level of protection that the CP systems can effectively providing to the buried pipework across our sites.

14.9. The combination of the above will require investment during RIIO-2 to manage the performance of the buried pipework on sites in the medium and long term and ensure continued fitness for purpose as a pressure vessel under PSSR.

Drivers for Investment

14.10. The key drivers for investment in the Buried Site Pipework, Coating and CP assets are:

- Legislation
- Asset Deterioration

14.11. **Legislation –** The above and below ground pipework at above ground installations are affiliated to the pipeline to enable their management as a pressure vessel under PSSR, therefore compliance with PSSR is required to enable it to continue to be used.

14.12. **Deterioration** – the performance of the CP systems is deteriorating:

- performance of the CP system deteriorates as more coating defects occur
- components within the CP system deteriorate due to age and usage
- the shorting of isolation joints.

Impact of No Investment

14.13. The performance of the CP system deteriorates over time which in turn leads to increasing corrosion of the buried site pipework. The integrity of the pipework must be maintained to enable continued use and compliance with PSSR and PSR.

14.14. Not remediating the current poor performance of the CP will result in corrosion of the buried pipework at locations where the coating has deteriorated. It is currently impossible to understand the full extent of any coating defects without exposing this pipework, some of which are up to 7m deep.

14.15. Unmanaged corrosion and unresolved defects will ultimately lead to loss of integrity of the buried pipework, loss of containment of high-pressure gas, unacceptable safety risks, and therefore require shutdown of parts of our site limiting the availability of the NTS and service to our customers.

Desired Outcomes

14.16. The desired outcomes of the investment during the period is to:

- Maintain medium- and long-term integrity of the buried pipework asset at lowest whole life cost through the management of the coating and cathodic protection of the buried pipework.
- Ensure continued compliance with PSSR and PSR and other legislative requirements.
- Stabilise, and where required remediate the asset deterioration and specific corrosion issues to ensure that they do not result in a loss of containment of high-pressure gas, present a safety risk, and are not a limiting factor on availability or performance of the NTS.

14.17. We consider our investment plans to be successful when these outcomes are met.

15. Buried Site Pipework - Probability of Failure

15.1. The table below shows the drivers for Plant and Equipment investments that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

SACs impacted by Plant & Equipment investments, by NARMs intervention category

NARMs Asset Intervention Category	Secondary Asset Class
Asset Refurbishment (PoF Driven) Included Major Refurbishments	Above Ground Pipe and Coating[5] Cathodic Protection

15.2. These are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this justification report.

Buried Site Pipework, Coating and CP Interventions

15.3. The table below shows the interventions for buried site pipework, coating and CP split by the type.

Plant & Equipment Interventions by Category

Intervention	SAC	Intervention Category
A22.12.1.5 / Resolve Existing AGI CP Priority 1 Defects	Cathodic Protection	Major Refurbishment
A22.12.1.6 / Resolve Existing AGI CP Priority 2 Defects	Cathodic Protection	Minor Refurbishment
A22.03.1.2 / CP Investigations & Rectification (Bacton)	Cathodic Protection	Major Refurbishment
A22.22.5.5 / Replacement of CP system at St Fergus	Cathodic Protection	Replacement
A22.12.1.4 / Replacement of Failed IJs on AGIs	Above Ground Pipe and Coating	Replacement
A22.03.1.1 / Replacement of Failed IJs on AGIs (Bacton)	Above Ground Pipe and Coating	Replacement

Data Assurance

15.4. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

[5] Above Ground Pipework SAC is used as this is a per-site unit of measure, whereas Below Ground Pipelines is a per-kilometre unit of measure

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

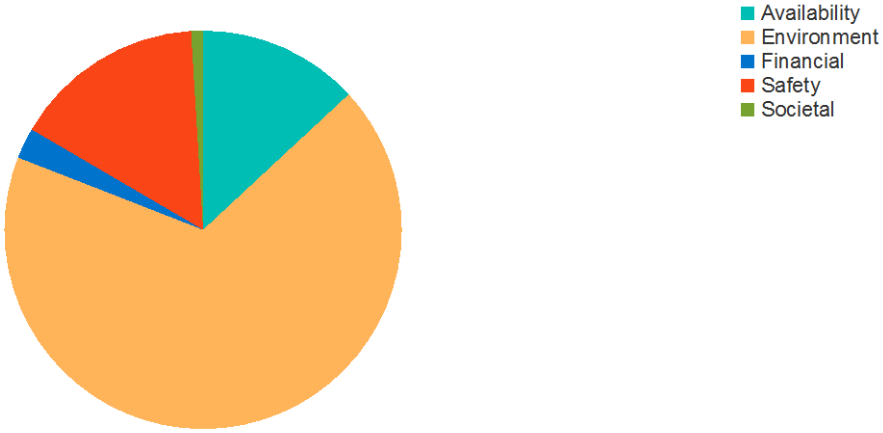
15.5. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

15.6. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally “not reject” the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

16. Buried Site Pipework - Consequence of Failure

16.1. The chart below shows the expected stakeholder impacts because of failures occurring on the buried site pipework, coating and CP assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact



16.2. The contribution of individual service risk measures towards the overall risk for Buried Site Pipework and Coating can be explained as follows, in order of significance:

- **Environmental risk** is associated with the loss of gas arising from a leak or rupture of the pipework caused by external interference, corrosion or other failure modes.
- **Safety risk** is associated with the potential for corrosion failure, mechanical failure, ground movement or damage, causing a pipework to leak or rupture.
- **Availability risk** is negligible, but is due to possible outages associated with the loss of pipework to downstream assets
- **Financial risk** is mostly associated with the costs of operating and maintaining the network at the current level of risk.

16.3. The risks associated with other service measures for Buried Site Pipework and Coating are negligible, based on the assigned failure modes.

17. Buried Site Pipework - Options Considered

Potential Intervention Options – CP Systems

CP System Surveys

17.1. Survey and assessment of the effectiveness of the CP system. The CP system is manually surveyed with the performance delivered by the CP system assessed by measuring the 'electrical potential' at defined points.

17.2. There are 4 types of survey undertaken at frequencies determined by the nature of the CP system being surveyed:

- Functional – The minimum number of readings at key locations to confirm that the CP system is functioning
- Interim - The minimum number of readings at a series of additional locations to a functional survey to confirm that the CP system is functioning, and current flow is being achieved broadly across the system.
- Major – A series of energised "on" and polarised "off" readings at each of the test posts to understand the performance of the CP system at strategic points.
- Close Interval Potential Survey – A series of energised "on" and polarised "off" readings across the whole site to understand the performance of the CP system.

17.3. Defects identified from each of these surveys will result in varying impacts on the performance of the CP systems and the ability to protect the buried pipework from corrosion. Equipment faults are dealt with through the normal fault remediation process. Performance issues require more detailed investigation which may require interventions ranging from CP System Enhancement through to isolation joint replacement, excavation and repair of degraded coating.

CP System Enhancement

17.4. The installation of additional CP system transformer rectifiers and associated assets to return the performance of the CP system to acceptable levels.

CP System Refurbishment

17.5. Replacement of existing transformer rectifiers, ground beds and test posts to restore the CP system to original performance.

Isolation Joint Investigation

17.6. Establish the reason for the failed electrical discontinuity and identify corrective action to be undertaken.

Isolation Joint Remediation

17.7. Replace welded inline Isolation Joint to ensure that electrical discontinuity can be maintained.

Potential Intervention Options – Pipework

Coating Repair

17.8. The excavation of the pipework and the preparation of the surface and application of an appropriate coating to reinstate the primary protection against corrosion. For buried site pipework significant excavation is required.

Pipework Repair

17.9. For the minor redressing of the pipework and reinstatement of the coating for external corrosion of the pipework and external interference damage. For buried site pipework significant excavation is required.

Pipework Refurbishment

17.10. For external corrosion of the pipework and external interference damage more significant issues can be resolved by the installation of a shell or clamp over the pipework and the reinstatement of the coating. For buried site pipeline significant excavation is required.

Pipework Replacement

17.11. For significant external corrosion, external interference damage or internal corrosion then a section of the pipework can be replaced which, due to the interactions with one or multiple pipelines, may also result in wider implications for shutdown, venting inventory, purge, cut out affected section and weld in replacement, reinstate coating and recommission. For buried site pipework significant excavation is required.

Intervention Unit Costs

17.12. The total RIIO-2 investment for buried site pipework, coating and cathodic protection represents 28% of the Plant and Equipment investment theme. All unit costs are supported by other estimation methods.

17.13. The low volume and lack of suitable actual cost information from RIIO-1 means the unit costs for resolving CP priority 1 and 2 defects and the replacement failed Insulation Joints have been estimated. This has been achieved by using outturn component rates where available combined with estimated component rates applied to a set of assumptions. The unit cost for replacing an Insulation Joint is a blend of estimated rates for a joint situated above ground and that of a joint located below ground. The unit costs for CP priority 1 and 2 defect repairs within AGIs have been derived from unit costs for CP remedial works on pipelines.

17.14. The table below provides the unit costs for all interventions on buried site pipework, coating and cathodic protection.

Intervention Unit Costs – Buried Site Pipework, Coating and Cathodic Protection

Intervention	Cost (£)	Unit	Estimate	Data Points	Overall value in BP
Cathodic Protection					
A22.12.1.5 / Resolve Existing AGI CP Priority 1 Defects	[redacted]	Per defect	Estimated - Other	0	£ 15,019,477
A22.12.1.6 / Resolve Existing AGI CP Priority 2 Defects	[redacted]	Per defect	Estimated - Other	0	£ 7,842,367
A22.03.1.2 / CP Investigations & Rectification (Bacton)	[redacted]	Per asset	Estimated - Other	0	£1,913,989
A22.22.5.5 / Replacement of CP system at St Fergus	[redacted]	Per site	Estimated - Other	0	£3,462,667
Above Ground Pipe and Coating					
A22.12.1.4 / Replacement of Failed IJs on AGIs	[redacted]	Per asset	Estimated - Other	0	£ 13,332,093
A22.03.1.1 / Replacement of Failed IJs on AGIs (Bacton)	[redacted]	Per asset	Estimated - Other	0	£ 1,922,151

Business Case

In this section we set out our overall investment plan for pipework, coating, cladding and cathodic protection on our sites. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

18. Business Case Outline and Discussion

Key Business Case Investment Drivers

18.1. The key drivers for investment in the site pipework, coating, cladding and cathodic protection assets are:

- Asset Deterioration
- Defects
- External Interference
- Operational
- Legislation.

Business Case Summary

Outcomes delivered

18.2. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Transport disruption

18.3. Failures of the pipework, coating, cladding and cathodic protection assets can impact on all these outcomes.

18.4. Maintaining the health of these assets is important in ensuring they continue to deliver the required network capability. Specific outcomes associated with this investment are:

- Maintaining the integrity of the above ground pipework and cladding now and in the long term efficiently and effectively through the management of painting and the remediation of defects.
- Maintaining legal compliance of all the above ground pipework assets, most notably with PSR and PSSR.
- Managing and remediating asset deterioration and specific corrosion issues to ensure that they do not result in a loss of containment of high-pressure gas,

present a safety risk, are not a limiting factor on availability or performance of the NTS.

- Ensure as far as possible all buried pipework on sites are protected by effectively cathodic protection systems.
- NG will continue to operate within our environmental permits relating to noise attenuation and continue to meet customer contractual obligations to ensure gas is supplied to the customer at the contractually agreed gas temperature.

18.5. Our proposed investment will ensure that we maintain our low levels of risk across all these outcomes.

Stakeholder Support

18.6. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it a challenge to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' Chapter 14 of the GT submission.

Programme Options

18.7. Our aim in developing the investment plan is to deliver value to our consumers and stakeholders. Hence, we have considered a range of options from the do nothing position through to reductions in risk across all measures. These have been used to explore the credible options for varying the investment and appraising the impact on our legal compliance, risk position and stakeholders.

18.8. In developing our plan, the following options have been considered for investment in the Above Ground Pipework, Cladding and CP assets. Please note that all programme options include any fixed 'no-regrets' investments associated with the Bacton and St Fergus sites.

Baseline – Do Nothing

18.9. The baseline position consists of reactive opex only, with no capex included in the baseline.

18.10. The impact of no investment in our Above Ground Pipework, Cladding and CP assets is an increase in service risk over a 10-year period, the most significant impact being a 60% increase in the volume of gas released to atmosphere every year caused by the loss of gas through corrosion and joint leaks. This option includes the reactive only investment across all Above Ground Pipework, Cladding and CP assets. This is the option against which all the other options are compared.

Programme Option 1 – Reactive Compliance

18.11. This option includes the minimal reactive investment to maintain compliance with PSSR and other legal obligations. All above ground pipework painting is reactive and only CM/4 category 5 and 6 corrosion defects are remediated. Minimal reactive cladding replacement is included within this option.

18.12. This and all other options include the investment required to remediate the issues with the site CP systems and insulation joints to return them to effective performance. Unlike NTS pipelines which can be internally inspected, presently there is no methods to provide the same level of integrity information for the buried AGI pipework. Where coating defects occur, we are fully reliant on the CP system as the primary protection for buried steel pipework.

Programme Option 2 – Minimal Proactive Compliance

18.13. This option maintains compliance through minimal proactive investment CM/4 category 4, 5 and 6 corrosion defects are remediated on a reactive basis. A small volume of painting is undertaken proactively. Minimal reactive cladding replacement is included within this option.

18.14. This option includes the investment required to remediate the issues with the site CP systems to return them to effective performance.

Programme Option 3 – Proactive Programme

18.15. This option undertakes a regular proactive painting programme which includes the appropriate mix of patch, partial and full site painting of the above ground pipework to maintain its integrity. All CM/4 category 4, 5 and 6 defects are remediated on a reactive basis. Risk based remediation of cladding is included within this option.

18.16. This option includes the investment required to remediate the issues with the site CP systems to return them to effective performance.

Programme Option 4 – Increased Proactive

18.17. This option includes increased proactive management of the assets above that included within Option 3. Increased proactive painting is undertaken with more sites receiving full and partial repaints rather than reactive patch painting. Increased cladding replacement is undertaken and partial CM/4 category 3 corrosion defect remediation is also included.

18.18. This option includes the investment required to remediate the issues with the site CP systems to return them to effective performance.

Programme Options Summary

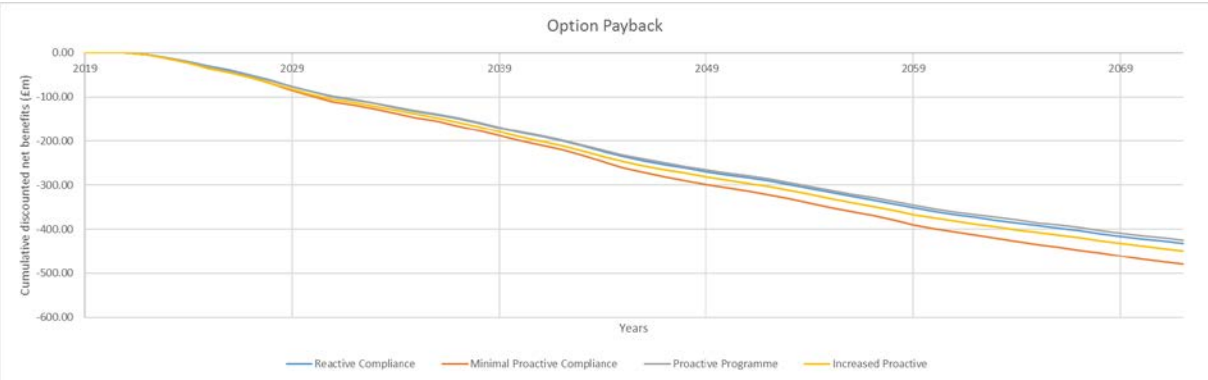
18.19. In considering the CBA for each of the programme options, a summary of all the potential programme options are provided in the table below.

Potential Programme Options

Option	RIIO-2 Invest' £ m	RIIO-3 Invest' £ m	PV Costs £ m	PV benefits £ m	Net NPV £ m	CB Ratio	Payback Period (years)
1 - Reactive Compliance	£122.72	£159.84	£419.42	£21.97	£(397.44)	0.05	Does not payback in the period
2 - Minimal Proactive Compliance	£134.50	£181.77	£464.77	£24.28	£(440.50)	0.05	Does not payback in the period
3 - Proactive Programme	£130.78	£144.42	£412.52	£22.23	£(390.29)	0.05	Does not payback in the period
4 - Increased Proactive	£144.04	£147.66	£436.88	£24.07	£(412.81)	0.06	Does not payback in the period

18.20. The graph shows the cumulative discounted NPV of the net benefit for each of the investment options.

Option Payback – Net NPV



Programme Options Selection

18.21. None of the potential options are cost beneficial over the 45-year analysis period. This is due to limitations in our modelling of low likelihood, but high consequence events such as fires or explosions resulting from loss of pipework integrity. The selection of the preferred option has been based on an assessment of the level of risk, maintaining our compliance with legislation and delivering value for consumers and stakeholders. The outcomes associated with each option are provided below:

Programme Option 1 – Reactive Compliance

18.22. The result of this option is an increased level of risk of non-compliance. CM/4 is a visual inspection that leads to further investigation work if required therefore leaving all CM/4 corrosion defects until are visually inspected as a category 5 has the risk that they are in a worse condition. It also leaves only a short time to remediate them before they become an unacceptable and unsafe category 6 defect. The costs of remediation of category 5 and 6 defects is significantly higher than lesser categories therefore the medium-term whole life costs of this option are also higher than the other options. Lack of proactive replacement of cladding can lead to further corrosion defects and a failure to maintain its performance of heat retention and noise attenuation.

Programme Option 2 – Minimal Proactive Compliance

18.23. An increase in overall risk and medium-term whole life cost also results from this option. Whilst the risk of non-compliance is less that with option 1, the lack of proactive painting programme still allows corrosion defects to become category 4 before being remediated. This increases the whole life cost of corrosion management as well as the risk that the defects are worse than a visual inspection would indicate. Lack of proactive replacement of cladding can lead to further corrosion defects and a failure to maintain its performance of heat retention and noise attenuation.

Programme Option 3 – Proactive Programme

18.24. This option delivers an acceptable level of risk that is sustainable in the medium term at an acceptable level of investment and minimal whole life cost. Compliance with all legislation is maintained. Risk based proactive replacement of cladding manages the risk of associated corrosion and maintains its performance related to heat retention and noise attenuation.

Programme Option 4 – Increased Proactive

18.25. This option includes increased investment in proactive painting, cladding replacement and early (CM/4 Category 3) corrosion defect remediation. The option delivers a further reduction in the level of risk over and above that in option 3. This reduction in risk and increase in investment over and above that required to maintain compliance and is not supported by our stakeholders.

Preferred Option

18.26. Our preferred option is Option 3 to maintain the current level of risk, because even though some of the other options are lower cost, they are less cost beneficial and they do not meet the required outcomes.

18.27. This is consistent with feedback from our stakeholder engagement who wanted at least the current level of risk maintained.

18.28. Our chosen strategy of maintaining effective Cathodic Protection across the sites together with the associated investigation and remedial work is by far lowest whole life cost/risk solution to managing the long-term health and performance of the buried pipework.

18.29. Maintaining the primary corrosion protection (paint) through periodic repainting combined with inspections and associated investigation and remediation of defects (to both paint and pipework) is also the lowest whole life cost/risk solution to managing the long-term health and performance of the above ground pipework.

18.30. A complete explanation of the selected option is provided in the next sections.

19. Investment Decision – Above Ground Pipework and Coating

19.1. In this section we set out our investment decision approach for above ground pipework and coating together with the benefits of the investment.

Key Drivers

19.2. The key drivers for investment in the above ground pipework and coating assets are:

- Asset Deterioration
- Defects
- External Interference
- Operational
- Legislation.

Interventions Scope

19.3. To deliver the outcomes for the investment period these assets require a balance of the intervention categories (defined previously) to deliver acceptable and affordable outcomes for our stakeholders.

19.4. Significant replacement of these aging assets is not a feasible option from either economic, technical, operational or logistical perspectives. Cathodic Protection is only effective on those sections of pipework that are below ground. Replacement is substantially more expensive than early intervention and maintenance. Therefore, a strategy of maintaining the primary corrosion protection (paint) through periodic repainting combined with inspections and associated investigation and remediation of defects (to both paint and pipework) is by far lowest whole life cost/risk solution to managing the long-term health and performance of this critical asset.

19.5. The investment proposed in the period is to:

- Continue to undertake the CM/4 inspections of the above ground pipework and paint to ensure legal compliance and inform our remediation strategy and plans
- Manage overall corrosion of above ground pipework through a 15-year painting programme with approximately a third of the sites addressed within RIIO-2 and a further third in RIIO-3. We will prioritise the work within RIIO-2 to cover the sites with a known category 6 CM/4 defect or sites with category 4 or 5 defects within more than three of the CM/4 asset classes (indicating widespread coating system breakdown). An assessment of the site will determine if a full or partial paint was required.

19.6. The actual frequency of the repaint will be varied depending upon the location and environment in which the site operates together with the number and type of defects found during inspections.

19.7. For sites not included within the painting programme we would anticipate that category 5 and 6 CM/4 defects would be identified through inspection and these would be assessed to determine if they should be remediated within RIIO-2. The actual scope and cost of each intervention will be determined following the detailed investigation and assessment of the defects.

19.8. The corrosion work at St Fergus has determined that the assets most at risk would be:

- Small diameter, and so thin wall pipe
- Corrosion under pipe supports (CUPS)
- Pit wall transitions
- The wind / water line
- Flanges (evidence of internal corrosion).

Benefits of Investment

19.9. The investment will ensure the integrity of the above ground pipework through a managed and minimum whole life cost strategy of appropriate site repainting supported by ongoing inspections and defect remediation.

19.10. Specifically, by the end of RIIO-2:

- 135 sites will have been subject to a full site repaint. The remaining sites will have remediation of Category 4, 5 and 6 defects along with partial site painting supported by patch painting.

20. Investment Decision – Pipework Cladding

20.1. In this section, we set out our investment decision approach for cladding together with the benefits of the investment.

Key Driver

20.2. The key driver for investment in the cladding assets is:

- Asset Deterioration.

Investment Decision Approach

20.3. To deliver the outcomes for the investment period, these assets require a balance of the intervention categories (defined previously) to deliver acceptable and affordable outcomes for our stakeholders.

- As part of the CM/4 inspections for each site continue to undertake the CM/4 inspections of the cladding to ensure legal compliance and inform our remediation strategy and plans.
- Included within the site painting strategy for all above ground pipework, manage overall corrosion under the cladding through the painting programme identified in the section above.

20.4. For sites not included within the painting programme we would anticipate that category 5 and 6 CM/4 defects would be identified through inspection and these would be assessed to determine if they should be remediated within RIIO-2. The actual scope and cost of each intervention will be determined following the detailed investigation and assessment of the defects.

20.5. In addition to the remediation of corrosion defects, cladding will be subject to the following:

Cladding Replacement - Cladding will be replaced in the following conditions and where there is still a valid requirement:

- if water ingress into the cladding could potentially lead to corrosion of the pipework underneath it
- when it no longer performs its function with noise and heat dissipation becoming excessive
- It may be possible to replace only sections of cladding. Sections of cladding extending from the damaged section would need to be removed to ensure the integrity of the pipework has not been compromised

Cladding Removal - Cladding will be removed when it has been identified that there is no longer a need to mitigate against the risk of excessive noise or heat retention is no longer required

20.6. The actual scope and cost of intervention will be determined following a detailed site assessment.

Benefits of the Investment

20.7. The investment will ensure the integrity of the cladding through a managed and minimum whole life cost strategy of appropriate repainting supported by ongoing inspections, defect remediation, replacement or removal.

20.8. Specifically, by the end of RIIO-2:

- cladding will have been replaced or removed as required on 15 sites. Other specific defects on cladding will be resolved on a risk basis

21. Investment Decision – Buried Site Pipework, Coating and Cathodic Protection

21.1. In this section we set out our investment decision approach for buries site pipework, coating and cathodic protection systems on sites together with the benefits of the investment.

21.2. The key drivers for investment in the above ground pipework and coating assets are:

- Legislation
- Asset Deterioration.

Interventions Scope

21.3. To deliver the outcomes for the investment period these assets require a balance of the intervention categories (defined previously) to deliver acceptable and affordable outcomes for our stakeholders.

21.4. Significant replacement of the buried pipework is not a feasible option from either economic, technical, operational or logistical perspectives. There is the option to undertake pipework replacement or coating reapplication, however this is extremely expensive. Therefore, maintaining effective Cathodic Protection across the sites together with the associated investigation and remedial work is by far lowest whole life cost/risk solution to managing the long-term health and performance of this critical asset

21.5. The investment proposed in the period is to:

- Continue to undertake the CP inspections to ensure legal compliance and inform our remediation strategy and plans
- Manage the performance of the CP systems with an ongoing programme of CP system upgrades and isolation joint remediation with approximately a half of the sites addressed within RIIO-2 and the remainder in RIIO-3. We will prioritise the work within RIIO-2 to cover the sites with the lowest CP performance.

22. Business Case Summary

22.1. In this section we set out our overall investment plan for pipework, coating, cladding and cathodic protection.

Preferred Option

22.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the Pipework, Coating, Cladding and Cathodic Protection assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

22.3. The profile of investment in the Filters, Scrubbers and Strainers assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

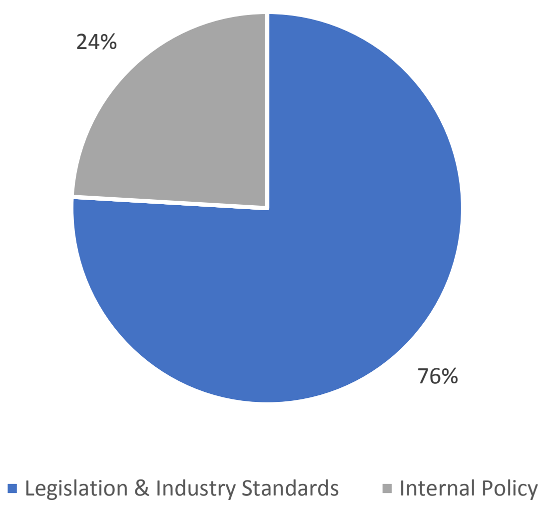
Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Above Ground Pipe and Coating	11,913	23,856	24,411	21,717	18,910	25,978	26,506	29,799	21,518	12,603
Cladding	486	229	615	243	157	143	143	114	14	0
Cathodic Protection	962	2,816	9,244	11,240	3,977	5,017	5,348	6,736	4,612	5,885
Total	13,361	26,901	34,270	33,200	23,044	31,138	31,997	36,649	26,145	18,488
	130,777					**144,417**				

Intervention Drivers

22.4. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that the majority of the investment consists of interventions that are required to meet legislative requirements and are based on accepted industry standards.

RIIO-2 Pipework, Coating, Cladding and Cathodic Protection Intervention Drivers[6]



Programme CBA

22.5. We are targeting an appropriate level of asset health investment in pipework, cladding, coating and CP to mitigate the reliability and safety risks from the ageing asset base.

22.6. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in pipework, cladding, coating and CP is value for money. We have considered costs and benefits over a 45-year period in a full cost benefit analysis (CBA).

22.7. As discussed previously, the CBA for the Buried Site Pipework, Coating and Cathodic Protection investment over the period is not cost beneficial over the 45-year period. This is shown below:

CBA Summary[7]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£99.83	£192.95	£289.94	£412.52
Present Value H&S benefits (£m)	£0.00	£0.00	£0.00	£0.00
Present Value non H&S benefits (£m)	£1.39	£5.24	£11.06	£22.22
Net Present Value (£m)	£(98.44)	£(187.71)	£(278.88)	£(390.29)

[6] See Appendix A for intervention driver category definitions
[7] A14.13.1 Pipework, Coating, Cladding and Cathodic Protection

22.8. We have challenged whether this is the right programme of work. In developing our plans and making our decision we have been fully cognisant of the need to develop plans that are value for money, acceptable, affordable and deliverable.

22.9. Our chosen strategy of maintaining effective Cathodic Protection across the sites together with the associated investigation and remedial work is by far lowest whole life cost/risk solution to managing the long-term health and performance of the buried pipework.

22.10. Maintaining the primary corrosion protection (paint) through periodic repainting combined with inspections and associated investigation and remediation of defects (to both paint and pipework) is the lowest whole life cost/risk solution to managing the long-term health and performance of the above ground pipework.

22.11. This level of investment will ensure we successfully manage asset deterioration and meet our legal obligations. It will ensure we deliver the outcomes that consumers and stakeholder tell us they want us to meet.

22.12. Across our stakeholders there is little support for keeping the costs the same as in RIIO-1, given the unacceptable consequential increase in risk.

22.13. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. The graph below shows the results of this compared to the preferred option.

Net Benefits of Upper and Lower Unit Cost Sensitivity

22.14. Whilst the level of cost benefit as the unit costs vary, the investment remains non-cost beneficial across the range of unit costs.

22.15. Based on our robust CBA assessment, and reviewing the programme against the drivers for investment and outcomes delivered, we are confident that our plans are value for money and in line with stakeholder views.

Preferred Option

23. Preferred Option Scope and Project Plan

23.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred option

23.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the Filters, Scrubbers and Strainers assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

23.3. The profile of investment in the Filters, Scrubbers and Strainers assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Above Ground Pipe and Coating	11,913	23,856	24,411	21,717	18,910	25,978	26,506	29,799	21,518	12,603
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Total	13,361	26,901	34,270	33,200	23,044	31,138	31,997	36,649	26,145	18,488
	130,777					**144,417**				

Delivery Planning

23.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change and provide an opportunity to reconsider the efficient timing of delivery.

23.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period. This maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

23.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single ‘campaign’ across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

23.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not ‘fit’ into the planned ‘campaign’ approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

23.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

23.9. The requirement for outages varies from asset to asset and depends on the extent/type of intervention required. For example, some partial painting may not require outages or pressure reduction, but more heavily corroded assets would. As a general principle, outages are planned to align with ILI Digs (pipelines work). Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

Filters, Scrubbers, Strainers and Preheaters (£17.2m)

This section of the case considers the investment in Filters, Scrubbers, Strainers and Preheaters that provide protection to our other operational assets on all types of sites across the NTS.

Filters, Scrubbers and Strainers

24. Filters, Scrubbers and Strainers - Equipment Summary

24.1. The purpose of filters and scrubbers is to remove dust, debris and liquids from the gas flow. They provide protection to pressure reduction, flow control equipment or compression plant. Asset types include:

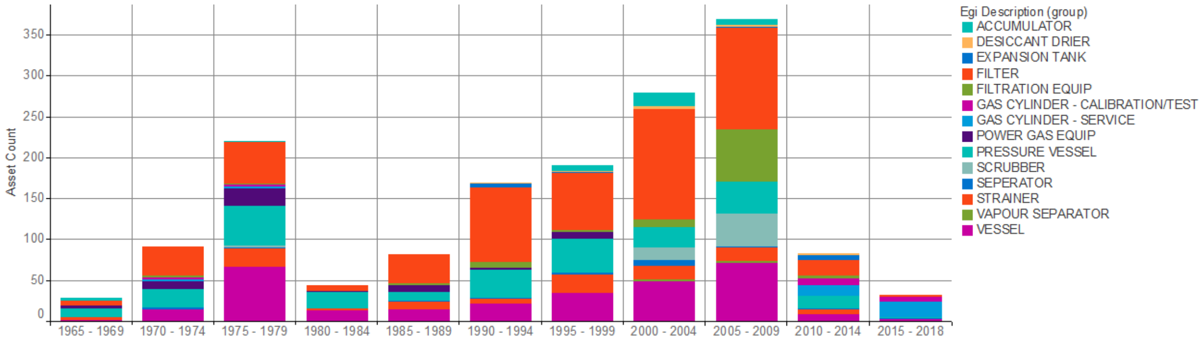
- Coalescing filters and filter vessels
- Scrubbers and the associated condensate tank
- Strainers.

Location and Volume

24.2. There are 228 Filters, 33 Scrubbers and 44 Strainers installed at 49 sites on the NTS

24.3. The chart below shows the age profile of filters, scrubbers and strainer assets.

Asset Age by Type



Pressure Ratings

24.4. The assets operate at the following maximum pressures:

- Coalescing filters and filter vessels - 94 bar
- Scrubbers and the associated condensate tank - 94 bar
- Strainers - 94 bar.

24.5. All the assets normally operate in the range 39 to 94 bar.

25. Filters, Strainers and Scrubbers - Problem Statement

25.1. Filters, Strainers & Scrubbers (inc Condensate Tanks) are installed on the NTS to remove debris, dust and liquids from the gas flow ensuring gas quality is to the required specification. These assets provide protection to both our assets and our customers downstream assets and equipment such as pressure Regulators and flow control valves.

25.2. Filters and Scrubbers are subject to Pressure Systems Safety Regulations 2000 which are in place to prevent serious injury from the hazard of stored energy. Failure to comply with these regulations could lead to serious injury and/or prosecution.

Drivers for Investment

25.3. The key drivers for investment in the filters, scrubbers and strainers are:

- Legislation - PSSR
- Asset Deterioration

25.4. In addition to the legal requirements of PSSR the assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with other legislative requirements.

25.5. The investment in the assets is driven by:

Legislation - Except for strainers these assets are captured under the Pressure System Safety Regulations 2000 (PSSR) and the aim of these regulations is to prevent serious injury from the hazards of stored energy. Compliance with PSSR drives inspection and validation of the assets and associated remediation of any defects found.

Asset Deterioration - The assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements. The elements of deterioration are:

- o deterioration of the coating
- o corrosion of the metal of the asset – both internal and external
- o fatigue due to pressure cycling or vibration

Obsolescence - there are several manufacturers/models of equipment that are approaching or exceeding their original design life and are now becoming obsolete. Some manufacturers are no longer trading others are no longer supporting or providing spares for some of the assets.

Impact of No Investment

25.6. Continued use of these assets without investing in inspections, revalidation and remediation will breach legal obligations of PSSR and PSR. Lack of investment in the inspections and revalidation will mean that assets are non-compliant with PSSR legislation.

25.7. Lack of investment in the remediation of faults found during inspections will also render the assets unable to be used to convey gas. Isolation of items of plant and equipment would reduce the resilience of the NTS, ultimately it may lead to the inability of NG to meet the service requirements of our customers. It is predicted that with no investment there will be assets with outstanding PSSR failures or significant defects by the end of the period.

25.8. The function of filters, scrubbers and strainers is to remove contamination from the gas flow that could damage plant equipment downstream which could result in a loss of gas supply or reduction in the capacity of the network. Failure to invest adequately will lead to a loss of performance will allow liquids and other contaminants to flow with the gas and potentially damage our or our customers' downstream equipment.

Filters and Scrubbers

- Failure or reduction in performance of these assets will lead to contamination of critical downstream equipment i.e. failure of a filter on a Pressure Reduction AGI could lead to damage of a pressure Regulator which can lead to security of supply issues

Strainers

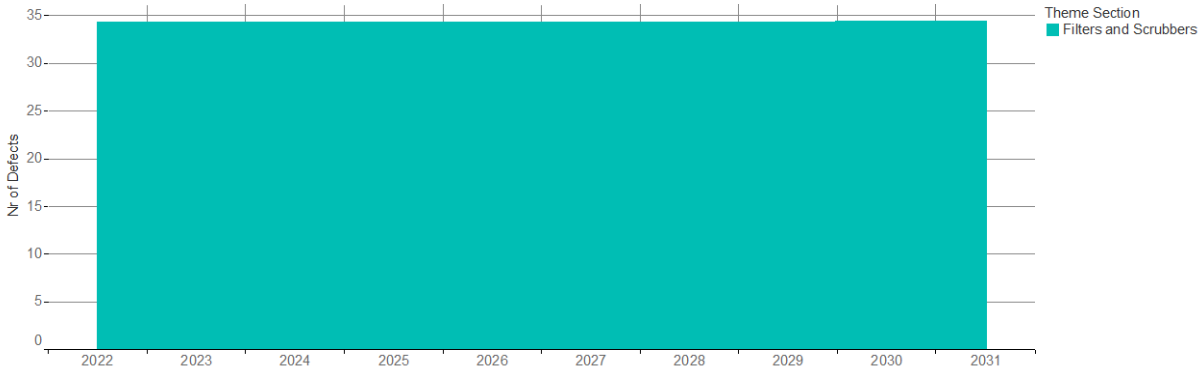
- Strainers on NTS Offtakes are for construction purposes only and should be removed as per IGEM/TD/13. Where the gas is filtered upstream there is no need for a strainer and they can be removed, in other cases filters will need to be installed prior to removal of the strainer. These can cause Regulator performance issues if they block as they can alter gas flow characteristics. The differential pressure (DP) can be measured across the strainer to help identify any blockages but no other maintenance or inspections can take place.
- Strainers can fail at welds and strainer material can enter downstream system causing mechanical damage on compressor sites and potential of associated security of supply issues

25.9. The NTS has a challenge to mitigate issues associated with dust and small amounts of free liquids in the pipeline systems. Oil leakage from the degradation of old wet seals on compressor systems, knock out of heavy hydrocarbon carryover and in some instances carryover of Tri-Ethylene Glycol from the sub-terminals presents issues in the operation of the network with changing flow patterns.

25.10. Dry Gas Seals on our pipeline compressors are very sensitive to small amounts of contamination as are our gas turbines and gas supplied to industrial power plants resulting in costly failures &/or increased maintenance costs.

25.11. The chart below shows the number of defects by for filters, scrubbers and strainer assets starting from current levels captured in work order data and predicted for future years using the equipment failure deterioration models in our NOMs methodology developed in 2017.

Predicted Defects with No Investment



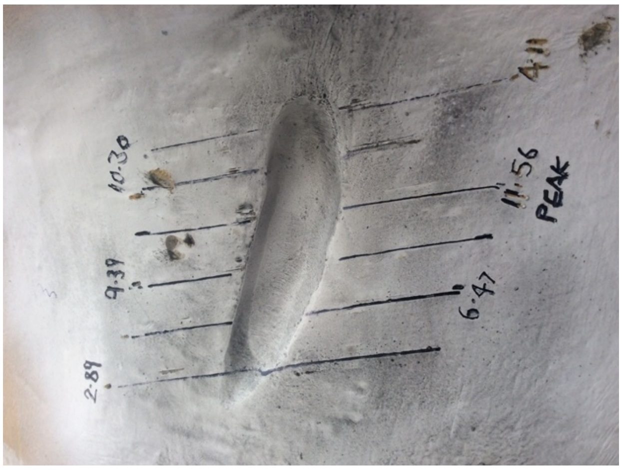
Examples of Problem

25.12. In 2017 gas contamination was reported by the end user downstream of one of National Grid's NTS Managed Offtakes. TEG Triethylene-Glycol was found downstream of a PRS at an AGI (Hayes Chemicals) and caused significant damage to the end users' equipment. Although National Grid had complied with all GSMR requirements with regards to filtration this is a prime example of the types of contamination that can be encountered and the requirement for filtration to prevent damage not only to National Grid assets but also customer's assets.

Image of filter basket and element showing excessive contamination in the form of TEG.

Image of liquid form of TEG found at Hayes Chemicals AGI.

25.13. During a 12 yearly PSSR Inspection a defect was found on the Shell 2 Incomer Main Filter at Bacton. The defect required further assessment as per National Grid's policy to allow a decision to made as to whether the defect can be repaired, or the filter needs to be replaced. In this instance the defect was able to be dressed out at a cost of approximately £40,000. Previously a filter on same site required replacing at a cost of £140,000.



25.14. Cone strainers installed between flanges at various locations have exhibited, on occasion, structural failures within the welds. A failure occurred at Kings Lynn whereby the failed cone strainer on the suction side of the compressor was ingested into the impellor causing a significant amount of damage and associated expense.

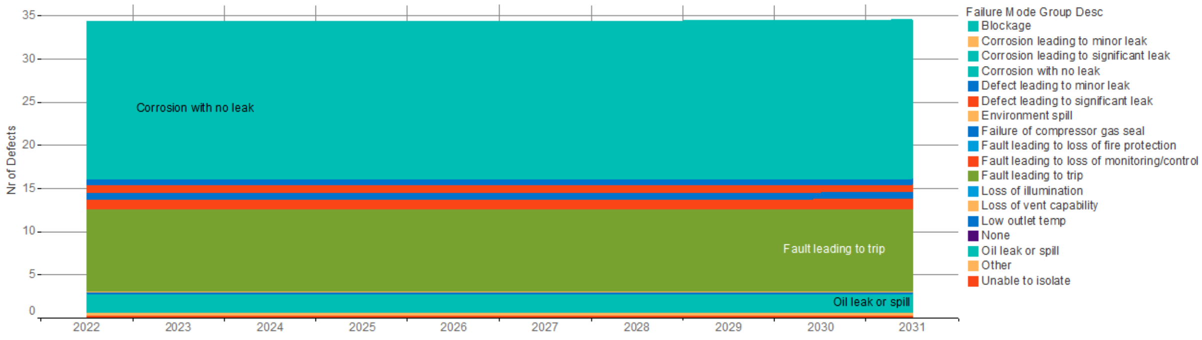
Spend Boundaries

25.15. The proposed investment includes all Filters, Scrubbers and Strainers on the NTS, including any ‘no-regrets’ site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

26. Filters, Scrubbers and Strainers - Probability of Failure

26.1. The probability of failure is modelled using our NOMs methodology. The chart below shows the predicted frequency of failures split by failure mode for filters, scrubbers and strainer assets.

Predicted Defects by Failure Mode with No Investment



26.2. For filters, scrubbers and strainers, the chart indicates that the failure modes that contribute most to the probability of failure are:

- Corrosion with no leak
- Fault leading to compressor trip
- Oil Leak or Spill.

Probability of Failure Interventions

26.3. The table below shows the drivers for Plant and Equipment investments that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

SACs impacted by Plant & Equipment investments, by NARMs intervention category

NARMs Asset Intervention Category	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Filters and Scrubbers (incl. Condensate Tanks)
Asset Replacement (PoF Driven) Includes Asset Replacements	Filters and Scrubbers (incl. Condensate Tanks)

26.4. These are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this justification report.

Filters, Scrubbers and Strainers Interventions

26.5. The table below shows the interventions for filters, scrubbers and strainers split by the type.

Plant & Equipment Interventions by Category

Intervention	SAC	Intervention Category
A22.12.2.1 / Filters PSSR Inspection & Major Overhauls	Filters and Scrubbers (incl. Condensate Tanks)	Major Refurbishment
A22.12.2.3 / Scrubber & Condensate Tank Internal Inspections & Estimated Major Refurbs	Filters and Scrubbers (incl. Condensate Tanks)	Major Refurbishment
A22.12.2.2 / Replace Strainers with Filters/Separators	Filters and Scrubbers (incl. Condensate Tanks)	Replacement
A22.03.3.2 / Filters PSSR Inspection & Major Overhauls (Bacton)	Filters and Scrubbers (incl. Condensate Tanks)	Major Refurbishment

Data Assurance

26.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

26.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

26.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

27. Filters Scrubbers and Strainers - Consequence of Failure

27.1. The chart below shows the expected stakeholder impacts because of failures occurring on the filters, scrubbers and strainers assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact

27.2. The contribution of individual service risk measures towards the overall risk for Filters and Scrubbers can be explained as follows, in order of significance:

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas from leaks and carbon emissions associated with asset maintenance. There is also environmental risk associated with leaks from fuel/oil systems on compressor sites
- **Financial risk** is mostly associated with the costs of operating and maintaining the assets at the current level of risk
- **Availability risk** is associated with the potential outages associated with failure of the pressure reduction system and subsequent isolation of downstream customers. This risk is partially mitigated through the presence of multiple pressure reduction streams at many sites
- **Safety risk** is associated with the possible risk of ignition and fires and explosions following a loss of gas event. This risk is small due to the low probability a of fire/explosion event and the low chance of employees or staff being nearby at the time
- **Societal risk** is associated with disruption to transport associated with potential fires and explosions

28. Filters Scrubbers and Strainers - Options Considered

Potential Intervention Options

28.1. The following intervention categories have been considered for the filters, scrubbers and strainers assets categorised by site type

Inspections – NTS Managed Offtakes, FCV Sites, Compressor Stations

Filters and Scrubbers – Filters and Scrubbers require regular inspections and revalidation to comply with PSSR.

6 Yearly Inspection - A visual examination of all external surfaces shall be carried out to check for damage, deformation and corrosion. This shall include all supports, bolting, flanges and fittings. Closures shall be examined internally and externally to ensure full integrity, with attention being paid to the components of the securing and locking mechanism, including the hinges. Castings shall be examined for the presence of shrinkage, porosity or sand inclusions. The results of the visual inspections shall be used to determine the need for further NDT.

12 Yearly Inspection and Revalidation - In addition to the elements of the visual inspection, the coating is removed during the major inspection to allow a detailed examination of the pressure vessel body and welds using Magnetic Particle Inspection (MPI).

Strainers – Strainers cannot be inspected as part of routine works due to the way in which they are installed. Site outages and major works are required meaning it is more beneficial to remove or replace.

Maintenance – NTS Managed Offtakes, FCV Sites, Compressor Stations

Scrubbers - Internal and external inspection and repainting

Filters – Annual Functional Check - Check, clean, lubricate filter closure mechanism & check filter basket/element for build-up of contamination or damage and replace immediately.

Strainers – Apart from checking the Differential Pressure across the strainer (if possible) there is no maintenance that can be performed. Site outages and major works are required meaning it would be more beneficial to just remove or replace.

Replacement – FCV Sites and Compressor Stations

Strainers – Replace strainer with filter or scrubber. This is only undertaken when filtration is required and can be carried out during associated site work/outages. Individual studies are undertaken in each case to determine if upstream filtration is suitable to protect downstream equipment and determine the required intervention.

Filters and Scrubbers – Replacement with a new unit or a refurbished unit if a suitable one is available. This is only when all repair options have been exhausted.

Replacement – NTS Managed Offtakes

Strainers – Due to all NTS Managed Offtakes having dedicated filtration system there is no requirement to replace any downstream strainers with either another strainer or other filtration system.

Filters and Scrubbers – Replacement with a new unit or a refurbished unit if a suitable one is available. This is only when all repair options have been exhausted.

Removal – FCV Sites and Compressor Stations

Strainers - Removal of the strainer where a safety and reliability assessment indicate that it is no longer required.

Filters and Scrubbers – a removal option is not applicable.

Removal – NTS Managed Offtakes

Strainers – All strainers located on NTS Managed Offtakes can be removed without the need for any type of replacement as all these sites have a filtration system upstream

Filters and Scrubbers – a removal option is not applicable.

Intervention Unit Costs

28.2. The total RIIO-2 investment for Filters and Scrubbers represents 7% of the Plant and Equipment investment theme. The unit costs that support the Filters and Scrubbers investment have been developed using historical outturn cost data points and where this has not been possible other estimation methods have been applied. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex.

28.3. 26% of costs for Filters and Scrubbers are supported by historical outturn information. The remaining 74% of costs for Filters and Scrubbers have been developed using other estimation methods.

28.4. The table below provides the unit costs for all the potential interventions on filters, scrubbers and strainers.

Intervention Unit Costs – Filters, Scrubbers and Strainers

Intervention	Cost (£)	Unit	Estimate	Data Points	Overall value in BP
Filters and Scrubbers					
A22.12.2.1 / Filters PSSR Inspection & Major Overhauls	[redacted]	Per asset	Outturn	1	£ 3,058,050
A22.12.2.3 / Scrubber & Condensate Tank Internal Inspections & Estimated Major Refurbs	[redacted]	Per asset	Estimated – Other	0	£ 1,958,063
A22.12.2.2 / Replace Strainers with Filters/Separators	[redacted]	Per asset	Estimated – Other	0	£ 6,486,317
A22.03.3.2 / Filters PSSR Inspection & Major Overhauls (Bacton)	[redacted]	Per asset	Estimated - Other	0	£ 185,071

Innovation

28.5. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of innovation into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

28.6. We are looking to continue to develop the following project and deliver benefit from it in this investment period:

Mobile Condensate Tanks - examining the possibility of replacing existing condensate tank infrastructure with mobile tanks, with considerable capex saving in the replacement and refurbishment of existing tanks.

Preheaters

29. Preheaters - Equipment Summary

29.1. The purpose of the preheater assets is to regulate temperature of gas during the pressure reduction process. Natural gas when it is reduced in pressure expands and cools. This temperature cooling is known as the Joules Thomson effect. Depending on the level of pressure reduction there may be a requirement to pre-heat the gas to avoid unacceptable low temperatures that could affect the integrity of the pipework, plant & equipment downstream of the Pressure Reduction Installation (PRI).

29.2. Preheating operates in the following key areas:

- Offtakes (in conjunction with Regulators)
- Compressor Unit fuel gas heating

29.3. There are three main types of gas pre-heating used:

Modular Boiler Systems/Heat Exchangers:

29.4. A series of modular boilers, pre-determined in design stage by the heating requirements, heat water in a closed-circuit loop. A pump is utilised to ensure there is a continuous flow of water when heating is required. The hot water is pumped from the boiler house and to the heat exchanger. Within the heat exchanger gas flows through relatively small diameter tubes that are housed within the shell. The outer shell contains and circulates the heating water. It is the heat from the water that heats the gas flowing through the tubes. To be efficient, shell and tube heat exchangers utilize round small tubes creating a large surface that doesn't take up unnecessary room.

Waterbath Heaters:

29.5. The Jenkins water bath is an indirect heater. It consists of a carbon steel firetube which lies below one, or a series of seamless steel gas coils. Both the firetube and gas coils are immersed in a bath of water. The bath shell which houses these components is constructed from thin walled carbon steel. This is possible since the heat transfer is carried out indirectly at or near atmospheric pressure.

29.6. By firing a burner into the firetube, the heat produced by combustion heats the firetube. It then transfers heat directly 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 being heated indirectly by the burner/firetube. The Jenkins bath heater incorporates a thermo—syphon baffle. This is effective in setting up thermal currents which improves the heat transfer efficiency of the heater. As the water temperature increases, the hot water rises and follows the line of the baffle, emerging at the end of the heater which incorporates the flue stack etc., circulation continues along the top of the baffle and then down back towards the section which houses the firetube. Since the water is circulating in this manner, there is less likelihood of steam being produced on the surface of the firetube and therefore scaling is prevented.

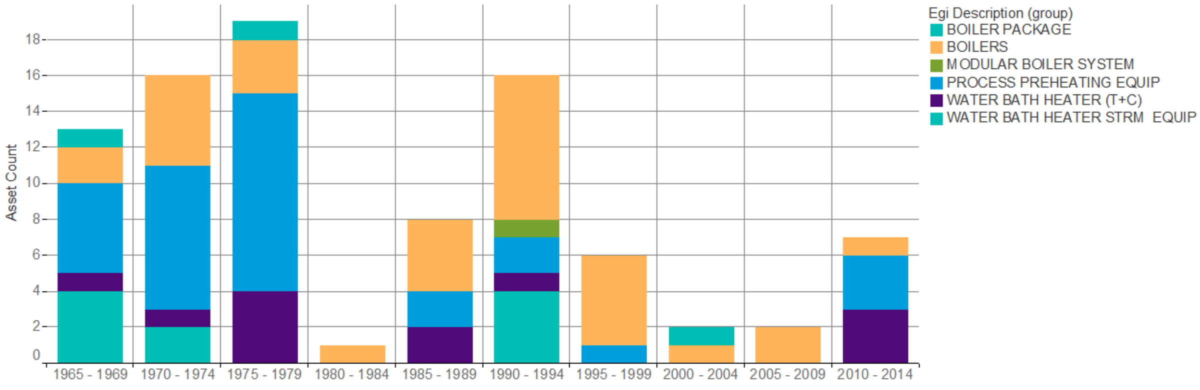
29.7. The assembly connected to the inlet side of the firetube consists of a main burner, pilot burner, flame arrestor, inspection port and ignition system. All these are housed together in a burner box, from which the air required for combustion is taken.

Location and Volume

29.8. There are 89 preheaters on Compressor Stations and 24 preheaters on AGIs.

29.9. The chart below shows the age profile of the individual pre-heater assets by asset type.

Asset Age by Type



Pressure Ratings

29.10. The elements of the preheaters operate at the following pressures:

- Heat Exchangers operate at NTS Line Pressure – 73 to 94bar
- Modular Boilers operate at low pressure
- Waterbath Heaters – Operate at full NTS Pressure – 73 to 94bar

30. Preheaters - Problem Statement

30.1. Waterbath heaters are an aging asset, with increasing corrosion defects, they are very inefficient in operation. The control systems are obsolete and there have been instances of corrosion and loss of wall thickness on the gas coils. This internal degradation is only found during 12-yearly revalidations. There are operating issues due to the age of equipment. They are often prone to reliability issues especially when normal operation is required usually during the winter period. Often at compressor stations the distance the pre-heated gas from the Waterbath heater must travel is too far, leading to excessive cooling of the gas.

30.2. Modular Boiler Systems and associated controls range from new installations to older ones in some cases containing obsolete parts. Some systems are towards the end of their expected life (15-20 years) and will start to encounter Programmable Logic Controller (PLC) issues along with material degradation of internal components. Numerous issues encountered throughout RIIO-1 were 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.

30.3. Heat Exchangers are an aging asset prone to corrosion related failure. There have been numerous heat exchanger failures that have led to further degradation of the heating system and other assets and defects that have only been identified during the PSSR Inspections such as loss of wall thickness on gas tubes.

Drivers for Investment

30.4. The key drivers for investment in the preheater assets are:

- Legislation
- Asset Deterioration
- Asset Performance
- Legislation
- Obsolescence
- Customer Obligations.

Legislation - Heat Exchangers are captured under the Pressure System Safety Regulations 2000 (PSSR) and the aim of these regulations is to prevent serious injury from the hazards of stored energy. Compliance with PSSR drives inspection and validation of the assets and associated remediation of any defects found. Waterbath Heaters and the modular boilers are not subject to PSSR.

Asset Deterioration - The assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements. The elements of deterioration are:

- deterioration of the coating
- corrosion of the metal of the asset – both internal and external
- fatigue

Asset Performance – Several pre-heating systems used for compressor fuel gas provide inadequate pre-heat to ensure that the gas quality entering the turbine on start-up is above the require hydrocarbon dew point. These pre-heating systems located too far away from the gas turbine, resulting in significant heat losses in the fuel gas supply.

Obsolescence – elements of some of the assets are obsolete and no longer supported by the manufacturers**.** The obsolescence of some of the assets can mean, despite a comprehensive spares strategy, a risk of increased impact when they fail.

Customer Obligations – At several offtakes managed by NG there is a contractual agreement to supply gas at a specific temperature to the end user.

Impact of No Investment

30.5. Continued use of these assets without investing in inspections, revalidation and remediation will breach legal obligations of PSSR. Lack of investment in the inspections and revalidation will mean that assets become non-compliant with PSSR legislation.

30.6. Lack of investment in the remediation of failures found during inspections will also render the assets unable to be used to convey gas. Isolation of these assets would result in failure to meet customer obligations to supply gas at agreed temperatures. It is predicted that with no investment there will be assets with outstanding PSSR failures or significant defects by the end of the period.

30.7. For the National Grid gas turbine fuel gas supply, pre-heating is required to ensure the gas quality entering the turbine is a minimum of 20°C above the hydrocarbon dew point of 0°C. Failure to provide the correct gas quality could lead to liquid drop out resulting in reduced life expectancy and therefore increased overhauls of the gas turbine. Low temperature fuel gas can also prevent the starting and operation of the compressor power train. Inability to run the compressors due to incorrect gas temperatures may result in network constraints.

30.8. Lack of investment leading to a loss of performance will allow condensate to flow with the gas and potentially corrode and damage other downstream equipment.

Modular Boiler systems – The majority of these systems are in operation on NTS Managed Offtakes which are required to provide an uninterrupted gas supply to an end user e.g. Power Station. Failure of these heating systems will lead to continuity of supply issues especially throughout winter periods.

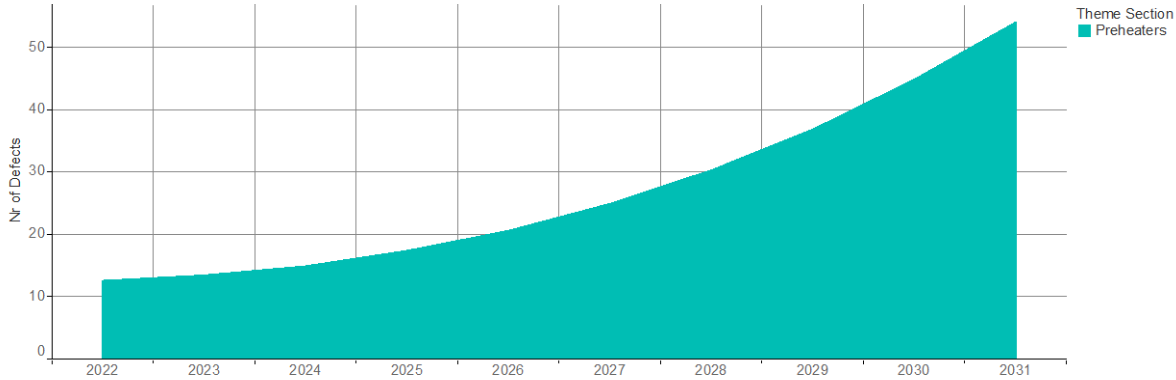
Heat Exchangers – Due to the nature of how these assets work e.g. constant internal contact with water there is a high risk of corrosion to both the shell and tube arrangement. Failure of the shell can lead to the dangerous release of stored energy. Failure of the tubes can lead to gas entering the water system and causing issues with the boilers.

Waterbath Heaters – the control systems are often obsolete and are increasingly inefficient to operate. Waterbath heaters located on compressor stations are often situated too far from units as discussed previously.

30.9. Lack of investment in the assets may also lead to loss of containment of high-pressure gas, safety related issues and environmental damage.

30.10. The chart below shows the number of defects for pre-heater assets starting from current levels captured in work order data and predicted for future years using the equipment failure deterioration models developed through our NOMs Methodology.

Predicted Defects with No Investment



Examples of the Problem

30.11. Waterbath Heater A at Weston Point has recently undergone revalidation and required repairs. Significant corrosion/erosion was found on the gas coils. Due to the defect location, the gas coil needed to have a section cut and removed and a new section manufacturing and welding in.

Images showing Weston Point Gas Coil Defect 1,2,3

30.12. Modular boiler systems at both Stallingborough and Deeside encountered issues that led to the failure of the pre-heating system and the ability to provide gas to the customer at the contractually agreed temperature. Several boilers in each package suffered from internal degradation and due to obsolesce required full replacement with new boilers and modifications to control systems.

Image showing Stallingborough Failed Boilers in Boiler House

Image showing debris in heater section taken from the Modular Boiler at Stallingborough

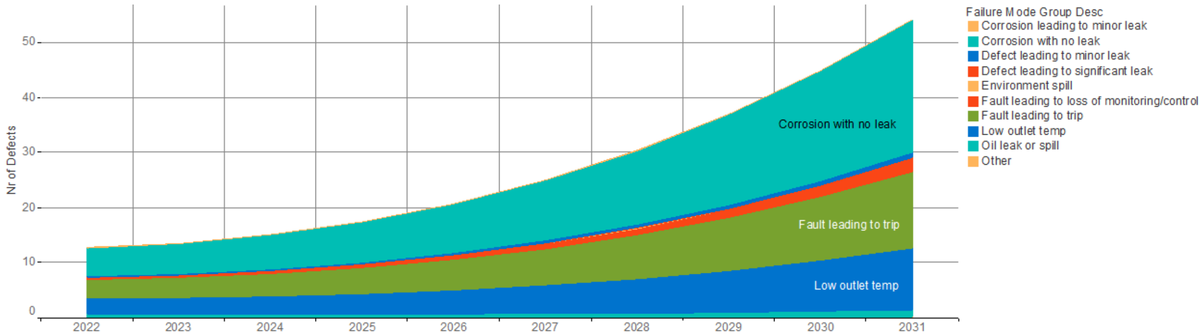
Spend Boundaries

30.13. The proposed investment includes all Preheaters on the NTS, including any 'no-regrets' site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

31. Preheaters - Probability of Failure

31.1. The probability of failure is modelled using our NOMs Methodology. The chart below shows the predicted frequency of failures split by failure mode for pre-heater assets.

Predicted Defects by Failure Mode with No Investment



31.2. For pre-heater assets the chart indicates that the failure modes that contribute most to the probability of failure are:

- Corrosion with no leak
- Failure leading to low outlet temperature
- Fault leading to a trip.

Probability of Failure Interventions

31.3. The table below shows the drivers for Plant and Equipment investments that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

SACs Impacted by Plant & Equipment Investments, by NARMs Intervention Category

NARMs Asset Intervention Category	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Preheaters
Asset Replacement (PoF Driven) Includes Asset Replacements	Preheaters

31.4. These are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this justification report.

Preheater Interventions

31.5. The table below shows the interventions for preheaters split by the type.

Plant & Equipment Interventions by Category

Intervention	SAC	Intervention Category
A22.12.2.6 / Preheater PSSR Revalidation, WBH Inspection & Major Refurbs	Preheaters	Major Refurbishment
A22.12.2.5 / Preheater Minor Refurb	Preheaters	Minor Refurbishment
A22.12.2.4 / Preheater AGI Boiler Replacement	Preheaters	Replacement
A22.12.2.7 / Preheater Upgrade - Compressor Fuel Gas @ Wooler	Preheaters	Replacement
A22.03.3.4 / Preheater PSSR Revalidation, WBH Inspection & Major Refurbs (Bacton)	Preheaters	Major Refurbishment

Data Assurance

31.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

31.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

31.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

32. Preheaters - Consequence of Failure

32.1. The chart below shows the expected stakeholder impacts because of failures occurring on the pre-heater assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact

32.2. The contribution of individual service risk measures towards the overall risk for Preheaters can be explained as follows, in order of significance:

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas from leaks and carbon emissions associated with asset maintenance. The environmental costs of running the preheating system (e.g. gas/electricity supplies) are not included

- **Financial risk** is mostly associated with the costs of operating and maintaining the assets at the current level of risk. Including routine inspection and repairs. Minor PSSR inspection costs (heat exchangers) and included, but major PSSR surveys are considered as proactive costs

- **Availability risk** is associated with the potential outages associated with failure of the pressure reduction system and subsequent isolation of downstream customers. This includes trips due to out-of-range temperatures and pressures. This risk is partially mitigated through the presence of multiple pressure reduction streams at many sites

- **Safety risk** is associated with the possible risk of ignition and fires and explosions following a loss of gas event. This risk is small due to the low probability a of fire/explosion event and the low chance of employees or staff being nearby at the time

33. Preheaters - Options Considered

Potential Intervention Options

33.1. The following intervention categories have been considered for the preheater assets.

Annual Maintenance

33.2. Test the functionality of the asset by carrying out all relevant safety checks and visual inspections as detailed in the relevant work procedure

PSSR Inspections

Heat Exchangers

33.3. The examination shall be carried out at a maximum scheduled interval of 10 years. All normally external and accessible outside surfaces of all welds (which form any parts of the body of the shell) and all external and accessible outside surfaces of all welds joining any attachments to the body of the shell, shall be subject to MPI examination. This will normally require grit blasting preparation to achieve a finish suitable for Magnetic Particle Inspection (MPI) or alternatively Dye Penetrant Inspection (DPI to be carried out. External ultrasonic wall thickness measurements shall be taken over all parts of the shell and the tubes wall thickness shall be measured using the Dinsearch electro-magnetic tube inspection technique or technical equivalent.

6-10 Yearly Maintenance Inspection

Waterbath Heaters

33.4. For WBH a frequency of 10 years would be expected for gas tubes in good condition, with no significant metal loss, where the heat transfer fluid quality is regularly monitored and maintained in satisfactory condition. The assessment of the gas coil assemblies should be conducted by National Grid approved T/PM/P/11 (P11) Mechanical Damage Assessors, who have received supplementary training in the interpretation, use and application of T/PM/P/23 (Management procedure for inspection, assessment and repair of damaged water bath heater gas coil assemblies). Other assessments should be supported by an independent Defect Assessor. Inspection of internal gas coils required including non-destructive testing to identify defects in all welds and wall thickness loss of gas coils. Magnetic Particle Inspection (MPI) is the method of testing for defects in metal.

Heat Exchangers

33.5. Internal gas tubes are removed and NDT/MPI inspections performed on both the tubes and shell.

33.6. The results of these inspection and tests determine what intervention below is required:

Water Quality Testing (Waterbath Heaters and Heat Exchangers only)

33.7. The quality of the water is regularly tested to identify whether internal corrosion is occurring. This is used to determine frequency of inspections i.e. if water quality is poor the inspection date is brought forward.

Repair / Minor Refurbishment

33.8. Waterbath Heaters: Replacement of consumable items such as thermocouples or soft spares for the control system

33.9. Modular Boilers: Replacement of consumable items such as ignitors, burner bars and pumps

33.10. Heat Exchangers: Replacement of consumable items such as Bursting Discs, isolating drain valves and instrumentation

Refurbishment

33.11. Waterbath Heaters: Integrity revalidation or other inspection has discovered unacceptable defects associated with the WBH. This may entail weld repairs. WBH has NDT inspection, pressure tested, painted & revalidated for another 6 to 10 years operational life. Burner control system Regulators receives a major overhaul with all soft parts replaced.

33.12. Modular Boilers: Replacement of sub assets within the modular boiler system e.g. circulation pumps or boilers or PLC controls system

33.13. Heat Exchangers: PSSR or other inspection has discovered unacceptable defects associated with the heat exchanger. This may entail weld repairs or tube replacement. Heat Exchanger has NDT inspection, pressure tested, painted and revalidated for another 6 to 10 years operational life.

33.14. Electric Heaters: Integrity revalidation or other inspection has discovered unacceptable defects. This may entail weld repairs. Electric Heater vessel has NDT inspection, pressure tested, painted & revalidated for another 12 years operational life. Major overhaul of electrical heating element.

Replacement

33.15. For NTS Managed Offtakes the heating systems can be defined as a single point of failure with regards to continuity of gas supply to end users/customers. Any pre-heating systems that cannot be repaired or refurbished due to obsolescence will be identified and replacement planned.

33.16. **Waterbath Heaters**: Reviewing the defect history, it may not be technically or economically feasible to refurbish the Waterbath Heater. We need to consider the condition of the gas burner supply and control as some of the components could be obsolete. The thermal efficiency of the WBH and its environmental impact also need to be assessed. An example at Weston Point AGI is described below:

- Due to revised customer flow rates the Waterbath Heaters, which were originally installed in 1972, are now oversized for the heating requirements leading to large inefficiencies.
- The control systems are in poor asset health condition and require upgrading. Due to policy requirements one of the two WBHs has recently undergone extensive revalidation maintenance where a sizeable defect was found on the burner coil.
- The cost to revalidate and repair this WBH was more than £60k. If both WBHs are not replaced over the RIIO-2 period, the second WBH will require the same work at an expected similar cost.

33.17. **Modular Boilers**: When it is more economical to replace the complete boiler house due to the condition of the housing and/or the cost of replacing individual boilers and other sub assets. The modular boiler system manufacturers/suppliers currently give the systems and approximate life expectancy of 20 years which aligns with National Grid's experience of these systems. In some cases, these systems do fail well before the 20 years. An example at Stallingborough AGI is described below:

- The boilers are obsolete and limited number of spares available. In 2017/2018 Stallingborough Phase 1 boilers (same AGI/end user but separate supply and separate pre-heating) suffered severe degradation and emergency work was required to install new boilers in the existing boiler house to ensure enough pre-heat was available during the winter period. Phase 2 boilers are the same and there are already visible signs of the same issues.

33.18. Heat Exchangers: Reviewing the defect history and it is not economical to refurbish the heat exchanger. Dependent on severity of defects found (i.e. amount of tubes required to be repaired) it will be more economically viable to replace the whole unit rather than repair) The assessment must consider the condition of the sub-assets.

33.19. Electric Heaters: Reviewing the defect history and it is not economical to refurbish the electric heater. The assessment must consider the condition of the sub assets. Replace (and if required relocate) the Boiler House These systems need to be rebuilt and positioned closer to the compressor units and where possible using the surplus heat generated by the gas and power turbine lubricating oil systems.

Intervention Unit Costs

33.20. The total RIIO-2 investment for Preheaters represents 4% of the Plant and Equipment investment theme. All unit costs for Preheaters are supported by other estimation methods in unit costs presented below, although outturn information is currently being analysed for preheater replacement projects completed by PMC.

33.21. The table below provides the unit costs for all preheater interventions.

Intervention Unit Costs - Preheaters

Intervention	Cost (£)	Unit	Estimate	Data Points	Overall value in BP
Preheaters					
A22.12.2.6 / Preheater PSSR Revalidation, WBH Inspection & Major Refurbs	[redacted]	Per asset	Estimated – Other	0	£3, 468,850
A22.12.2.5 / Preheater Minor Refurb	[redacted]	Per asset	Estimated – Other	0	£ 93,356
A22.12.2.4 / Preheater AGI Boiler Replacement	[redacted]	Per asset	Estimated – Other	0	£ 1,288,195
A22.12.2.7 / Preheater Upgrade - Compressor Fuel Gas @ Wooler	[redacted]	Per asset	Estimated – Other	0	£ 515,278
A22.03.3.4 / Preheater PSSR Revalidation, WBH Inspection & Major Refurbs (Bacton)	[redacted]	Per asset	Estimated - Other	0	£104,066

Innovation

33.22. During RIIO-1, we have continued to develop a dynamic portfolio of projects aligned to the Gas Network Innovation Strategy which deliver real value to our customers, stakeholders and the wider industry. We will be continuing to focus on the implementation of innovation into business as usual to drive value throughout everything we do. We will also remain committed to sharing these ideas and best practice across the wider industry to deliver a safe, reliable and efficient network that benefits gas consumers across the UK.

33.23. An example of a non-asset health project that delivered a benefit relevant to the preheater asset was the **Direct Replacement Preheat Package (DRPP)**. This is a study concluded that DRRP can improve preheating capability and was incorporated into FEED documents for future upgrade programmes.

Business Case

In this section we set out our overall investment plan for filters, scrubbers and Preheaters. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

34. Business Case Outline and Discussion

Key Business Case Investment Drivers

34.1. The assets deteriorate over time and with use. This in turn prevents them from performing their required functions and can also result in them no longer complying with current and future legislative requirements.

34.2. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment on these assets:

- PSSR Legislation
- Asset Deterioration
- Asset Performance
- Obsolescence
- Customer Obligations

34.3. Considering these drivers ensures that we develop plans that meet our legal obligations to inspect and intervene and ensures we select the right assets for investment.

Business Case Summary

34.4. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk

34.5. Failures of filters, scrubbers, strainers and preheaters can impact on all these outcomes.

34.6. Maintaining the health of these assets is important in ensuring they continue to deliver the required network capability.

Outcomes delivered

34.7. The outcome of this investment is to:

- To maintain continued compliance with PSR and PSSR.

- To ensure the filter, scrubber, strainer and preheaters assets prevent accelerated deterioration of and do not affect the availability and performance of the compressors and other assets on the NTS.

Stakeholder Support

34.8. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it difficult to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to ‘I want to take gas on and off the system where and when I want’ Chapter 14 of the GT submission.

Programme Options

34.9. Our aim in developing the investment plan is to deliver value to our consumers and stakeholders. Hence, we have considered a range of options from the do nothing position through to reductions in risk across all measures. These have been used to explore the credible options for varying the investment and appraising the impact on our legal compliance, risk position and stakeholders.

34.10. In developing our plan, the following options have been considered for investment in the filters, scrubbers and preheaters assets. Please note that all programme options include any fixed ‘no-regrets’ investments associated with the Bacton and St Fergus sites.

Baseline – Do Nothing

34.11. The baseline position consists of reactive opex only, with no capex included in the baseline.

34.12. The impact of no investment in our Filters, Scrubbers and Preheater assets is an increase in service risk over a 10-year period, the most significant being a three-fold increase in the number of potential major transportation network closures every year, in response to gas leaks and potential fires or explosions. There is also a doubling in the number of potential outages every year caused by failures in pressure reduction systems and the subsequent isolation of downstream customers. This includes trips due to out-of-range temperatures and pressures. This option includes the reactive only investment across all Filters, Scrubbers and Preheater assets and is the option against which all the other options are compared.

Programme Option 1 – PSSR and other Legal Compliance

34.13. This option includes only that required to maintain compliance with PSSR and other legislation. All PSSR related remediation works are included to enable the assets to continue to be operated on the NTS.

Programme Option 2 – Direct Customer Impact

34.14. This option includes the investment within Option 1 together with that required to mitigate any risk to any of our directly connected customers. Investment to mitigate the risk of supplying out of specification gas or damaging our customers downstream assets is included.

Programme Option 3 – Direct Customer and NTS Impact

34.15. Option 3 includes the investment within the previous options plus that required to mitigate the risk that failures of the assets have to the NTS. Investment to mitigate the risk of damage to the NTS assets through the passing of liquids and or debris is included. Also included is the investment to ensure the preheaters provide the correct specification of gas to allow the NTS compressors to operate efficiently and without increased risk to their long-term damage.

Programme Options Summary

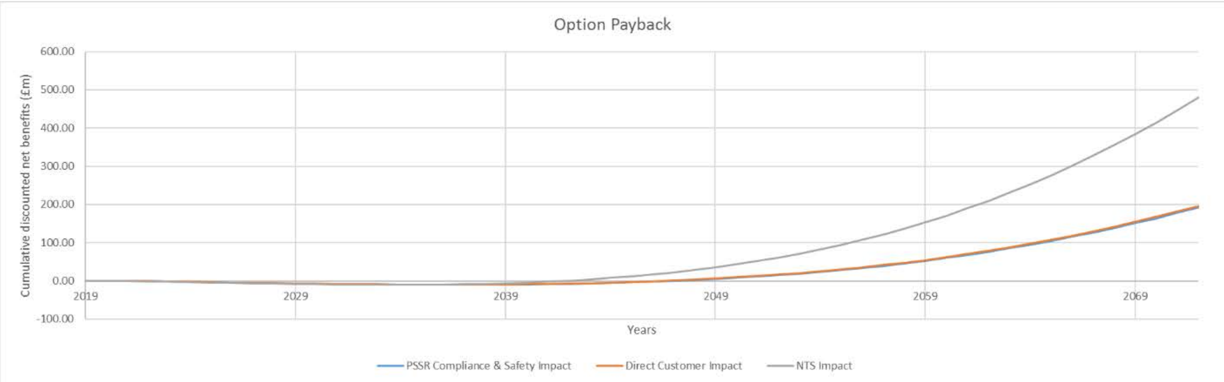
34.16. In considering the CBA for each of the programme options, a summary of all potential programme options is provided in the table below.

Potential Programme Options

Option	RIIO-2 Invest' £ m	RIIO-3 Invest' £ m	PV Costs £ m	PV benefits £ m	Net NPV £ m	CB Ratio	Payback Period (years)
1 - PSSR Compliance & Safety Impact	£13.99	£12.90	£37.31	£152.91	£115.60	4.10	25
2 - Direct Customer Impact	£13.24	£12.15	£35.85	£154.35	£118.50	4.31	25
3 - NTS Impact	£17.16	£16.07	£47.99	£349.78	£301.79	7.29	20

34.17. The graph shows the cumulative discounted NPV of the net benefit for each of the investment options.

Option Payback – Net NPV



Programme Options Selection

34.18. All potential options are cost beneficial over the 45-year analysis period. The selection of the preferred option has therefore been based on an assessment of the level of risk, maintaining our compliance with legislation and delivering value for consumers and stakeholders. The outcomes associated with each option are provided below:

Programme Option 1 – PSSR and other Legal Compliance

34.19. Whilst maintaining compliance with PSSR and other legal obligations, this option carries an unacceptable risk of providing out of specification gas to our customers, or damage to their downstream equipment and any associated outages. The option also presents an unacceptable risk of damage to NTS assets and the associated impact on its availability and resilience.

Programme Option 2 – Direct Customer Impact

34.20. This option manages the risk of impacting our directly connected customers but does not mitigate the risks that the failure of the filter, scrubber and strainer assets present to our assets and the associated availability of the NTS.

Programme Option 3 – Direct Customer and NTS Impact

34.21. The risk that the failure of the filter, scrubber and strainer assets present to the NTS and our customers are effectively mitigated to an acceptable level by this investment programme option.

Preferred Option

34.22. Our preferred option is Option 3 to maintain the current level of risk, because even though some of the other options require less investment, they do not meet the required outcomes and are not as cost beneficial as the chosen option. This is consistent with feedback from our stakeholder engagement who wanted at least the current level of risk maintained. Our chosen option meets the desired outcomes at least whole life cost with a cost beneficial level of investment.

34.23. A complete explanation of the selected option is provided in the next section.

35. Investment Decision – Filters, Scrubbers and Strainers

35.1. In this section we set out our investment decision approach for filters, scrubbers and strainers together with the benefits of the investment.

Key Drivers

35.2. Therefore, in developing our risk forecasts and proposed plans we have considered the impact of the following drivers for investment on these assets:

- PSSR Legislation
- Asset Deterioration

Investment Decision Approach

35.3. To deliver the outcomes for the investment period the assets require a mixture of the intervention categories defined in the section above. The decision on the volume of each of the interventions required on the assets during the investment period is driven by:

- The inspection comprises a mandated 6 yearly visual and 12 yearly major PSSR inspection for filters and scrubbers only (not strainers). Any defects identified require resolution within defined timescales - to comply with PSSR for the vessel itself.
- The volume of each inspection type is based on the time since the last inspection for each individual asset.
- The remediation works have been determined based on a risk-based assessment of **each individual asset** which includes:
    - o the current number and type of outstanding defects
    - o the number of defects predicted to arise during the period
    - o the future requirement for the asset
    - o the criticality of the asset within the site and the criticality of the site overall
- The proposed mix of interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing Filter and Scrubber PSSR inspections

35.4. The interventions required for Strainers vary by the type of site on which they are situated:

NTS Managed Offtakes – The Strainers used on these types of sites were initially installed during original site construction. Their purpose was to ensure no debris from construction works could enter the downstream system. As per IGEM/TD/13 these Strainers should have been removed one winter period following initial site commissioning. Due to the long duration that these Strainers have been installed there is a high possibility of them becoming blocked which has the potential to lead to customer gas supply issues. The intervention required is 'Remove' as there is no requirement for additional filtration.

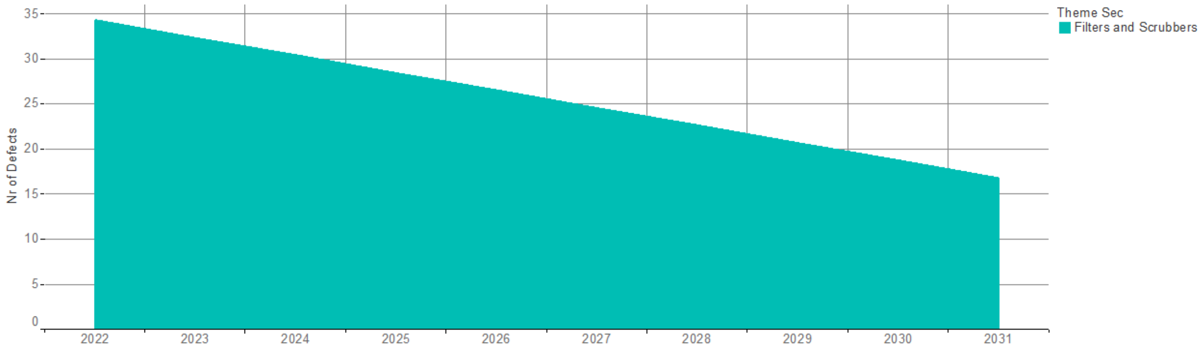
Sites with Flow Control Valves – The root cause of the issue is similar to NTS Managed Offtakes. An individual assessment of each site would be required to determine if upstream filtration is enough to provide protection for the FCV. If upstream filtration is enough then the strainer can be removed, if not then the strainer shall be replaced with a filter.

Compressor Station Strainers –Although strainers are predominantly used following construction there are several compressor stations where a strainer is the only form of filtration for the downstream compressor. Due to the complexities of compressor stations there will be significant station pipework modifications required to remove strainers. A strategy will be determined during the investment period for which strainers can feasibly be removed.

Investment Benefits

35.5. The investment will achieve the following improvement in the number of defects. The chart below shows the predicted defects following the preferred programme of investment for filters, scrubbers and strainers. The number of defects will fall from a predicted 34 at the end of RIIO-3 with no investment to 17 with the proposed investment.

Predicted Defects with Preferred Investment Option



36. Investment Decision – Preheaters

36.1. In this section we set out our investment decision approach for preheaters together with the benefits of the investment.

Key Drivers

36.2. The key drivers for investment in the preheater assets are:

- PSSR Legislation
- Asset Deterioration
- Asset Performance
- Obsolescence
- Customer Obligations.

Investment Decision Approach

36.3. To deliver the outcomes for the investment period the assets require a mixture of the intervention categories defined. The decision on the volume of each of the interventions required on the assets during the investment period is driven by:

36.4. All Preheating equipment is inspected and maintained on a yearly basis.

36.5. In addition, the PSSR inspection comprises a mandated 6 yearly visual and 12 yearly major inspection. Any defects identified require resolution within defined timescales to comply with PSSR for the vessel itself. The volume of each inspection type is based on the time since the last inspection for each individual asset.

36.6. The remediation work has been determined based on a risk-based assessment of each individual asset which includes:

- the current number and type of outstanding defects
- the number of defects predicted to arise during the RIIO-2 period
- the original design of the asset and its current performance
- the future requirement for the asset
- any obsolescence or lack of spares availability
- the criticality of the asset within the site and the criticality of the site overall

NTS Managed Offtakes Pre-Heating

- Modular Boilers and Boiler Control PLC: Require upgrading/replacement due to reaching end of life expectancy
- Heat Exchangers: Interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing Heat Exchanger PSSR inspections. Water analysis results should be reviewed to modify the period between PSSR inspections

- Waterbath Heaters: Require assessment of their suitability with a view to replace with more efficient means of pre-heating. At one site in particular, one waterbath heater has recently been revalidated and repaired to a cost of **approx**. £60k, the second waterbath heater also requires revalidating and similar costs could be occurred if repair is required

Multi-junction Sites

- Modular Boilers: No modular boiler systems are expected to require interventions in RIIO-2 but possibly at the start of RIIO-3. Ongoing annual maintenance will identify if any interventions are required through the RIIO-2 period
- Heat Exchangers: Interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing Heat Exchanger PSSR inspections. Water analysis results should be reviewed to modify the period between PSSR inspections

Compressor Stations

- Modular Boilers: Require upgrades to 1 system due to age/defects.
- Heat Exchangers: Interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing Heat Exchanger PSSR inspections. Water analysis results should be reviewed to modify the period between PSSR inspections

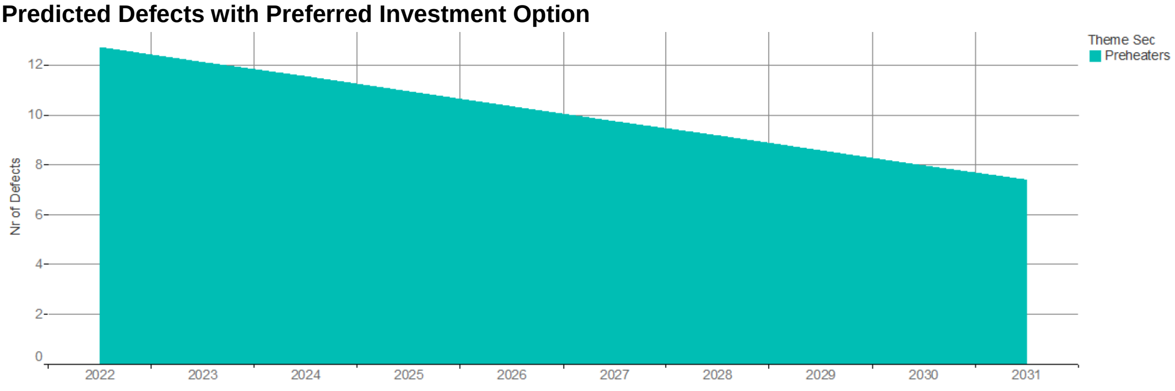
36.7. There are still several older waterbath heater units on compressor stations and offtakes. The long-term strategy is to replace these on failure with a lower whole life cost modular boiler packages.

36.8. The proposed mix of interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing Heat Exchanger PSSR inspections.

Investment Benefits

36.9. The investment will achieve the following improvement in the number of defects. The chart below shows the predicted defects following the preferred programme of investment for preheaters. The number of defects will fall from a predicted 54 at the end of RIIO-3 with no investment to 8 with the proposed investment.

Predicted Defects with Preferred Investment Option



37. Business Case Summary

37.1. In this section, we set out our overall investment plan for the assets.

Preferred Option

37.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the Filters, Scrubbers and Strainers assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

37.3. The profile of investment in the Filters, Scrubbers and Strainers assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

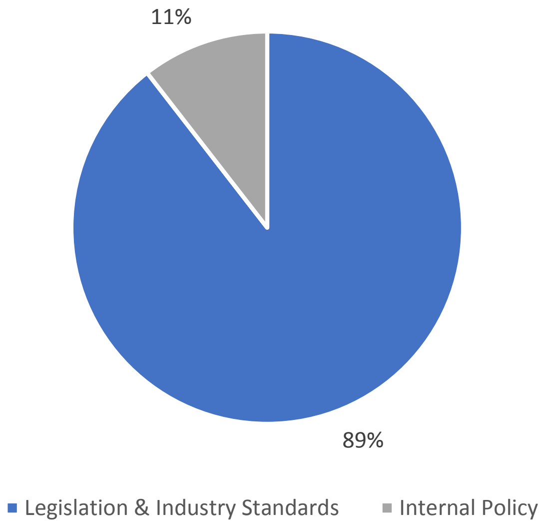
Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Filters and Scrubbers	2,338	2,245	2,167	2,522	2,416	2,156	2,328	2,885	1,689	1,689
Preheaters	366	2,227	711	1,147	1,019	470	469	2,088	1,149	1,149
Total	2,704	4,473	2,877	3,668	3,435	2,626	2,797	4,972	2,838	2,838
	17,157					**16,071**				

Intervention Drivers

37.4. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that the majority of the investment consists of interventions that are required to meet legislative requirements and are based on accepted industry standards.

RIIO-2 Filters, Scrubbers, Strainers and Preheaters Intervention Drivers[8]



Programme CBA

37.5. We are targeting an appropriate level of asset health investment in Filters, Scrubbers, Strainers and Preheaters to mitigate the reliability and safety risks from the ageing asset base.

37.6. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in Filters, Scrubbers and Strainers is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

37.7. The CBA for the Filters, Scrubbers, Strainers and Preheaters investment over the period is cost beneficial over the 45-year period. This investment pays back in 21 years, and over 45 years is significantly cost beneficial. This is shown below.

CBA Summary[9]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£12.26	£23.26	£34.06	£47.99
Present Value H&S benefits (£m)	£0.01	£0.10	£0.44	£2.05
Present Value non H&S benefits (£m)	£2.69	£21.14	£85.84	£347.73
Net Present Value (£m)	£(9.56)	£(2.02)	£52.22	£301.79

37.8. We have challenged whether this is the right programme of work. In developing our plans and making our decision we have been fully cognisant of the need to develop plans that are value for money, acceptable, affordable and deliverable.

[8] See Appendix A for intervention driver category definitions
[9] A14.13.2 Filters, Scrubbers and Preheaters CBA

37.9. The proposed investment is cost beneficial and is the least cost option to ensure that we successfully manage the deterioration and obsolescence of these assets. The investment will manage the risk of short- and medium-term damage to both the assets on the NTS and to those of our customers it also enables us to maintain our compliance with PSSR and PSR legislation.

37.10. The programme of investment will deliver the outcomes that consumers and stakeholder tell us they want us to meet. Across our stakeholders there is little support for keeping the costs the same as in RIIO-1, given the unacceptable consequential increase in risk.

37.11. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. The graph below shows the results of this compared to the preferred option.

Net Benefits of Upper and Lower Unit Cost Sensitivity

37.12. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs.

37.13. Based on our robust CBA assessment, and reviewing the programme against the drivers for investment and outcomes delivered, we are confident that our plans are value for money and in line with stakeholder views.

Preferred Option

38. Preferred Option Scope and Project Plan

38.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred option

38.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the Filters, Scrubbers and Strainers assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

38.3. The profile of investment in the Filters, Scrubbers and Strainers assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Filters and Scrubbers	2,338	2,245	2,167	2,522	2,416	2,156	2,328	2,885	1,689	1,689
Preheaters	366	2,227	711	1,147	1,019	470	469	2,088	1,149	1,149
Total	2,704	4,473	2,877	3,668	3,435	2,626	2,797	4,972	2,838	2,838
	17,157					**16,071**				

Delivery Planning

38.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change and provide an opportunity to reconsider the efficient timing of delivery.

38.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period. This maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

38.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single ‘campaign’ across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

38.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not ‘fit’ into the planned ‘campaign’ approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

38.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes clearer through our survey work.

38.9. The extent of the intervention for filters, scrubbers and preheaters will be determined by inspection, and this will more specifically define the requirements for outages. As a general principle, outages are sought to be aligned with ILI Digs (pipelines work). Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

Pressure Reduction, Flow Control and Slamshuts (£8.5m)

This section of the case considers the investment in Pressure Reduction, Flow Control and Slamshuts that provide control and protection to our and our customers operational assets on all types of sites across the NTS.

Pressure Reduction and Flow Control

39. Pressure Reduction and Flow Control - Equipment Summary

39.1. The purpose of flow or pressure regulation is to allow control of gas pressure/flow characteristics from the NTS pressure to that required for use by customers, actuation of valves or to provide fuel gas to compressors.

39.2. A Flow Control Valve allows GNCC to remotely control the flow of gas and pressure between two or more sections of pipeline. In some circumstances this equipment is situated on a pressure boundary and depending on the pressure differential between the sections of pipeline there could also be a pressure control valve installed.

39.3. Pressure reduction streams are pneumatically operated installations and control the pressure between two different pressure tiers and their prime purpose is to control and regulate the pressure into the downstream pipeline or pipework.

39.4. Flow or Pressure Regulators can be divided as follows:

- Pressure or Flow Control Valves
- Pressure Regulator Streams
- Compressor Station pressure reduction.

Location and Volume

39.5. There are 37 flow control valves, 11 pressure control valves, 24 pressure Regulator streams on AGIs and 120 pressure Regulators on compressor stations.

39.6. The chart below shows the age profile of pressure reduction and flow regulation assets by asset type.

Pressure Ratings

39.7. Pressure reduction and flow control assets operate predominantly NTS pressure, 76 to 94 bar but also have pressure Regulators that reduce pressure to low pressure (mbar).

40. Pressure Reduction and Flow Control - Problem Statement

40.1. Most pressure Regulators on the NTS used to regulate pressure to end users are the ERS HP Regulator. These Regulators were developed in the late 1980s/early 1990s specifically to suit the requirements of gas fired power station. Over the years the power station requirements have changed (increase or decrease in flow, non-continuous running) and now in some instances the Regulators suffer from performance issues.

40.2. The ERS pressure regulation streams were originally designed by British Gas which sold the rights to Mokveld who have since ceased to support the Regulators. As such these Regulators are obsolete and only supported by a single engineering company, AES. The obsolescence of these assets results in an increased restoration time, due to the challenge of implementing an effective spares strategy for obsolete assets. This can affect the ability to supply individual customers as well as the longer outage times impacting the overall resilience of the NTS.

40.3. The main issues NG have experienced with the Flow Control Valves are associated with the failure of the control systems. Also, National Grid are experiencing pressure differentials across these valves which indicate that overhauls are required.

Drivers for Investment

40.4. The key drivers for investment in the pressure reduction and flow control assets are:

- Legislation - PSSR
- Asset Deterioration
- Obsolescence

40.5. In addition to the legal requirements of PSSR the assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with other legislative requirements.

Legislation - These assets are included under the Pressure System Safety Regulations 2000 (PSSR) and the aim of these regulations is to prevent serious injury from the hazards of stored energy. Compliance with PSSR drives inspection and validation of the assets and associated remediation of any defects found.

Asset Deterioration - The assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements. The elements of deterioration are:

- - deterioration of the coating
- - corrosion of the metal of the asset
- - wear due to the duty in terms of number of on/off cycles

Obsolescence – elements of some of the assets are obsolete and no longer supported by the manufacturers**.** The obsolescence of some of the assets can mean, despite a comprehensive spares' strategy, a risk of increased impact when they fail.

Impact of No Investment

40.6. Continued use of these assets without investing in inspections, revalidation and remediation will breach legal obligations of PSSR. Lack of investment in the inspections and revalidation will mean that assets are non-compliant with PSSR legislation.

40.7. Lack of investment in the remediation of failures found during inspections will also render the assets unable to be used in a pressurised environment. In some cases, they will not be able to be used at all. It is predicted that with no investment there will be assets with outstanding PSSR failures or significant defects by the end of the period.

40.8. Pressure/Flow Control Valves have a significant effect on the flow and pressures in the NTS. Their performance is critical to managing the flexibility, operation and line-pack of the NTS. For each Flow Control Valve, GNCC have several remote operating modes available to them. The majority of FCV's were installed in the period from the mid 80's to late 90's. the flow of gas has significantly changed in the NTS and their desired performance and operating modes need to be revalidated. Loss of main line pressure/flow control can lead to failure to meet network demand.

40.9. The pneumatic controllers on the flow control valves continually vent gas to atmosphere increasing the environmental impact of NG.

40.10. Loss of offtake pressure regulation streams could lead to loss of customer supply or gas supplied at the incorrect pressure. Loss of compressor station (fuel gas) pressure Regulators would lead to compressor unit unavailability. Incorrect pressures can also lead to damage to the integrity of any downstream equipment.

40.11. Some key issues experienced with FCV's on the NTS include:

[redacted]

[redacted]

[redacted]

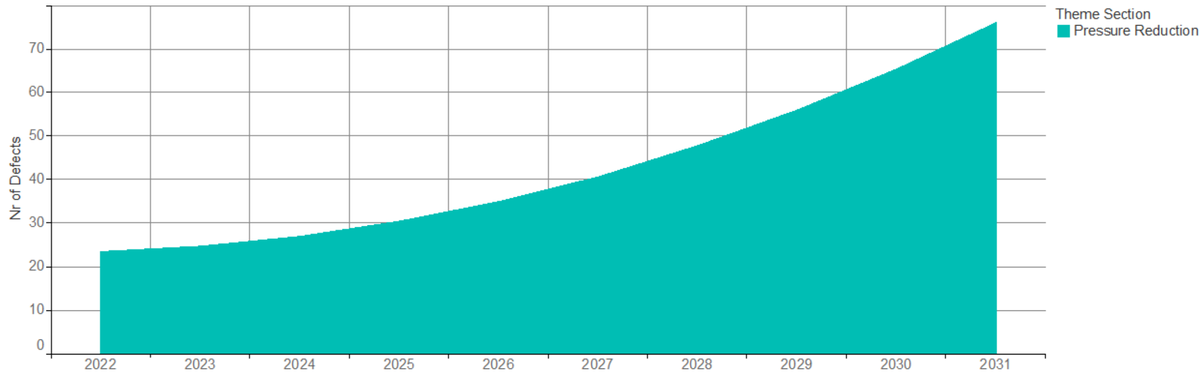
[redacted]

[redacted]

[redacted]

40.12. The chart below shows the number of defects by for pressure reduction and flow regulation assets starting from current levels captured in work order data and predicted for future years using the equipment failure deterioration models in our NOMs methodology developed in 2017.

Predicted Defects with No Investment



Examples of the Problem

40.13. **Didcot AGI –** The operating conditions and requirements of the power station have changed over recent years. The power station now has a higher maximum flow requirement as well as a low flow requirement. Both of these changes potentially contributed to the recent vibration related failure. Parts of the Regulator have failed due to the repetitive on/off nature of the running of the power station, it is no longer a constant 365 days per year.

Images showing failure of piston tab on ERS Regulator at Didcot AGI

40.14. Whitwell AGI - The Paladon volumetric flow and pressure control instrumentation on stream 2 is obsolete and at end of life with no OEM support. The Flow control valve FCV4 has been in service for many years, leading to concern regarding their condition and possible blockage / damage to the valve trim. The stream inline strainer is generating high differential pressure during high flow conditions.

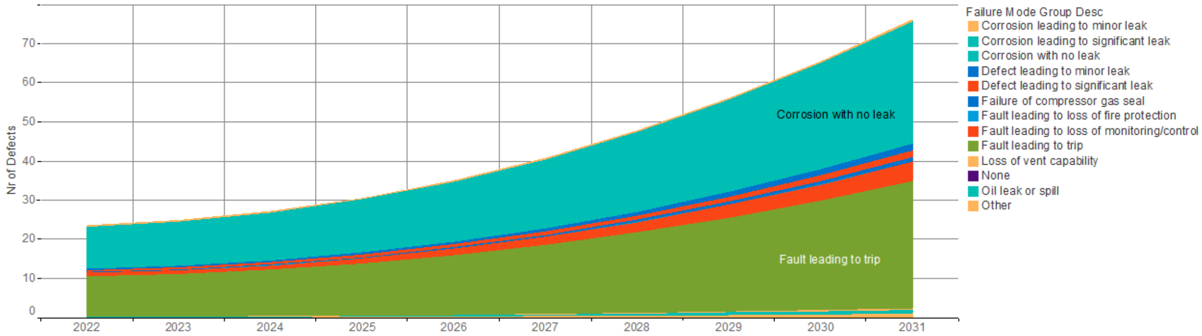
Spend Boundaries

40.15. The proposed investment includes all Pressure Reduction and Flow Control Systems on the NTS, including any ‘no-regrets’ site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

41. Pressure Reduction and Flow Control - Probability of Failure

41.1. The probability of failure is modelled using our NOMs Methodology. The chart below shows the predicted frequency of failures split by failure mode for pressure reduction and flow regulation assets.

Predicted Defects by Failure Mode with No Investment



41.2. For pressure reduction and flow regulation assets the chart indicates that the failure modes that contribute most to the probability of failure are:

- Corrosion no leak
- Fault leading to trip
- Low or no pressure downstream
- High pressure downstream
- Loss of pressure/flow control.

Probability of Failure Interventions

41.3. The table below shows the drivers for Plant and Equipment investments that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

SACs Impacted by Plant & Equipment Investments, by NARMs Intervention Category

NARMs Asset Intervention Category	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Flow or pressure Regulators
Asset Replacement (PoF Driven) Includes Asset Replacements	Flow or pressure Regulators
Asset Refurbishment (PoF Driven) Included Major Refurbishments	Flow or pressure Regulators

41.4. These are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this justification report.

Pressure Reduction and Flow Control Interventions

41.5. The table below shows the interventions for pressure reduction and flow control split by the category of intervention.

Plant & Equipment Interventions by Category

Intervention	SAC	Intervention Category
A22.12.3.1 / Pressure Reduction - Flow Control Valve Upgrade	Flow or pressure Regulators	Replacement
A22.12.3.2 / Pressure Reduction Offtakes - Regulator Replacement	Flow or pressure Regulators	Replacement
A22.12.3.3 / Pressure Reduction Skid Replacement - Compressor Stations	Flow or pressure Regulators	Replacement
A22.12.3.4 / Pressure Reduction Streams - Major Overhauls	Flow or pressure Regulators	Major Refurbishment

Data Assurance

41.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

41.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

41.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

42. Pressure Reduction and Flow Control - Consequence of Failure

42.1. The chart below shows the expected stakeholder impacts because of failures occurring on the pressure reduction and flow regulation assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact

42.2. The contribution of individual service risk measures towards the overall risk for Pressure and Flow Regulators can be explained as follows, in order of significance:

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas from leaks and carbon emissions associated with asset maintenance
- **Financial risk** is mostly associated with the costs of operating and maintaining the assets at the current level of risk. Including routine inspection and repairs
- **Societal risk** is associated with disruption to transport associated with potential fires and explosions
- **Safety risk** is associated with the possible risk of ignition and fires/explosions following a loss of gas event. This risk is small due to the low probability a of fire/explosion event and the low chance of employees or staff being near the asset at the time of failure.

43. Pressure Reduction and Flow Control - Options Considered

Potential Intervention Options

43.1. The following intervention categories have been considered for the pressure reduction and flow control assets.

Repair / Minor Refurbishment

43.2. Replacement of soft parts or other components within the Regulator or Flow Control Valve to maintain its functionality. Repair of sub assets such as pilot control valves, impulse pipework and fittings and associated instrumentation. The requirement for repair will be based on results of 6 monthly functional inspections.

Refurbishment

43.3. **Flow Control Valve** - Overhaul Control Valve, Replace Actuator, Replace Control System / Metering. Following a diagnostic inspection, usually by OEM, it may be necessary to complete a refurbishment of the FCV and associated equipment. Each asset would require an individual assessment to ascertain its requirement on the network. To refurbish an FCV a spare FCV would be required to slot in during the refurbishment works. This could include the upgrade of the actuator to electric to remove the constant venting of the pneumatic actuators.

43.4. **Pressure Regulator** – It may be necessary, following results of functional check or due to poor performance that the asset is refurbished. This may involve replacing certain parts that do not fall under the ‘soft spares’ category such as valve seats and may require special or reverse engineering. Pressure Regulator associated equipment such as pilots may need to be fully refurbished if they are obsolete or the integrity of the asset has failed.

Replacement

43.5. When mechanical and soft parts are obsolete or when it is not economical to refurbish the regulator/skid or Flow Control Valve and its control system.

Removal

43.6. Decommissioning of asset where no longer required. This requires network analysis. Consideration should be given to retaining the asset for use elsewhere on the network or for use as a strategic spare.

Intervention Unit Costs

43.7. The total RIIO-2 investment for Flow and Pressure Regulators represents 5% of the Plant and Equipment investment theme. All of the costs for Flow and Pressure Regulators are supported by other estimation methods because of a lack of outturn cost information being available. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex.

43.8. The table below provides the unit costs for all interventions for flow control valves or pressure regulators.

Intervention Unit Costs – Flow Control Valves and Pressure Regulators

Intervention	Cost (£)	Unit	Estimate	Data Points	Overall value in BP
Flow Control or Pressure Regulators					
A22.12.3.1 / Pressure Reduction - Flow Control Valve Upgrade	[redacted]	Per Asset	Estimated - Other	0	5,313,803
A22.12.3.2 / Pressure Reduction Offtakes - Regulator Replacement	[redacted]	Per Asset	Estimated - Other	0	1,133,611
A22.12.3.3 / Pressure Reduction Skid Replacement - Compressor Stations	[redacted]	Per Asset	Estimated - Other	0	£ 386,458
A22.12.3.4 / Pressure Reduction Streams - Major Overhauls	[redacted]	Per Asset	Estimated - Other	0	£ 277,010

Slamshuts

44. Slamshuts - Equipment Summary

44.1. Slamshuts are protective devices which automatically operate if the downstream pressure increases above the maximum operating pressure, to protect the downstream pipe work from over pressure failure. All Slamshuts operating in above 7 bar systems are covered by PSSR legislation.

44.2. Slamshuts typically consist of:

- Associated valve vent and sealant pipework and fittings
- Valve stem extension
- Valve operator (actuator) and associated fittings and actuating medium storage vessels
- Actuating medium up to the point of isolation, including impulse pipework
- Controls cabinet inclusive of all contents e.g. Regulators, relief valves, pressure switches, solenoid valves etc.
- Instrumentations inherent with the actuations systems e.g. pressure transmitter, flow measurement, PLC, valve position switch etc.

Pressure Ratings

44.3. Slamshuts operate in the range of approximately 10 mbar up to the full NTS pressure of 94 bar.

45. Slamshuts - Problem Statement

45.1. By the end of RIIO-3, 60% of the slam shut assets will be over 35 years old. The number of defects is rising and are predicted to continue to do so at an increasing rate. Some of the slam shuts do not operate when required to do so, others do not provide an effective seal in some cases their triggers point of closure is incorrect.

45.2. In some cases, the time taken for the slam shuts to operate is insufficient to safely and effectively protect the downstream assets. This is either due to original design or degradation in performance. Some Slamshuts are an actuated ball valve which have a risk of downstream over pressurisation due to slow closure times. These assets that are critical to safety require replacing with fast acting slam shut valves.

Drivers for Investment

45.3. The key drivers for investment in the slamshut assets are:

- PSSR Legislation
- Asset Deterioration
- Obsolescence
- Customer Obligations

Legislation - These are captured under the Pressure System Safety Regulations 2000 (PSSR) and the aim of these regulations is to prevent serious injury from the hazards of stored energy. Compliance with PSSR drives inspection and validation of the assets and associated remediation of any defects found.

Asset Deterioration - The assets deteriorate over time and with use which leads to their inability to perform their required function. This can also result in them no longer complying with direct legislative requirements. The elements of deterioration are:

- deterioration of the coating
- corrosion of the metal of the asset
- wear and tear
- age related failure of the control components

Obsolescence – elements of some of the assets are obsolete and no longer supported by the manufacturers. The obsolescence of some of the assets can mean that, despite a comprehensive spares' strategy, a risk of increased impact when they fail.

Impact of No Investment

45.4. Continued use of these assets without investing in inspections, revalidation and remediation will breach legal obligations of PSSR. Lack of investment in the inspections and revalidation will mean that all Slamshut assets will be non-compliant with PSSR legislation.

45.5. Lack of investment in the remediation of failures found during inspections will also render the assets unable to be used in a pressurised environment. In some cases, they will not be able to be used at all. It is predicted that with no investment all Slamshut assets will have outstanding PSSR failures or significant defects by the end of the period.

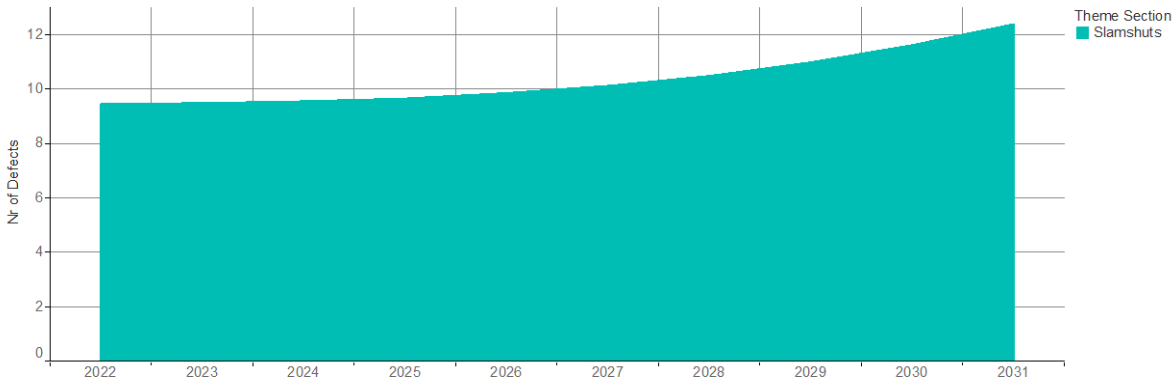
45.6. Loss of appropriate Slamshut functionality can lead to damage to the integrity of any downstream equipment. Failure to isolate a pipeline section following an incident has the potential to result in non-compliance with legislative requirements, reputational and commercial damages. The failure mode of a slam shut valve should be fail closed as their duty is to protect the downstream pipeline/pipework from over-pressurisation.

45.7. Several Slamshut valves also act as the main inlet isolation valve for Regulator streams and reduced isolation integrity by non-sealing valves, presents increases the isolation size and the associated amount of gas that is vented.

45.8. All pneumatically actuated slam shut valves vent gas when they operate. This occurs during 6 monthly testing and in an event of operation of the valve due to over-pressurisation of the downstream system due to failure of pressure Regulators.

45.9. The chart below shows the number of defects by for pressure reduction and flow regulation assets starting from current levels captured in work order data and predicted for future years using the equipment failure deterioration models in our NOMs Methodology developed in 2017.

Predicted Defects with No Investment



Examples of the Problem

45.10. **Shellstar AGI** – The slam shuts currently installed at Shellstar AGI take approx. 8 seconds to fully close when triggered. A recent incident at Shellstar saw the downstream pipework over pressurised to full inlet pressure. This was due to the customer having a safety shut off valve located downstream that closed due to loss of mains power. The sudden stop of the flow of gas caused a back surge. The slam shuts saw this pressure increase and started to close, but the 8 seconds taken was excessive.

Images showing Shellstar Slamshut valve and controls

45.11. **Didcot AGI –** Following vibration related failure the slam shuts at Didcot AGI were removed and the existing stream isolation valves were converted to operate as Slamshuts. As per the Shellstar example, these valves take approximately 6 seconds to close when triggered. Data from transient analysis carried out on the AGI gives a required closure time of 2 seconds. There is currently work under way to build a new PRS with fast acting Slamshuts.

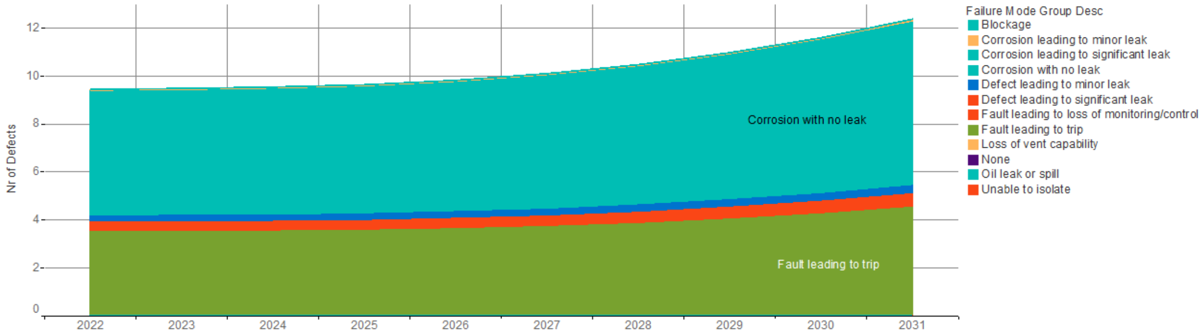
Spend Boundaries

45.12. The proposed investment includes all Slamshuts on the NTS, including any 'no-regrets' site investments at both St Fergus and Bacton to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms.

46. Slamshuts - Probability of Failure

46.1. The probability of failure is modelled using our NOMs Methodology. The chart below shows the predicted frequency of failures split by failure mode for Slamshut valve assets.

Predicted Defects by Failure Mode with No Investment



46.2. For Slamshut valve assets the chart indicates that the failure modes that contribute most to the probability of failure are:

- Corrosion no leak
- Fault leading to trip
- Loss of downstream supply
- Loss of Regulator stream redundancy
- Over-pressure of downstream system.

Probability of Failure Interventions

46.3. The table below shows the drivers for Plant and Equipment investments that are related to the current and future Probability of Failure (PoF). This includes investments that are driven by future PoF deterioration.

SACs Impacted by Plant & Equipment Investments, by NARMs Intervention Category

NARMs Asset Intervention Category	Secondary Asset Class
Extension of Expected Asset Life Includes Minor Refurbishments	Slamshut
Asset Replacement (PoF Driven) Includes Asset Replacements	Slamshut
Asset Refurbishment (PoF Driven) Included Major Refurbishments	Slamshut

46.4. These are defined as PoF driven investments as the risk change delivered through investment is modelled as a direct consequence of replacing or refurbishing the asset. The benefits delivered through these investments will be reported as a Network Asset Risk Metric (NARM) as a reduction in monetised risk, arising from a lower PoF delivered through investment. Investment benefits vary depending on the intervention category and are consistent with the Cost Benefit Analysis (CBA) accompanying this justification report.

Slamshut Interventions

46.5. The table below shows the interventions for slamshuts split by the category.

Plant & Equipment Interventions by Category

Intervention	SAC	Intervention Category
A22.12.3.8 / Pressure Reduction Streams - Minor Overhauls	Slamshut Valve	Minor Refurbishment
A22.12.3.5 / Pressure Reduction - Flow Control Valve Upgrade	Slamshut Valve	Replacement
A22.12.3.6 / Pressure Reduction Offtakes - Regulator Replacement	Slamshut Valve	Replacement
A22.12.3.7 / Pressure Reduction Skid Replacement - Compressor Stations	Slamshut Valve	Replacement

Data Assurance

46.6. All PoF and CoF values are taken from the National Grid Gas Transmission 'Methodology for Network Output Measures' (the Methodology). The Methodology was originally submitted for public consultation in April 2018, with three generally favourable responses received in May 2018. On this basis, Ofgem were happy to provisionally not reject the Methodology pending further work to:

- Produce a detailed Validation Report, confirming the validity of data sources used in the Methodology
- Test a range of supply and demand scenarios and incorporate an appropriate scenario to best represent Availability and Reliability risk

46.7. A review of the Methodology by independent gas transmission experts has been carried out and several improvements identified and incorporated.

46.8. At the time of writing, the final Validation Report has been submitted to Ofgem. We understand that once this work is complete Ofgem will formally "not reject" the Methodology and a License change progressed to restate our RIIO-1 targets in terms of monetised risk commenced.

47. Slamshuts - Consequence of Failure

47.1. The chart below shows the expected stakeholder impacts because of failures occurring on the Slamshut valve assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Expected Stakeholder Impact

47.2. The contribution of individual service risk measures towards the overall risk for Slamshut valves can be explained as follows, in order of significance:

- **Environmental risk** is the largest proportion of overall service risk and is associated with the loss of gas from leaks and carbon emissions associated with asset maintenance
- **Financial risk** is mostly associated with the costs of operating and maintaining the assets at the current level of risk. Including routine inspection and repairs
- **Societal risk** is associated with disruption to transport associated with potential fires and explosions
- **Safety risk** is associated with the possible risk of ignition and fires and explosions following a loss of gas event. This risk is small due to the low probability a of fire/explosion event and the low chance of employees or staff being in proximity at the time

47.3. The possibility of the Slamshut valve failing open or closed, which might potentially cause supply outages are generally mitigated by the presence of effective fail-safe systems.

48. Slamshuts - Options Considered

Potential Intervention Options

48.1. The following intervention categories have been considered for the Slamshut assets.

6 Yearly Inspection – Visual

48.2. Visual inspection of the asset.

12 Yearly Inspection and Revalidation

48.3. In addition to the elements of the visual inspection, the coating is removed during the major inspection to allow a detailed examination of the pressure vessel body and welds.

Repair / Minor Refurbishment

48.4. Replacement of soft parts or other components within the Slamshut valve, Regulator or Flow Control Valve to maintain its functionality. Repair of sub assets such as pilot control valves, impulse pipework & fittings and associated instrumentation.

Refurbishment

48.5. Complete major overhaul of the Slamshut valve, regulator or Flow Control Valve with all soft parts replaced and defect/worn mechanical components replace. Slamshut Valve is repainted and pressure tested. Sub assets such as pilot control valves, impulse pipework and fittings and associated instrumentation is either overhauled/calibrated or replaced.

Replacement

48.6. Replace Slamshut Valve and ancillary assets.

Intervention Unit Costs

48.7. The total RIIO-2 investment for Slamshut Valves represents 1% of the Plant and Equipment investment theme. All of the unit costs for Slamshut Valves are supported by other estimation methods because of a lack of outturn cost information being available. Full details of our RIIO-2 unit cost methodology can be found in the Asset Health Unit Cost Annex

48.8. The table below provides the unit costs for all Slamshut interventions.

Intervention Unit Costs - Slamshut

Intervention	Cost (£)	Unit	Estimate	Data Points	Overall value in BP
Slamshut Valves					
A22.12.3.8 / Pressure Reduction Streams - Minor Overhauls	[redacted]	Per Asset	Estimated - Other	0	£ 55,714
A22.12.3.5 / Pressure Reduction - Flow Control Valve Upgrade	[redacted]	Per Asset	Estimated - Other	0	£ 1,210,944
A22.12.3.6 / Pressure Reduction Offtakes - Regulator Replacement	[redacted]	Per Asset	Estimated - Other	0	£ -
A22.12.3.7 / Pressure Reduction Skid Replacement - Compressor Stations	[redacted]	Per Asset	Estimated - Other	0	£ 128,819

Business Case

In this section we set out our overall investment plan for Flow Control Valves, Regulators and Slamshuts. This section demonstrates why the proposed investment levels are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

49. Business Case Outline and Discussion

Key Business Case Investment Drivers

49.1. The key drivers for investment in the Flow Control Valves, Regulators and Slamshut assets are:

- PSSR Legislation
- Asset Deterioration
- Obsolescence
- Customer Obligations.

Business Case Summary

Outcomes delivered

49.2. In appraising asset health investment, we have considered how assets can impact on several outcomes:

- Reliability risk
- Environmental risk
- Safety risk
- Societal risk

49.3. Failures of flow control valves, pressure Regulators and Slamshuts can impact on all these outcomes.

49.4. Maintaining the health of these assets is important in ensuring they continue to deliver the required network capability. Specific outcomes associated with this investment are to:

- Maintain compliance with PSSR
- Ensure that flow control valves enable effective management of the flexibility, operation and line-pack of the NTS
- Ensure Slamshut valves operate at the correct firing point, close within sufficient time and select effectively to safely protect the downstream NG and customer assets
- Ensure that pressure Regulators do not limit the availability of the compressor units

- Continue to meet customer contractual obligations to provide an uninterruptable gas supply at the correct pressures through the effective operation of the pressure regulation streams and the prevention of spurious/unwanted operation of Slamshuts that would lead to loss of supply.

49.5. Our proposed investment will ensure that we maintain our low levels of risk across all these outcomes.

Stakeholder Support

49.6. Consumer and stakeholder research and engagement has been integral to the development of our asset health investment plans. Early discussions realised that to engage in meaningful dialogue, our plan outputs should be presented at a programme rather than asset level of detail. This is due to the integrated nature of our Asset Health plan which makes it a challenge to disaggregate and engage on individual elements. For details of our stakeholder engagement approach please refer to 'I want to take gas on and off the system where and when I want' Chapter 14 of the GT submission.

Programme Options

49.7. Our aim in in developing the investment plan is to deliver value to our consumers and stakeholders. Hence, we have considered a range of options from the do nothing position through to reductions in risk across all measures. These have been used to explore the credible options for varying the investment and appraising the impact on our legal compliance, risk position and stakeholders.

49.8. In developing our plan, the following options have been considered for investment in the pressure reduction, flow control and Slamshut system assets. Please note that all programme options include any fixed 'no-regrets' investments associated with the Bacton and St Fergus sites.

Baseline – Do Nothing

49.9. The baseline position consists of reactive opex only, with no capex included in the baseline.

49.10. The impact of no investment in our Pressure Reduction, Flow Control and Slamshut system assets will increase service risk over a 10-year period, the most significant impact being a three-fold increase in the number of fatalities every year caused by loss of asset integrity and the possible ignition of escaping gas, resulting in fires and explosions. This option includes the reactive only investment across all Pressure Reduction, Flow Control and Slamshut system assets and is the option against which all the other options are compared.

Programme Option 1 – PSSR Compliance and Safety Impact

49.11. This option includes only that investment within the assets that is required to maintain compliance with PSSR and other legislation together with those that have a significant potential safety risk. All PSSR related remediation works are included to enable the assets to continue to be operated on the NTS.

Programme Option 2 – Direct Customer Impact

49.12. Option 2 includes the investment within option 1 together with that required to mitigate the risk to any of our directly connected customers. This includes investment within the pressure regulation streams to mitigate the risk of loss of supply.

Programme Option 3 – Direct Customer and NTS Impact

49.13. In addition to the investment included within the previous options, this option includes the investment in pressure regulation streams and flow control valves to enable continued effective management and operation of the NTS.

Programme Options Summary

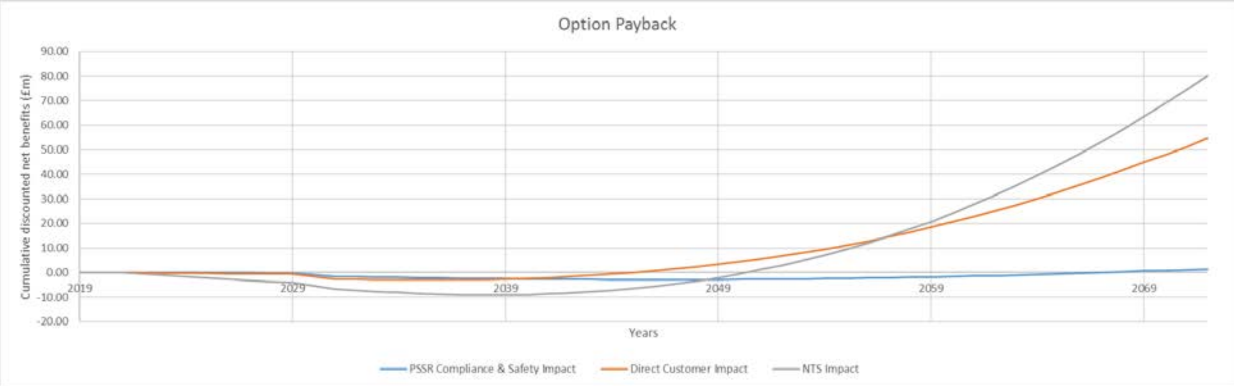
49.14. In considering the CBA for each of the programme options, a summary of all potential programme options is provided in the table below.

Potential Programme Options

Option	RIIO-2 Invest' £ m	RIIO-3 Invest' £ m	PV Costs £ m	PV benefits £ m	Net NPV £ m	CB Ratio	Payback Period (years)
1 - PSSR Compliance & Safety Impact	£0.42	£6.35	£4.72	£4.45	£(0.27)	0.94	Does not payback in the period
2 - Direct Customer Impact	£1.71	£11.23	£9.57	£45.27	£35.70	4.73	24
3 - NTS Impact	£8.51	£15.88	£29.84	£78.38	£48.54	2.63	29

49.15. The graph shows the cumulative discounted NPV of the net benefit for each of the investment options.

Option Payback – Net NPV



Programme Options Selection

49.16. Options 2 and 3 are cost beneficial over the 45-year analysis period with Option 1 being non-cost beneficial. The selection of the preferred option has been based on an assessment of the level of risk, maintaining our compliance with legislation and delivering value for consumers and stakeholders. The outcomes associated with each option are provided below:

Programme Option 1 – PSSR Compliance and Safety Impact

49.17. Whilst maintaining compliance with PSSR and other legal obligations, this option carries an unacceptable risk of providing out of specification gas to our customers, or damage to their downstream equipment and any associated outages. The option also presents an unacceptable risk of damage to NTS assets and the associated potential impact on its availability and resilience.

Programme Option 2 – Direct Customer Impact

49.18. This option manages the risk of impacting our directly connected customers in providing gas at the correct pressures through the effective operation of the pressure regulation streams and the prevention of spurious/unwanted operation of Slamshuts that would lead to loss of supply.

Programme Option 3 – Direct Customer and NTS Impact

49.19. The risk that the pressure regulation and Slamshut assets present to the NTS and our customers are effectively mitigated to an acceptable level by this investment programme option. This option also ensures that flow control valves enable effective management of the flexibility, operation and line-pack of the NTS.

Preferred Option

49.20. Our preferred option is Option 3 to maintain the current level of risk, because even though some of the other options require lower investment they do not meet the required outcomes. This is consistent with feedback from our stakeholder engagement who wanted at least the current level of risk maintained. Our chosen option meets the desired outcomes at least whole life cost with a cost beneficial level of investment.

49.21. A complete explanation of the selected option is provided in the next section.

50. Investment Decision – Pressure Reduction and Flow Control

50.1. In this section we set out our investment decision approach for pressure reduction and flow control assets together with the benefits of the investment.

Key Drivers

50.2. The key drivers for investment in the pressure reduction and flow control assets are:

- PSSR Legislation
- Asset Deterioration
- Obsolescence.

Interventions Scope

50.3. To deliver the outcomes for the investment period the pressure reduction and flow control assets require a mixture of the intervention categories defined in the section above. The decision on the volume of each of the interventions required on the assets during the investment period is driven by:

- The PSSR inspection comprises a mandated 6 yearly visual and 12 yearly major inspection. Any defects identified require resolution within defined timescales - to comply with PSSR for the vessel itself.
- The volume of each inspection type is based on the time since the last inspection for each individual asset
- The remediation works have been determined based on a risk-based assessment of **each individual asset** which includes:
    - the current number and type of outstanding defects
    - the number of defects predicted to arise during the RIIO-2 period
    - the future requirement for the asset
    - the future flow capacity requirements
    - the criticality of the asset within the site and the criticality of the site overall

Flow Control Valves

50.4. **Upgrades:** FCVs require upgrades when there is still a requirement, but it is subject to one or more of the following:

- Non-compliance with specs/policies
- No Primary Protective Device
- Obsolescence (control systems etc)
- Insufficient capacity for Network

50.5. **Decommission:** FCVs should be decommissioned when they are no longer required on the Network. There are instances where FCVs are not operating in the way they were designed. Individual assessment required.

50.6. **Major Overhaul:** There are no issues currently reported that would require a major overhaul (replacement of soft spares etc). These will be carried out when maintenance indicates an issue.

NTS Managed Offtakes – Pressure Regulators

50.7. **Repair / Minor Refurbishment:** Pressure Regulators shall be repaired on indication of fault following maintenance/functional checks. This shall include the replacement of soft spares and other small components to maintain the functionality of the Regulator. This category of intervention and programme of work will be continually reassessed and reprioritised using the results of the ongoing annual maintenance.

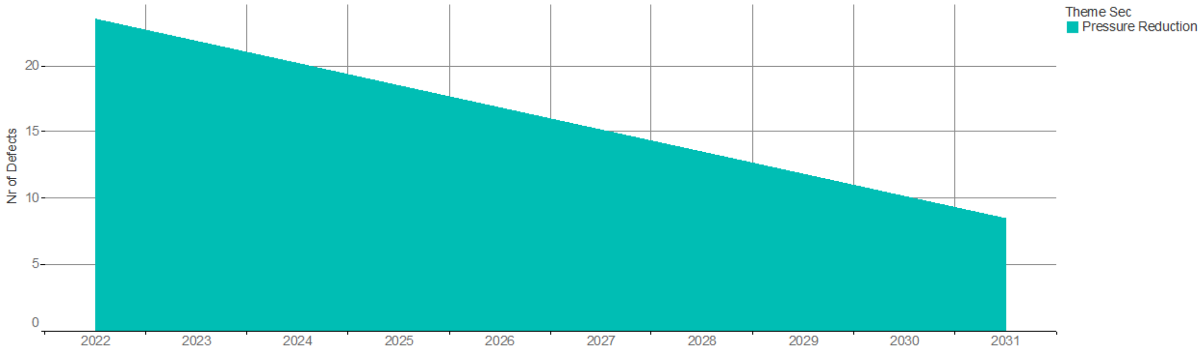
50.8. **Refurbish:** Regulators shall be refurbished if there are functionality issues that cannot be resolved by repair.

50.9. **Replace:** Regulators shall be replaced if they are obsolete or it is not economical to refurbish. Many ERS Regulators have been experiencing issues due to the change in operating conditions/requirements of the downstream customer.

Benefits of Investment

50.10. The investment will achieve the following improvements in the number of defects. The chart below shows the predicted defects following the preferred programme of investment for pressure reduction and flow regulation assets.

Predicted Defects following the Preferred Investment Option



51. Investment Decision – Slamshut

51.1. In this section we set out our investment decision approach for Slamshut assets together with the benefits of the investment.

Key Drivers

51.2. The key drivers for investment in the Slamshut assets are:

- PSSR Legislation
- Asset Deterioration
- Obsolescence
- Customer Obligations.

Investment Decision Approach

51.3. To deliver the outcomes for the investment period the Slamshut assets require a mixture of the intervention categories defined in the sections above. The decision on the volume of each of the interventions required on the Slamshut assets during the investment period is driven by results of PSSR Inspections and Functional Checks.

51.4. Slam shuts operating above 2 bar are classed as Primary Protective Devices and the inspection of these assets falls under PSSR and are required to be functionally tested annually. Any defects or faults identified during the inspection require resolution within defined timescales

51.5. The remediation work has been determined based on a risk-based assessment of each individual asset which includes:

- the current number and type of outstanding defects
- the number of defects predicted to arise during the investment period
- the test and timing results
- the future requirement for the asset
- the criticality of the asset within the site and the criticality of the site overall.

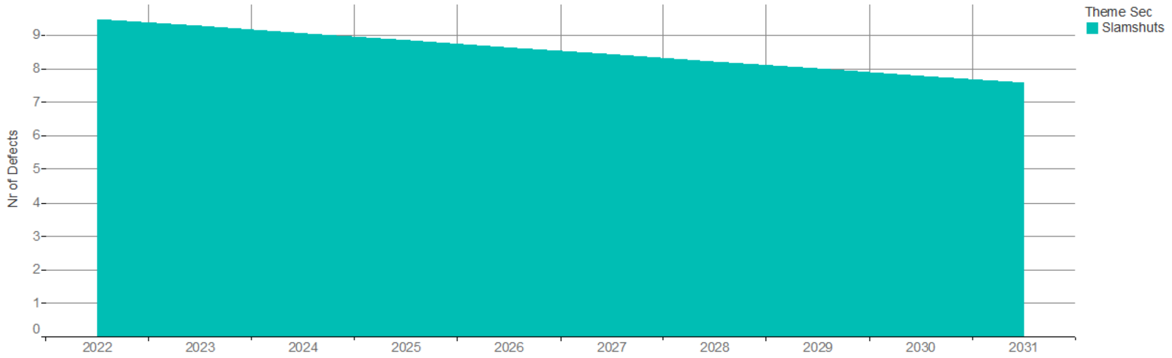
51.6. Slamshuts that are an actuated ball valve will be replaced with a fast acting Slamshut due to transient downstream pressures and the risk of downstream over pressurisation due to slow closure times of the Slamshut valve.

51.7. Interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing Slamshut PSSR inspections.

Investment Benefits

51.8. The investment will achieve the following improvements in the Slamshut assets. The chart below shows the predicted defects following the preferred programme of investment for slam shut valve assets.

Predicted Defects following the Preferred Investment Option



52. Business Case Summary

52.1. In this section, we set out our overall investment plan for the flow/pressure regulator and slamshut assets.

Preferred Option

52.2. To deliver the required outcomes for our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the Flow/Pressure Regulator and Slamshut assets over the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

52.3. The profile of investment in the pressure reduction, flow control and Slamshut assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Spend Profile

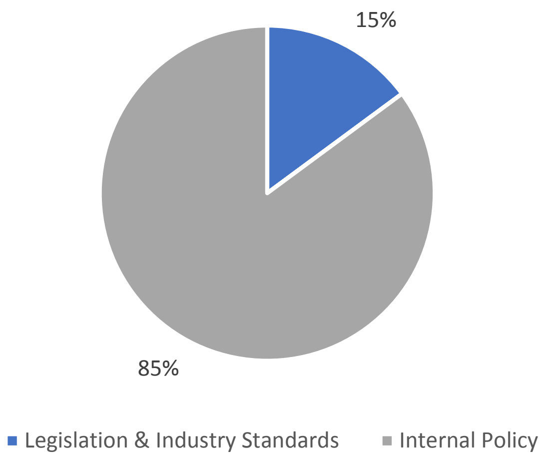
Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Flow or Pressure Regulators	1,419	1,423	1,423	1,423	1,423	1,423	1,423	1,423	2,138	2,138
Slamshut Valves	279	279	279	279	279	279	279	279	3,247	3,247
Total	1,698	1,702	1,702	1,702	1,702	1,702	1,702	1,702	5,385	5,385
	8,506					**15,877**				

Intervention Drivers

52.4. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that whilst some of the investment consists of interventions that are required to meet legislative requirements and are based on accepted industry standards, the majority is based on internal policy.

RIIO-2 Pressure Reduction, Flow Control and Slamshuts Intervention Drivers[10]

[10] See Appendix A for intervention driver category definitions



Programme CBA

52.5. We are targeting an appropriate level of asset health investment in pressure reduction, flow control and Slamshut to mitigate the reliability and safety risks from the ageing asset base.

52.6. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in pressure reduction, flow control and Slamshut is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA).

52.7. The CBA for the pressure reduction, flow control and Slamshut investment over the period is cost beneficial over the 45-year period. This investment pays back in 30 years, and over 45 years is significantly cost beneficial. This is shown in the table below:

CBA Summary[11]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£7.87	£15.71	£22.19	£29.84
Present Value H&S benefits (£m)	£0.01	£0.08	£0.30	£1.25
Present Value non H&S benefits (£m)	£1.26	£7.10	£23.07	£77.13
Net Present Value (£m)	£(6.60)	£(8.54)	£1.18	£48.54

52.8. We have challenged whether this is the right programme of work. In developing our plans and making our decision we have been fully cognisant of the need to develop plans that are value for money, acceptable, affordable and deliverable.

52.9. The proposed investment is cost beneficial and is the least cost option to ensure that we successfully manage the deterioration and obsolescence of these assets. The investment will enable continued effective management of the flow of gas across the NTS and within individual sites. The investment also allows the operation of the safety critical slamshut valves to be maintained, preventing the risk of damage to both the assets on the NTS and to those of our customers. Investment is necessary to continue our compliance with PSSR and PSR legislation.

[11] A16.13.3 Pressure Reduction, Flow Control and Slamshuts CBA

52.10. The programme is lowest while life cost option to deliver the outcomes that consumers and stakeholder tell us they want us to meet. Across our stakeholders there is little support for keeping the costs the same as in RIIO-1, given the unacceptable consequential increase in risk.

52.11. We have used the potential range of unit cost variance to assess the sensitivity of the Cost Benefit Analysis to the upper and lower limits. The graph below shows the results of this compared to the preferred option.

Net Benefits of Upper and Lower Unit Cost Sensitivity

52.12. Whilst the level of cost benefit and the payback period changes as the unit costs vary, the investment remains cost beneficial across the range of unit costs.

52.13. Based on our robust CBA assessment, and reviewing the programme against the drivers for investment and outcomes delivered, we are confident that our plans are value for money and in line with stakeholder views.

Preferred Option

53. Preferred Option Scope and Project Plan

53.1. The section summarises our preferred investment plan required to deliver acceptable and affordable outcomes for our stakeholders.

Preferred option

53.2. To deliver the required outcomes for all our stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the pressure reduction, flow control and Slamshut assets in the investment period.

[redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

53.3. The profile of investment in the pressure reduction, flow control and Slamshut assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Flow or Pressure Regulators	1,419	1,423	1,423	1,423	1,423	1,423	1,423	1,423	2,138	2,138
Slamshut Valves	279	279	279	279	279	279	279	279	3,247	3,247
Total	1,698	1,702	1,702	1,702	1,702	1,702	1,702	1,702	5,385	5,385
	8,506					**15,877**				

Delivery Planning

53.4. At this point in time the delivery of our RIIO-2 and RIIO-3 plans are in principle deliverable based on initial assessments of work. We will regularly review the plan to consider any known or changing constraints, customer impacts and bundling opportunities. In the event of churn our plan must be reoptimised to reflect the impact of the change, and provide an opportunity to reconsider the efficient timing of delivery.

53.5. We recognise that many of our asset classes are co-located across the NTS pipe network and sites. Much of our investment delivery also requires outages of the associated pipelines or plant and equipment. The availability of outages is extremely limited across most of the NTS. It is therefore most efficient from both financial and network risk points of view to bundle investment across asset classes within the same outage period. This maximises the work undertaken in any outage whilst ensuring efficient delivery through minimised project overheads.

53.6. This approach is particularly effective when applied at a feeder level or for a whole site. In which case the preparatory inspection, investigation, risk assessment, planning and procurement activities can be completed as far as possible before the outage. This allows the maximum amount of intervention and risk reduction to be bundled into a single ‘campaign’ across the length of the feeder. During RIIO-1 this has proved to be an extremely efficient and effective approach to delivery of our programmes of work.

53.7. We recognise that whilst this is in many cases the most efficient method of delivery there are still individual or groups of assets that present a risk to our performance that do not ‘fit’ into the planned ‘campaign’ approach. We will ensure that these risks are remediated as efficiently as possible through individual or small groups of targeted interventions.

53.8. A small number of locations on the network require an alternative solution to the usual outage approach to mitigate the risk of disruption to customer supply. This could be for example due to customers on single network spurs. While it may be possible in some cases to negotiate commercial solutions to this, costs per day are expected to be significant and it is likely that an alternative asset solution will be required in the form of stopples (bypasses). We will seek to identify alternative more efficient solutions with our delivery units and suppliers as the nature of the interventions on each site becomes more clear through our survey work.

53.9. Regulators and Slamshuts are highly likely to require outages. Records. As a general principle, outages are planned to align with ILI Digs (pipelines work). Where asset interventions do not require outages then the campaign approach will still be applied to maximise the opportunity for delivery of the same type of work across many locations. This enables efficient procurement through significant volumes of common works.

Appendices

Appendix A – Intervention Driver Categories

Intervention Driver Categories

	Name	Definition
A	Legislation & Industry Standards	Intervention required to ensure compliance with relevant safety legislation and/or adopted industry standards.
B	OEM Guidance	Intervention recommended by OEM to maintain intended asset performance and safe operation. Any deviation from this guidance shall be specifically risk-assessed to ensure compliance with relevant safety legislation.
C	Internal Policy	Internal policy defined intervention required to maintain asset performance, and to align with relevant safety legislative requirements