Appendix 09.08

Governors (District, I&C and Service)

RIIO-2 Spend: XXXX

Investment Decision Pack Overview

This investment pack outlines the scope, costs and benefits for our proposals. We have prepared an Engineering Justification Paper (EJP) and a Cost-Benefit Analysis (CBA) for these assets. A brief overview is provided below.

Overview

This investment case covers our below 7 bar governors and, more specifically, the pressure-reduction systems within these governor stations. These governors provide the step-down from the high pressures of gas received from Cadent's above 7 bar Local Transmission System (LTS). This reduced pressure is then fed into our domestic and commercial customers' premises through the wider distribution network operated by Cadent.

The most critical components of the pressure-reduction systems are the regulators which provide this pressure-reduction function and the slamshut devices which protect the downstream network from over-pressurisation. Our investments, therefore, have focused on these two system components.

Several of our regulators and slamshuts are obsolete and unreliable. We have considered both obsolescence and reliability and have devised a cost-efficient and targeted plan to address assets which pose the highest risks to safety and security of supply. Our Reliability Centred Maintenance (RCM) failure data has been the primary source of information in this regard.

To understand investment needs, we have used advice from external independent specialists and in-house engineering and operations teams to identify the specific makes and models of regulators and slamshuts which need investment most urgently. We have blended this bottom-up engineering advice with a CBA and NARMs modelling to better understand the investment plan.

Our objective is to build a plan which best reflects customer and stakeholder expectations. To achieve this, we have developed a methodology which links asset performance to customer impacts, making use of models to evaluate options based on CBA. We have used our learning from historical projects to derive our unit costs for RIIO-2 interventions, which ensures the effectiveness of the proposal.

Our drivers for this investment case are to ensure our pressure-reduction system assets remain operating safely, efficiently and reliably in order to maintain:

- Security of supply to customers
- Safety: specifically, compliance with Regulations: Pressure Systems Safety Regulations 2000 (PSSR) and Gas Safety (Management) Regulations (GS(M)R) 1996
- Value for money (efficiently carrying out intervention to manage customers' bills)

From our analysis, the most material driver for our below 7 bar governors is safety. Over 30% of the net present value (NPV) is as a result of reducing the risk of fatalities and non-fatal injuries. Other benefits stem from reducing environmental risk, financial risk and interruptions.

This is a stripped back, highly targeted programme of work designed to mimimise costs whilst maintaining service. It will allow monetised risk to increase during the period whilst improving key safety metrics.

Summary of preferred option	**£m**
RIIO-2 Expenditure	Redacted due to commercial sensitivity
NPV	

Material Changes Since October Submission

We have refined and improved our approach to CBA modeling to better represent the planned investment. The cost base has been uplifted to 18/19 prices.

Table of Contents

2. Introduction

This document covers the investment case methodology for the pressure-reduction systems (PRSs) within below 7 bar (< 7 bar) governors. Governors have the following sub-categories:

- District governors
- Industrial and commercial (I&C) governors
- Service governors

A PRS is comprised of several individual components the function of which is to safely, efficiently and reliably reduce the pressure to a level suitable for the downstream network.

Across all these categories of governors, pressure reduction is carried out by the PRS. Several other systems (e.g. Housings, Fences, Instrumentations and Electrics) are also present at governors; however, the focus for this paper is only the PRSs. The following components are typically included within a PRS: inlet and outlet valves, filters, slamshuts, monitor and active pressure regulators, relief valves, non-return valves, stream and auxiliary pipework and equipment relating to these assets for below 7 bar installations. The spend boundary is explained in more detail in Section 4.2.

As part of transporting gas from the National Transmission System (NTS) to customers' properties, we need to reduce the pressure of the gas. Reduction is achieved via pressure regulators which step down the pressure in various stages. The active regulator performing this task is known as the 'protected device' and is supported by suitable 'protective devices' (e.g. monitor regulators and slamshuts) which protect the downstream network from over pressurising if the active regulator fails to perform correctly. There is a statutory requirement to maintain these assets to ensure that the system operates safely, in line with the Pressure System Safety Regulations (PSSR) 2000, and continues to provide a safe and reliable service to our customers.

Although the obligations under PSSR 2000 do not apply to the MP (75mbar to 2bar) and LP (below 75mbar) tiers, the obligations under Pipeline Safety Regulations 1996, Regulation 6 to maintain a safe distribution network do apply to all pressures. PSR '96 Regulation 6 states, *"The operator shall ensure that no fluid is conveyed in a pipeline unless it has been provided with such safety systems as are necessary for securing that, so far as is reasonably practicable, persons are protected from risk to their health or safety."* PRSs are crucial to the fulfilment of this obligation.

For below 7 bar assets, the business uses reliability centred maintenance (RCM) to minimise unplanned failures or faults as far as reasonably practicable. This means that assets that have a greater frequency of faults and a higher criticality to the network are visited and maintained more frequently than those assets with higher levels of reliability.

We are aware that some of our assets across these sites are obsolete: there is either a total lack of spares or spares are only available for a limited time in the future (i.e. foreseeable future obsolescence). Obsolete components cannot be replaced but are still proactively maintained to ensure avoidance of failure. Where soft parts (e.g. rubber seals, diaphrams and other perishable sub-components) are available within the discontinued units, they are proactively replenished where required. However, if the obsolete equipment fails, getting a suitable non-obsolete component to replace it may not be quick and may require site reconfiguration and the replacement of additional equipment to ensure compatibility. Our monetised-risk model does not fully capture the complexity of this obsolescence risk. We have therefore chosen to undertake a detailed engineering assessment, looking at the obsolescence of our equipment, to inform one of our investment scenarios.

We have taken an innovative approach to this assessment, providing our asset and failure data to an external specialist and asking them to build an investment option unconstrained by our current way of working. We have used our monetised-risk model to assess this option and compared it against other investment scenarios.

The result of this study has prompted a change in approach from RIIO-1, where we have been basing our decision-making process primarily around obsolete assets without analysing reliability in parallel. Our RIIO-2 approach blends obsolescence, reliability and asset criticality into the decision-making process and suggests interventions on the most unreliable and critical assets which are obsolete. This does mean that we will have some obsolete assets (that have been working reliably and/or which have a low impact on the security of supply and safety) that have not been proposed for the proactive replacement plan. The risk from such assets will need to be managed in the RIIO-2 period and any deterioration in their reliability will be considered for the RIIO-3 planning process.

In summary, we have used a combination of our Asset Investment Manager (AIM) monetised-risk model and a bottom-up engineering assessment to select the optimum investment programme for RIIO-2. We have considered the four options set out below:

- Option 0: Do nothing: carry on reactively maintaining
- Option 1: Engineering assessment of obsolescence and criticality within District and I&C governors
- Option 2: Minimum investment to maintain stable risk
- Option 3: Maximum whole-life benefit
- Option 4: Continue with RIIO-1 investment levels at least failure

3. Equipment Summary

This investment-case paper has assessed all Pressure Regulating Installations (PRIs) operating below 7 bar and, therefore, covers pressure-reduction systems within the following types of PRIs:

- District governors
- Industrial and commercial (I&C) governors
- Service governors

Cadent has 13,667 below 7 bar PRIs (also referred to as Governor Stations or Governors) across the four gas distribution networks, including district and I&C governors. These PRIs provide a step down from the IP (between 2 bar and 7 bar) or MP (between 75 mbar to 2 bar) tiers to the low pressure (LP) (below 75mbar) that is supplied to our customers. We also have PRIs dealing with a pressure reduction that is within the IP or MP boundaries (i.e. IP-to-IP and MP-to-MP pressure reduction) which is further reduced to LP by a subsequent PRI before it reaches the customers. Some IP sites reduce pressure directly to LP as well. I&C governors are installed to supply gas to large customers which are fed directly from the IP or MP network; these, however, have the same components and systems on-site as district governors have. Figure 1 below illustrates the interaction between the NTS, the above 7 bar LTS and the below 7 bar governors on the distribution system.

Although I&C governors are within the scope of this investment paper, only 1.4% volume of the chosen makes and models is associated with this category of governors. Therefore, to simplify the focus and calculations, all the proposed spend has been attributed to district governors within the Enzen engineering assessment and in NARMs, CBA modelling and the Business Plan Data Tables (BPDT).

Service governors are installed on the distribution network, connecting some of our domestic customers directly to the IP or MP network. These are not included in our investment case. We will have a ‘fix on fail’ approach for these, low cost units in line with the RIIO-1 strategy.

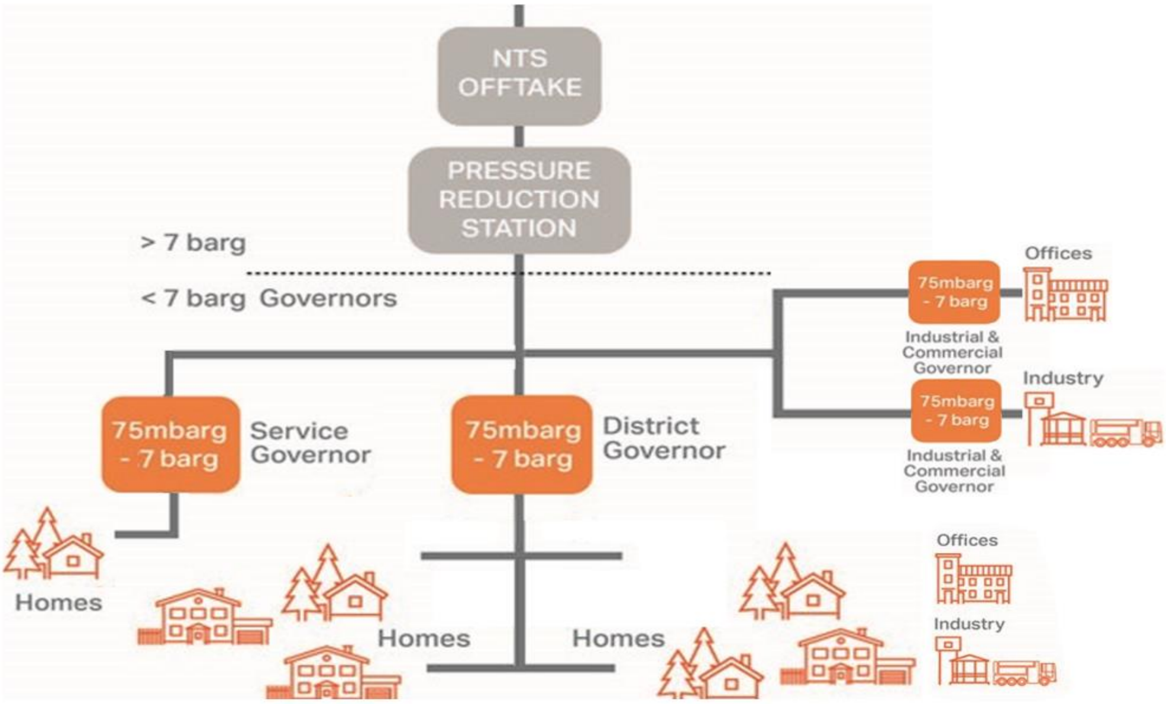

Figure 1: Diagrammatic representation of gas distribution network showing < 7 bar PRIs

A summary by region and asset type is shown below for <7bar assets:

Distribution Network	District Governor Stations	I&C Governor Stations	Service Governor Stations	Grand Total
East of England	3,822	1,856	18,045	**23,723**
North London	1,020	179	13,814	**15,013**
North West	2,753	1,503	2,523	**6,779**
West Midlands	1,810	724	3,581	**6,115**
Grand Total	**9,405**	**4,262**	**37,963**	**51,630**

Table 1: < 7Bar Governors Asset Stock April 2019: Sites containing PRSs

Pressure-Reduction Systems: How they work

The following diagram shows the key components of below 7 bar PRSs, which is a sub-system within a PRI, among the various other systems as described previously. These components are included within the scope of this document.

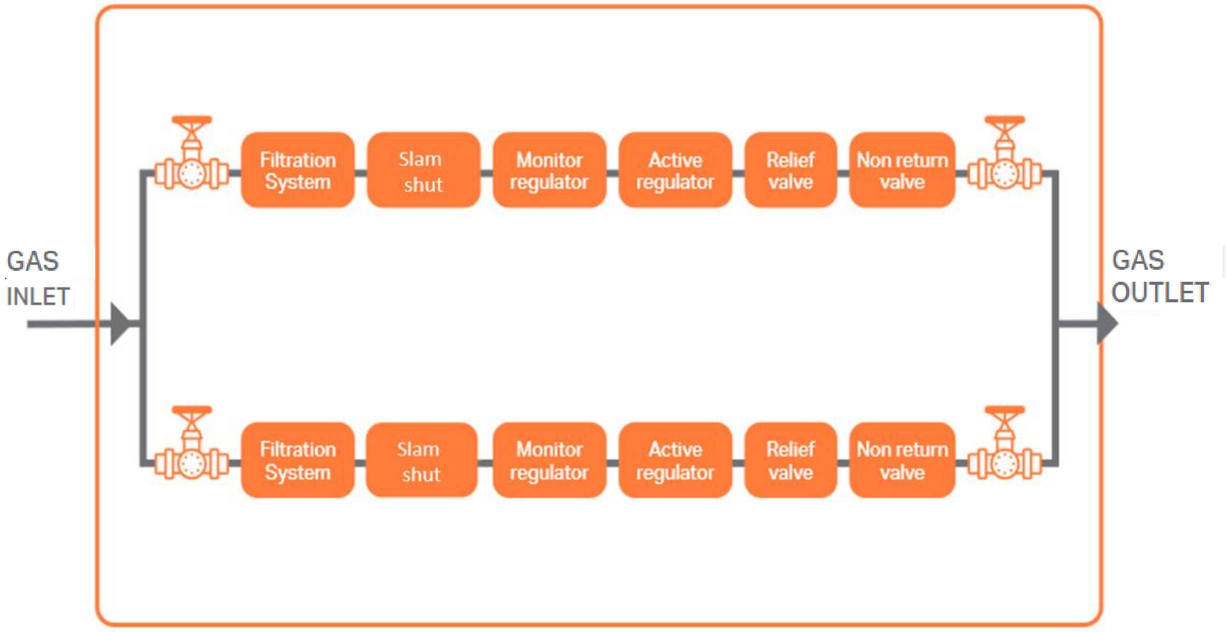

Figure 2: < 7 bar pressure-reduction system arrangement

A typical below 2 bar pressure-reduction installation will contain a stream inlet isolation valve, a filter, an over-pressure protective device (which could be a slamshut valve or a monitor regulator or a combination of both based on the design criteria applied at the time of construction) a pressure active regulator, a relief valve and a stream outlet isolation valve. An Intermediate Pressure (> 2bar) installation will have both a slamshut valve and a monitor regulator to prevent over-pressurisation downstream. The scope of this paper does not include the gas supply regulators on the profiling or pressure control systems.

The majority of below 7 bar pressure-reduction installations are designed as twin-stream installations which contain one working and one standby stream. Other configurations of below 7 bar PRI's have been used which include more than two streams for additional capacity, multiple single-stream installations supplying the same network (to optimise network resilience) and single stream installations where no redundancy is required. Typically, single-stream-systems will be supplying to smaller I&C customers where the customers have opted for the single stream.

These assets typically operate continuously, with their demand fluctuating throughout the day and year depending on gas demand.

The majority of below 7 bar PRIs have streams containing equipment that is ageing, (many installed pre-1960s) but remains in good condition and provides adequate performance. However, in some cases, the principal components of these installations are now obsolete: spares are unavailable and failure rates are elevated. The assets being proposed for replacement generally include such components.

Typical Pressure-reduction System components

Across these various PRSs, there are several key components, however, Pressure Regulators and Slamshuts have been deemed by Cadent to be the most critical equipment within the system and are therefore the focus of this investment paper. Photographs of some of these components are shown below:

Slamshuts

All our pressure control equipment, including slamshuts, can either be installed above or below ground. The following images show an example of the various installation types.

Figure 3: A Donkin 303 slamshut valve

Figure 4: Donkin vector buried module containing an internal slamshut

Regulators

Figure 5: An example of a Twin stream Donkin 280, Donkin 305 'Active/Slam auxiliary controlled with Wafer check'

Figure 6: A Donkin 280 regulator

Asset stock: Pressure-reduction System components

Regulators

The following table summarises the total number of < 7 bar PRIs, which contain the specific makes and models of regulators listed in the table. It should be noted that in the MP PRIs, there is normally a 1:1 ratio of regulators to slamshuts, whereas in IP systems, two regulators are generally incorporated in each stream and thus there are more regulators than the number of governors.

Regulator Model	Site population[1]		Asset obsolete (spares not available)
Donkin 280	3,276	23.8%	No
Donkin 680	3,012	21.9%	No
Donkin 270/277	2,881	21.0%	**No***
IGA 1800 Series	963	7.0%	No
ERS Module	752	5.5%	No
Jeavons J123	458	3.3%	No
Jeavons J81	**358**	**2.6%**	**Yes**
IGA Axial Flow	294	2.1%	No
Donkin 678/679	275	2.0%	No
IGA Orpheus	241	1.7%	No
IGA 3000 Series	218	1.6%	No
Fisher 99	162	1.2%	No
Rockwell 243	**218**	**1.6%**	**Yes**
Donkin 670/688 Reynolds	**132**	**1.0%**	**Yes**
Donkin Idaflo	**90**	**0.7%**	**Yes**
Krysalis	80	0.6%	**No****
Actaris 4000	69	0.5%	No
Tartarini	57	0.4%	No
Vector	49	0.4%	**No****
FlowGrid	48	0.3%	No
Jeavons J125	44	0.3%	No
Rockwell 121	**25**	**0.2%**	**Yes**
Fisher 298	**13**	**0.1%**	**Yes**
Actaris 2000	13	0.1%	No
Donkin 800	9	0.1%	No

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[1] For circa 25% of the sites, model and/or make of the regulators is unknown. These have been proportioned across the possible options using a simple distribution matching the proportion of assets in each class.

Regulator Model	Site population[1]		Asset obsolete (spares not available)
Donkin 320	5	0.0%	No
Actaris 3000	4	0.0%	No
Total	**13,667**	**100.0%**	

Table 2: Regulator population, by make and model

*The MK1 sub-category of Donkin 270s is obsolete but its population within the other variations is unknown and therefore no spend is proposed for them.

** Donkin Krysalis and Donkin Vector modules are categorised by the manufacturer as LSA (Limited Spares Availability); they are discontinued equipment where spares of the soft parts remain obtainable subject to demand and availability.

Units of Intervention: ‘Regulators sub-system’

To keep the analysis simpler, all regulators of the same make and model, the linked pilot regulators and the associated auxiliary pipework around the regulators, which form a ‘regulator-sub-system’ are counted as one unit of intervention. Therefore, if a governor station contains two of the regulators that need intervention and another two regulators which have not been proposed for intervention, one unit of intervention will mean the replacement of the proposed regulator units, all linked pilot regulators and any associated impulse pipework. From our SAP data, we know that there are 26,940 commissioned regulators on these 13,667 sites, which averages 1.97 regulators per site. Our RIIO-2 approach is to target intervention at components within a system rather than replace a whole system.

Slamshuts

The following table summarises the total number of slamshut population on below 7 bar PRIs, by makes and models.

Slamshut Model	Site population[2]		Asset obsolete (spares not available)
Donkin OPCO	3,076	22.68%	No
Donkin 305	2,934	21.64%	No
Jeavons J98	2,009	14.82%	**Yes***
IGA 100	1,258	9.28%	No
IGA OPSO	1,092	8.05%	No
Donkin 303	937	6.91%	**Yes**
ERS/Internal	864	6.37%	No
ERS Module	752	5.55%	No
IGA Orpheus	241	1.78%	No
Donkin 309	190	1.40%	No
Krysalis	80	0.59%	**No****
Tartarini BM5	49	0.36%	**Yes**
Donkin Vector	49	0.36%	**No****
IPSL	12	0.09%	No

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[2] For circa 28% of sites, the model and/or make of the Slamshuts is unknown. These have been proportioned across the possible options using a simple distribution matching the proportion of assets in each class.

Slamshut Model	Site population[2]		Asset obsolete (spares not available)
Audco Lineguard	10	0.07%	**Yes**
Donkin 302	6	0.04%	**Yes**
Fiorentini	1	0.01%	No
Total	**13,560**	**100%**	

Table 3: Above-ground slamshut population, < 7bar sites, by make and model

* Soft spares are available for 6” and 8” versions

** Donkin Krysalis and Donkin Vector modules are categorised by the manufacturer as LSA (Limited Spares Availability); they are discontinued equipment where spares of the soft parts remain obtainable subject to demand and availability.

Units of Intervention: ‘Slamshut sub-system’

From our SAP data, we know that there are 13,560 slamshuts on 13,667 governors, which gives us a 0.99 slamshuts/governor ratio. Similar to the regulator sub-system, if there are more than one slamshuts of the same make and model on one site, they are grouped together to count as the slamshut sub-system and denote one unit of investment.

4. Problem Statement

As our assets age and deteriorate, they are more prone to failures, which can, in turn, affect their ability to meet safety and reliability requirements. We have an absolute duty to comply with safety legislation.

These governors are critical in ensuring that our downstream systems are protected from over-pressurisation and an explosive release of gas, with the resulting risk to lives and properties. They also allow us to maintain downstream pressures to levels as low as possible to minimise leakage while keeping acceptable pressure at customers’ premises. These systems have fail-safes and therefore most failures will result in an interruption to supply downstream as the regulators/slamshuts fail-close. However, depending on the nature of the fault, the failure may occur in a fail-open position which may cause over-pressurisation of the downstream network, with potential safety implications.

Our base case supply-demand scenario for this investment case is our peak 1-in-20-year demand to comply with our licence obligations. The variability of demand in future forecasts is small; our demand would have to change significantly to require a step-up or down in the scope and scale of the proposed investment, and as such we have only considered one supply-demand scenario.

During 2019, we commissioned an independent specialist consultant, Enzen, to study the obsolescence in our asset stock and the RCM failure data. We provided Enzen with our asset population and attributes, obsolete equipment list (as at April 2018) and RCM data, and asked them to identify an appropriate investment proposal to hold risk flat through time. From this review, we identified several different components that were obsolete and without commercially available spares. This ‘asset obsolescence’ will prevent effective repairs in the future during planned and reactive maintenance, leading to a higher fault frequency as parts become worn. This, in turn, results in higher opex costs and the eventual failure of the asset with potential consequences of supply interruptions and safety incidents.

The following table summarises the obsolescence and reliability risks identified from this study.

	Medium reliability medium-frequency maintenance visits (24-30 months)	**Low reliability high-frequency maintenance visits (below 24 months)**
Obsolete: no spares available	Fisher 298 Jeavons J98 Donkin 303 Donkin/Rockwell 243 Donkin Idaflow Jeavons J81/J98 Slamshut combination	Jeavons J81 Donkin/Rockwell 121 Donkin 670/688 'Reynolds Governors' Donkin 302 Audco Lineguard Tartarini BM5

Table 4: Obsolescence risk identified from Engineering Study: 2019

Investment drivers

Two drivers of investment must be considered: Legislative (safety) and Interruptions to supply. In addition, we recognise the importance of investment plans that deliver optimum value for money. It is our obligation to provide the most efficient and cost-effective long-term solution to minimise customer bills while maintaining our legal obligation to provide a safe and reliable gas distribution system.

Legislative (safety): We invest in these assets to comply with the Pressure Systems Safety Regulations 2000 (PSSR). The PSSR covers the safe design and use of pressure systems and applies specifically to IP pressure tier.


Approved Code of Practice and guidance

The Pressure Systems Safety Regulations 2000 (PSSR) cover the safe design and use of pressure systems. The aim of PSSR is to prevent serious injury from the hazard of stored energy (pressure) as a result of the failure of a pressure system or one of its component parts.

Figure 7: HSE Code of Practice

The equipment must be maintained in such a way that pressures in the system are not compromised. If a pressure reducing unit fails, this could lead to pressure in the downstream system being increased to an inappropriate level, leading to failure of the downstream network and an uncontrolled escape of gas at pressures higher than the network design parameters.

We also need to comply with GS(M)R 1996 which mandates us to work in accordance with our safety case to ensure safe operation of our network.

Interruptions to supply: The failure of pressure regulating equipment can cut off gas to the downstream customers. Hence, failure to manage these assets appropriately increases the likelihood of interruptions to supply for all downstream customers.

Required outcomes

We have an absolute duty to comply with our legal obligations. The increase in safety risk stemming from no investment is unacceptable. Customers and stakeholders have consistently told us that worsening levels of reliability and network security is not in line with their views.

In summary, the required outcomes for this investment are a safe and reliable system. Success is measured by ensuring safe operation, legal compliance, and avoidance of any failure which leads to downstream interruptions or over/under-pressurisation.

We will consider our investment plans to be acceptable and appropriate, if and only if, these outcomes are met.

4.1. Narrative Real-life Example of Problem

The example below illustrates our RIIO-1 RCM process, identifying unacceptable failure rates on a specific make and model of a slamshut device, which is a critical safety feature of the pressure-reduction system.

PSSR considers the slamshut in a PRS as the 'primary protective device.' It is the final or ultimate device to prevent safe operating limits being exceeded. As the last line of defence, it is therefore essential that all slamshuts within Cadent's network comply with industry standards and specifications.

All BM5 slamshuts are fitted with the OS/88 actuator, which is an adapted version of the OS/80 actuators. The OS/80 actuator was known to operate unreliably with slight external vibration, with a potential impact of downstream under-pressurisation.

Figure 8: BM5 Slamshut device

The BM5 OS/88 Actuator continues to cause issues within Cadent's networks, and there is ample fault data evidence logged in the RCM database of the slamshuts failing to operate during functional checks due to multiple failure modes, with stiction (inability to overcome the friction between stationary parts) standing out as a leading defect type.

RCM fault data analysis indicates 53% of these faults recorded on the BM5s occurred in the open position (major risk of over-pressurisation), 14% in the closed position (risk of under-pressurisation), and 33% on all other types of failure. While there are several causes of these failures, a consistently evidenced underlying factor points to a poor adaptation design of the slamshut models.

Compliance with PSSR 2000 and IGEM Industry Standard IGEM/TD/13 requires that a slamshut operates within 10% of its setpoint during a functional check, and anything above 10% of its setpoint or greater than the Safe Operating Limit (SOL) is considered unacceptable and should be reported as an A2 (serious) fault as stipulated by PSSR 2000.

The impact of these failures has a wider implication for the entire network pressure configuration and poses a serious process safety risk to our customers. If the BM5 slamshut fails to operate on a stream where there is a regulator with an existing fault, it may fail to prevent a downstream over-pressurisation, exceeding the SOLs. This would require us to disconnect the downstream network to make it safe which will cause loss of supply to customers and a breach of the PSSR 2000 requirements. There is also a risk of injury or death to staff and/or the general public as a result of a downstream over-pressurisation.

During RIIO-1, a number of these slamshuts are being replaced under this investment area. The RCM and fault reporting process will continue to monitor our equipment during RIIO-2 and to highlight equipment that fails the acceptable risk threshold. For RIIO-2, we have combined our internal analysis with a review by an external consultant examining our RCM and fault data to identify interventions on assets which pose the most process safety risk to Cadent and our customers.

4.2. Spend Boundaries

Figure 2 shows the typical arrangement of equipment with these assets. The spend boundaries are within the orange border.

There can be a final element of pressure control at the customer's property – a service governor. We do not have a specific programme of service-governor replacement, instead, these low-cost assets will be replaced as part of other work (e.g. a service relay or operational repair). We are therefore not forecasting any specific spend for service governors in RIIO-2.

This document also does not include any specific capex investment to cover the filters, which are upstream and outside of the pressure reduction system boundary. All < 7 bar assets (including these < 7 bar filters) are not covered by the maintenance regime stipulated within Pressure System Safety Regulations (PSSR). During RIIO-2 however, they are included in our routine maintenance schedule. We propose to continue the current programme of inspection and reactive fix-on-fail maintenance for them, based on the RCM process.

5. Probability of Failure

Introduction

We have used our historical fault data on our below 7 bar pressure-reduction systems, to update our monetised risk-reporting model to evaluate risk.

The Network Output Measures (NOMs) methodology, developed with Ofgem, is an approach that allows us to understand the risk on our assets and the benefit that investment will have. We have followed good practice set out in the NOMs methodology[3] in developing our probability of failure and consequence of failure estimates for pressure-reduction system components. This is summarised below and in Section 6. This approach models the entire pressure-regulating system rather than individual components within the PRS.

We commissioned an independent consultant, Enzen, to review the asset stock with regard to the likelihood and consequences of failures. This included an examination of obsolescence and RCM fault data.

This obsolescence risk is not well represented in our model at a granular level. The impact of obsolescence is complex but is explained further below.

Obsolescence means that, while the asset can continue to be inspected and functionally tested, without spares to deal with wear and tear or damage, there is an increased risk of a total failure of the equipment.

A few of the obsolete assets identified are showing a higher maintenance frequency, other obsolete assets still appear to be operating reliably. The RCM process ensures that our reliability is managed by adjusting the frequency of maintenance. However, on obsolete assets, when they fail, they will need to be replaced reactively, and reacting to such a failure in a controlled manner will not be possible due to the obsolescence. The unreliable obsolete assets have a greater probability of failure and therefore pose a greater risk.

The maintenance frequency has been considered with respect to the optimum solution for RIIO-2 and 3. Refer to the options summary in Section 7 for further information.

Failure modes

The same failure modes are used across the assets, albeit with different failure rates.

- **Capacity failure** – where the governor is under-sized to meet downstream demand (this particular failure mode is not relevant for this investment case)
- **Fail closed –** where a regulator fault has been assessed to result in a fail in the closed mode
- **Fail open** – where a regulator fault has been assessed to result in a fail in the open mode
- **Interference failure** – for example, third-party damage
- **Corrosion failure** – corrosion of the internal pipework
- **Governor emissions** – background leakage from the system
- **Control System failure** – failure of the telemetry or associated electrical or instrumentation systems and profilers

Our assessment of the probability of failure is part of developing our end-to-end analytical framework for these assets, which is shown in the risk map below. The yellow nodes show the failure effects (we do not consider the different detailed asset component failures that could drive these failure effects).

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[3] NOMS, March 2016, Appendix C.
https://www.ofgem.gov.uk/system/files/docs/2019/03/2_gdnssectoralrebasingmethodology.pdf

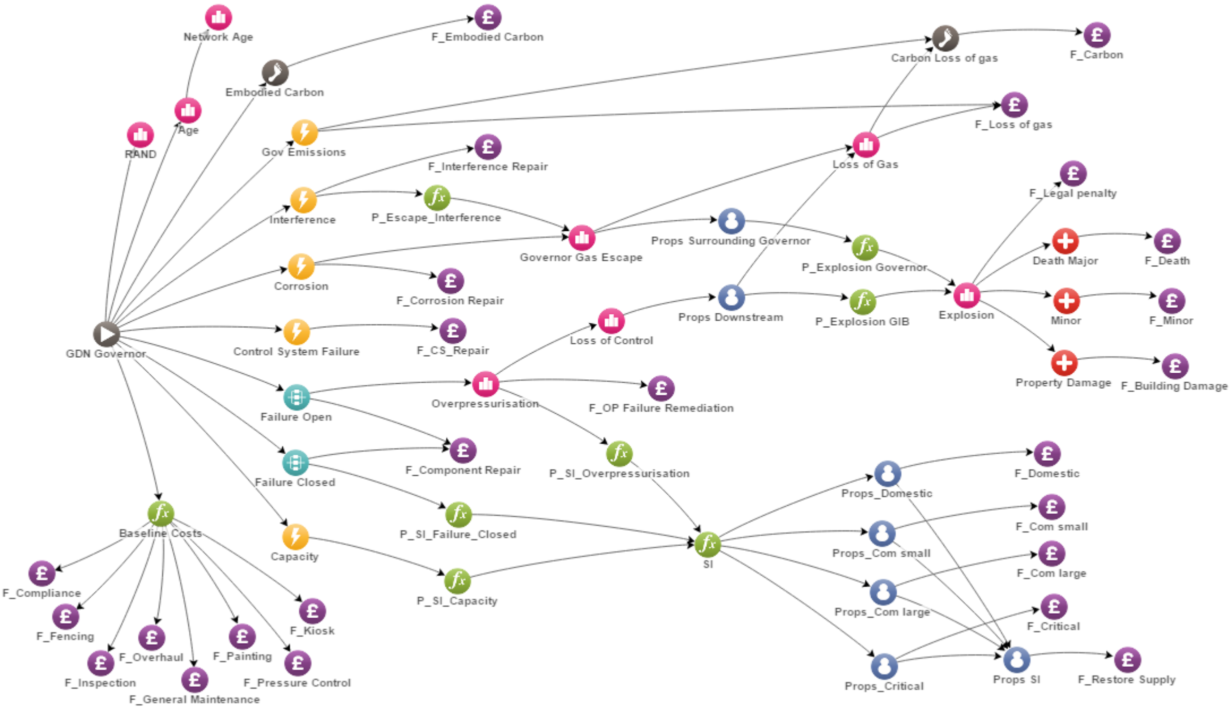

Figure 9: Governors Risk Map

This risk map also shows the consequences of failure, which is explained in the next section. Applying the failure models to our asset base gives the following predictions of failures over time.

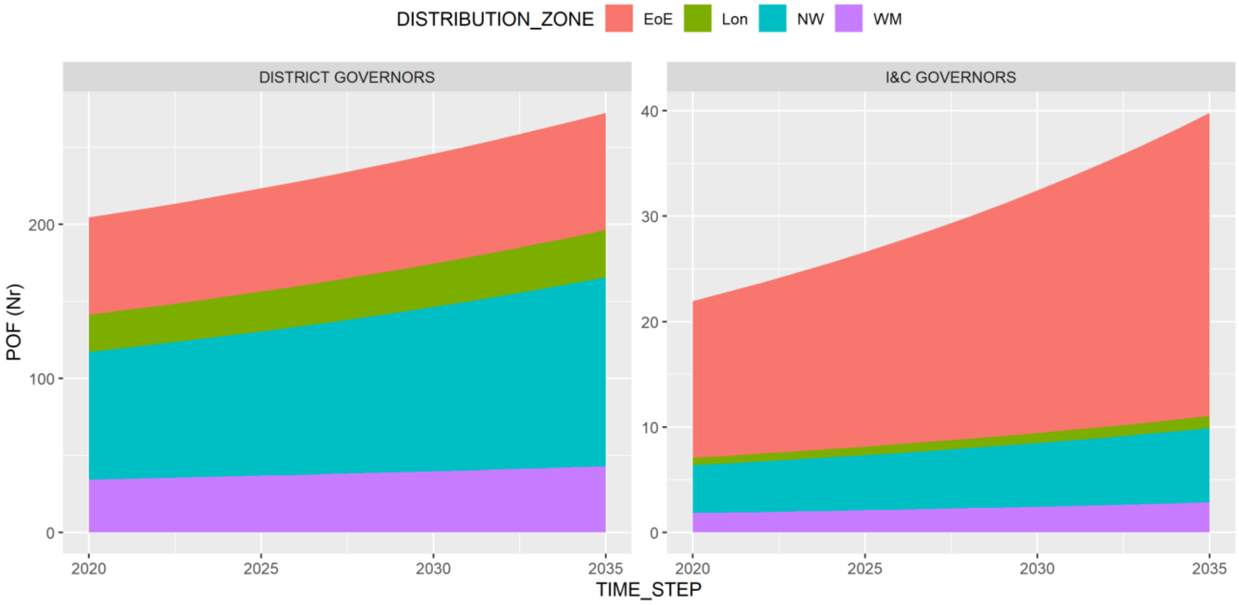

Figure 10: Probability of failure (PoF) over time for reactive only (no investment) split by asset category coloured by distribution zone. (N.B. the Y-axis is independent for each plot)

The ‘reactive only’ plot shows an increasing trend of PoF across all networks with North West (blue) the largest for District Governors (left plot) and East of England (pink) the largest for I&C (right plot). The plot below shows the normalised failure POF (failures per 1000 assets) per network over time with North West the highest for District Governors and East of England for I&C with District also showing higer failures for all networks.

To show the impact of condition and observed failures alone, the plot below shows the normalised failure POF (failures per 1000 assets) per network over time - with North West the highest for District Governors and East of England for I&C with District also showing higher failures for all networks.

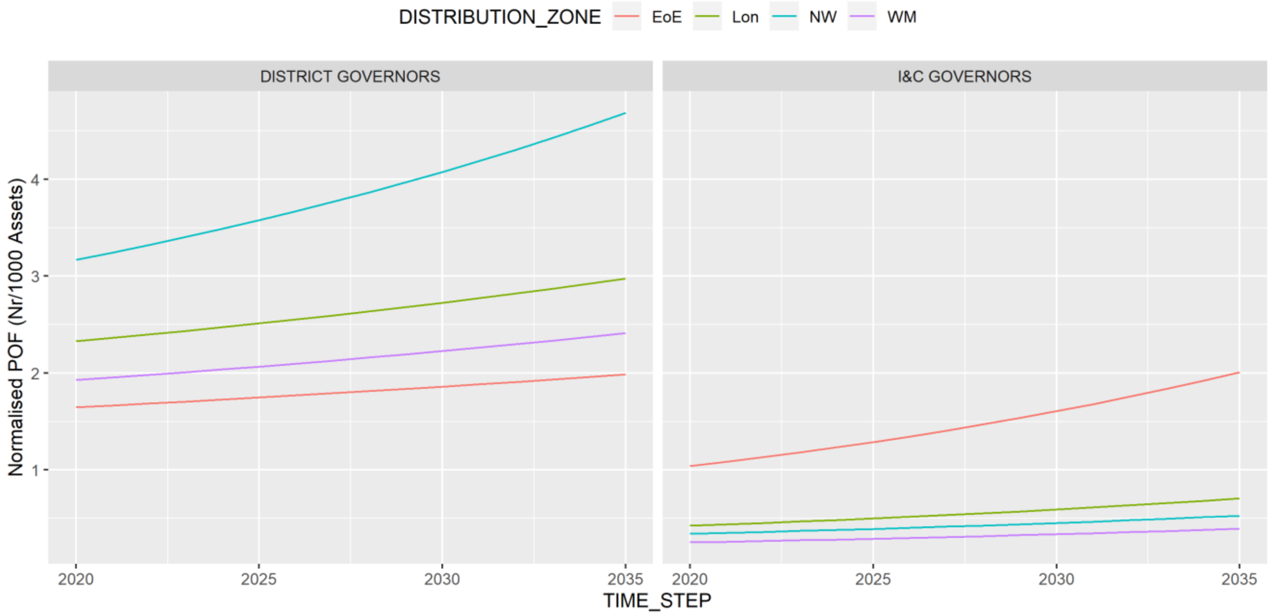

Figure 11: Normalised Probability of failure (PoF) over time for reactive only (no investment) split by asset category coloured by distribution zone

Associated with failures are asset and performance risks. The key risks associated with the reactive-only position is shown below:

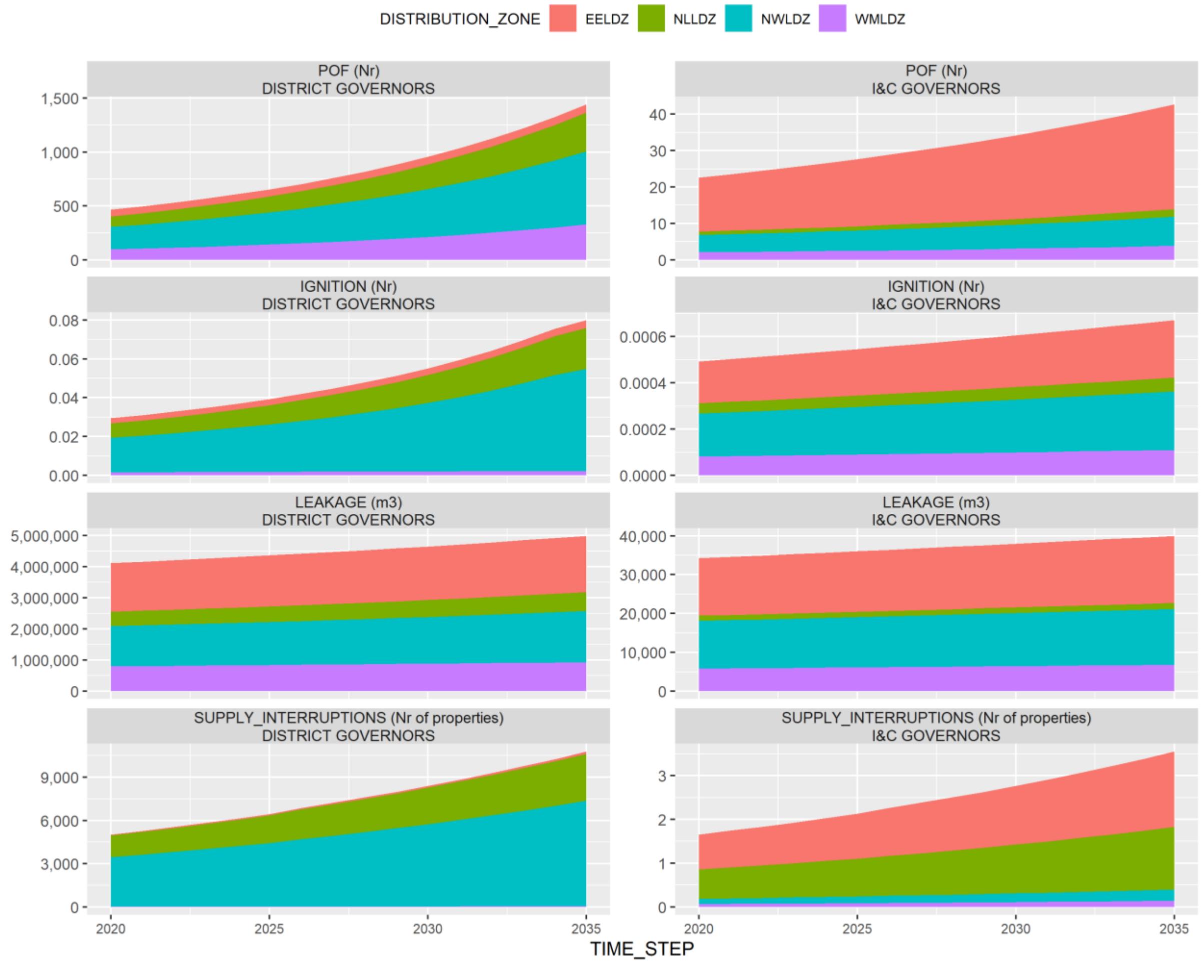

Figure 12: Key asset health and performance measures over time for reactive only (no investment) split by asset category coloured by distribution zone (N.B. the Y-axis is independent for each plot)

The key asset health and performance measures reactive only plot shows an increasing trend across all networks with North West (blue) more proportional for District Governors, and East of England for I&C due to having proportionally more failures which drives subsequent risk.

5.1. Probability of Failure Data Assurance

These failure models are taken from the NOMs methodology. We have applied these models to our asset base. Asset-base data is sourced from SAP and NOMS.

Cadent has used the core system (SAP) and RCM supporting data to define PoF for governors at a system level, in line with existing RCM processes. RCM analyses governor performance based on the configuration and make and model of the regulator/slamshut for category 1 (fail open) and 2 (fail closed) type failures which have a downstream impact. This analysis uses a temporal range of four years and is weighted more heavily to the recent years’ failure rates. Depending on the mean time before failure (MTBF), the RCM process alters maintenance frequencies to ideally achieve a flat failure rate or a rate within the thresholds defined in our policies and design specifications. In general, the RCM process is well defined.

RCM only considers these two failure types as they are the predominant factors in the operational risk for governors; however, the monetised risk-methodology also considers additional failure types including corrosion, third-party interference, control-system failure and capacity issues. The data source used for these failure types is fault data captured through mobile data capture (MDC) fault forms. This includes detail of the fault cause, defective part and consequences. In general, the data is of a reasonable quality, allowing trend analysis and setting of PoF by installation type. The temporal range for this data set is 7.6 years and includes approximately 16,000 records relating to mechanical failures that are specific to governor installations. There are some data deficiencies as not all records are recorded at an asset level and some of the data fields can be subjective.

We have assured the application of the NOMs models to our asset base. This has involved using our decision support tool, AIM, to apply the failure models each year to our asset base. The outputs of this process have been subject to ongoing validation checks:

- Do the predicted total yearly failure counts align with historical data and with expert judgement?
- Are the failure counts by equipment type aligned with historical data and with expert judgement?

Based on this analysis, we are confident that we have applied the models correctly.

Our engineering assessment, produced by Enzen, has used the following data in its assessment:

- RCM frequency has been derived from the “SAP District & IC Governors with Equipment Details” (the file was provided on 2nd April 2019).
- The Asset Base has been derived from the “SAP District & IC Governors with Equipment Details” (the file was provided on 2nd April 2019).
- Cost data has been taken from “Governors F_Replace Lookup table”, the file was provided on 30th May 2019.

6. Consequence of Failure

Linking failures to consequences

Using the NOMs methodology, our monetised-risk model links failure modes to the probability of failures and their potential consequences. The consequences of failure used within the model are:

Risk	Description
Safety Risk	Uncontrolled release of gas or ignition – either at the governor station itself or in the downstream network
Interruptions to supply	Interruptions to customers in the network downstream of the governor station
Environmental Risk	Loss of gas - arising from the governor station itself or the downstream network
	Governor gas escape - that could result in increased numbers of escapes being reported by the public
Other	Loss of control – this results in a sub-optimum pressure leaving the station but is not severe enough to result in a supply interruption

Table 5: Consequences of failure

Each potential consequence has been expressed as monetary values as per the agreed industry NOMs methodology, as shown below:

Customer Driver	Data source
Environment – GHG emissions	Redacted due to commercial sensitivity
Safety – injuries and deaths	
Interruptions to supply – per property	
Other societal impacts	
Financial impact – cost of repairs (unit)	
Financial impact – cost of replacement (unit)	

Table 6: Sources of societal benefits

These have been estimated using a range of sources, including our own willingness-to-pay (WTP) research with our consumers as well as published government values for carbon, risk of fatality, and non-fatal injuries.

We have also included the financial consequences associated with fixing failures as they occur (e.g. repair costs) and remedying the consequences of failures (e.g. clean up and compensation). Our financial impacts are based on a robust assessment of our costs.

All these consequences can be seen in the risk map presented in Section 5. The pink nodes represent the consumer and environmental impacts, the red nodes are the safety impacts, and the purple nodes are the financial consequences.

The plot below shows the percentage contribution of monetised risk components as described in Table 5 above. This plot shows the proportion of key risk components for each asset category over time. An increasing proportion of environmental (pink) and system (purple) risk can be seen with a large proportion of financial risk (green) particularly for I&C governors, associated with repairs, maintenance and other financial impacts as described in the table above.

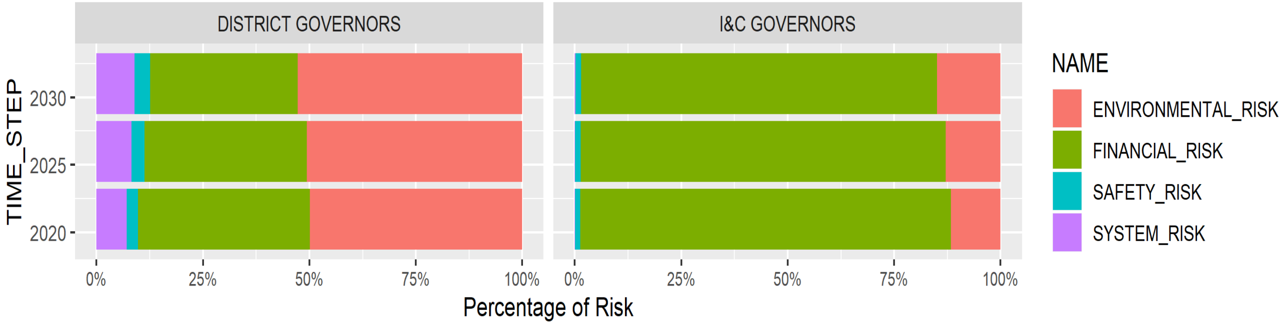

Figure 13: Proportion of risk components over time split by asset class

7. Options Considered

Introduction and overall approach used

Our objective is to build a plan which best reflects customer and stakeholder expectations. In RIIO-1 we invested in the AIM decision-making tool to allow us to build asset management capability using the NOMs approach.

We have used bottom-up engineering assessments and our NOMS monetised-risk model to develop and appraise investment options for our RIIO-2 plan.

We have developed a full option list to consider in our CBA. This represents a mix of cost and activity levels and provides a comprehensive set of options to develop and challenge our investment plans for this asset.

The options we have considered are summarised below, and include several options considered as part of sensitivity testing which are for comparison purposes only.

Option	Description
0	**Reactive only**
1	**Engineering volumes option (Chosen)** This option involves targeted investment to meet our requirements. This is a bottom-up engineering assessment; with the NPV of the option derived using our monetised risk model.
2	**Minimum investment to maintain stable risk (RIIO-2 only)** This option minimises the investment (capex spend) required to hold monetised risk flat until the end of RIIO-2
3	**Maximum whole-life benefit (RIIO-2 only)** This option maximises the whole life net benefit (CBA) – selecting those investments that are cost beneficial for our customers.
4	**Continue with RIIO-1 investment levels at least failure (RIIO-2)** This option uses our monetised risk model to continue the level of RIIO-1 investment into RIIO-2. In this option we minimise the number of failures given the RIIO-1 investment constraint – and ignore any other requirements on investment.
5	**Maximum whole-life benefit (RIIO-2 and RIIO-3)** This comparative scenario shows the RIIO-3 investment associated with Option 2. It is useful in showing the additional spend in RIIO-3 from delivering cost beneficial investment.
6	**Continue RIIO-1 volumes in RIIO-2 (Reactive)** For comparison purposes, we have considered Option 4 again, but have not assumed that the RIIO-2 investment will be delivered to minimise failures. This option recognises that investment may be reactive (in response to other drivers of investment); and shows how cost beneficial it is to continue RIIO-1 investment into RIIO-2 under the reactive targeting of investment. Taken with Option 4, this gives the range of benefits we can expect to achieve from continuing RIIO-1 investment levels into RIIO-2.
7	**Engineering volumes option with maximum benefits** For comparison purposes, we have also considered our preferred option using our monetised risk model to select volumes that will maximise the benefits to customers. It may not be possible to pick these in reality to meet our obligations, but this shows the potential maximum benefits associated with our legal requirements.
8	**Chosen option less customer WTP** For comparison purposes, we have also considered our preferred option excluding customer willingness to pay for interruptions to see if the option is still value for money without this element considered.

Table 7: The Options Modelled

Options 2, 3 and 4 focus on replacement options (spares are not available for the obsolete assets under consideration and as such refurbishment has not been examined). Option 1 has, however, looked at different solution options to derive its preferred investment programme.

Our approach to modelling:

We are using AIM to support the build of the RIIO-2 plan. AIM allows us to model different investment scenarios and produce optimised plans and test their cost benefit. The CBA capability within AIM has the ability to find the solution to a problem with many restrictions and offer potentially millions of possible solutions.

Using AIM to model these assets involves forecasting how the asset base will perform into the future in terms of asset failures, the impacts on consumers and the environment, and the financial impact.

The unit costs used in the model are summarised in ‘Options Cost Summary’ below.

Our approach to CBA and options analysis

We have used CBAs in assessing the costs and benefits of investment to determine if the benefits outweigh the costs. Our approach to discounting aligns with the Spackman method, which has been embedded within AIM.

For any scenario, we have understood the year on year totex costs, together with monetised risk impacts in a CBA. Costs and benefits are discounted and shown in present value (PV) terms in line with Ofgem requirements and HM Treasury Green Book.

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7.1 Preferred Option 1: Engineering Volumes Option to Replace Obsolete Asset Components

This option has been derived from a detailed engineering assessment undertaken by Enzen between March and August 2019.

Enzen identified 11 makes and model of regulators and slamshuts that were obsolete. They used fault data to assess the optimum investment strategy to maintain asset reliability throughout RIIO-2 and 3 at the lowest whole-life cost at a component level.

This Enzen study has built on learning from RIIO-1. During RIIO-1, we developed a targeted investment programme focussed on replacing components that were obsolete. We have further-refined our approach during RIIO-2, as part of our Option 1, derived from the engineering study. We have looked at ways to further extend the life of our obsolete assets, by carrying out a suitable volume of proactive replacements early on to create a stock of critical spares that can then be used to maintain the remaining stock of obsolete components. We look to prioritise the proactive replacement of our obsolete assets where there is evidence of poor reliability. In this way, we minimise spend while increasing the asset life of our asset-base in a planned-way. We are therefore confident that our Option 1 gives value-for-money and is an appropriate way to manage the reliability of our assets.

Obsolete, no spares	Medium reliability	Proactive replacement of small % of sites, to provide critical spares for remaining asset stock
Obsolete, no spares	Low reliability	Proactive replacement of all assets over 5 years

Figure 14: Chosen approach to targeting investment in RIIO-2

The following scenarios have been considered based on the availability of spares and asset reliability of each equipment type:

- **Option A**: Soft spares are available for a limited period - Continue to maintain ‘as is’ and reassess strategy for RIIO-3
- **Option B**: Spares not available, high or medium reliability so manage risk during RIIO-2 – Replace in RIIO-3 or reassess strategy for RIIO-3
- **Option C**: Spares not available, medium reliability (medium probability of failure /medium maintenance frequency), begin proactive replacement programme with only critical sites replaced in RIIO-2, retain a stock of refurbished units for emergency use and replace remaining assets in RIIO-3
- **Option D:** Spares not available, and due to low reliability (high probability of failure/ high maintenance frequency) or the small size of the asset stock, full replacement is recommended over five years.
- **Option E:** Spares not available and low reliability, replacement of all asset stock recommended over RIIO-2 and RIIO-3 years to manage deliverability constraints

The preferred recommendations for the investment strategy for each of the 11 items are summarised below.

Asset component	Description of Problem	Preferred option	Recommendation: RIIO-2 strategy	Recommendation RIIO-3 strategy	Unit Cost Details
Jeavons J81 (Regulators)	257 J81 Regulators currently have a 3-monthly RCM inspection, indicating high failure rates and thereby a very low level of reliability No spares available	**Option E:** Proactively replace all J81 regulators phased over RIIO-2 and RIIO-3.	Replace 132 regulators and slamshuts. 51% in RIIO-2	Replace 125 regulators and slamshuts. 49% in RIIO-3	Redacted due to commercial sensitivity
Jeavons J81/J98 (Regulator - Slamshut combination)	86 installations with J81 and J98 slamshut combinations, where inspection intervals are 21 months, suggesting medium reliability combination No spares available	**Option B:** Medium reliability so manage risk during RIIO-2. Replace in RIIO-3 or reassess strategy for RIIO-3.	No replacement in RIIO-2	Replace all 86 in RIIO-3	
Donkin/Rockwell 243 (Regulators)	218 active/slamshut configurations require inspections at 30 months, suggesting they are steadily becoming unreliable. Some IP site intervals are 24 months. No spares available	**Option B:** Higher reliability so manage risk during RIIO-2. Replace in RIIO-3 or reassess strategy for RIIO-3.	No replacement in RIIO-2	Replace all Rockwell 243 regulator and ageing slamshut units at 218 sites 132 on MP and 65 on IP network	
Donkin/Rockwell 121 (Regulators)	26 Donkin/Rockwell 121 regulators where the average inspection is 12 months, but 1 unit at a 3-month frequency indicates that they are becoming increasingly unreliable. The fleet is now obsolete and no longer supported by the Original Equipment Manufacturer.	**Option D:** Low reliability - proactively replace all in RIIO-2.	Replace 26 regulators and slamshut combinations in RIIO-2	No replacement in RIIO-3	
Fisher 298 (Regulators)	13 sites with a variety of slamshuts. A small number of sites implying that it is uneconomical to continue to operate these installations	**Option D**: Proactively replace all in RIIO-2, as it isn't economical to source spares due small number in asset stock.	Replace 13 regulators and ageing slamshuts combinations in RIIO-2	No replacement in RIIO-3	
Donkin 670/688 'Reynolds Governors' (Regulators)	132 'Donkin 670/688 Reynolds regulators'. These have had technical obsolescence issues over the years and have a significant risk of a failed closed failure.	**Option C:** Replace only critical sites in RIIO-2, retain a stock of replaced units for emergency use. Replace remaining assets in RIIO-3.	Replace 30 (23%) in RIIO-2	Replace 102 (77%) in RIIO-3	

Asset component	Description of Problem	Preferred option	Recommendation: RIIO-2 strategy	Recommendation RIIO-3 strategy	Unit Cost Details
Donkin Idaflow (Regulators)	90 Donkin Idaflow sites, mainly IP. Maintenance intervals are between 48 months and 72 months. No spares available	**Option B:** Expect completion of RIIO-1 plan to replace all during RIIO-1. If any remaining, replace in RIIO-2.	No additional funding required	No additional funding required	
Jeavons J98 (Slamshuts)	2009 J98 slamshuts in use. While still effective, they are over 20 years old and deteriorating. No spares available	**Option C**: Proactively replace on critical site, retain replaced equipment for spares. Reassess RIIO-3 strategy	Replace 95 MP and 5 IP slamshuts	Reassess strategy for RIIO-3	
Donkin 302 (Slamshuts)	5 Donkin 302 sites have these slamshuts installed which need to be replaced as there is a very small number of them, also obsolete	**Option D**: Proactively replace all in RIIO-2.	Replace 5 in RIIO-2	No replacement in RIIO-3	
Donkin 303 (Slamshuts)	937 Donkin 303 sites where obsolete parts cannot be re-engineered due to legal (Intellectual Property) issues. No spares available	**Option C:** Proactively replace on critical sites, retain replaced equipment for spares. Reassess strategy for RIIO-3	Replace 94 MP and 5 IP slamshuts in RIIO-2	Reassess strategy for RIIO-3	
Audco Lineguard (Slamshuts)	9 Audco Lineguard sites have complex and ageing systems for actuating ball or plug stream valves. These are outdated and now unconventional. No spares available	**Option D:** Proactively replace all in RIIO-2.	Replace all 9 in RIIO-2 using site-level unit costs due to complexity and integration of the system	No replacement in RIIO-3	
Tartarini BM5 (Slamshuts)	49 x Tartarini BM5 slamshuts where reliability issues are occurring. No spares available	**Option E**: Proactively replace all phased over RIIO-2 and RIIO-3	Replacement of 55% of the BM5s: 26 IP and 3 MP slamshuts	Replacement of the remaining 45%: 20 IP slamshuts	
Buried Modules	Difficult to access Spares available for all, except for Donkin Vector and Krysalis modules, which only have soft spares available subject to demand and availability.	**Option A:** Soft spares available for limited time (for Krysalis and Vector), continue to maintain as-is and re-assess strategy for RIIO-3.	No replacement in RIIO-2	Reassess strategy for RIIO-3	

Table 8: Option 1: Summary of recommendations from Enzen study

A summary table showing the unit costs used for this engineering assessment is shown below.

Medium Pressure Unit Costs				
Component Size	**Regulator**	**Slam shut**	**Complete site**	**Notes**
2"				
3"				
4"				
6"	Redacted due to commercial sensitivity			
8"				
12"				
Mean				

Intermediate Pressure Unit Costs				
Component Size	**Regulator**	**Slam shut**	**Complete site**	**Notes**
2"				
3"				
4"				
6"	Redacted due to commercial sensitivity			
8"				
12"				
Mean				

Note: The mean has been calculated by excluding the unit costs for 12" components. The number of 12" assets in our asset stock is very low and would unrealistically skew the mean cost for this category

Table 9: Unit Costs used for Medium Pressure components within Option 1

Based on the above recommendations, our Option 1 has the following cost profile for RIIO-2 and 3.

Equipment type	Capex/yr. (£s)										RIIO-2 Total	RIIO-3 Total
	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31		
Jeavons J81												
Jeavons J81/J98 Slamshut												
Donkin/Rockwell 243												
Donkin/Rockwell 121												
Fisher 298												
Donkin 670/688 'Reynolds Governors'												
Donkin Idaflow												
Jeavons J98												
Donkin 302												
Donkin 303												
Audco Lineguard												
Tartarini BM5												
Buried Modules												
TOTAL												

Redacted due to commercial sensitivity

Table 10: Option 1: proposed cost profile

The corresponding spend profile split into our four gas distribution networks, for the above spend, is shown below:

	Capex/yr. (£s)										RIIO-2 Total	RIIO-3 Total
	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31		
East of England												
North London												
North West												
West Midlands												
TOTAL												

Redacted due to commercial sensitivity

Table 11: Option 1: proposed cost profile split by gas distribution network

7.2 Option 2: Minimum Investment to Maintain Stable Risk (RIIO-2 Only)

We have used our NOMs monetised-risk model to assess the investment needed to 'hold monetised risk flat'. Constraints are applied so that the total monetised risk is maintained, this allows individual risk categories (e.g. safety, environment, etc) to increase or decrease in delivering stable risk.

This model run has chosen the following intervention volumes and recommended the following RIIO-2 spend profile.

Volumes of interventions/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	3	288	473	457	661	**1,882**
Lon	0	1	0	0	0	**1**
NW	1	0	0	0	1	**2**
WM	3	142	256	291	345	**1,037**
Total	**7**	**431**	**729**	**748**	**1,007**	**2,922**

Table 12: Proposed RIIO-2 intervention volume profile for Option 2

£m/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 13: Proposed RIIO-2 spend profile for Option 2

7.3 Option 3: Maximum Whole-life Benefit (RIIO-2 Only)

This option maximises the whole life net benefit (CBA) – selecting those investments that are cost beneficial for our customers.

Volumes of interventions/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	0	0	0	0	0	**0**
Lon	2	1	0	4	2	**9**
NW	9	10	11	7	9	**46**
WM	0	0	0	0	0	**0**
Total	**11**	**11**	**11**	**11**	**11**	**55**

Table 14: Proposed RIIO-2 intervention volume profile for Option 3

£m/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 15: Proposed RIIO-2 spend profile for Option 3

7.4 Option 4: Continue RIIO-1 Volumes at Least Failure (RIIO-2 Only)

This option uses our monetised risk model to continue RIIO-1 investment levels into RIIO-2 minimising the number of failures. In this option, we deliver this to minimise the number of failures in our assets. The model therefore minimises the number of failures, subject to the RIIO-1 investment constraint.

Volumes of interventions/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	263	262	251	262	258	**1,296**
Lon	214	153	130	119	123	**739**
NW	202	172	131	172	157	**834**
WM	110	106	105	101	75	**497**
Total	**789**	**693**	**617**	**654**	**613**	**3,366**

Table 16: Proposed RIIO-2 intervention volume profile for Option 4

£m/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 17: Proposed RIIO-2 spend profile for Option 4

7.5 Option 5: Maximum Whole-life Benefit (RIIO-2 and RIIO-3)

This comparative scenario shows the RIIO-3 investment associated with Option 2. It is useful in showing the additional spend in RIIO-3 from delivering cost beneficial investment.

Volumes of interventions/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	0	0	0	0	0	**0**
Lon	2	1	0	6	0	**9**
NW	9	10	11	5	11	**46**
WM	0	0	0	0	0	**0**
Total	**11**	**11**	**11**	**11**	**11**	**55**

Table 18: Proposed RIIO-2 intervention volume profile for Option 5

£m/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 19: Proposed RIIO-2 spend profile for Option 5

7.6 Option 6: Continue RIIO-1 Volumes in RIIO-2

For comparison purposes, we have considered Option 4 again, but have not assumed that the RIIO-2 volumes will be delivered in a way that minimises failures. This option recognises the other drivers of investment; and shows how cost beneficial it is to continue RIIO-1 average annual volumes into RIIO-2 with differing assumptions about the targeting of investment applied. This is applied in AIM as an annual investment limit. Taken with Option 4, this gives the range of benefits we can expect to achieve from continuing RIIO-1 volumes into RIIO-2.

Volumes of interventions/yr.						
Region	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EoE	127	131	130	127	135	**650**
Lon	112	106	109	112	106	**545**
NW	98	93	94	98	94	**477**
WM	53	57	58	55	58	**281**
Total	**390**	**387**	**391**	**392**	**393**	**1,953**

Table 20: Proposed RIIO-2 intervention volume profile for Option 6

£m/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 21: Proposed RIIO-2 spend profile for Option 6

7.7 Option 7: Engineering Volumes Option with Maximum Whole-life Benefit

For comparison purposes, we have also considered our preferred option using our monetised risk model to select volumes that will maximise the benefits to customers. It may not be possible to pick these in reality to meet our obligations, but this shows the potential maximum benefits associated with our legal requirements.

Volumes of interventions/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	**Total**
EoE	46	40	40	37	36	**199**
Lon	21	17	18	14	14	**84**
NW	22	19	18	17	17	**93**
WM	19	13	13	12	12	**69**
Total	**108**	**89**	**89**	**80**	**79**	**445**

Table 22: Proposed RIIO-2 intervention volume profile for Option 7

£m/yr.						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 23: Proposed RIIO-2 spend profile for Option 7

7.7 Option 8: Chosen option less customer WTP

For comparison purposes, we have also considered our preferred option excluding customer willingness to pay for interruptions to see if the option is still value for money without this element considered.

The costs and volumes associated with this option are as per the preferred option, and are not repeated here.

7.8 Options Technical Summary Table

Option	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Description	Engineering Volumes Option (Chosen)	Min Investment to Maintain Stable Risk (RIIO-2 only)	Max Whole-life Benefit (RIIO-2 only)	Continue RIIO-1 Investment at Least Failure (RIIO-2)	Max Whole-life Benefit (RIIO-2 and RIIO-3)	Continue RIIO-1 investment in RIIO-2 (annual constraint)	Engineering Volumes Option with Max Benefits
First year of spend	Year 1	Year 1	Year 1	Year 1	Year 1	Year 1	Year 1
Last year of spend	Year 5	Year 5	Year 5	Year 5	Year 5	Year 5	Year 5
Volumes of interventions	443	2,922	55	3,366	55	1,953	445[4]
Types of interventions	Replacement only	Replacement only	Replacement only	Replacement only	Replacement only	Replacement only	Replacement only
Equipment design life	Various: 20-30 years	Various: 20-30 years	Various: 20-30 years	Various: 20-30 years	Various: 20-30 years	Various: 20-30 years	Various: 20-30 years
Total installed cost	Redacted due to commercial sensitivity						

Note: Option 8 has the same results as Option 1.

Table 24: Options Technical Summary Table

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[4] The small difference between Option 1 and 7 is due to rounding.

7.9 Options Cost Summary Table

The overall capex costs of the options are shown below. Option 8 is not shown in the tables, as this is the same as Option 1.

Option Number	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Option 1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 4	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 5	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 6	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Option 7	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 25: Options Cost Summary Table. (Capex)

All modelled options have used the following unit costs. We have used the ‘regulator sub-system’ (defined previously as all the regulators of the same make and model on one governor station) as the ‘unit of investment’. The cost is still a component level cost, as the regulator sub-system has been considered as a component of the Pressure-reduction System. Similarly, ‘1 unit of slamshuts’ is all slamshuts of the same make and model on one governor station.

Unit costs for regulators used for modelling are based on an average cost of intervention across the various regulator types. We are proposing to invest a total of XXXX across 201 regulator units, which given us an average per unit of XXXX. Similarly, an intervention cost of XXXX across 242 slamshut units gives us an average unit cost of XXXX.

Type	< 7 bar Regulator	< 7 bar Slamshut
Unit costs	[redacted]	[redacted]

Table 26: Unit costs used for modelled scenarios

Our RIIO-2 forecasts, as well as adjusting for workload and work mix factors, also include ongoing efficiencies flowing from our transformation activities including from updating and renewing our contracting strategies. Our initiatives are outlined in Appendix 09.20 Resolving our benchmark performance gap. For Capex activities this seeks a 2.9% efficiency improvement by 2025/26 on the end of RIIO-1 cost efficiency level. We have applied an average efficiency to this investment area of 0.90% over 5 years. Commencing at 0.3% in first year rising to 1.50% in fifth year. All costs in this document are post efficiency.

For below 7 bar governors our confidence is defined as being within the Detailed Design stage with a range of +/-10%.

8. Business Case Outline and Discussion

8.1. Key Business Case Drivers Description

Our objective is to build a plan which best reflects customer and stakeholder expectations and meets the required outcomes for this investment. To achieve this, we have developed a methodology which links asset performance to customer impacts, making use of models to evaluate options using CBA.

Our drivers for this investment case are to ensure our pressure-reduction system assets remain operating safely, efficiently and reliably in order to maintain:

- Security of supply to customers
- Safety — specifically compliance with Regulations: PSSR and GS(M)R
- Value for money (efficiently carrying out intervention to reduce customers' bills)

From our analysis the most material driver for our below 7 bar governors is safety. Over 30% of the NPV results from reducing the risk of fatalities and non-fatal injuries. Other benefits stem from reducing environmental risk, financial risk, and interruptions.

8.2. Business Case Summary

Options analysis and conclusions

The results of the analysis over RIIO-2 are shown in the tables below. For any scenario, we have understood the year-on-year totex costs, together with monetised-risk impacts in a CBA.

The table shows the discounted present value of costs for each option to 2071.

Option No.	Option description	PV Expenditure & Costs (£m)	PV Environment (£m)	PV Safety (£m)	PV Reliability (£m)	PV Other (£m)	Total PV (£m)	NPV (£m)
0	Reactive Only	Redacted due to commercial sensitivity						
1	Engineering Volumes Option (Chosen)							
2	Min investment to maintain stable risk (RIIO-2 only)							
3	Max Whole Life Benefit (RIIO-2 only)							
4	Continue RIIO-1 volumes in RIIO-2 Min Failures							
5	Max Whole Life Benefit (RIIO-2 and RIIO-3)							
6	Continue RIIO-1 volumes in RIIO-2							
7	Engineering Volumes Option with Max Benefits							
8	Engineering Volumes Option exc. WTP							

Table 27: PV and NPV for scenarios

Table Notes

- Costs are presented as negative value. The total PV is the summation of the five categories of costs.
- PV expenditure and costs shows discounted sum of proactive investment (replacement or refurbishment costs), maintenance, repairs and other ongoing opex costs. Proactive investment has been considered over RIIO-2, although we have included some scenarios that consider 10 years of investment: RIIO-2 and RIIO-3. All other financial costs are considered over the full period to 2071. All financial costs are discounted using the Spackman approach.
- PV environment shows the discounted sum of leakage and shrinkage, using the base case cost of carbon.
- PV safety shows the discounted sum of the risk of fatalities and injuries, as valued using the Ofgem stated costs per Fatality and cost per non-fatal injury.
- PV reliability shows the discounted sum of interruption risk, as valued using our own valuation research (e.g. the willingness to pay study into the cost of interruptions to homes and businesses).
- PV other shows the discounted sum of any other impacts, as valued using our research into the cost of property damage and transport disruption.
- The baseline has been specified as the minimum investment position. The NPV for each option is computed as the difference between the total PV for each option and the total PV for the baseline. A positive NPV means an option has less costs associated with it relative to the baseline and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial of the options considered.

The table below summarises the cost benefit results for each option:

Option No.	Option description	NPV - Relative to baseline (£m)	Cost beneficial	Payback Year	RIIO-2 spend (Replace, Refurb) (£m)	Ratio NPV to RIIO-2 replace/ refurb spend
0	Reactive Only	Redacted due to commercial sensitivity				
1	Engineering Volumes Option (Chosen)					
2	Min investment to maintain stable risk (RIIO-2 only)					
3	Max Whole Life Benefit (RIIO-2 only)					
4	Continue RIIO-1 volumes in RIIO-2 Min Failures					
5	Max Whole Life Benefit (RIIO-2 and RIIO-3)					
6	Continue RIIO-1 volumes in RIIO-2					
7	Engineering Volumes Option with Max Benefits					
8	Engineering Volumes Option exc. WTP					

Table 28: Cost-benefit summary for all scenarios

Table Notes:

- The NPV for each option is computed as the difference between the total PV for each option and the total PV for the baseline. A positive NPV means an option has less costs associated with it relative to the baseline and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial of the options considered.
- Payback shows the year when the sum of costs associated with an option is lower than that of the baseline i.e. this is the point at which the option can be considered to be cost beneficial. This is driven by the profile of the costs and the capitalisation rate.
- The table shows the RIIO-2 proactive expenditure. If applicable the RIIO-3 proactive expenditure is also shown.
- The ratio of NPV to RIIO-2 spend shows how much NPV per £ spent in RIIO-2 the options generate. A positive figure means the investment is cost beneficial. The higher the figure the most cost beneficial the option is.
- We have also provided the ratio of NPV to the combined RIIO-2 and RIIO-3 spend for those options where 10 years of proactive expenditure has been considered.
- In assessing these CBA results, we recognise we need to balance NPV, payback, and the ratio of NPV to proactive spend, alongside other considerations such as affordability and compliance with legal standards and obligations.

Options discussions

We have analysed 4 main options and have then carried out various CBA scenarios for these options for illustrative purposes or to test sensitivity. The following list shows the main options and the supporting CBA scenarios.

- **Engineering volumes** (Option 1)
    - Option 7, for comparative purposes - looks to deliver our chosen investment in a way that maximises value
    - Option 8 looks at how the NPV for option 1 changes when the WTP from supply interruptions is excluded from the CBA.
- **Minimum investment to maintain stable risk** (Option 2)
- **Maximum whole life benefits** (Option 3)
    - Option 5 extends the investment into RIIO-3 to see the resulting capex spend profile.
- **Continue RIIO-1 volumes into RIIO-2** (Option 4) – least failures
    - Option 6 extend the investment into RIIO-3 to see the resulting capex spend profile.

The following section discusses these four main option and how the supporting CBA scenarios have influenced our conclusions.

The two CBA tables above show that the preferred option, our bottom up assessment of Engineering volumes (Option 1) is very cost beneficial. Our payback computations show that the benefits of this investment exceed the costs XXXX and the risk of asset stranding is very low. This is also the level of spend needed to ensure we are compliant with our legal obligations. This ‘stripped back’ targeted approach does carry some risk and this is reflected in an increase in monetised risk through the period. However performance against key safety and reliability metrics are mainatined (Table 29).

The most cost-beneficial option, Option 3, involves spending less than the chosen option throughout RIIO-2 and allowing a higher level of asset failure; this level of spend would make us non-compliant with our PSSR regulations. If we were to apply the costs and volumes of this option in RIIO-2 we would fail our safety obligations. Moreover Option 5 shows that the most cost beneficial option would continue to see low levels of investment during RIIO-3, which would continue to see us fail to meet our obligations. Non-compliance with our safety and regulatory obligations means that Option 3 is not a viable option for us to consider.

The option to maintain stable risk, Option 2, has significantly more investment in RIIO-2 than the chosen option. Under this option we would reduce risks in all categories relative to the chosen option – this option is therefore consistent with our legal duties and responsibilies. However, the additional expenditure assocatied with this option over the bottom up engineering assessment of Option 1 is not cost beneficial. This option is still cost beneficial overall, but including non cost beneficial investment means it is less value for money and has a lower payback period and worse benefit/spend ratio. The considerable increase in investment in RIIO-3 also makes this Option 2 unfavourable.

Option 4 shows that continuing with our RIIO1 investment levels is likely to be cost beneficial. If we were to continue with RIIO-1 investment levels into RIIO-2, we would wish to deliver this in a way that reduces failures. This would be cost beneficial overall, but less cost beneficial and considerably more expenisve that the chosen option. There is also a risk with this option – as shown in the comparative Option 6 – that this level of investment may actually be non cost beneficial, if it is not targetted in such a way that reduces the risks faced by our customers. We do not believe that this level of investment is value for money or affordable for our customers and we have therefore discounted this option.

Option 7 illustrates for comparative purposes that if we deliver our chosen investment in a way that maximises value, our investment will be more value for money for our customers. This scenario would depend on a coincidental overlap between sites with high monetised risk benefits and components with high failure frequencies. However, the NPV of Option 7 is not significantly more than Option 1, demonstrating that the bottom up engineering volumes identified will target excellent value-for-money, risk-reductions for our customers.

Option 8 looks at whether our preferred option is still cost beneficial even without considering willingness to pay benefits from avoding supply interruptions. Our chosen option is still very cost beneficial even if this is discounted.

In conclusion, our chosen option (Option 1) ensures we are compliant with legal obligations, is value for money for our customers and reflects the right balance of investment in RIIO-2. We are confident this is the right balance of investment to manage our risks through RIIO2 and into RIIO3, deliver our outcomes, and ensure affordable levels of invesment.

Below, we further illustrate why Option 1 is the right option to deliver value for our customers whilst meeting our absolute duties around safety.

We recognise that any failures of our pressure reduction systems (fail-open, fail-closed) put our assets at risk from over / under-pressurisation of the downstream network and therefore posing a major safety risk. We have analysed each of the options and assessed the reduction in "failures".

The table below shows the change in the monetised risk between the end of 2020 and the end of 2025. Positive numbers reflect an increase in risk over RIIO-2; negative numbers denote a desirable decrease in risk over RIIO-2.

Option	Expected change in "fail-open" failures	Expected change in "fail-closed" failures	RIIO-2 spend (Replace, Refurb)
	(Number of Failures)	(Number of Failures)	£m
0: Reactive Only	8.44	4.03	Redacted due to commercial sensitivity
1: Engineering volumes option (Chosen)	-8.64	-5.62	
2: Min investment to maintain stable risk (RIIO-2 only)	4.33	1.74	
3: Max whole-life benefit (RIIO-2 only)	-0.41	-1.10	
4: Continue R1 volumes at least failures (RIIO-2)	-2.01	-2.05	
5. Max whole-life benefit (RIIO-2 and RIIO-3)	-0.41	-1.10	
6. Continue RIIO-1 volumes in RIIO-2	5.65	3.78	
7. Engineering volumes option with max benefits	-7.32	-3.43	

Note: Option 8 has the same results as Option 1.

Table 29: Risk reduction for each option

The table shows that the reactive position sees risk rise from 2020. This means we need to invest to manage these risks.

Our chosen option gives the best reduction in risk from a Fail-Open and Fail-Closed failure mode whilst being affordable and value for money.

Option 2 shows that maintaining stable risk at least cost will see these risks rise. The model would manage total monetised risks by investing in other areas and allowing these safety metrics to deteriorate.This option is expensive and would result in a worsening of health and safety risk.

Option 4 and Option 6 shows that continuing our RIIO-1 investment levels delivers a safe level of failures, but at a significantly increased cost. Continuing RIIO-1 into RIIO-2 is much less value for money and affordable for our customers.

Option 3 (and Option 5) show an improvement in the overall number of failures, although this is signficantly less safe than our chosen option. Moreover, this option involves a small amount of money spent in North London (XXXX) with the rest of the invesment in the North West region (with XXXX). Overall this option associated with an increase in risk across the regions.

For this reason, we have discounted other options in favour of Option 1.

Our CBA results for each Network:

We have also assessed the the CBA results across the four networks . The table below shows the results for the regions for the preferred Option 1:

	NPV (£m)	Cost Benefit	Payback	RIIO-2 spend (£m)
District Governors				
EoE				
Lon				
NW		Redacted due to commercial sensitivity		
WM				
TOTAL				
I&C Governors				
EoE				
Lon				
NW		Redacted due to commercial sensitivity		
WM				
TOTAL				
Combined Total				
EoE				
Lon				
NW		Redacted due to commercial sensitivity		
WM				
TOTAL				

Table 30: Cost-benefit summary for the chosen scenario by region and type

The results show that overall our plans are cost beneficial, with London and the North West investment plans providing the most benefit.

Our NOMS-based Governors risk model shows that single stream governors have significantly higher failure-to-consequence probabilities. Therefore, each failure on a single stream governor can cause significant safety and reliability risk.

The consequences for health and safety and supply interruptions are largely based on a combination of the resilience at each of our governors by virtue of having additional pressure reduction streams and the number of customers supplied by the governor. We have robust estimates of the numbers of customers supplied by our governors (as provided by synergy network analysis).

In the EoE and WM regions, the single stream governors that we need to invest in have a smaller number of customers served by them, whilst in the Lon and NW regions we have a higher concentration of customers connected to single stream governors. This means that investment in our Lon and NW networks results in a higher cost-benefit. More people gain from improved relaibility.

We have challenged whether we can reduce the scope of investment in EoE (and WM) in light of these findings. However, the proposed work is needed to meet our legal obligations under PSSR 2000 and PSR ’96 Regulation 6, particularly around ensuring a safe and reliable network. We have also analysed the safety benefit of the chosen option (Option 1) per network related to the fail-open and fail-closed failure modes and compared this with Option 0 (Reactive Only). Results, shown in Table 31 below, show that our proposed investment is reducing the risk of both fail-open and fail-closed failure modes (compared to the reactive-only approach) in all networks, including EoE and WM.

Change in Number of Failures from 2020 - 2025 Chosen Option Compared to Reactive Only				
Failure Modes	**EoE**	**Lon**	**NW**	**WM**
Fail Open	-0.35	-1.29	-13.7	-1.73
Fail Closed	-0.15	-0.58	-7.93	-0.97

Table 31: Comparison of chosen option with reactive-only approach

As such although the EoE intervention plan is not cost beneficial it does deliver safety benefits and ensures relaibility to our customers. It would be unreasonable to allow a lower level of service to customers in EoE because it is more sparsely populated.

We have chosen not to blend more cost beneficial schemes in the EoE with the engineering option chosen as this would not comply with the principles of analysis followed.

The following diagrams show the modelled results, from each of the options assessed.

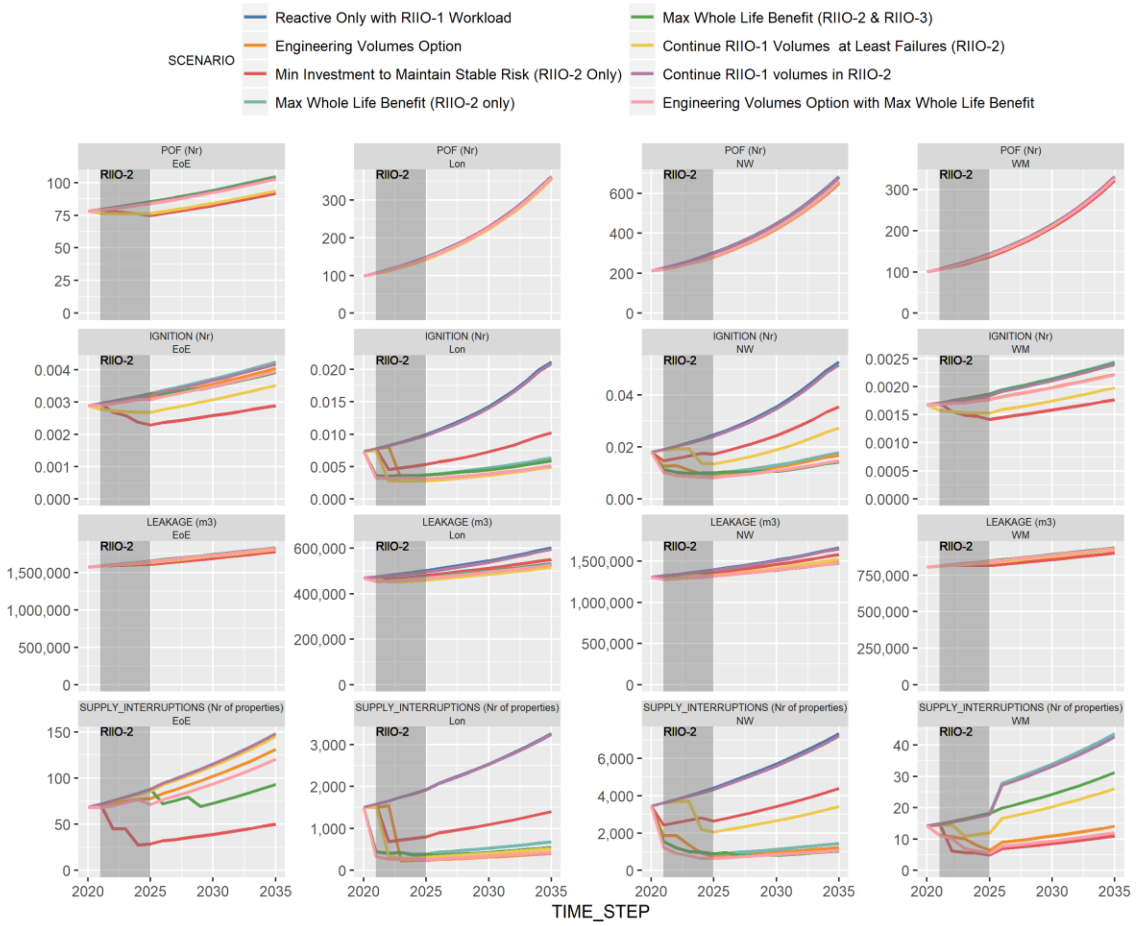

Figure 15: Summary of Options

This plot shows several varying scenarios of investment and risk that were investigated and compared to the reactive only scenario (blue line) for each asset category (District and I&C). All scenarios can be seen to either hold constant or reduce key performance measures over RIIO-2 (dark grey shading). All scenarios were assessed and compared against the final chosen scenario - based on an engineering assessment of all options (Engineering Volumes Option).

Benefits of our chosen option

This section provides further information on our preferred option. This further shows the value that our preferred option delivers.

The improvements in performance as a result of the chosen investment Option 1 is provided below. This has been compared against the do-nothing option in the following table.

Measure	Scenario Type	2020	2025	2030	2035
POF (Events)	Reactive Only	1,411	1,788	2,327	3,108
	Chosen	1,411	1,759	2,289	3,060
IGNITION (Nr)	Reactive Only	0.0556	0.0683	0.0874	0.1159
	Chosen	0.0556	0.0456	0.0533	0.0634
LEAKAGE (m3)	Reactive Only	4,535,178	4,810,043	5,126,099	5,497,111
	Chosen	4,535,178	4,690,215	4,951,634	5,235,308
SUPPLY INTERRUPTIONS (Props)	Reactive Only	5,273	6,771	8,806	11,307
	Chosen	5,273	1,365	1,800	2,311

Table 32: Comparison of the performance improvements of Do nothing versus Option 1

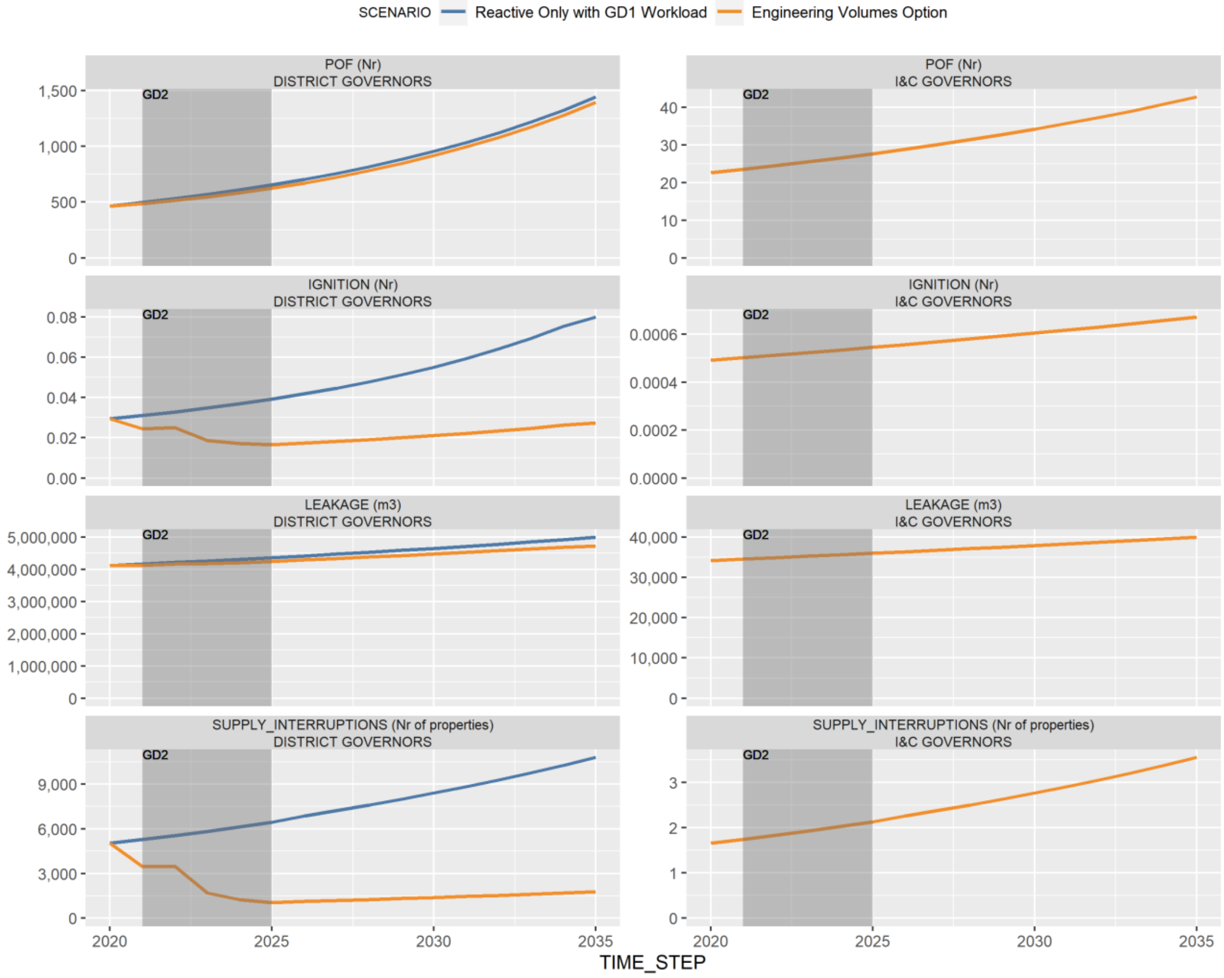

Figure 16: Summary of Baseline v Preferred Option 1

This plot shows a comparison of reactive only (no investment) compared directly to the chosen scenario for four key asset health and performance measures. The chosen scenario shows a relatively flat risk position at the end of RIIO-2 for both District and I&C governors. No spend is on I&C governors.

9. Preferred Option Scope and Project Plan

All figures have been updated to match final 18/19 prices, post efficiency.

9.1. Preferred Option

Our preferred option for RIIO-2 is Option 1, based on the targeted investment programme derived from the Enzen engineering study, which investigated asset obsolescence, reliability and criticality.

9.2. Asset Spend Profile

The following table shows the spend and workload volume profile by distribution network and governor category. This amounts to a total volume of 443 units of intervention with a XXXX overall cost.

Asset Category	Scenario Name	Network	COST					WORKLOAD_VOLUME				
			2021	2022	2023	2024	2025	2021	2022	2023	2024	2025
DISTRICT GOVERNORS	Governors Engineering Volumes Chosen	EoE	Redacted due to commercial sensitivity					46	40	40	37	36
		Lon						20	17	18	14	14
		NW						22	19	18	17	17
		WM						18	13	13	12	12
I&C GOVERNORS		EoE						0	0	0	0	0
		Lon						0	0	0	0	0
		NW						0	0	0	0	0
		WM						0	0	0	0	0
Totals		**All**						106	89	89	80	79

Table 33: RIIO-2 Spend profile for Option 1

9.3. Investment Risk Discussion

The interventions on governors are routine activities undertaken by our supply chain and operations team, as such, there are no material delivery risks associated with this investment case.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.08 - 001	Supply & Demand deliverability risk of Resource availability within the Gas industry	Potential cost increases in labour / commodity markets as demand is greater than supply	Low	Intelligent procurement and market testing. Apprenticeship and Training programmes to fill skills gaps
09.08 - 002	Stretching efficiency targets may not be deliverable (unit costs increase)	Outturn costs are not met increasing overall programme costs.	Low	Established marketplace - ability to manage the known commodity market
09.08 - 003	Unforeseen outages and failures restrict access for planned work	Programme and delivery slippage due to delay of planned outages and or site access	Low	Proactive asset management with ongoing condition surveys and response plans to prevent failures
09.08 - 004	Unseasonal weather in 'shoulder months', Autumn and Spring reduce site access/outage windows	Increased demands affecting access to sites and planned outages delay and cost increases	Low	Controlled forecasting and maintenance of flexibility to react to unforeseen events. Detailed design solutions to minimise outages and reduce exposure.
09.08 - 005	Unexpected / uncommunicated obsolescence during RIIO-2 period of equipment components	Inability to maintain equipment at full capacity with risk of impact upon supply	Low	Maintain a close relationship with equipment supply chain and manage a proactive early warning system where spares / replacements become at risk.
09.08 - 006	Legislative change - There is a risk that legislative change will impact the delivery of our work.	Potential increase in the amount of consultation and information exchange required and require us to align our plans with the safety management processes operated by 3rd Party landowner / asset owners. The potential impact is more engagement and slower delivery	Med	We have established management teams to address these issues. We have also identified UMs for key areas.

Table 34: Risk Register

9.4 Regulatory Treatment

This investment will be tracked through the NARMs methodology, the benefits are recorded in our submitted NARMs tables.

This investment is accounted for in the Business Plan Data Table 3.03 within the District Governors Sub Table.