Annex
A14.08
Cab Infrastructure 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 Compressor Cab 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 Cab Infrastructure assets are secondary assets but fundamental to ensure safe operation of the compressor train and compliance with environmental and safety legislation. Faults and degradation on these secondary assets will impact upon the availability of the compressor train due to inherent process safety risks. The Cabs must therefore be maintained to ensure compressor train availability, preventing atmospheric conditions that could escalate to an explosion. Our Cab Infrastructure Asset Health plan proposes a rolling campaign that brings our Cabs into compliance over a 10-year period, allowing the primary compressor train to remain operational. This plan aligns with our need to refurbish and replace many of the fire suppression systems, to manage potential emergencies within the Cab enclosures. Our Cab Infrastructure plan is the least whole life cost to maintain availability and reliability for customers.

The Compressor Cab asset health programme has 2 sub-themes and seeks to address defects across our entire compressor fleet during RIIO-2 and RIIO-3. In total, we propose to spend £31.29m (5.1% of the 7 themes that comprise the overall asset health plan) ensuring risk levels and compliance with the appropriate legislation is maintained across our Compressor Cab assets during RIIO-2.

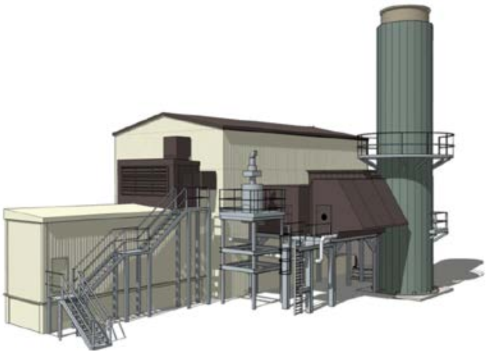
Sub-theme	Intervention Volumes	Cost
Cab Infrastructure	[redacted]	£24,327,297
Fire Suppression Systems	[redacted]	£6,963,797
Total	[redacted]	**£31,291,094**

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

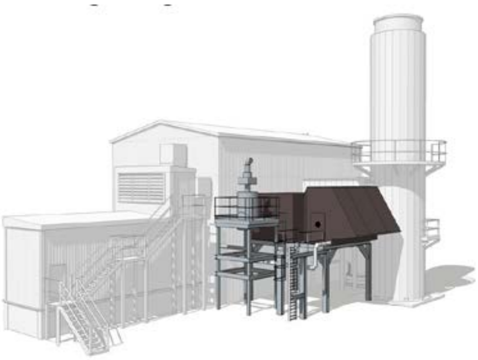
Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Total	7,013	8,909	5,965	4,222	5,182	7,427	9,270	9,907	6,939	4,138
	31,291					**37,680**				

The Assets

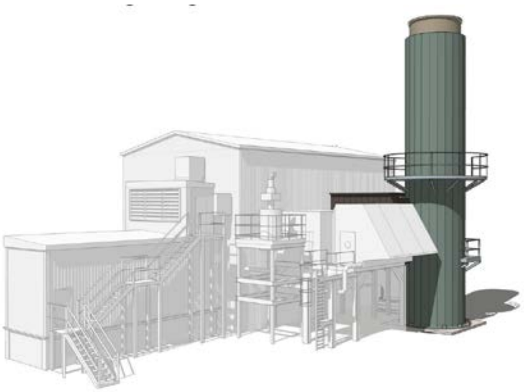
There are 61 Gas Generator powered Compressors Trains and 9 Electrically powered Compressors Trains across the NTS with associated cab infrastructure assets. Cab Infrastructure is made up of a weather-tight and noise attenuating **Cab Enclosure**, an **Air Intake** for the combustion air in the gas compressor, a **Ventilation system** to maintain safe and operable conditions within the enclosure, an **Exhaust system** to compliantly remove combustion gases and attenuate noise, and a **Fire Suppression system** to deal with fires within the enclosure. The body of this document covers each of these aspects separately.



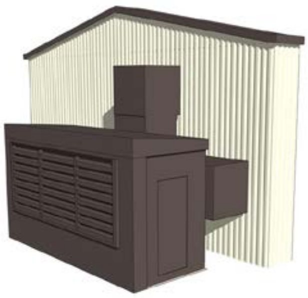
Compressor Cab



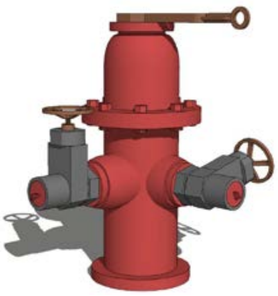
Compressor Cab Air Intake



Gas Generator - Exhaust



Compressor Cab Ventilation systems



Fire Suppression Systems

These assets were installed at the same time as the compressor fleet and as such are towards the end of their design lives. There is evidence of increasing defects and failures on these assets leading to compressor unit trips and the associated unavailability of compressor units for the duration of any investigation and repair.

When any significant work is undertaken on the Fire Suppression systems they require to be re-certified. A fixed fire protection system should be installed to mitigate the consequences of a fire on the Compressor Train. This should be to an appropriate standard, such as NFPA 750,1 BS ISO 145202 or BS 5306 and, as a minimum, designed to be capable of at least suppressing a fire on the Compressor Train or within its enclosure. The design and installation of fixed fire protection systems is a specialist field and it is recommended that companies experienced in fire protection engineering are consulted. The intervention options are chosen based on the gaps between existing assets and the current standards and the associated risk. Significant manual handling issues also exist on these assets and will be resolved as part of the investment.

There is also considerable variation in the supply and demand scenarios the NTS observes, driving the need to operate individual machines at short notice. As such, a high degree of readiness needs to be maintained across the compressor fleet and the associated Cab Infrastructure assets inherently supports this.

The increasing age of the asset and related defect count means that the consequences (non-compliance with environmental legislation or our inability to run a compressor) become more likely and drive an increasing risk profile over the period.

Impacts of no investment

Cab Infrastructure is essential in enabling the optimal and efficient operation of the Compressor Train whilst maximising their life and minimising expensive overhaul costs. They are an essential element of our legal compliance with PM84 HSE / ISO21789 Control of Risk around Compressor Train Enclosures. They are also instrumental in maintaining our compliance with environmental legislation and permits regarding noise and exhaust emissions. By supporting the optimal performance of the gas generators, the Cab also supports our compliance with the Emissions Regulations and the European Industrial Emissions Directive (IED).

Without a functioning and compliant Cab, a compressor cannot be operated. An inability to operate critical compressor equipment would have considerable impacts on the ability to balance supply and demand on the NTS, to meet the needs of our customers.

Proposal Development

The Cab Infrastructure assets comprising Cab Air Intake, Enclosure, Ventilation and Exhaust have been subject to cost benefit analysis separately from Fire Suppression due to their integrated nature. Neither of the analyses indicate cost beneficial intervention programme options for this asset. However, the investment in Cab Infrastructure is essential for the safe, efficient and compliant running of our fleet of compressors. The investment is fully integrated with our Compressor Emissions Compliance Strategy (CECS) and provides for replacement or full re-lifing of Cab Infrastructures where compressors are required in the longer term. Fire suppression systems must be upgraded to meet current standards.

The compressors that will be decommissioned or subjected to lower running hours will receive investment corresponding to their shorter remaining life. It is vital for the supply of gas to our customers that our compressors remain available and resilient to the demands and changes on the NTS, and investment in our compressor Cab Infrastructure is essential to ensure this availability is not compromised.

In defining our proposed intervention approach, we have considered a range of programme options and compared these against a baseline option that assumes a reactive intervention stance. In deciding on the proposed intervention strategy, we have considered the ability to meet the desired engineering and stakeholder outcomes and the resulting cost-benefit.

In choosing the option to be carried forward into our plan, we have considered the results of our cost-benefit 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 cost-benefit analysis has limitations, in terms of how indirect benefits of assets that do not directly impact on the safe transport of gas are estimated. For example, the likelihood of a Cab integrity failure causing a compressor unit outage. Furthermore, modelling of low frequency, high consequence events where we have used the expected probability of failure and consequence, as estimated through our NOMs Methodology. These are areas for future improvement as we continually assess our approach to NARMs.

In these cases, where proposed investments are not cost-beneficial we have made a sound asset management argument to justify the best mix of interventions to deliver customer/stakeholders expectations.

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

To deliver these outcomes….
• Ensure compliance with legislation, standards and permits • Ensure that changes to the asset are managed to meet the evolving stakeholder demand on the NTS. • Stabilise the asset deterioration to ensure no limitations on availability or performance, or damage to the gas turbines or safety equipment • Remove the manual handling issues that exist in the original installation design • Maintain reliable energy supplies across the NTS • Meeting the expectations of our customers and stakeholders and keeping risk stable
…by intervening like this…
• Refurbishing compressor Cabs to reduce risks and deliver changing ventilation demands • Addressing environmental issues with noise, sampling and gas dispersal through refurbishing exhaust systems

- Refurbishing air intakes to reduce the impact of icing and support extension of compressor overhaul intervals
- Replacing and refurbishing fire suppression systems to meet current standards, remove manual handling issues and reduce whole life costs

…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
- An evaluation of the legislative requirements on the performance of the asset and risks associated with it.
- Knowledge of the volumes of cab infrastructure and compressor assets that are currently obsolete or forecast to be obsolete during the investment period.
- An assessment of the changes in customer behaviour that demand modification of the operation of the compressor Cabs

RIIO-2 Compressor Cab Asset Health Investment Proposal Summary

Compressor Cab Asset Health investment proposal headlines

- The total RIIO-2 proposed expenditure for this theme is £31.29m
- 26% of our Cab Infrastructure programme is based upon interventions to address known defects requirements (23%) and high confidence work volumes based on historical trends (3%). The remaining work volumes are reasonably well known but has required some assumptions and extrapolation.
- Two thirds of the compressor Cab interventions are driven directly by legislation and ISO Standard requirements (PM84 HSE / ISO21789 and PSSR). The remaining third relates to air intake and exhaust interventions and is justified separately.
- None of the Compressor Cab investments are included in our NARMs model. Price Control Deliverables will be agreed on the significant areas of this proposal to assure the outputs are delivered

Where appropriate, a range of options has been considered for each sub-theme of work:

Sub-theme	RIIO-2 Plan (£)	Percentage of Theme	Options considered	Option summary / considerations
Cab Infrastructure	£24,327,297	77.7%	3	A range of options have been assessed and our chosen option is non-cost beneficial, however, maintains risk whilst maintaining compliance with standards
Fire Suppression Systems	£6,963,797	22.3%	3	A range of options have been assessed and our chosen option is non-cost beneficial, however, maintains risk whilst maintaining compliance with standards

We have estimated unit costs across all our proposed Cab Infrastructure 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.

68% of costs for Cab Infrastructure in our plan are supported by historical outturn costs which provides a medium-high level of confidence overall. There are many factors that differentiate costs, some of which can be attributed to the different ages and designs of our compressor cabs. There can be numerous works carried out as part of cab infrastructure asset health investments, which can include partial disassembly of the cab structure itself, and cranage to remove and install assets where they simply do not fit through the door. Alternatively, some may be installed at height in the cab, requiring the additional installation of temporary access platforms. Compatibility of existing infrastructure with replacement assets can also generate variability in costs, where additional works are required to interface new and old components. Increased complexity in the work mix introduces more uncertainty to the direct costs and greater variation in indirect costs that can allocated to a UID.

The table below summarises the evidence used to produce the Cab Infrastructure unit costs.

Investment sub-theme	Secondary Asset Class	RIIO-2 Business Plan	Evidence		
			Outturn	Quotations	Other
Cab Infrastructure	Air Intake	£3,778,017	100%		
	Cab ventilation	£5,408,356	100%		
	Civils – buildings and enclosures	£9,800,584	36%		64%
	Exhausts	£5,340,340	95%	5%	
Fire Suppression Systems	Fire suppression	£6,963,797	51%	2%	47%
Total		**£31,291,095**	**68%**	**1%**	**31%**

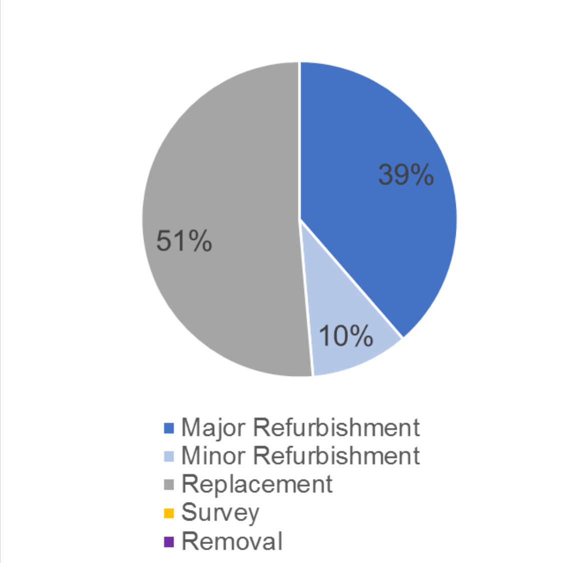
We have set out full details of our process for estimating unit costs across our asset health proposals in our Asset Health Unit Cost Annex.

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

Sub-theme & Intervention	RIIO-2 Volumes	Legislation/ Safety Case & Risk Tradable	Risk Tradable	Legislation & Safety Case	Non-lead Assets
Cab Infrastructure					
Air Intake Major Refurb	[redacted]	£0	£0	£0	£1,855
Exhaust Minor Refurb	[redacted]	£0	£0	£0	£260
Exhaust Replacement	[redacted]	£0	£0	£0	£3,287
Cab Structure Major Refurbishment	[redacted]	£0	£0	£3,504	£0
Air Intake Minor Refurb	[redacted]	£0	£0	£0	£315
Air Intake Replacement	[redacted]	£0	£0	£0	£1,608
Cab Ventilation Major Refurb	[redacted]	£0	£0	£2,886	£0
Cab Ventilation Minor Refurb	[redacted]	£0	£0	£330	£0
Cab Ventilation Replacement	[redacted]	£0	£0	£2,193	£0
Cab Structure Minor Refurb	[redacted]	£0	£0	£783	£0
Cab Structure Replacement	[redacted]	£0	£0	£4,483	£0

Exhaust Major Refurb	[redacted]	£0	£0	£0	£1,793
Cab Structure Minor Refurb (St Fergus)	[redacted]	£0	£0	£0	£0
Cab Ventilation Minor Refurb (St Fergus)	[redacted]	£0	£0	£0	£0
Minor remediation works (St Fergus)	[redacted]	£0	£0	£0	£1,031
Fire Suppression Systems					
Fire water ringmain replacement	[redacted]	£0	£0	£1,625	£0
Fire Suppression Major Refurb	[redacted]	£0	£0	£429	£0
Fire Suppression Minor Refurb	[redacted]	£0	£0	£408	£0
Fire Suppression Replacement of Electric Water Pump System	[redacted]	£0	£0	£2,705	£0
Fire Suppression Replacement of Nitrogen Bottle System (MAU)	[redacted]	£0	£0	£155	£0
Fire water ringmain replacement (St Fergus)	[redacted]	£0	£0	£1,642	£0
Total	[redacted]	**£0**	**£0**	**£21,142**	**£10,149**

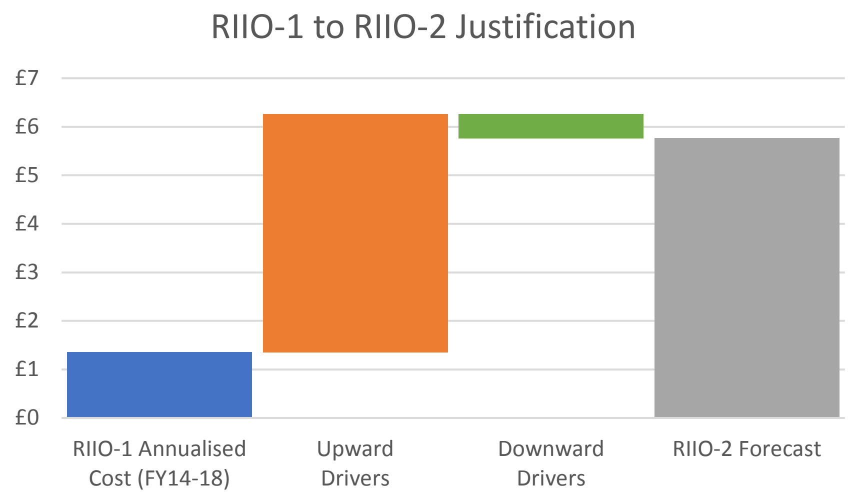
Compressor Cab Asset Health theme outputs and intervention categories:



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

The annualised RIIO-2 spend has increased when compared to RIIO-1 from £1.4m to £5.8m for the Compressor Cab 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.



Upward Drivers

Asset Health prioritisation during RIIO-1 focussed spend on high criticality assets resulting in lower overall investment in compressor cabs, compared to forecasts at the start of RIIO-1. In part this has been driven by a significantly lower compressor utilisation (25% reduction in running hours from the forecast at the start of RIIO-1) but also a recognition that emissions legislation and lowering demand forecasts both made the future of our compression fleet requirements uncertain.

There are a significant number of compressor cab defects that require resolution in the near term. Furthermore, there is a need to bring many of our Fire Suppression systems up to current standards and this investment is a priority for RIIO-2.

Downward Drivers

All efficiencies in this area are driven through our business change programme “Richmond”. Better asset data, enhanced planning tools and a sharp focus on unit costs all enable lower overall cost to delivery through enhanced, longer term delivery contracting.

In preparing our compressor cab asset health plans we have ensured consistency with Network Capability and our fleet strategy. This has resulted in lower overall costs by avoiding spend at cabs planned for decommissioning and driving down interventions and costs at cabs with low use units in RIIO-2 and RIIO-3.

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1. Summary

Name of Scheme/Programme	*Cab Infrastructure*
Primary Investment Driver	*Asset Health*
Scheme reference/ mechanism or category	*A22.08*
Output references/type	-
Cost	*£31.3m*
Delivery Year	*2022-2026*
Reporting Table	*3.03b*
Outputs included in RIIO-1 Business Plan	-

2. Introduction

2.1. There are 61 Gas Generator powered Compressors Trains and 9 Electrically powered Compressors Trains across the NTS with associated cab infrastructure assets. Cabs Infrastructure is made up of a weather-tight and noise attenuating **Cab Enclosure**, an **Air Intake** for the combustion air in the gas compressor, a **Ventilation system** to maintain safe and operable conditions within the enclosure, an **Exhaust system** to compliantly remove combustion gases and attenuate noise, and a **Fire Suppression system** to deal with fires within the enclosure. The body of this document covers each of these aspects separately.

Structure of the Case

2.2. This document summarises the justification for the required investment in our Cab Infrastructure Assets. All the assets have been assessed using a consistent overall risk based analytical framework.

2.3. The investment case for Cab Infrastructure investment is organized into two groups of assets. The groups enable the assets with similar drivers, purpose and impacts to be discussed and assessed collectively.

- Compressor Cab which comprises:
    - Cab Enclosure
    - Air Intake (not applicable on electric drive)
    - Ventilation
    - Exhaust (not applicable on electric drive)
- Fire Suppression (not applicable on electric drive)

2.4. For each group of assets the following structure has been followed:

- Equipment summary – which provides a summary and profile of the asset base
- Problem statement – the issues facing the assets, drivers for investment and impact of no investment
- Probability of failure and Probability of consequence – sections which set out the way the assets fail and the subsequent stakeholder impacts
- Options considered – the potential mix of interventions to be considered for each of the assets within a range of programmes with differing objectives
- Business case outline and discussion – the preferred programme option and reasons, given the cost benefit analyses and assessment of other drivers, stakeholder requirements and business objectives
- Preferred option and plan – the final selected option restated, along with the spend profile

Overview of the Cab Infrastructure Assets

2.5. The purpose of the compressor cab infrastructure is to enable efficient and safe operation of individual compressors whilst meeting environmental permits and legislative requirements. Each of the gas-powered compressors has its own Cab infrastructure which consists:

- Cab enclosure – protects all compressor assets in a weatherproof, sound attenuating and sealed enclosure enabling safety systems to operate and any gas / fire risk to be contained. Good inner enclosure integrity prevents recirculation of hot air and potential gas leaks to maintain acceptable conditions.
- Air intake – provides clean air to the gas generator
- Ventilation – cools the enclosure and prevents buildup of an undetectable explosive atmosphere within the Cab. It does this by ensuring that gas leaks are directed towards detection and are diluted below explosive limits and potentially explosive mixes from stagnating near ignition sources such as hot surfaces in excess of 500 deg C.
- Exhaust – enables effective dispersal of exhaust gases and attenuation of the exhaust noise in line with legislative and planning requirements.
- Fire Suppression – suppresses fires within the enclosure preventing escalation and minimising safety and environmental risk and plant and associated plant damage. It used specialist designs using high pressure and specialist spray heads to generate a high density of small water droplets that smother and cool a fire.

2.6. The Cab infrastructure is essential in enabling the optimal and efficient operation of the gas turbine generators whilst maximising their life and minimising expensive overhaul costs. They are an essential element of our legal compliance with PM84 HSE / ISO21789 Control of Risk around Gas Turbine Enclosures. They are required for maintaining our compliance with environmental legislation and permits regarding noise and exhaust emissions. By supporting the optimal performance of the gas turbines, the Cab also supports our compliance with the Emissions Regulations.

Compressor Cab (£24.3m)

3. Equipment Summary

3.1. The compressor Cab consists of four main elements which work together to provide the environment allowing the safe, efficient and legal operation of the compressor and power train.

3.2. **Cab Enclosure** - Compressor machinery is housed within a building, the primary function being to attenuate noise emissions from the Gas generator in line with the permitted noise levels. The enclosure also serves to protect from weathering effects and the subsequent damage to vulnerable plant and equipment. The integrity of the Cab is critical for ensuring ventilation operates effectively to avoid heat or gas build up and to minimise the risk of explosion to manage the safety risk. Cab designs vary by age and compressor technology, either taking the form of a space-efficient, close-fitting enclosure around the compressor unit, or a much larger building providing easier access. All the elements below are integral to the Cab enclosure.

3.3. **Air Intake** - The air intake provides clean combustion air for use in the gas generator to allow it to operate efficiently whilst seeking to minimise the risk of damage by reducing moisture and foreign objects. The air intake ensures air drawn into the gas generator engine for compression and combustion is contaminant-free and non-turbulent. The air intake inlet filtration system provides protection from dust, oils, salts, liquids and aerosols which otherwise could lead to fouling, erosion and corrosion of the gas generator. The assembly may also house anti-icing (heating) systems, blow in (by pass) doors and weather (snow) hoods, and incorporates design features to reduce noise emissions from the gas generator. The structural integrity must be maintained, or the intake will become a source of contamination and damage for the gas generator.

3.4. **Exhaust** - The exhaust is part of the gas turbine compressor unit and is vital in allowing exhaust gases (typically 400°C – 500°C) to disperse into the atmosphere away from ground level while limiting heat emitted into the Cab. The exhaust also ensures the attenuation of any exhaust noise to ensure it remains within the limits of the environmental permits. The exhaust asset comprises the exhaust itself as well as external cladding, noise attenuation features (typically 'bullets baffles' to smooth airflow) and exhaust gas sampling, monitoring and inspection points. The exhaust is a large steel structure, the height of which is integral in ensuring the effective dispersion of exhaust gases; exhausts vary in height from 5m to 15m with diameters of 4m+. As with a car exhaust system, the nature of the operating cycle is such that corrosion of the carbon steel ductwork is a significant issue and the exhaust ducts have a finite life.

3.5. **Ventilation System -** Gas generator cabs require ventilation systems to provide suitable airflow through the enclosure to remove the heat lost from the gas generator and compressor, to prevent overheating and associated trips and equipment deterioration. On gas generator cabs these are complex forced ventilation systems with emergency backup fans. They ensure that a safe (Zone 2) atmosphere is always maintained and that any small gas leaks are effectively diluted to below the lower flammable limit to avoid any risk of a build-up of gas reaching flammable or explosive limits (the latter as defined by HSE Guidance Document PM84 which is now incorporated into ISO21789).

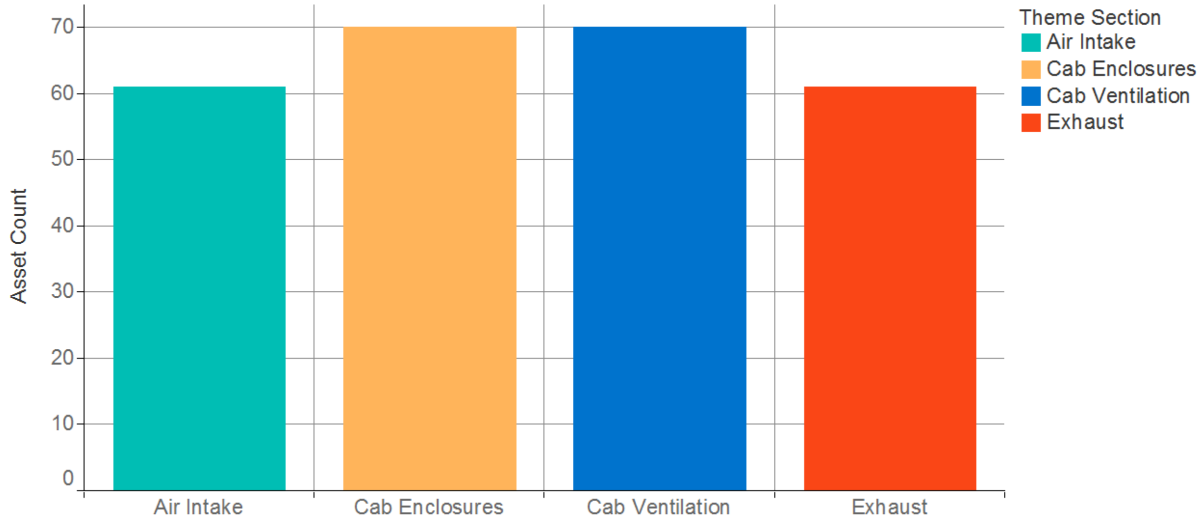
3.6. Cab ventilation assets include primary and emergency back-up ventilation fans, fan motors (usually AC for primary fans and DC for the emergency back-up fans), motor control and protection systems, cabling, ducting, filters and louvres.

Location and Volume

3.7. There are 61 compressor cabs protecting gas generator powered compressor trains and 9 protecting electric powered compressors permanently installed on sites across the NTS. All the cabs have an enclosure, ventilation and fire suppression, with those protecting gas generator power trains also having an air intake and exhaust.

3.8. The chart below shows the volume of each of the elements of the compressor cab on the NTS.

Asset Volume by Type



Redundancy

3.9. The compressor Cabs are designed to operate either very slightly above or very slightly below atmospheric pressure according to the design of the ventilation system (forced or induced draft). The design pressures involved are of the order of millibar gauge above or below atmospheric pressure although because of the large surface areas involved, even with these low design pressures, the forces involved can be very significant.

4. Problem Statement

4.1. The compressor cabs across the NTS are an aging asset that suffers from corrosion and wear related deterioration. Compressor availability and performance is reliant on the performance of the Compressor Cab. Reduced performance of these assets leads to increased compressor unit trips and the potential to reduce capacity or increase risks and unavailability of the compressor, often with a long lead time to resolve.

4.2. We are experiencing ongoing defects on all the assets that form the compressor cab which if unresolved will lead to non-compliance with legislation and potential asset, safety and environmental damage. In addition, changes in the pattern of use of compressors is imposing additional demands on critical systems such as the ventilation system whilst extreme weather events such as the 'Beast from the East' highlighted the requirement for effective anti-icing systems to maintain compressor operation at times of critical peak demand.

4.3. The significant deterioration of assets at St Fergus where structural corrosion has been identified and where degradation of cladding and the exhaust system has led to exhaust gas escaping into the cab, causing overheating and limiting power output and compressor capacity highlights some of the risks of not moving to a more pro-active replacement strategy.

Drivers for Investment

4.4. The key drivers for investment in the Compressor Cab assets are:

- HSE Guidance PM84 - for legislative compliance
- Asset Deterioration
- Environment
- Customers

4.5. In addition to the requirements of PM84 HSE / ISO21789 the assets deteriorate over time resulting in them no longer complying with direct legislative requirements, such as environmental legislation. National Grid have adopted a risk-based approach to comply with the requirements of PM84 / ISO 21789, but some upgrade work remains to be completed and that is covered by this submission.

4.6. **HSE Guidance Document PM84 / ISO21789** for Control of Safety Risk at Gas Turbine Enclosures. - PM84 was introduced several years ago, following several fatal explosions involving gas turbines in acoustic enclosures. Examples of requirements include maintaining a fully functional ventilation system and suitably sealed building inner enclosure with building integrity as a fire break and suitable fire protection to mitigate process safety risks. The requirements of PM84 have been incorporated into ISO21789.

4.7. Whilst not a direct legal obligation this guidance, issued by the HSE, provides good practice that should be complied with to demonstrate all reasonable measures have been taken to comply with the overarching legislation.

4.8. **Asset Deterioration –** Corrosion, mechanical wear, and component failure are primary drivers for investment in the exhaust stack, air intakes and buildings. Increasing numbers of defects are being identified. Where deterioration of asbestos containing material occurs there is a need to mitigate this.

4.9. **Environmental Permits** - Planning and environmental permits govern exhaust stack design and they must continue to perform in line with noise and environmental requirements. EA and SEPA also require compliant emission sample lines or measuring points with suitable access to be installed. Cab infrastructure deterioration will result in excessive noise leakage into the atmosphere which may result in an inability to achieve the statutory noise limits for the site and can lead to prosecution.

Impact of No Investment

4.10. No investment in the cab infrastructure assets will lead to their continued and increasing deterioration, limiting their effective operation. If these assets are not operating effectively they make the compressor units unsafe and inoperable, driving a decision to isolate the compressor unit and an increased risk to the availability of the gas supply. Limiting compressor numbers limits resilience and backup to allow for downtime for maintenance, breakdown and replacement of compressors which in turn leads to further units becoming unsafe to operate and a network unable to meet customer needs.

4.11. Exhausts have layers of material that fail and can lead to the stack not functioning correctly, becoming unsafe and material falling and damaging the power turbine with potential costs above £1m to replace. The exhaust and volutes have lagging that deteriorates over time and this leads to increased heat in the cab and compressor trips. The failure of integrity of an inner cab will lead to the positive pressure forcing hot air into the outer cab where this heated air (and any gas) is recirculated back into the inner cab further increasing temperatures. Integrity failures also reduce noise attenuation capability which may result in customer complaints and noise permits being breached, with improvement notices or in extreme cases prosecution if proven. The ventilation which is designed for the positive pressure and air volume changes required can deteriorate as ducting, motors, fan blades and louvres lose their integrity and performance, reducing the effectiveness of heat and gas removal. Ultimately the units may trip on high temperatures, this is an operational risk, but also a risk to temperature rated safety devices and cabling for fire, gas and smoke detection. Further failure of outer cab integrity also leads to water ingress causing corrosion and potential failure of safety devices, electrical equipment and building structure. In addition, the fire suppression system must perform to ensure the system can put out electrical or oil fires that can escalate and lead to significant asset damage and operational downtime.

4.12. The typical life of an exhaust stack without major performance issues is expected to be 20-30 years, therefore replacement of this asset should be considered in these timescales. Experience in RIIO-1 has seen performance and availability issues. There have also been failures of the structural integrity resulting in increasing safety risks and potential compressor unit damage through falling material. These must be managed through of exclusion zones and ultimate decommissioning of compressors due to risk of working in and around unpredictable failings of the asset.

4.13. Any reduction in performance of the ventilation system (for example as a result of corrosion or damage to fans, ductwork and louvres) will reduce the effectiveness of the cooling system resulting in the power output of the gas generator being limited and compressor throughput reduced. Reduced efficiency of the ventilation system may result in reduction in the effectiveness of both the gas detection system and the efficiency with which small gas leaks are dispersed resulting in noncompliance with the requirements of PM84 / ISO21784 and an increased safety risk.

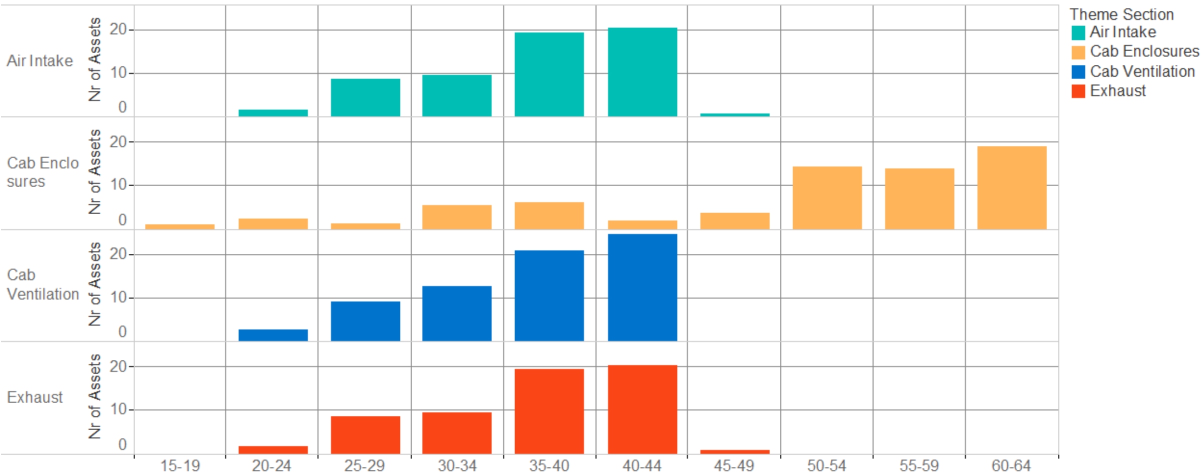
4.14. Process safety risks are managed through maintaining the Compressor Cab. The assets mitigate against damage to safety equipment, gas leaks, fires and explosions. Compressor enclosure investment is required to manage its deterioration and prevent the leakage or ineffective flow of ventilation through the Cab to cool the gas generator and enable gas detection and fire suppression systems to operate effectively. The integrity of the Cab is also required to protect against failure of the gas generator or compressor assets.

4.15. No investment in the air intake and its components will lead to increased corrosion, wear and failure causing inefficient running, increased wear and high cost damage to the multi-million-pound gas generators. The air intake system is key to ensuring the gas generator operates effectively as it holds the filters that clean the air. If it deteriorates then unclean air and foreign objects can enter and cause significant damage, failure and extensive overhaul costs as well as significant downtime. With age, the integrity of the intake housing fails, and fragments of metal and coating can enter the compression train. The air intake systems are also typically at height and where corrosion is present, and sections are not replaced they become a safety risk. During peak conditions air intake anti-icing systems have not always maintained compressor availability, teams of staff had to be deployed around the clock to keep the air intakes clear of snow to keep the compressors operational. In addition to the hazards involved with this task, having to deploy staff to keep the air intakes clear prevented them from being deployed elsewhere on the network.

4.16. The chart below shows the age profile of the compressor Cab assets by the end of the investment period if there is no investment.

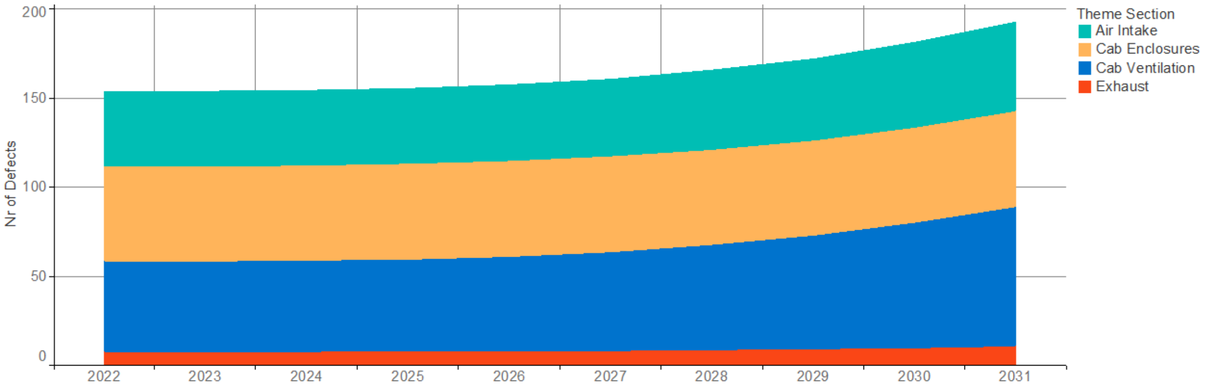
4.17. Without investment, the asset age profile below shows that many assets will be around 30 to 40 years old. This compares with a typical design life of 30 years.

Asset Age by end of RIIO-3 with no investment



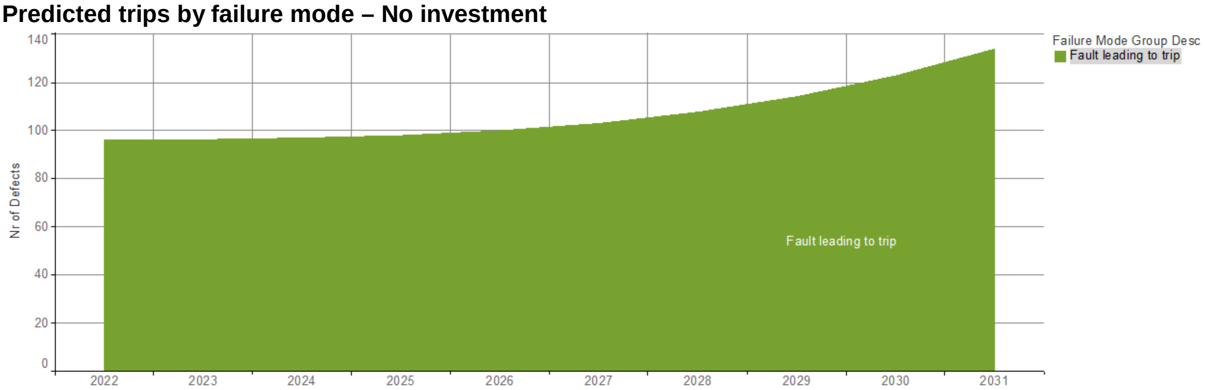
4.18. The chart below shows the predicted number of defects by year if there is no investment for the compressor cab assets. The currently identified defects will remain unresolved and are forecast to increase from 153 to over 192 by the end of 2031. The chart below shows the number of defects by compressor cab asset type starting from current levels captured in Ellipse work order data and predicted for future years using the equipment failure deterioration models in our NOMs methodology developed in 2017.

Predicted defects – No Investment



4.19. Predicted defects causing trips, or failures to start, of the compressor due to compressor cab assets failing due to deterioration are predicted to increase from 96 to over 134 by 2031. This will limit the availability of individual compressors and depending upon location and timing may impact the availability of parts of the NTS. In addition, every trip of a compressor vents gas to atmosphere.

Predicted trips by failure mode – No investment



Examples of the Problem

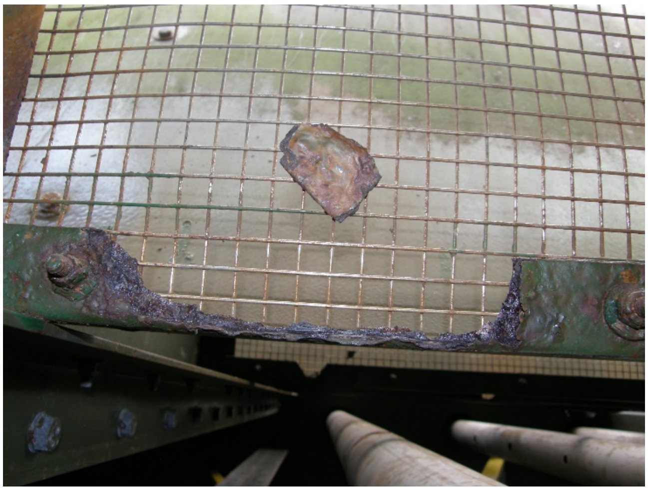
4.20. The photographs below provide examples of some of the infrastructure and issues occurring on the can infrastructure assets.

Cab Enclosure

Failing inner cab roof seal leading to ineffective cab ventilation exacerbated by a cramped cab

Felindre Air Intake

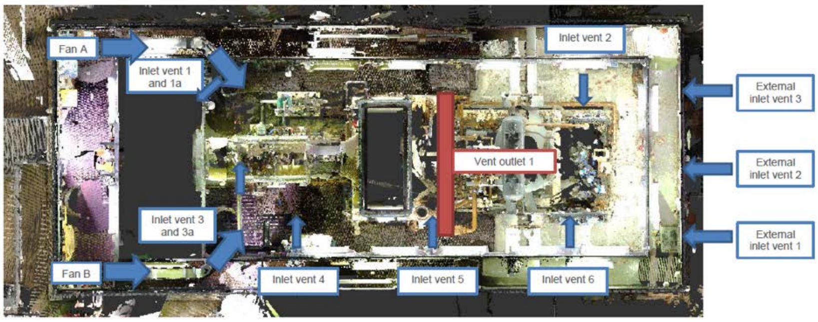
Safety cordon to prevent injury risk from corrosion of the intake



Inside the intake showing structural corrosion

Ventilation

Kings Lynn gas generator showing stagnant areas below the engine that required additional ducting



Kings Lynn Ventilation ducting layout shown for GT enclosure, fans and air intake/outtake

Exhaust Stacks

Felindre outer exhaust stack

Power turbine/exhaust volutes lose internal lagging over time and cause overheating inside the cab

4.21. The significant deterioration of assets seen in RIIO-1 such as gas generators at St Fergus restricted to 80% power due to overheating caused by a deterioration of the cab infrastructure assets is an indication of the potential fleetwide impact if reactive repair is not carried out. Some units also have precautionary chain restraints to mitigate structural failings in the exhaust stacks.

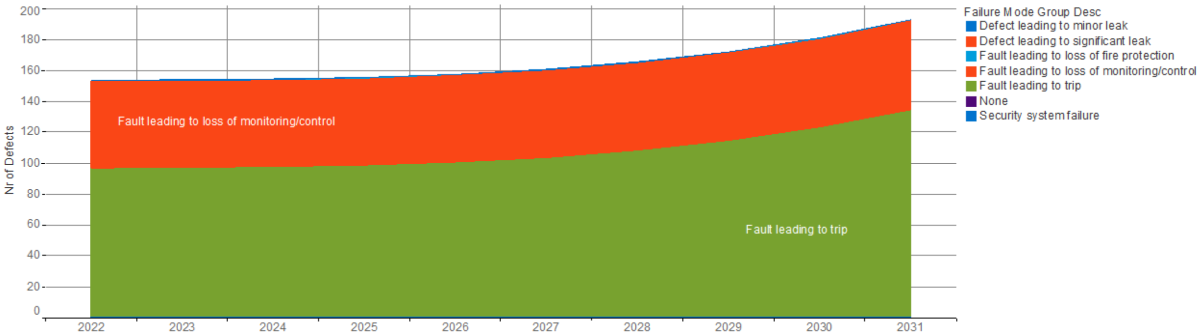
Spend Boundaries

4.22. The proposed investment includes all current compressor cabs and their associated components installed on the NTS, including any ‘no-regrets’ site investments at St Fergus to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms. Investment associated with compressor cabs for new compressor units is excluded as this is included in the separate compressor investment business plan.

5. 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.

Predicted defects by Failure Mode – No Investment



5.2. For compressor cab assets, the chart indicates that the failure modes that contribute most to the probability of failure are:

- Loss of unit/gas drive leading to trip
- Fault leading to loss of monitoring/control

Probability of Failure Interventions

5.3. All cab Infrastructure interventions are defined as consequential interventions. This is because the prime function of the cab is to protect the assets comprising the compressor train and ensure noise is within permitted levels. All risk benefits associated with cab infrastructure are therefore considered to align with the following definition of a consequential risk intervention:

"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."*

Consequential Interventions

5.4. The table below shows the drivers for cab Infrastructure investment that are defined as Consequential Interventions.

NARMs Interventions

NARMs Asset Intervention Categories	Secondary Asset Classes
Consequential Interventions (Non-risk tradeable)	Cab structure
	Air Intake
	Exhausts
	Cab ventilation

5.5. Our NOMs Methodology attempts to model the indirect benefits delivered by these assets in terms of the reduction in Probability of Failure (PoF) or Consequence of Failure (CoF) upon a related and/or adjacent asset (e.g. the benefit of air intakes on the numbers of compressor trip and vents). These quantified, but indirect, impacts are used within the Cost Benefit Analysis (CBA) accompanying this justification report but are not considered to be reliable enough for use as a NARMs monetised risk metric.

Cab Infrastructure Interventions

5.6. The table below lists the potential interventions for compressor cabs together with their associated SAC and Intervention Category.

Can Infrastructure Intervention

Intervention	SAC	Intervention Category
A22.08.1.1 / Air Intake Major Refurb	Air Intake	Major Refurbishment
A22.08.1.10 / Exhaust Minor Refurb	Air Intake	Minor Refurbishment
A22.08.1.11 / Exhaust Replacement	Air Intake	Replacement
A22.08.1.12 / Cab Structure Major Refurbishment	Cab Ventilation	Major Refurbishment
A22.08.1.2 / Air Intake Minor Refurb	Cab Ventilation	Minor Refurbishment
A22.08.1.3 / Air Intake Replacement	Cab Ventilation	Replacement
A22.08.1.4 / Cab Ventilation Major Refurb	Cab Ventilation	Minor Refurbishment
A22.08.1.5 / Cab Ventilation Minor Refurb	Civil assets - buildings/ enclosures	Major Refurbishment
A22.08.1.6 / Cab Ventilation Replacement	Civil assets - buildings/ enclosures	Minor Refurbishment
A22.08.1.7 / Cab Structure Minor Refurb	Civil assets - buildings/ enclosures	Replacement
A22.08.1.8 / Cab Structure Replacement	Civil assets - buildings/ enclosures	Minor Refurbishment
A22.08.1.9 / Exhaust Major Refurb	Civil assets - buildings/ enclosures	Minor Refurbishment
A22.22.1.1 / Cab Structure Minor Refurb (St. Fergus)	Exhausts	Minor Refurbishment
A22.22.1.9 / Cab Ventilation Minor Refurb (St. Fergus)	Exhausts	Replacement
A22.22.2.8 / Minor remediation works (St. Fergus)	Exhausts	Major Refurbishment

Data Assurance

5.7. 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 favorable 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

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

5.9. 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. Consequence of Failure

6.1. The chart below shows the expected stakeholder impacts because of failure occurring on the Compressor Cab assets. The charts show the relative numbers of consequence events, not relative monetised risk.

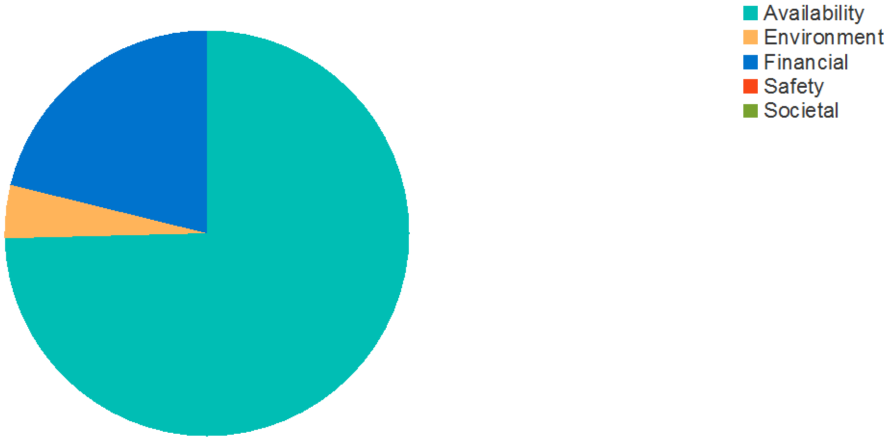
Air Intake (stakeholder impacts)

6.2. The contribution of individual service risk measures towards the overall monetised risk for air intakes can be explained as follows, in order of significance:

- Environmental risk is associated with the loss of gas through trips and vents of the compressor unit
- Financial risk is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk

6.3. The risk associated with other service risk measures for air intakes is negligible, based on the assigned failure modes.

Cab Enclosure (Stakeholder impacts)



The contribution of individual service risk measures towards the overall monetised risk for air intakes can be explained as follows, in order of significance:

- **Availability risk** is associated with the potential outages associated with the loss of compressor trains because of failure of the cab enclosure. This is an indirect effect and only a small proportion of enclosure failures will generate a unit trip and associated outage

- **Financial risk** is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk
- **Environmental risk** is associated with compressor trips and vents associated with the failure of the cab enclosure. This is an indirect effect and only a small proportion of enclosure failures will generate a unit trip and associated vent of gas

6.4. The risk associated with other service risk measures for cab enclosures is negligible, based on the assigned failure modes.

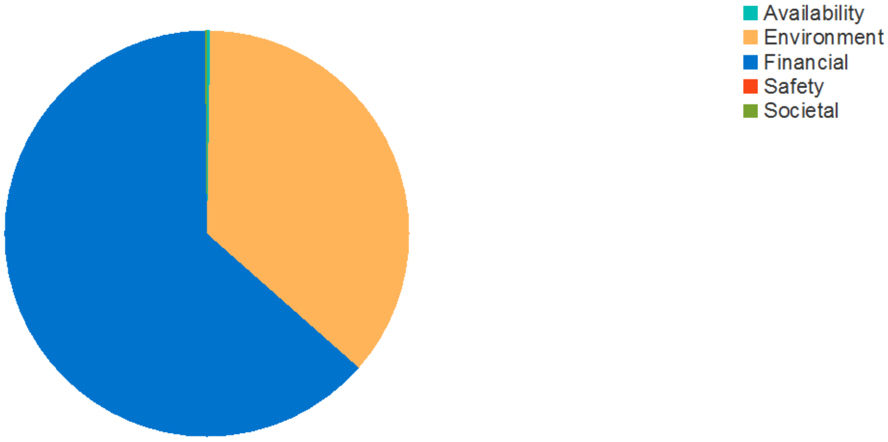
Cab Ventilation (Stakeholder impacts)

The contribution of individual service risk measures towards the overall monetised risk for Cab Ventilation can be explained as follows, in order of significance:

- **Financial risk** is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk

6.5. The risk associated with other service risk measures for Cab Ventilation is negligible, based on the assigned failure modes.

Cab Exhaust (Stakeholder impacts)



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

- Financial risk is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk
- Environmental risk is associated with the loss of gas through trips and vents of the compressor unit caused by exhaust failure. This is an indirect effect and only a small proportion of exhaust failures will generate a unit trip and associated vent of gas

6.6. The risk associated with other service risk measures for exhausts is negligible, based on the assigned failure modes.

7. Options Considered

Potential Intervention Options

Minor Refurbishment

7.1. The following repair, or minor refurbishment, intervention options apply to the Compressor Cab assets:

- Air Intakes - This asset is typically fabricated from galvanised carbon steel which suffers from localised corrosion with any corrosion downstream of the filters having serious implications for the integrity of the gas generator. This intervention consists of localised repair of the corrosion on the clean side of the filters and replacement of filters where required.
- Exhaust – Repairs due to bellows failing, water ingress and cracking, the repairs on this asset include the localised repair of corrosion, cracking and failing seals together with the replacement of associated individual elements and components. The extent of any repairs is limited by the impact of operation of the equipment at sustained high temperatures on the metallurgy of the parent metal.
- Ventilation Systems - Due to the deterioration of the many components (such as ducting, fire dampers, intake housings, fans and louvres) of this asset, the repairs on this asset include localised repair of corrosion, cracking and failing seals, replacement individual elements and components. There is the option to improve long term downtime due to fan failures on old ventilation systems by buying a spare for each type of system. This removes the typical 25-week lead items but does not remove the risk of multiple failures and system wider deterioration
- Enclosures - Repairs are typically carried out on this asset due to localised corrosion, failing of seals on roofs, and localised cracking or failing of the outer structure.

Refurbishment

7.2. The following refurbishment intervention options apply to the Compressor Cab assets:

- **Air Intake –** Refurbishment addresses the corrosion issues of this asset through the replacement of components with stainless steel alternatives, such as structural steels. For assets with high levels of corrosion throughout, replacement of several components such as the air intake heating, snow hood and intake box. Refurbishment also typically resolves the poor performing anti-icing issues which impact availability on many compressors in cold weather.
- Additionally, refurbishment activities can also include upgrading the filter technology to HEPA filters, which has additional operational benefits of reducing gas generator overhauls frequency and cost. Furthermore, the internal washing of the compressor become less frequent, significantly reducing maintenance. This activity excludes full replacement of the housing and exposed steel structures.
- **Exhaust** – Refurbishment activities include replacement of damaged horizontal exhaust stack where fitted (not all units have these horizontal sections but

where fitted, failure of these is regular and significant), a survey of the insulation and replacement as required, replacement of cladding where required and re-welding of baffle plates. Also to include fitting compliant emissions sample lines to meet EA and SEPA requirements for emissions sampling on certain gas generators.

- **Ventilation** Systems – To restore functionality so airflow is sufficient, refurbishment of this asset consists of replacing failing components and iterative improvements to air flow to resolve stagnant areas in line with HSE guidance (and current standards through limited redesign of the system.
- **Enclosure** – Refurbishment of this asset consists of replacement of seals and doors, rework to pipe penetrations and metal sheet repairs. This manages more severe issues with these assets, such as overheating due to poor ventilation, roof deterioration and ineffective leak dilution and detection due to poor fire suppression.

Replacement

7.3. The following replacement options apply to the Compressor Cab assets:

- **Air Intake -** replacement of most the air intake housing, snow hoods and filters components
- **Ventilation System** - where the original design of the ventilation system is not satisfactory for current use e.g. not suitable for summer running, significant stagnant areas or deterioration is significant, then a replacement system with improved design is required.
- **Exhaust –** Full replacement of the exhaust stack is required when its structural integrity is compromised, or performance degrades to an unacceptable level and is unable to be remediated by any other means.
- **Enclosure –** Replacement activities for this asset include full recladding of buildings, roof replacements and limited structural steel repairs of the structure usually due to corrosion issues.

Intervention Unit Costs

7.4. The total RIIO-2 investment for the sub-theme Cab Infrastructure represents 78% of the investment theme. The unit costs that support the Cab Infrastructure investment have been developed using a significant number of 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

7.5. 73% of costs for Cab Infrastructure are supported by historical outturn information, where we have been able to reference 18 data points gathered from 9 sanction papers. The remaining 27% of costs for Cab Infrastructure have been developed using supplier quotations where obtainable (1%), or through other estimation methods (26%) due to the low frequency and the variability in the works that could be performed making obtaining supplier quotations very difficult.

7.6. The table below provides the unit costs for all the potential Cab Infrastructure interventions.

Intervention Unit Costs - Cab Infrastructure

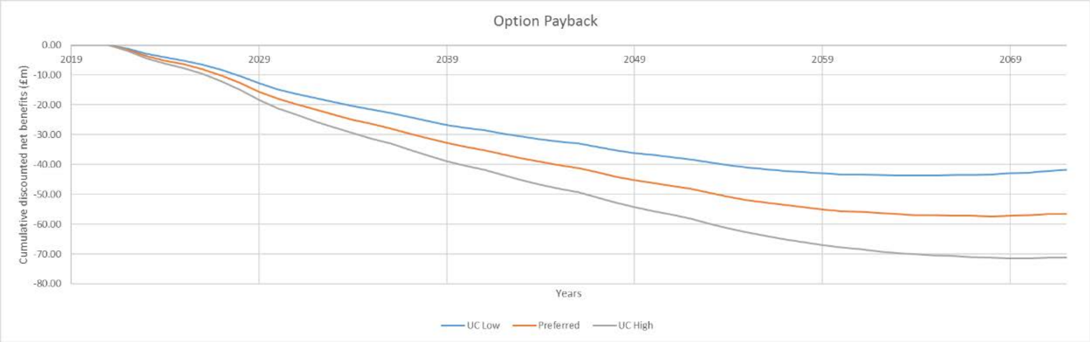
Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Cab Infrastructure					
Air Intake					
A22.08.1.2 / Air Intake Minor Refurb	[redacted]	Per asset	Outturn	2	£ 315,350
A22.08.1.1 / Air Intake Major Refurb	[redacted]	Per asset	Outturn	1	£ 1,855,000
A22.08.1.3 / Air Intake Replacement	[redacted]	Per asset	Outturn	3	£ 1,607,667
Cab Ventilation					
A22.08.1.5 / Cab Ventilation Minor Refurb	[redacted]	Per asset	Outturn	1	£ 329,778
A22.08.1.4 / Cab Ventilation Major Refurb	[redacted]	Per asset	Outturn	3	£ 2,885,556
A22.08.1.6 / Cab Ventilation Replacement	[redacted]	Per asset	Outturn	3	£ 2,193,022
A22.22.1.9 / Cab Ventilation Minor Refurb (St. Fergus)	[redacted]	Per asset	Estimated - Other	0	£ -
Civil assets - buildings/ enclosures					
A22.08.1.7 / Cab Structure Minor Refurb	[redacted]	Per asset	Estimated - Other	0	£ 783,222
A22.08.1.8 / Cab Structure Replacement	[redacted]	Per asset	Estimated - Other	0	£ 4,482,917
A22.08.1.12 / Cab Structure Major Refurbishment	[redacted]	Per asset	Outturn	1	£ 3,503,889
A22.22.1.1 / Cab Structure Minor Refurb (St. Fergus)	[redacted]	Per asset	Estimated - Other	0	£ -
A22.22.2.8 / Minor remediation works (St. Fergus)	[redacted]	Per asset	Estimated - Other	0	£ 1,030,556
Exhausts					
A22.08.1.10 / Exhaust Minor Refurb	[redacted]	Per asset	Estimated Quotation	1	£ 259,700
A22.08.1.9 / Exhaust Major Refurb	[redacted]	Per asset	Outturn	3	£ 1,793,167
A22.08.1.11 / Exhaust Replacement	[redacted]	Per asset	Outturn	1	£ 3,287,473

7.7. Efficiencies arise from working in longer term partnerships with an agreed scope where efficiencies are gained through minimising design work across multiple sites and through volume discounts. Limited opportunities will arise for reuse of decommissioned assets as elements of the cab infrastructure can be bespoke to each installation and spares are readily available to support other units at a lower cost.

Unit Cost Sensitivities

7.8. 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



7.9. Whilst the level of cost benefit changes as the unit costs vary, the investment remains non cost beneficial across the range of unit costs. The potential range of unit costs does not cause our decision to change.

Innovation

7.10. In the RIIO-1 period, no specific innovation work has been implemented which is relevant to cab enclosures, however innovation used in other investment areas will be utilised where appropriate. In RIIO-1, we have taken a smarter approach to resolving key risk factors on our cab infrastructure assets, which may inform future innovation projects as we move through the investment period.

7.11. One example of potential innovation is where contractors have developed techniques that may be available to repair generally good condition exhaust stacks with foam insulation injection, laser scanning and innovative repairs for cracks on internals that will help ensure they meet their design life in good condition. This may deliver benefits for future regulatory periods but is yet to be tested.

8. Programme Options

8.1. 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.

8.2. In developing our plan, the following options have been considered for investment in the compressor cabs and associated assets. Please note that all programme options include any fixed 'no-regrets' investments associated with the St Fergus site.

- Baseline
- Maintain Risk
- Refurbishment Only
- Full Re-lifing

Baseline – Do nothing

8.3. The impact of no investment in our Cab Infrastructure generates a small increase in service risk over a 10-year period, across all service risk categories. This does not include indirect impacts on Compressor Train asset failure. This option includes the reactive only investment across all Cab Infrastructure and is the option against which all the other options are compared.

Programme Option 1 – Maintain Risk

8.4. This option undertakes a mix of replacement, refurbishment and reactive repairs to maintain the current levels of risk across all the compressor cabs and their component parts.

Programme Option 2 – Refurbishment Only

8.5. This option reduces the investment in cab enclosures to that required to manage short term risk through refurbishment and fully reactive minor refurbishments, as and when significant issues arise.

Programme Option 3 – Full Re-lifing

8.6. This option significantly reduces the risk of the impact cab infrastructure assets on compressor availability. Full re-lifing of all appropriate cabs is undertaken except those not required in the long term.

Programme Options Summary

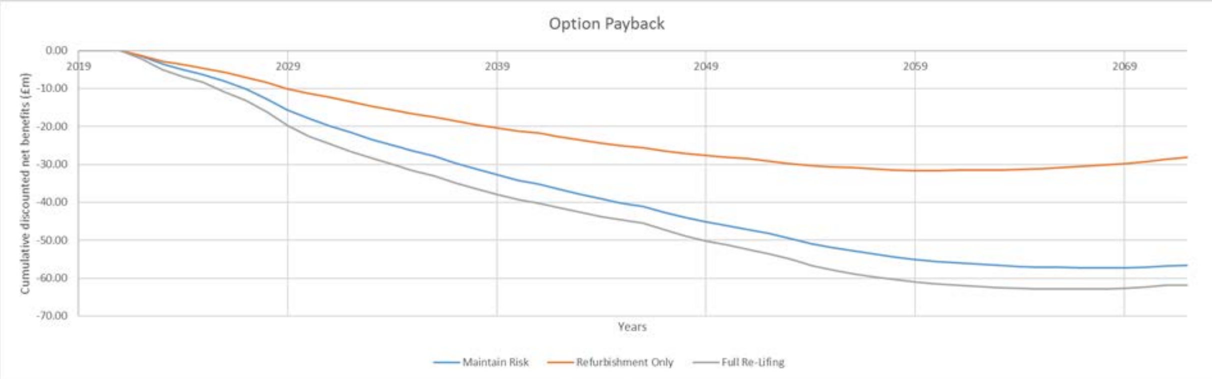
8.7. In considering the CBA for each of the programme options, a summary of all the potential programme options is provided in the table below.

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 – Maintain Risk	£24.33	£32.79	£79.39	£22.28	£(57.11)	0.28	Does not payback in the period
2 – Refurb Only	£16.89	£17.13	£52.08	£21.29	£(30.80)	0.41	Does not payback in the period
3 - Full Re-life	£32.66	£36.68	£87.47	£24.69	£(62.78)	0.28	Does not payback in the period

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

Option Payback – Net NPV



Programme Options Selection

8.9. None of the 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 of the impact of the cab infrastructures assets on the availability of our compressors,
- ensuring the continued safety of our staff
- maintaining our compliance with legislation – PM84, DSEAR and Environmental Permits
- delivering value for consumers and stakeholders.

However, when combined with Compressor Train investments, where the primary risk of asset failure exists, Cab investment becomes more cost-beneficial. The outcomes associated with each option are provided below:

Programme Option 1 – Maintain Risk

8.10. This option maintains all risk at current levels with no significant impact of the cab enclosure on the compressor availability.

Programme Option 2– Refurbishment Only

8.11. This option results in increased reactive repairs (i.e. fix on fail) across most of the cab infrastructure asset types and there is a potential impact the availability of the compressors. There is also an increased safety risk, and this option also results in an increased environmental impact when compressor trips occur and require venting.

Programme Option 3 – Full Re-lifing

8.12. This option predominantly reduces the risk on the compressor cab assets below levels at the start of RIIO-2, with the associated required increase in investment. There is no support for such a reduction in risk from stakeholders and no requirement for that reduction in risk, to allow us to continue to meet and manage our service and compliance levels.

Preferred Option

8.13. Our preferred option is Option 1, to maintain the current level of risk. Even though some of the other options have a lower investment requirement and are more cost beneficial, they do not meet the required outcomes of:

- Meeting legal requirements and agreed safety standards
- Ensuring ongoing compliance with PM84 HSE / ISO21789
- Managing the risk from deterioration of the assets such that they do not limit availability and performance of or cause damage to the gas turbines or safety systems.

8.14. This is consistent with feedback from stakeholders, who want at least the current level of risk maintained. Our chosen option is non-cost beneficial, however, meets the desired outcomes at least whole life cost.

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

9. Business Case Outline and Discussion

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

Key Business Case Drivers Description

9.2. Compressor cab assets deteriorate over time. 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.

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

- Legislation
- Asset Deterioration
- Environment
- Customers

9.4. In addition to the requirements for compliance with the requirements of PM84 / ISO21789, the requirements of DSEAR as well as environmental permits, the arduous operating conditions mean that these assets deteriorate with time and use which leads to their inability to perform their required function.

9.5. While the gas supplies are not directly linked to the cab infrastructure assets, any failure or significant deterioration causes the associated compression to be unavailable and hence does indirectly affect the availability of the network and compression assets. However, this risk is quantified against Compressor Train assets rather than the Cab assets that provide this protection.

Business Case Summary

Outcomes delivered

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

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

9.7. On failure, most of the compressor cab elements have a financial or environmental impact, this is shown in the consequences of failure section. However, failure of the enclosure can particularly impact the availability of the associated compressor.

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

- Meet legal requirements and agreed safety standards
- Ensure ongoing compliance with PM84 HSE / ISO21789 Control of Risk around Gas Turbine Enclosures
- Manage deterioration of the assets such that they do not limit availability, performance or cause damage to the gas turbines or safety systems.

9.9. Our proposed investment in the compressor cab assets will ensure that we maintain our low levels of risk across all these outcomes.

Stakeholder Support

9.10. 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].

Investment Decision Approach

9.11. To deliver the outcomes for the investment period the Compressor Cab assets require a mixture of the intervention categories defined previously. The decision on the volume of each of the interventions required has been determined using the following methodology.

- The need for the compressor unit and therefore the Compressor Cab is treated separately. Where a compressor is required, there is a need for cab infrastructure to house and facilitate the safe running of that compressor.
- The chosen approach is to be proactive in resolving issues ahead of fleetwide deterioration while developing asset strategy based on learning from ongoing condition analysis. There needs to be a minimum level of pro-active asset intervention planned ahead of significant asset condition and risk. Within RIIO-1 we reviewed and mitigated risks around gas turbine enclosures in line with HSE guidance and this approach must be continued through the investment period as these assets deteriorate with age and use.
- A forecast of the number of repairs based on the historical information combined with the knowledge of the proposed replacement and refurbishment work.

9.12. A risk assessment approach was used to develop an asset-by-asset list of the appropriate category of intervention to be undertaken. This risk assessment approach included:

- Issues and defects currently identified and those forecast to arise through the period
- Asset age, condition and probability of failure informed through impacts of deterioration in current regulatory period.
- Remaining Life of the Compressor Unit

- Forecast run hours of the Compressor Unit
- Local resilience requirement for the Compressor Unit.
- Compressor unit outages where staggering of work on and across sites is required to ensure local compression is available to meet demand scenarios.
- Deliverability in terms of internal and external cost and resource.

9.13. Prior to intervention on a compressor cab asset, inspections and investigations are completed for evidence that an intervention is required and to define the most effective intervention option to resolve the issues found.

9.14. The investment proposed in the period is to:

- Remediating the highest risk defects together with those which are forecast to be identified during scheduled routine inspection and maintenance activities

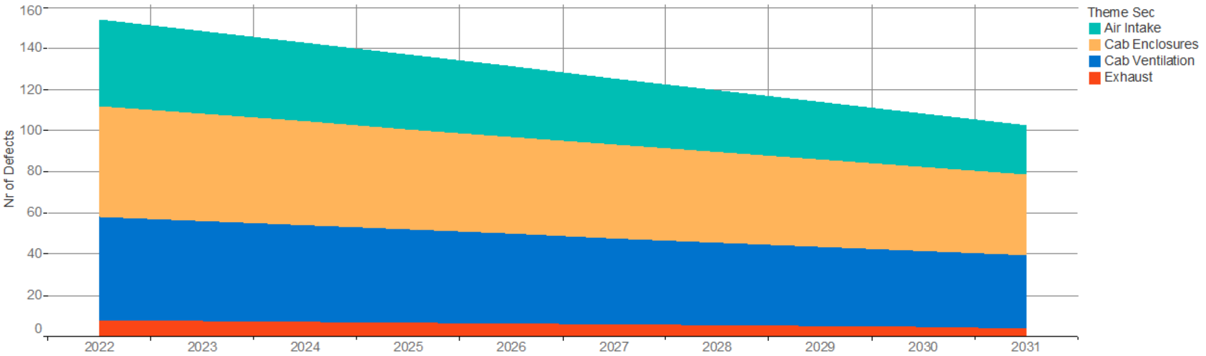
9.15. The proposed mix of interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing inspections in line with maintenance policy, defect trend and investigation and performance of the assets.

Benefits of the Investment

Defects

9.16. The currently identified 153 defects (which includes backlog) are predicted to be below 103 by the end of 2031. This compares with a forecast to rise to 160 by the end of 2026 and up to 192 by the end of 2031 without investment. The chart below shows the predicted defects following the preferred programme of investment for compressor cabs by asset type.

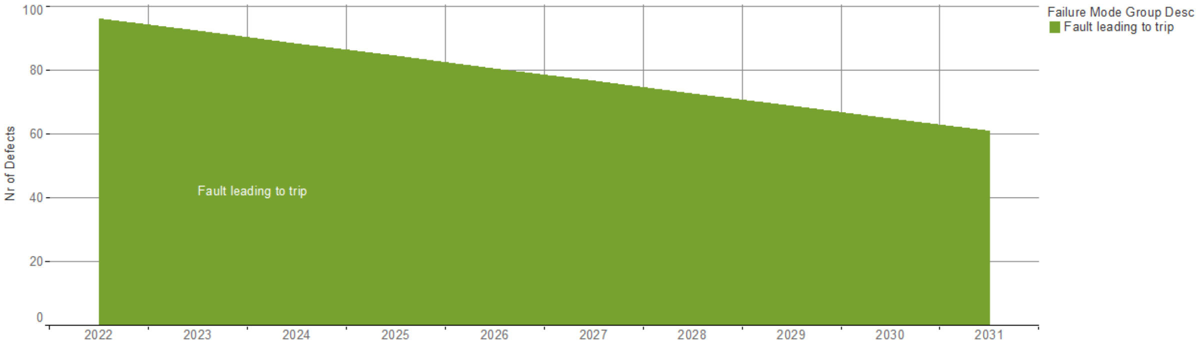
Predicted Defects with Preferred Investment Option



Predicted Compressor Trips

9.17. The chart below shows the predicted level of trips due to compressor cab assets failing after investment.

Predicted Number of Trips with Preferred Investment Option



Preferred Option

9.18. To deliver the required outcomes for stakeholders we have developed the most effective combination of efficient interventions. These form the programme of work for the compressor Cab assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

9.19. The profile of investment in the compressor cab assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

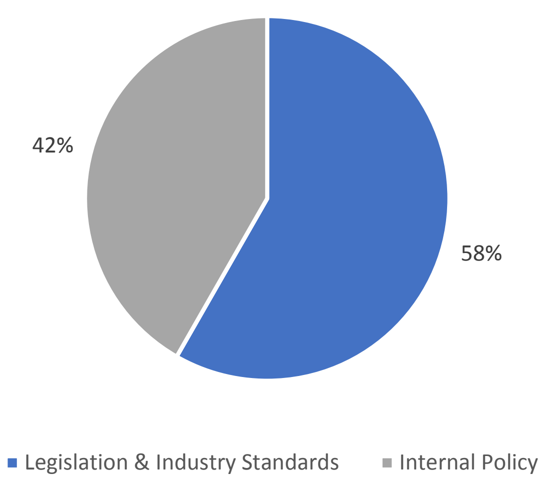
Compressor Cab Asset Health Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Air Intake	804	1,309	687	436	542	990	1,116	1,278	804	412
Cab Ventilation	800	1,468	925	892	1,323	2,030	2,181	2,444	1,313	783
Civil assets - buildings/ enclosures	3,102	2,540	1,360	1,139	1,659	2,133	1,901	2,247	912	886
Exhausts	882	1,688	1,253	587	930	1,161	2,979	2,932	2,911	1,371
Total	5,588	7,005	4,226	3,055	4,454	6,315	8,177	8,901	5,940	3,452
	24,327					**32,786**				

Intervention Drivers

9.20. 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 driven by legislation and based on industry standards, the remainder is based on Internal Policy.

RIIO-2 Cab Structure Intervention Drivers[1]



Preferred Programme CBA

9.21. We are targeting an appropriate level of asset health investment in compressor cabs to mitigate the reliability, safety and environmental risks from the ageing asset base. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in compressor cabs is value for money. We have considered costs over a 45-year period through a CBA.

9.22. The CBA for the compressor cabs investment over the period is not cost beneficial over the 45-year period. As described previously, this is because the primary risk of

[1] See Appendix A for intervention driver category descriptions

asset failure lies on the Compressor Train asset, which is analysed separately. Should we combine Compressor Train with Cab Infrastructure, the Cab related investment would become more cost-beneficial. A summary of the Cab Infrastructure only CBA is shown below.

Cost Benefit Analysis[2]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£20.71	£38.85	£56.12	£79.39
Present Value H&S benefits (£m)	£0.00	£0.01	£0.03	£0.17
Present Value non H&S benefits (£m)	£0.88	£3.70	£8.94	£22.11
Net Present Value (£m)	£(19.83)	£(35.14)	£(47.15)	£(57.11)

9.23. 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.

9.24. There are no credible options for investment in the compressor cabs that are directly cost beneficial. However, the investment in compressor cabs is essential to the safe and efficient running of our fleet of compressors. The investment is fully integrated with CECS and provides life extensions for those cab infrastructures whose compressors are required in the longer term. Those compressors that will be decommissioned or subject to lower running hours will receive investment corresponding to their shorter remaining life. It is vital for the supply of gas to our customers that our compressors remain available and resilient to the demands and changes on the NTS and investment in our compressor cab infrastructure is essential to ensuring this availability is not compromised.

9.25. We have assessed the sensitivity of the Cost Benefit Analysis to the full range of unit costs. The results of this analysis are presented in the Unit Cost section above.

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

[2] A16.09.1 Cab Infrastructure CBA

10. Preferred Option Scope and Project Plan

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

Preferred option

10.2. 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 compressor cab assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

10.3. The profile of investment in the compressor cab assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

Compressor Cab Asset Health Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Air Intake	804	1,309	687	436	542	990	1,116	1,278	804	412
Cab Ventilation	800	1,468	925	892	1,323	2,030	2,181	2,444	1,313	783
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Total	5,588	7,005	4,226	3,055	4,454	6,315	8,177	8,901	5,940	3,452
	24,327					**32,786**				

Delivery Planning

10.4. 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.

10.5. 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 can be limited across 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. Cab infrastructure work requiring outages will be aligned with compressor train work where possible. For cabs and compressor train projects it may be possible to take more localised outages bypassing the unit. This depends on network flow conditions and the availability of local/supporting units. Therefore, the availability and reliability of the supporting units are also critical factors. Our deliverability assessment and phasing of the work has accounted for supporting unit availability and the availability of sites which can provide similar compression requirements. By providing options to "re-direct" gas flows, compression availability also influences the likelihood of outages on other parts of the network.

10.6. The bundling 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. Additionally, where work is necessary on both compressor trains and cabs these projects can be easily/locally bundled where larger scale outages are unavailable and this could be an option where 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.

10.7. 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.

10.8. These assets are assessed and contracted together as they all fall into the skillset of contractors on a framework set up specifically to deliver this work. The framework includes industry experts who can provide the latest learning and technology and deliver the work directly without an intermediary engineering and design contractor.

Fire Suppression Systems (£7.0m)

11. Equipment Summary- Fire Suppression Systems

11.1. The purpose of these assets is to provide specialist fire suppression designed for gas turbine enclosures in the event of a fire. The condition of these assets is critical. In the event of a fire they prevent escalation and minimise the risk to people, the environment and the compression assets.

11.2. There are three main types of fire suppression:

- 200 bar nitrogen bottles are used to directly pressurise water bottles when the system is fired – for small enclosures where volume can be covered by up to 4 spray heads.
- 200 bar nitrogen bottles drive a gas driven pump taking water from a large water tank these can protect large volumes but requires approximately 30 nitrogen bottles for each fire that must then be replaced
- Electric motor driven pumps taking water from a larger water tank. These remove issues with nitrogen but requiring electric supply infrastructure to be installed.

11.3. A fire suppression system typically includes:

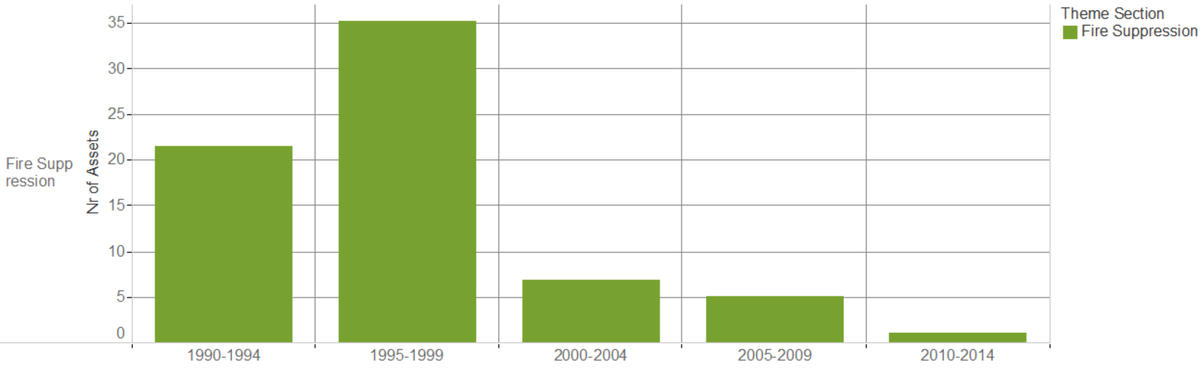
- A temperature-controlled enclosure including thermostat and electric heater to maintain bottles at suitable temperature to avoid a pressure drop and to stop water from freezing.
- 200bar Nitrogen or a nitrogen/electric driven pump.
- Water cylinders or a bulk water storage tank
- Discharge manifold, distribution piping and spray heads (stainless steel)
- Electrical solenoid actuator valves
- Pneumatically actuated slave valves
- Pressure switches (to monitor nitrogen cylinder pressure and confirm system operation)
- High pressure flexible hoses
- System isolation valve and limit switch
- A changeover switch from main to reserve system
- Some utilise a pump unit and water storage tank rather than water cylinders

Location and Volume

11.4. Fire suppression systems are permanently installed on every gas generator enclosure on sites across the NTS. Where the fire suppression is not available the compressor must not be operated.

11.5. The chart below shows the asset age profile of the compressor cab fire suppression assets.

Asset Age Profile – Fire Suppression



Pressure Ratings

11.6. The nitrogen bottles and all fittings in use within the fire suppression system are operated at 200 bar.

Redundancy

11.7. There are typically two banks of nitrogen, primary and reserve for each compressor cab with a manual changeover to allow for maintenance, repair and refurbishment and availability following a discharge of the primary bank. No automated change-over exists so any failure of the primary systems impact the availability of the whole compressor unit.

12. Problem Statement – Fire Suppression Systems

12.1. The fire suppression systems are an aging asset that suffers from corrosion and wear related deterioration. We are experiencing ongoing defects on the assets which are reducing their effectiveness and are causing them not to operate when tested. If these remain unresolved and allowed to deteriorate it will lead to non-compliance with legislation and potential asset, safety and environmental damage. Many of the systems are not suitable for the design of the cab that they are installed to protect. There are access and manual handling issues and associated safety risks on some of the systems, particularly the nitrogen bottles that are installed at height in some locations.

12.2. Without a fully functioning fire suppression system the associated gas compressor cannot be used. This limits the availability of the compressor unit and can impact the overall resilience of the NTS.

12.3. The firewater ring mains at both Bacton and St. Fergus terminals are original aging assets that are impacted by external corrosion and internal scale deposits that can affect the performance and integrity of the system. These assets form part of the utility system that is required for continued safe operation of these COMAH sites. They supply water to fire hydrants around the site, in the case of an emergency requiring a fire suppression response. If this asset was to fail on demand in an emergency, there is a risk that the necessary response to a fire would not be possible.

Drivers for Investment

12.4. The key drivers for investment in the Fire Suppression assets are:

- Legislation – PSSR
- HSE Guidance PM84/ BS IS)21789 - for legislative compliance drives for fire suppression
- NFPA 750 and BS ISO 145202 or alternative sets the standard for the changes being made and for the required improvements.
- Suitability
- Asset Deterioration
- Safety

12.5. In addition to the requirements of PM84 HSE / ISO21789 and PSSR the assets deteriorate over time and with use which leads to their inability to perform their required function e.g. actuators sticking. This can also result in them no longer complying with other legislative requirements.

12.6. **Legislation - PSSR –** requires 5-year and 10-year inspections and revalidation of high-pressure elements of the fire suppression system.

12.7. **HSE Guidance -** PM84 / ISO21789 for Control of Safety Risk at Gas Turbine Enclosures. - PM84 was introduced several years ago, following several fatal explosions involving gas turbines in acoustic enclosures. Examples of requirements include maintaining a fully functional ventilation system and suitably sealed building inner enclosure with building integrity as a fire break and suitable fire protection to mitigate process safety risks. The requirements of PM84 have been incorporated into ISO21789.

12.8. Whilst not a direct legal obligation this guidance, issued by the HSE, provides good practice that should be complied with to demonstrate all reasonable measures have been taken to comply with the overarching legislation.

12.9. As part of the technical measures for active/passive fire protection [redacted], provided by the HSE, it is stated that an active firefighting system needs to be reliable and should be supplied by a secure water supply. Therefore, the fire water ring main at both Bacton and St. Fergus terminals should be able to supply water to fire hydrants reliably on demand.

12.10. **Suitability –** The fire suppression system relies on specially designed heads that ensure a fine mist of water droplets of certain diameters is produced, this relies on a working system that is within the design limits of the system to provide the pressure and volume of water for these droplets to form consistently to cool and smother a fire. Currently, there are large differences between the size of the cab and the number of spray heads that the type of system is certified for and the actual cab size and number of installed spray heads. This results in non-certified and tested systems, insufficient fire time, and inferior capability to extinguish a fire compared to the required certification standard.

12.11. Requirements for discharge time to meet guidance and certification has progressed since the systems were installed approximately 20 years ago, and a move towards increasing discharge time in line with current standards along with other improvements and replacement with certified systems by current standards will begin in RIIO-2.

12.12. **Asset Deterioration –** Elements of the assets are deteriorating due to age, corrosion and wear. Increasing defect numbers are being recorded and the assets are becoming unreliable and fail to work when called upon. As systems age, deposits in pipework, bottles and hoses repeatedly block spray heads which reduce effectiveness.

12.13. **Safety** - The location and design of the cabinets that contain the nitrogen and water cylinders gives rise to both safety and manual handling issues. Manual handling and access issues are associated with the need to replace up to 30 large nitrogen bottles (weighing up to 77 kg) when the systems are fired for safety or maintenance purposes. This can take more than a day and where a reserve bank is not available will mean that the compressor is unavailable. The current design of the cabinets is also not ideal for maintenance and mitigation activities are required for each maintenance activity. When considering the investment in replacing systems the removal of the risk of injury will be a priority.

Impact of No Investment

12.14. If due to continued asset deterioration or other factors the fire suppression system is not fully functional then the associated gas turbine cannot be run. This impacts on the availability of the compressor units and increases availability risk on the NTS.

12.15. With no investment, the assets would continue to deteriorate which will increasingly result in their inability to perform their duty when required to do so. Failure of these assets is not necessarily known until they are required to operate.

12.16. If the fire suppression system fails to operate correctly on demand, a cab fire could fail to be extinguished and escalate. The system primarily provides asset protection but depending on the fire scenario there is also a risk to personnel safety and the environment.

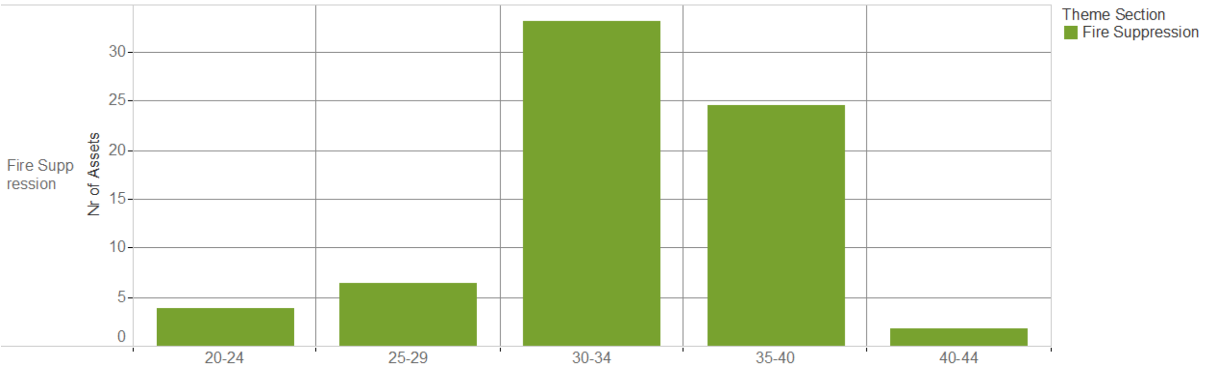
12.17. The current gas turbine enclosure fire suppression systems have several design flaws which generate personnel safety, maintainability and operational availability issues. These issues have led to increasing the probability that the system will fail to operate effectively on demand. Surveys were carried out by a fire suppression company to validate the gaps.

12.18. The firefighting systems at Bacton and St. Fergus must be supplied by a secure water supply system, as stated in the HSE's technical measures for active fire suppression [redacted] If there is no investment in the fire water ring main asset, its condition will continue to deteriorate and there will be an increased risk of asset failure. This would likely leave the asset in a condition which is not fit for purpose and non-compliant with safety legislation.

Asset Age

12.19. The chart below shows the age profile of compressor cab fire suppression assets by end of RIIO-3 with no investment.

Asset Age Profile – Fire Suppression



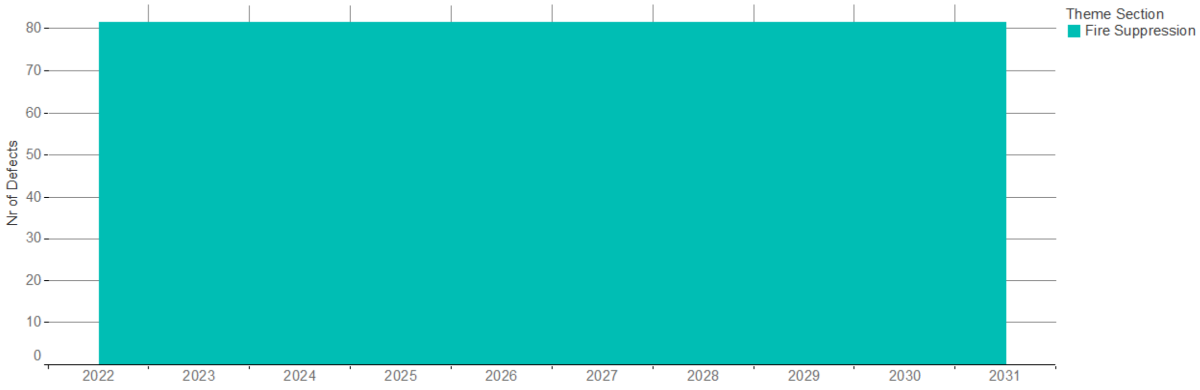
Suitability

12.20. There are 66 fire suppression systems installed across the NTS. 11 of these have been recently installed and their design is generally suitable and supportable for the cab in which they are installed. The remaining 55 have a larger gap to their suitability for the cab they are installed in and to a certified system.

Defects

12.21. The chart below shows the predicted number of defects if there is no investment in compressor cab fire suppression assets.

Predicted Defects – No Investment Fire Suppression



Examples of the Problem

12.22. The photograph below provides an example of some of the issues present on cab infrastructure assets.

Nitrogen bottles and hoses

12.23. Pressure switches at height behind bottles that are difficult to maintain as work is required above, and through, the 200bar nitrogen bottles and hoses.

12.24. Also visible are solenoid valves that have failed to operate on demand due to age.

12.25. These bottles weighing up to 77kg need manually swapping from the cabinet after a fire.

Spend Boundaries

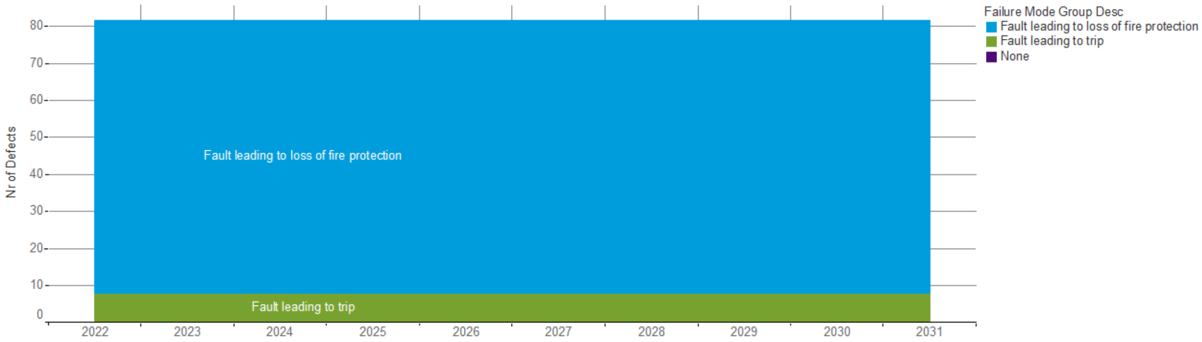
12.26. The proposed investment includes all compressor fire suppression and their associated components installed on the NTS, including any 'no-regrets' site investments at both St Fergus and Bacton[3] to keep them safe and operational whilst the separate funding mechanism for the proposed projects are progressed via Uncertainty Mechanisms. Investment associated with compressor cabs for new compressor units is excluded as this is included in the separate compressor investment business plan.

[3] There is no Cab Infrastructure at Bacton, however, the fire water ringmain replacement at site has been mapped to the Fire Suppression sub theme hence the investment resides within this Engineering Justification Report.

13. Probability of Failure – Fire Suppression Systems

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

Predicted Defects by Failure Mode – Fire Suppression



13.2. For compressor cab fire suppression assets, the chart indicates that the failure modes that contribute most to the probability of failure are:

- Loss of unit leading to trip

Probability of Failure Interventions

13.3. All Fire Suppression interventions are defined as Consequential Interventions. This is because the prime function of the Cab is to protect the assets comprising the Compressor Train. All risk benefits associated with Fire Suppression are therefore considered to align with the following definition of a Consequential risk intervention:

"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."

Consequential Interventions

13.4. The table below shows the drivers for Fire Suppression investment that are defined as Consequential Interventions.

Fire Suppression Investment

NARMs Asset Intervention Categories	Secondary Asset Classes
Consequential Interventions (Non-risk tradeable)	Fire Suppression

13.5. Our NOMs Methodology attempts to model the indirect benefits delivered by these assets in terms of the reduction in PoF or Consequence of Failure (CoF) upon a related and/or adjacent asset (e.g. the benefit of air intakes on the numbers of compressor trip and vents). These quantified, but indirect, impacts are used within the CBAs accompanying this justification report but are not considered to be reliable enough for use as a NARMs monetised risk metric.

Fire Suppression Interventions

13.6. The table below lists the potential interventions for fire suppression systems together with their associated SAC and Intervention Category.

Fire Suppression Interventions

Intervention	SAC	Intervention Category
A22.03.3.3 / Fire water ringmain replacement (Bacton)	Fire Suppression	Major Refurbishment
A22.08.2.1 / Fire Suppression Major Refurb	Fire suppression	Major Refurbishment
A22.08.2.2 / Fire Suppression Minor Refurb	Fire suppression	Minor Refurbishment
A22.08.2.3 / Fire Suppression Replacement of Electric Water Pump System	Fire suppression	Replacement
A22.08.2.4 / Fire Suppression Replacement of Nitrogen Bottle System (MAU)	Fire suppression	Replacement
A22.22.1.12 / Fire water ringmain replacement (St. Fergus)	Fire suppression	Replacement

Data Assurance

13.7. 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 favorable 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

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

13.9. At the time of writing, 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.

14. Consequence of Failure – Fire Suppression Systems

14.1. The chart below shows the expected stakeholder impacts because of failures occurring on the compressor cab fire suppression assets. The charts show the relative numbers of consequence events, not relative monetised risk.

Stakeholder Impacts – Fire Suppression

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

- **Environmental risk** is associated with the loss of gas through trips and vents of the compressor unit, caused by the failure of a fire suppression system. This is an indirect effect and only a small proportion of fire suppression system failures will generate a unit trip and associated vent of gas
- **Financial risk** is mostly associated with the OPEX costs of operating and maintaining the network at the current level of risk

14.3. The risk associated with other service risk measures for Fire Suppression is negligible, based on the assigned failure modes. It should be noted that the predominant failure model is a compressor trip and vent, caused by the failure of the fire suppression system itself. The probability of the failure of a unit due to a fire and subsequent failure of the fire suppression system is very low. Therefore, Safety risk has been modelled to be negligible in relation to Financial and Environmental risk.

15. Options Considered – Fire Suppression Systems

Potential Intervention Category Options

15.1. The following intervention category options apply to the Fire Suppression assets:

- **Repair / Minor Refurbishment** - Repairs are carried out on this asset to individual components that have failed. Additionally, any actuators, corroded fittings and spray heads are also tested and replaced.
- **Major Refurbishment and Revalidation** - completes the revalidation against PSSR and changes all aged hoses (5-years), water bottles (10-years), actuators and fittings. Furthermore, iterative improvements to the system are applied where the gap between the actual system installation and ideal system design is smaller and can be mitigated. For those systems that will retain nitrogen bottles then access is improved to resolve manual handling issues and the associated safety risks.
- **Replacement** - Replacement of the entire system is the only intervention category that ensures the systems are fully suitable for the compressor cab design. Replacement fire suppression systems (typically required due to age and design) are designed to a standard (e.g. NFPA) and FM or UL approved equipment is procured. Replacement brings a fire suppression system up to the certifiable standard.
- **Fire water ring main replacement** – Replace the existing steel pipework with plastic pipe. Replacement of the whole fire water ring main would ensure that the system is in a condition that can be relied upon in an emergency to provide firefighting capability.
- **Fire water ring main refurbishment** – Insert plastic lining within the sections of pipework that have been most affected by corrosion and scaling. This option would only resolve integrity issues in the most affected sections of pipework, and not the whole pipework.
- **Electric Pump System** - Installation of electric pumped systems will remove the need for the high-pressure nitrogen bottles (up to 30 for primary bank). This results in lower maintenance activities with no nitrogen leaks and associated availability and asphyxiation risk, significant reduction in numbers of hoses on 5-year replacement, no water bottles on 8-year replacement, no ongoing hire or replacement of nitrogen bottles after each real or test fire, less head replacement due to deposits from old water bottle and fitting corrosion. They also improve the availability and resolves the manual handling issues and associated safety risks.
- **Replacement Nitrogen Bottle System** – This utilises nitrogen bottles firing into water bottles and will only be purchased as a replacement where the cab volume is suitably small and has clear space for the suppression system to get coverage with only 4 heads which is the limit of the certification. There are limited opportunities for this intervention due to existing cab design.
- **Replacement Nitrogen Pump System** – This system utilises nitrogen bottles to drive a gas pump. While these are certified for larger, more complex volumes they typically need 30 nitrogen bottles for the primary bank only. This increases

the volume of the problems previously listed for the simpler nitrogen bottle system. Electric pumped systems are preferable to nitrogen powered pumps.

Intervention Unit Costs

15.2. The total RIIO-2 investment for Fire Suppression Systems represents 22% of the investment theme. The unit costs that support the Fire Suppression Systems 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

15.3. 51% of costs for Fire Suppression Systems are supported by historical outturn information, where we have been able to reference 7 data points gathered from 3 sanction papers. The remaining 49% of costs for Fire Suppression Systems have been developed using supplier quotations where obtainable (2%), or through other estimation methods (47%) due to the low frequency and the variability in the works that could be performed making obtaining supplier quotations very difficult.

15.4. The table below provides the unit costs for all the potential Cab Infrastructure interventions.

Intervention Unit Costs - Fire Suppression

Intervention	Cost (£)	Unit	Evidence	Data Points	Overall value in BP
Fire Suppression System					
A22.08.2.2 / Fire Suppression Minor Refurb	[redacted]	Per asset	Outturn	2	£ 408,100
A22.08.2.1 / Fire Suppression Major Refurb	[redacted]	Per asset	Outturn	2	£ 428,711
A22.08.2.3 / Fire Suppression Replacement of Electric Water Pump System	[redacted]	Per asset	Outturn	3	£ 2,705,209
A22.08.2.4 / Fire Suppression Replacement of Nitrogen Bottle System (MAU)	[redacted]	Per asset	Estimated Quotation	1	£ 154,583
A22.03.3.3 / Fire water ringmain replacement (Bacton)	[redacted]	Per asset	Estimated - Other	0	£ 1,625,388
A22.22.1.12 / Fire water ringmain replacement (St. Fergus)	[redacted]	Per asset	Estimated - Other	0	£ 1,641,806

15.5. Opportunities are included for efficiency where we are installing electric pumps to install one pump-set between multiple cabs. While this is technically feasible and will saves cost, it makes the system more complex with pipework selection, longer cross site pipe runs, and complex logic to address multiple cab fires. It also reduces resilience of the site as a failure of the system would remove availability of all units that are covered by that electric pump. This final decision to do this will be based on criticality of the units and the mitigation that can be put in place in terms of spares, support contracts etc. These become more efficient to implement with a volume of similar systems being installed.

Unit Cost Sensitivity

15.6. 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

15.7. Whilst the level of cost benefit changes as the unit costs vary, the investment remains non cost beneficial across the range of unit costs. Our decision on the preferred programme of investment is not changed as a result of this analysis.

Innovation

15.8. In the RIIO-1 period, no specific innovation work has been conducted which is relevant to Fire Suppression, however innovation used in other investment areas will be utilised where appropriate. In RIIO-1, we have taken a smarter approach to resolving key risk factors on our cab infrastructure assets, which may inform future innovation projects as we move through the investment period.

16. Programme Options

16.1. In developing our plan the following options have been considered for investment in the fire suppression systems.

16.2. 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.

16.3. In developing our plan, the following options have been considered for investment in the fire suppression systems. Please note that all programme options include any fixed 'no-regrets' related investments associated with the Bacton[4] and St Fergus sites.

- Baseline
- Maintain Risk
- Refurbishment Only
- Full Re-lifing

Baseline – Do Nothing

16.4. The impact of no investment in our Fire Suppression assets increases service risk over a 10-year period, the most significant being a three-fold increase in the volume of gas released to atmosphere every year generated through trips and vents of the Compressor unit resulting from failure of a fire suppression system. There is also an equivalent increase in the number of potential outages every year caused by Fire Suppression asset failures and the subsequent isolation of assets on the NTS. This option includes the reactive only investment across all the Fire Suppression assets and is the option against which all the other options are compared.

Programme Option 1 – Maintain Risk

16.5. This option undertakes a mix of replacement, refurbishment and reactive repairs to maintain the current levels of risk across all the fire suppression systems. This option also remediates defects and resolves the manual handling issues associated with the large nitrogen and water bottles.

Programme Option 2 – Refurbishment Only

16.6. This option reduces the investment in fire suppression to that required to ensure legal compliance and manage short term risk through refurbishment and fully reactive minor refurbishments as and when significant issues arise.

Programme Option 3 – Full Re-lifing

16.7. This option significantly reduces the risk of fire suppression assets impacting on compressor availability. Full re-lifing of all appropriate systems is undertaken except those not required in the long term.

[4] There is no Cab Infrastructure at Bacton, however, the fire water ringmain replacement at site has been mapped to the Fire Suppression sub theme hence the investment resides within this Engineering Justification Report.

Programme Options Summary

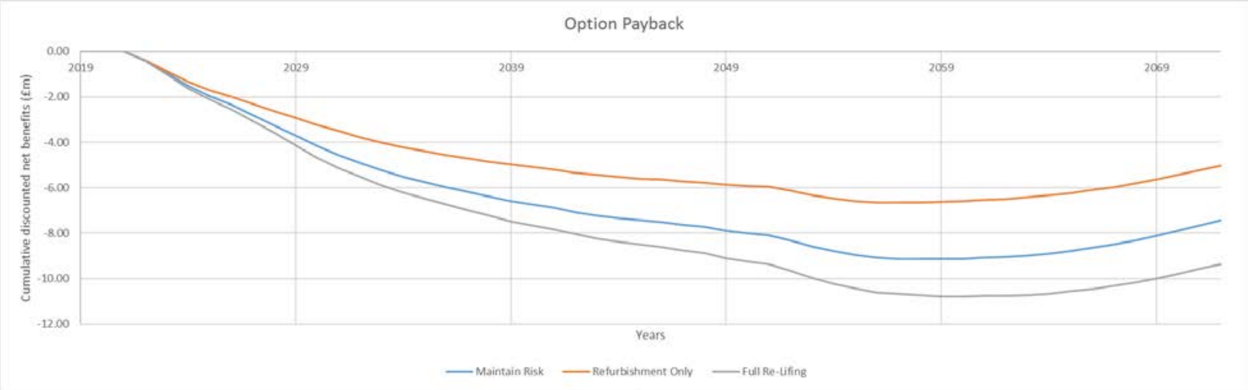
16.8. In considering the CBA for each of the programme options, a summary of all the potential programme options is provided in the table below. The CBA results should be treated with caution as the CBA does not properly take into account the criticality of the fire suppression systems in maintaining the capability of the compressor fleet.

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 - Maintain Risk	£6.96	£4.89	£13.55	£4.91	£(8.64)	0.36	Does not payback in the period
2 - Refurb Only	£5.81	£2.83	£10.05	£3.95	£(6.11)	0.39	Does not payback in the period
3 - Full Re-life	£7.57	£5.97	£15.43	£4.99	£(10.44)	0.32	Does not payback in the period

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

Option Payback – Net NPV



Programme Options Selection

16.10. None of the potential options are cost beneficial over the 45-year analysis period but this is due to known issues with the CBA where the criticality of the fire suppression systems are fully recognised. The selection of the preferred option has therefore been based on an assessment of:

- the continued safety of our staff
- damage to our assets
- the level of risk of the impact of the fire suppression systems on the availability of our compressors,
- maintaining our compliance with legislation – PM84 and PSSR
- delivering value for consumers and stakeholders.

16.11. As discussed previously, this is because the primary risk lies on the Compressor Train asset protected by the fire suppression system. When modelled in combination, fire suppression investments become more cost-beneficial. The outcomes associated with each option are provided below:

Programme Option 1 – Maintain Risk

16.12. This option maintains the level of risk and performance in the medium term whilst reducing current defects and resolving the current manual handling and design issues with the fire suppression assets.

Programme Option 2– Refurbishment Only

16.13. This option results in increased reactive minor refurbishment (i.e. fix on fail) across the fire suppression systems. There is a potential impact the availability of the compressors, together with an increased safety risk.

Programme Option 3 – Full Relifing

16.14. This option predominantly further reduces the risk on the fire suppression systems below the point at the start of RIIO-2 with the associated increase in investment. There is no support for such a reduction in risk from stakeholders and no requirement for it to manage our service and compliance levels.

Preferred Option

16.15. Our preferred option is Option 1 to maintain the current level of risk and, because even though some of the other options have a lower investment requirement and are more cost beneficial, they do not meet the required outcomes. This is consistent with feedback from our stakeholder engagement who require at least the current level of risk to be maintained. Our chosen option is non-cost beneficial, however, meets the desired outcomes at least whole life cost.

16.16. Our preferred option:

- ensures that the lack of availability of a functioning fire suppression system is not a limiting factor in the availability of the compressor fleet
- manages the safety risk associated with the manual handing on some of the current fire suppression systems
- maintains our compliance with PM84 and PSSR legislation

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

17. Business Case Outline and Discussion – Fire Suppression Systems

17.1. In this section we set out our overall investment plan for fire suppression systems. This section demonstrates why the proposed investment levels for fire suppression systems are the right levels to ensure the health and reliability of these assets for the investment period and beyond.

Key Business Case Drivers Description

17.2. The key drivers for investment in the Fire Suppression assets are:

- Legislation - PM84 HSE / ISO21789 and PSSR
- Suitability
- Asset Deterioration
- Safety

17.3. In addition to the requirements of PM84 HSE / ISO21789 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 safety legislative requirements.

Business Case Summary

Outcomes delivered

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

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

17.5. The key outcome affected by the failure of the fire suppression systems is the reliability risk to the compressor units that cannot be run without a fully functioning fire suppression system.

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

- Manage deterioration of the assets such that they are fully functional and of suitable design as to not limit availability of the compressor units or cause damage to the Compressor Trains assets that they are designed to protect.
- Meet legal requirements and agreed safety standards that define how long these systems should fire for to ensure fires are extinguished and what systems are suitable for gas turbine enclosures with the high temperature metal surfaces and complex machinery filled spaces.
- Ensure ongoing compliance with PM84 HSE / ISO21789 Control of Risk around Gas Turbine Enclosures

- Improve the safety of working on the fire suppression systems through the removal of the manual handling issues associated with heavy nitrogen bottles installed at height, removing risk of injury through replacement of high-pressure hoses and pipework and limiting nitrogen asphyxiation risk.

17.7. Our proposed investment in the fire suppression systems will ensure that we maintain our low levels of risk across all these outcomes.

Stakeholder Support

17.8. 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].

Investment Decision Approach

17.9. To deliver the outcomes for the investment period the Fire Suppression assets require a mixture of the defined intervention categories. The decision on the volume of each of the interventions required has been determined using the following approach.

- Compliance with the requirements of PSSR for the inspection and validation of all high-pressure components
- A strategy of moving towards replacement systems that have appropriate designs by current standards for the cabs they operate in will be applied for those cabs with an estimated life beyond 2030. In these cases, where possible electric pumps that remove the manual handling issues associated with replacing the 200 barg nitrogen bottles every time the system is discharged. These will increase availability and remove significant and maintenance issues.
- *Compressor units and cabs that are not expected to operate beyond 2030 will be refurbished wherever possible and will include the resolution of any manual handling and asphyxiation risks associated with the use of high pressure nitrogen cylinders in confined spaces.*
- A forecast of the number of repairs based on the historical information combined with the knowledge of the proposed replacement and refurbishment work.

17.10. A risk assessment informed by fire suppression specialist surveys has been used to develop an asset by asset list of the appropriate category of intervention to be undertaken. This risk assessment included:

- Issues and defects currently identified and those forecast to arise through the period
- Results of an OEM survey of fire suppression system design undertaken during RIIO-1 to identify current condition and the gap between current installation standard and certification standard.

- Review of run hours and criticality.
- Assessment of any manual handling issues
- Asset age, condition and probability of failure
- Remaining Life of the Compressor Unit
- Local resilience requirement for the Compressor Unit - Critical for 1 in 20
- Forecast run hours of the Compressor Unit
- Compressor Unit outages

17.11. The proposed mix of interventions and programme of work will be continually reassessed and reprioritised using the results of the ongoing inspections, performance of the assets and any one-off defects.

17.12. Over 20 cabs will be protected by modern certified fire suppression systems with easier and reduced maintenance, ensuring continued reliability of the system.

17.13. At least 8 other systems will have iterative improvements where investment is needed but they are deemed a lower priority due to identified gaps being smaller. This will reduce manual handing and maintenance issues and re-life current components.

17.14. 24 other systems will have the minimum requirement of a re-life of components in line with ongoing inspection and maintenance to meet minimum standards. These will be planned for a future replacement or mitigated through being very low use/short life compressors with minimal identified gaps to a compliant maintainable system.

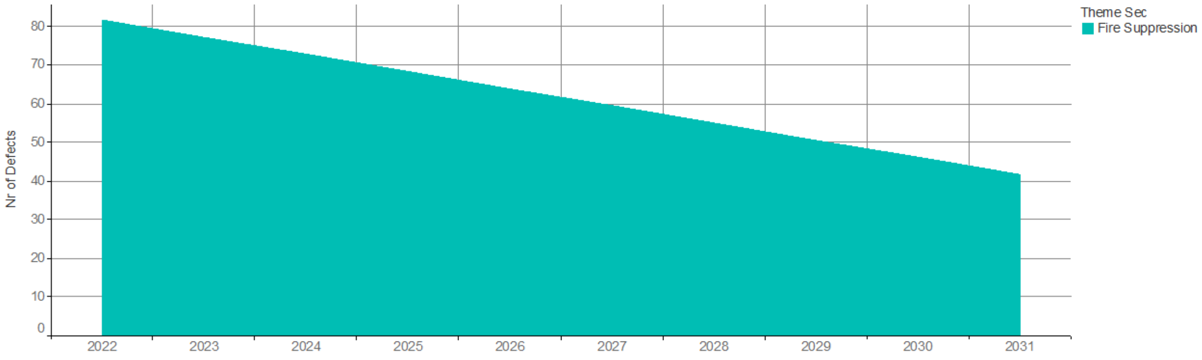
Benefits of Investment

17.15. The investment will achieve the following improvements in the Fire Suppression assets.

Defects

The chart below shows the predicted number of defects after investment.

Predicted Fire Suppression System Defects – with Preferred Option



Preferred Option

17.16. 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 fire suppression system assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

17.17. The profile of investment in the fire suppression systems assets, driven from the derived volumes of work and the efficient unit costs, for the period is shown is the table below:

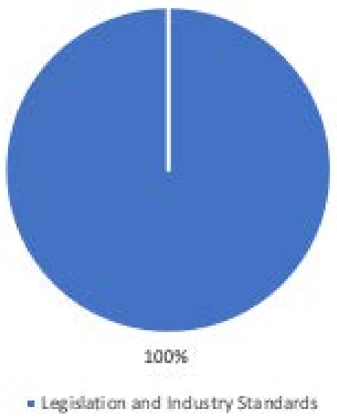
Spend Profile

Investment (£ 000's)	RIIO-2					RIIO-3				
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Fire suppression	1,425	1,905	1,738	1,168	728	1,112	1,092	1,006	999	685
Total	1,425	1,905	1,738	1,168	728	1,112	1,092	1,006	999	685
	6,964					**4,894**				

Intervention Drivers

17.18. The following chart shows the breakdown of investment across each of the intervention drivers. This shows that all of the investment consists of interventions that are driven by legislation and based on industry standards.

RIIO-2 Fire Suppression Intervention Drivers[5]



[5] See Appendix A for intervention driver category definitions

Preferred Programme CBA

17.19. We are targeting an appropriate level of asset health investment in fire suppression systems to mitigate the reliability and safety risks from the ageing asset base.

17.20. In line with HM Treasury Green Book advice and Ofgem guidance we have appraised whether investment in fire suppression systems is value for money. We have considered costs over a 45-year period in a full cost benefit analysis (CBA), as set out above the full criticiality of the fire suppression systems is not fully appreciated by the CBA.

17.21. The CBA for the fire suppression systems investment over the period is not cost beneficial over the 45-year period. This is shown below.

CBA Summary[6]

	10 years	20 years	30 years	45 years
Present Value costs (£m)	£4.67	£7.42	£9.67	£13.55
Present Value H&S benefits (£m)	£0	£0	£0	£0
Present Value non H&S benefits (£m)	£0.10	£0.53	£1.59	£4.91
Net Present Value (£m)	£(4.57)	£(6.89)	£(8.08)	£(8.64)

17.22. 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.

17.23. We have assessed the sensitivity of the Cost Benefit Analysis to the full range of unit costs. The results of this analysis are presented in the Unit Cost section above.

17.24. There are no credible options for investment in the fire suppression systems that are cost beneficial. Investment in fire suppression systems ensures that they continue to directly protect both the compressor trains themselves, the people who work around them and the assets in their vicinity on our sites. The lack of availability of a functioning fire suppression system should not be a limiting factor in the availability of the compressor fleet.

17.25. As with the compressor cabs the investment is fully integrated with CECS. All fire suppression systems on compressors remaining in the medium term will be of an appropriate design and specification. Others will receive minimised refurbishment and repair expenditure to manage their operation until they are decommissioned.

17.26. The investment will resolve the manual handling issues and associated safety risks. This ensures that we continue to support safe working practices wherever possible. Delaying or deferring investment is not acceptable to our stakeholders. Across our stakeholders there is little support for continuing with or increasing our safety risk.

17.27. This level of investment will ensure we successfully manage asset deterioration and obsolescence, whilst meeting our legal obligations. It will ensure we deliver the outcomes that consumers and stakeholders tell us they want us to meet.

[6] A16.09.2 Fire Suppression CBA

18. Preferred Option Scope and Project Plan – Fire Suppression Systems

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

Preferred option

18.2. 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 fire suppression system assets in the investment period. [redacted]

Intervention Volumes

[redacted]

Asset Health Spend Profile

18.3. The profile of investment in the fire suppression systems 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
Fire suppression	1,425	1,905	1,738	1,168	728	1,112	1,092	1,006	999	685
Total	1,425	1,905	1,738	1,168	728	1,112	1,092	1,006	999	685
	6,964					**4,894**				

Delivery Planning

18.4. 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 re-optimised to reflect the impact of the change and provide an opportunity to reconsider the efficient timing of delivery.

18.5. 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 due to the radial nature of the network. It is therefore most efficient from both financial and network risk points of view to bundle investment undertaken in any outage whilst ensuring efficient delivery through minimised project overheads. Cab infrastructure work requiring outages will be aligned with compressor train work where possible. For cabs and compressor train projects it may be possible to take more localised outages bypassing the unit. This depends on network flow conditions and the availability of local/supporting units. Therefore, the availability and reliability of the supporting units are also critical factors. Our deliverability assessment and phasing of the work has accounted for supporting unit availability and the availability of sites which can provide similar compression requirements. By providing options to “re-direct” gas flows, compression availability also influences the likelihood of outages on other parts of the network.

18.6. The bundling 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. Additionally, where work is necessary on both compressor trains and cabs these projects can be easily/locally bundled where larger scale outages are not available and this could be an option where 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.

18.7. 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.

18.8. These assets are assessed and contracted together as they all fall into the skillset of contractors on a framework set up specifically to deliver this work. The framework includes industry experts who can provide the latest learning and technology and deliver the work directly without an intermediary engineering and design contractor.

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