Cadent
Your Gas Network

Appendix 09.07

Offtakes & PRS Slamshut/Regulators

RIIO-2 Spend: XXXX

Investment Decision Pack Overview

This Asset Health Engineering Justification Framework 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 slamshuts and regulators at Offtakes and PRS sites at operating pressures above 7 bar. The Offtake and PRS assets are modelled together but reported seperatly through the document.

As part of transmitting gas from the National Transmission System (NTS) to customers' properties, we need to reduce the pressure of the gas. This is achieved via regulators or governors, which step down the pressure. These devices are supported by suitable protective devices (including monitor regulators and slamshuts) which protect the downstream network from over or under pressurisation if the primary regulator fails to operate correctly. We need to maintain this asset stock to ensure that it provides a reliable service to our customers and operates safely in accordance with the Pressurised Systems Safety Regulations (PSSR) 2000 legislation.

We have assessed a number of options for investment in these assets, either based on detailed engineering studies or via computerised monetised risk models. The key options are:

- A targeted range of interventions based on a comprehensive review of all equipment, conducted with an independent expert. The aim of the review was to identify equipment that is unreliable and obsolete and hence has a higher likelihood of failure (high PoF)
- The minimum level of investment to maintain stable risk (as identified from modelling)
- The level of investment that would maximise whole life benefits (as identified from modelling)

We have also considered some further scenarios as part of sensitivity testing and analysis.

Our analysis shows that a targeted investment into specific components, resulting from engineering consultant analysis, with the highest failure rates to provide the best balance between ensuring asset health is maintained, while being affordable and deliverable. The chosen option is significantly NPV positive.

Summary of preferred option	£m
RIIO-2 Total Expenditure	Redacted due to commercial sensitivity
RIIO-2 Expenditure (excluding Bristol Controllers) [1]	
Project NPV (excluding Bristol Controllers)	

Material Changes Since October Submission

The Pneumatic Control Systems (**XXXX**) have been removed from this investment case, as they are low cost and not included in the NARMs model.

We have also improved our approach to CBA assessment to better reflect component level investment.

The paper is now written in a 2018/19 price base.

[1] Bristol controllers are not modelled in NARMs and therefore have also been omitted from CBA analysis. They have been separated for clarity of matching costs with BPDTs and CBA tables.

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2. Introduction

The following Asset Health Engineering Justification Paper (EJP) document covers the investment case methodology for Offtakes and PRS slamshuts and regulators. These above 7 bar systems include pressure regulators, slamshuts, stream inlet and outlet valves and any auxiliary pipework and equipment relating to these assets.

As part of transmitting gas from the National Transmission System (NTS) to customers' properties, we need to reduce the pressure of the gas. This is achieved via regulators or governors, which step down the pressure. These devices are supported by suitable protective devices (including monitor regulators and slamshuts) which protect the downstream network from over or under-pressurisation if the primary regulator fails to work correctly. We need to maintain this asset stock to ensure that it provides a reliable service to our customers and operates safely in accordance with the Pressurised Systems Safety Regulations (PSSR) 2000 legislation.

Our approach to this investment case has been to review fault data of all equipment across all sites that contain above 7 bar pressure reduction systems and identify equipment that is unreliable and obsolete. This equipment has a higher likelihood of failure and a higher consequence of system failure or outage, due to the limited or lack of availability of spares. This study, conducted with independent experts, has identified four key asset makes and models that are obsolete and have fault data that demonstrates their low reliability. We have used this to derive a detailed asset-specific replacement plan for these assets in RIIO-2 and RIIO-3. This innovative approach has challenged our internal thinking and brought a fresh perspective to our work in this area.

We have then used our computer models to assess this option and a number of other investment scenarios in order to help us build a full picture of monetised risk. The risk-monetisation model is limited in that it does not model asset components across our pressure-reduction systems and does not take account of the escalated risk posed by obsolescence. It does, however, provide an additional lens through which to assess our investment case against customer expectations.

We have considered three options:

1. A targeted range of interventions based on fault data and obsolescence of key asset components
2. A model run to conduct the 'minimum investment to maintain stable risk'
3. A model run to provide 'maximum whole-life benefits'

We have also considered some further scenarios as part of sensitivity testing and analysis.

3. Equipment Summary

Cadent has 614 above-ground installation (AGI) and Offtake sites operating above 7 bar, that contain some form of pressure-reduction system (PRS) across the four gas distribution networks. Of the 614 sites, there are 50 Offtakes and 564 Local Transmission System (LTS) AGIs.

The Offtake/PRS boundary does not create a split in assets, i.e. assets of the same size and type, with the same ageing and fault mode mechanisms, can be found on both PRS and Offtake site assets. As such within this investment case we have focused on understanding of asset performance and then applied the Offtake/PRS split at the end of the process. We have therefore documented one complete investment case.

Summary of asset stock: key components

A summary by region and asset-component is shown below for above 7 bar assets:

	Sites	Systems	PRS Major Components		
Region	**No. of > 7 bar sites**	**No. of Pressure Reduction Systems**	**No. of Regulators**	**No. of Valves**	**No. of Slamshuts**
EoE	283	354	1,192	1,188	591
Lon	82	101	375	223	190
NW	124	188	562	370	249
WM	125	157	554	365	252
Total	**614**	**800**	**2,683**	**2,146**	**1,282**

Table 1: Above 7 Bar PRS Sites, System and PRS Components Asset Stock, March 2019

The table above has been derived from our NOMs monetised risk model, which in turn was derived from our SAP asset data, extracted in March 2019. The model does not cover all asset components: the number of controllers and the actuators associated with the slamshut protective devices are not shown.

Pressure Reduction Systems: how they work

The key components of pressure-reduction and flow-control systems of Offtakes and AGI sites are highlighted in the diagram below:

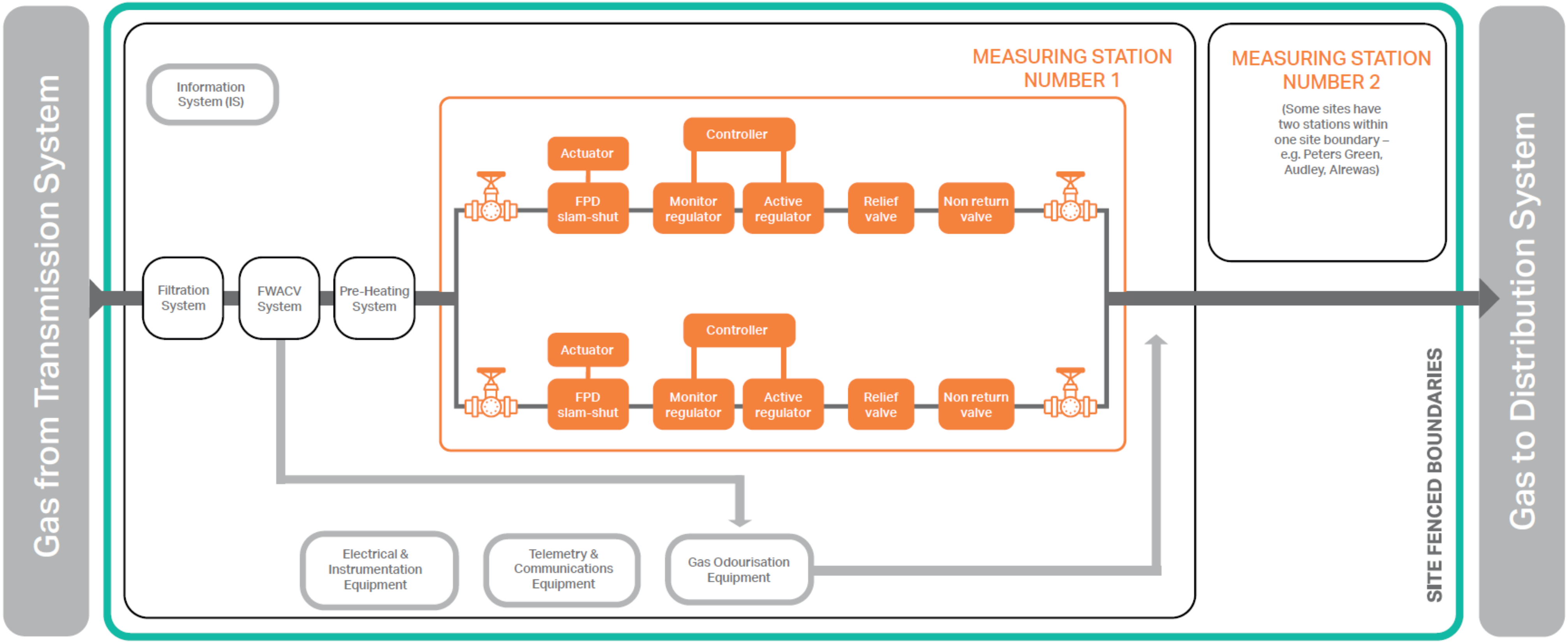


Diagram illustrates a site with a separate filtration system. In some sites, the filters are included within the PRS. The filters would be positioned between the first valve and the FPD slamshut component.

Figure 1: Pressure reduction and flow control systems of the Offtakes and AGIs

PRS – Pressure reduction stream – typically, within a pressure-reduction station there are two streams which contain an inlet valve which may be part of the final protective device (FPD), two pressure regulators and an outlet valve.

FPD – Final protective device – sometimes termed slamshut valve. The FPD is designed to operate and close should the pressure exceed set limits downstream.

FCV – Flow control valve – controls the rate of flow rather than the pressure. FCVs will operate to a profile set and controlled by DNCC to ensure sufficient gas enters the network to meet demand. FCVs require a controller to position the valve to achieve the desired flow rate.

REG – Regulator – controls the pressure rather than the rate of flow. Regulators will operate to a profile set to ensure sufficient gas enters the network to meet demand.

These PRSs typically operate continuously, with their action fluctuating throughout the day/year depending on gas demand. Historically, a minimum level of redundancy has been factored in across all sites, to ensure a duty-standby arrangement is available to prevent supply interruptions, as far as reasonably practicable.

It is usual for all above 7 bar pressure reduction streams to operate with a working and standby stream. On some sites, there may be additional streams, depending on the configuration of the site.

Typical Pressure Reduction System components

Across these various pressure-reduction systems, there are a number of key components. Photographs of some of these components are shown below:

Regulators

The Jetstream regulator operates by using a high-density rubber plug, the shape being controlled by pressurisation with hydraulic oil. The plugs have a history of failure by disintegration. The regulator requires removal from the stream for maintenance and has a separate control system.

Figure 2: Jetstream type regulator

A Fisher V25 regulator typically operates as a volumetric flow control valve. These regulators are noisy, complex to maintain and require removing from the stream for maintenance. They have a separate control system usually located remotely from the control valve.

Figure 3: Fisher V25 regulator

Slamshut/final protective device and associated actuator

A slamshut valve will close automatically in the event of pressure changes outside of the designed tolerance, they protect the downstream system form over / under pressurisation. Audco actuators are typically part of the FPD and, as such, are the last line of defence to prevent over-pressurisation of the downstream network.

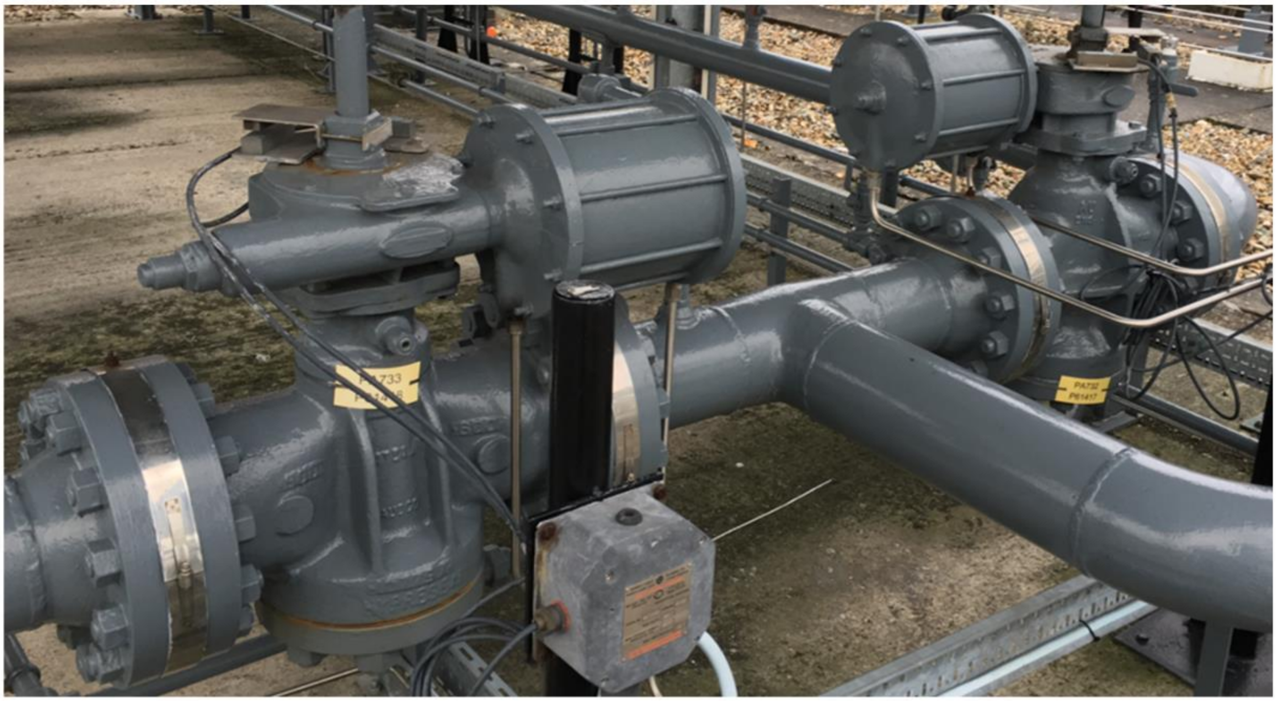


Figure 4: Slamshut

Figure 5: Audco Actuator associated with Slamshut

Controllers

Bristol Controllers provide the positioning signal to Fisher V25 regulators that are typically operating as FCVs to achieve the desired flow rate.

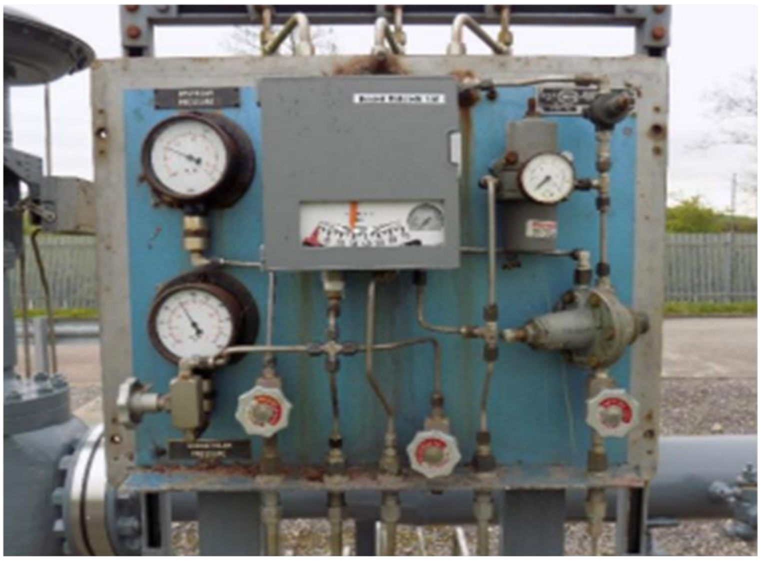


Figure 6: Bristol Controllers

4. Problem Statement

As our assets age and deteriorate they are more prone to a failure, which in turn affects their ability to meet safety and reliability requirements. We have an absolute duty under the Pressure Systems Safety Regulations (2000), PSSR, to ensure they are suitably maintained (and by doing so to protect the downstream network from over pressurisation).

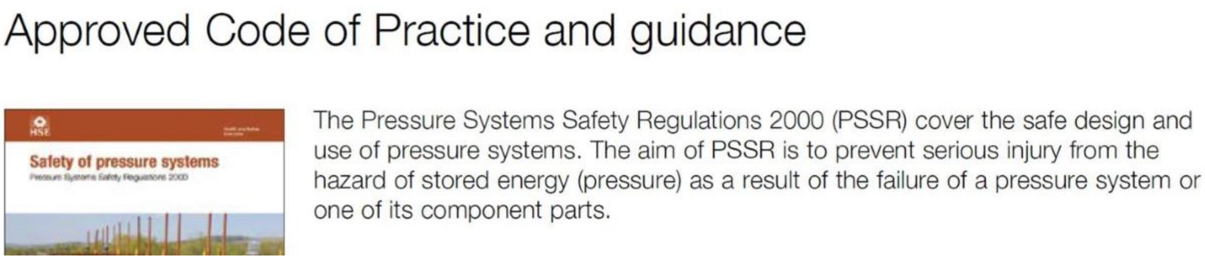
Our baseline case supply-demand scenario for this investment case is our peak 1-in-20 year demand to comply with our licence obligations. The variability of demand in future forecasts is small; our demand would have to change significantly to require a step-up or down in model-size of regulator and slamshut required. We have therefore only considered one supply-demand scenario.

Cadent commissioned a detailed engineering study in 2019 to look at the reliability of all pressure-control asset components across our networks. From this review, we identified a number of different components that were both unreliable and obsolete. These assets have already had a number of failures and, with obsolescence, cannot be adequately maintained. The difficultly to repair without available spares, will only increase over future years. As these systems are old, spare parts are no longer manufactured and bespoke units cannot be produced to the required tolerances. Higher frequencies of faults are predicted in RIIO-2 as parts become worn, leading to higher opex costs and eventual asset failure.

Investment drivers – Why are we doing this work and what happens if we do nothing?

Two drivers of investment must be considered: Legislative (safety) and interruptions to supply. In addition, we recognise the importance of investment plans that provide value for money. It is imperative we provide the most efficient and cost-effective long-term solution to minimise customer bills.

Safety (legislative): We invest in these assets to comply with the Pressure Systems Safety Regulations 2000 (PSSR).


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 (above its design ratting) leading to failure and an uncontrolled escape of gas.

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

Required outcomes – How will we understand if the spend has been successful?

We have an absolute duty to comply with our PSSR regulations. 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 preferences.

The required outcome for this investment is a safe and reliable system. Success is measured by ensuring a safe operation, legal compliance, and avoiding any failure which leads to downstream interruptions.

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 incident

South Mimms AGI forms part of the London Network, receiving gas from Peters Green in the East Anglia Network and supplying gas into the London Network through the North Orbital Pipeline (NOP) - typically 30% of the London gas supply. The South Mimms supply into the NOP is supported by Hedgerley to the west, Luxborough Lane and Horndon to the east. At the time of the incident supplies into the NOP from Hedgerley were unavailable due to the unreliability of the V25 regulators on that site. In addition, the second stream at South Mimms was isolated due to an existing fault with the active flow control valve.

On the morning of 14 January 2010 at 06.35 am after filling the NOP with linepack overnight the high-pressure override controller at South Mimms was activated. This controller failed to release once the pressure began to decay on the morning load. As a result, the feed from Peters Green to South Mimms was isolated at South Mimms. Distribution Network Control Centre (DNCC) increased flows through Luxborough Lane and Horndon together with using all available holder stock to support the network.

The fault was traced to a broken linkage in the Bristol Babcock Controller. The controller linkage was replaced, and the site brought back on line at 09.20 am. Later, the same morning at 10.11 am, the linkage failed once again and flows from South Mimms fell to zero.

A second temporary repair was made to the controller prior to the opening of the site bypass valves. This action effectively passed flow control to Peters Green (the upstream site). Opening the site bypass valves safeguarded supplies into the NOP; however, it resulted in the loss of 0.6mcm of linepack storage. The design of Peters Green Offtake is such that it does not have any slamshut valves (i.e. a final protective device). Protection of the NOP from overpressure was provided by the FPDs (slamshut valves) at South Mimms and override trips at Peters Green. During this arrangement (several weeks) both Peters Green and South Mimms sites were manned 24/7 to ensure that any faults that activated the slamshuts at South Mimms could be rectified without putting at risk supplies to North London.

Once control of the site had been established, temporary configuration arrangements were agreed and put in place.

Consequences of the incident

There were at least two operations staff needed on each site 24/7 for the duration of manual operation, plus supervision and management support for part of that time. In addition, repairs costs of around **XXXX** were incurred.

There was a heightened risk to loss of supply of 30% of the London Network at the time of the incident – a cold January.

If no remedial and mitigating action was undertaken then major disruption to the gas supplies in London would have occurred, resulting in a sigificant impact for customers and communities.

4.2. Spend Boundaries

The assets within the scope of this investment case are pressure-reduction and flow-control systems of the Offtakes and AGIs operating at pressures above 7 bar and are shown in the diagram below:

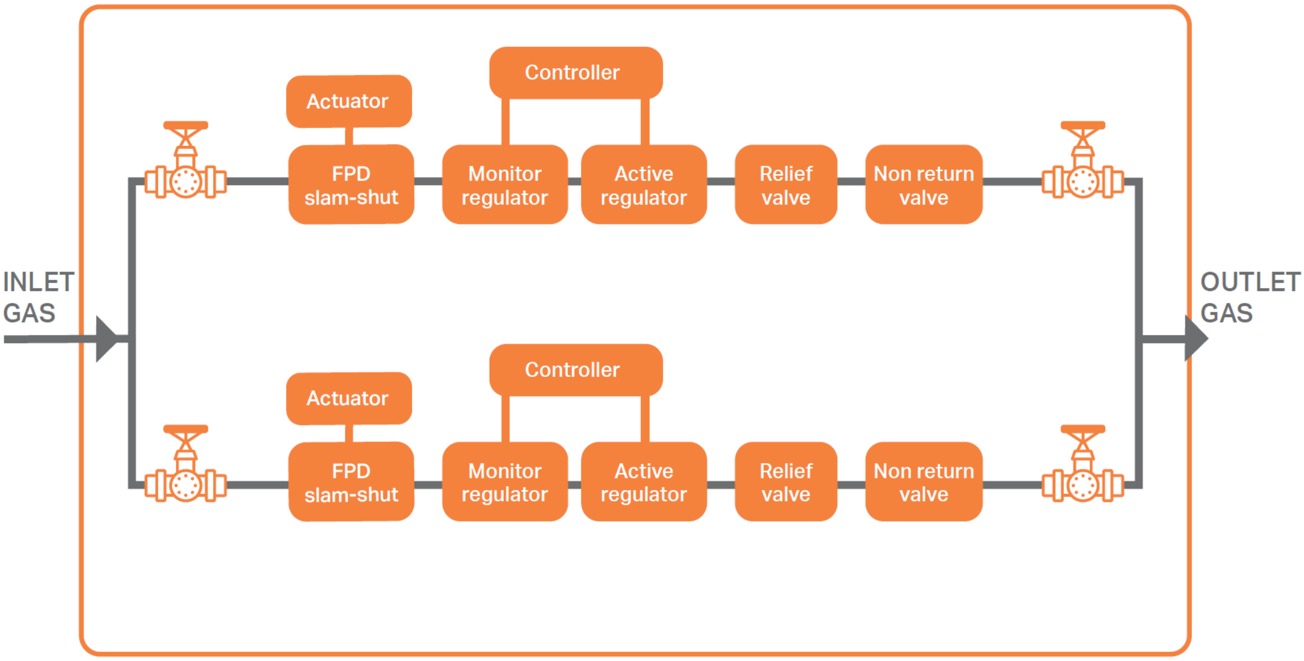


Diagram illustrates a site with a separate filtration system, which is not included in this diagram. In some sites, the filters are included within the PRS. The filters would be positioned between the first valve and the FPD slamshut component.

Figure 8: Spend boundary for pressure regulating systems above 7 bar

5. Probability of Failure

We have used our historical fault data on our above 7 bar pressure-regulating systems to update our risk-reporting model to evaluate risk.

The NOMs methodology, developed with Ofgem, is an approach that allows us to report risk on our assets and the benefit that investment will have. We have followed good practice set out in the NOMs methodology[2] in developing our probability of failure estimates for regulators. This approach models the entire pressure regulating system rather than individual components within the PRS.

We then commissioned an independent consultant, Enzen, to review the asset stock and identify any assets that were obsolete, where spare components are not commercially available, and to analyse the probability of failure at a component level. This more granular approach improved the targeting of investment.

The obsolescence risk is not represented in our risk monetisation model.

Obsolescence means that while the asset can continue to be proactively maintained, without spares to deal with wear and tear, there is an increased risk of either total failure of the equipment or an increasing maintenance frequency, as wear and tear, which cannot be resolved, causes more reactive faults.

This section focuses on the failure modes and probability of failure used within our models. Our model has been used to predict how the probability of failure will increase over time with no investment.

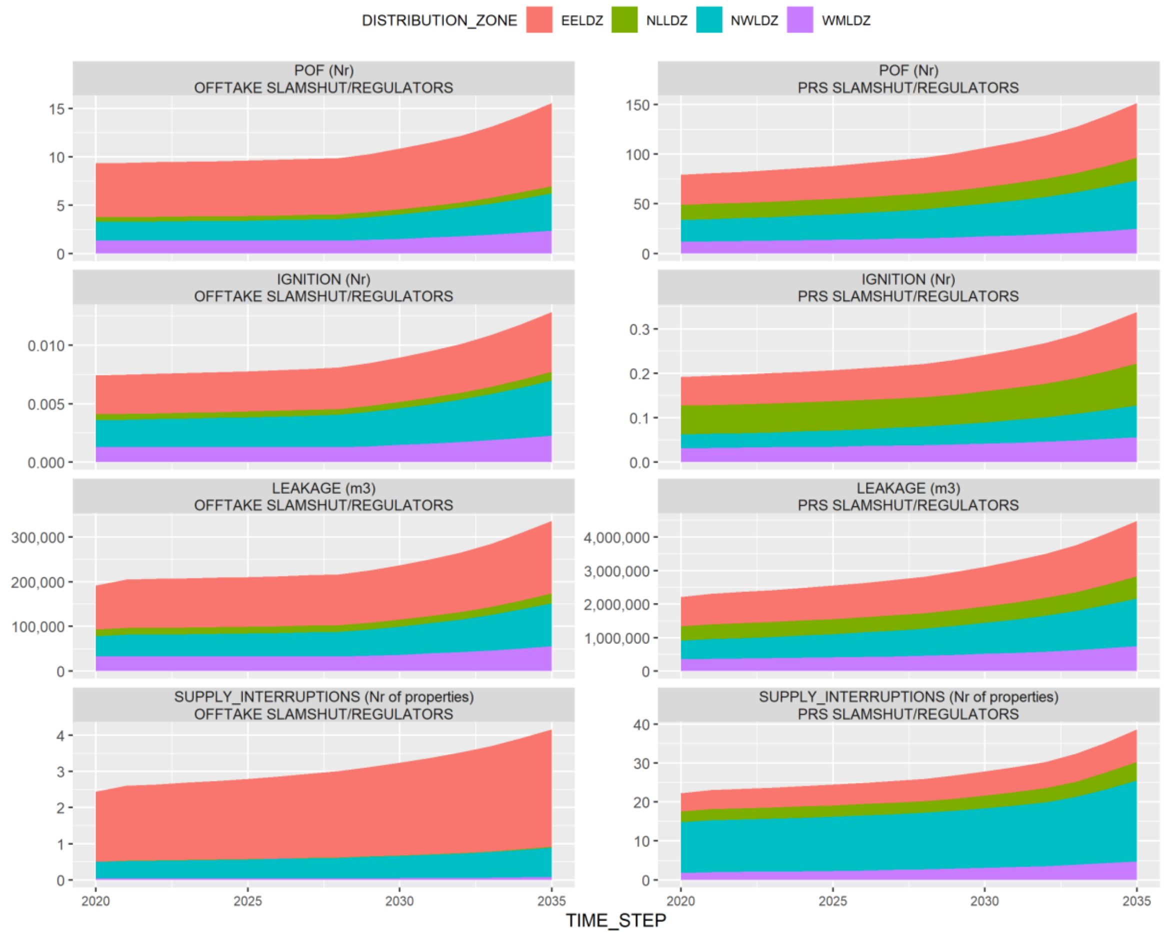


Figure 9: Key asset health and performance measures over time for reactive only (no investment) split by asset category coloured by distribution zone (N.B. the Y-axis is independent for each plot)

The key asset-health and performance measures 'reactive only' chart shows an increasing trend across all networks with increases in Offtakes typically rising at an increased rate after 2025. For PRS sites the risk rises within the years 2020 to 2025 and start a ramp up of deterioriation before 2030.

[2] NOMS, March 2016, Appendix C.

East of England has a high proportion of the Offtake asset-health and performance measures, relative to the other networks, but is a lower proportion of the PRS sites, relative to the other networks, reflecting the relative risks of the assets in this and the other networks, against the defined KPIs.

Enzen identified the makes and models of PRS components (slamshuts, regulators, actuators and controllers) that were obsolete and were those components had high numbers of faults.

The following obsolete asset components were identified within our asset stock:

System Component	Purpose of component	Make & Model	Total number in Asset Stock
Regulator	Regulates gas flow to the network downstream	**Jetstream**	176
Regulator	Regulates gas flow to the network downstream	**Fisher V25**	37
Actuator	Operates the final protective device to close the gas stream when gas pressure exceeds set limits	**Audco**	658
Controller	Provides the positioning signal to the regulators to achieve the desired flow rate	**Bristol 624**	75

Table 2: Above 7 Bar PRS obsolete asset types

The table below details the average annual fault rates in RIIO-1 (i.e. the % of components showing a fault each year):

Sytem Component	Percentage average RIIO-1 annual fault rates
Jetstream Regulator	11%
Fisher V25 Regulator	6%
Audco Actuator	16%
Bristol Controller	13%

Table 3: Average RIIO-1 above 7 Bar PRS fault rates by component

To put the actuator severity of faults into context, Enzen's report includes an analysis of the performance against RIIO-1 Output Measure for PSSR Faults which shows an increasing failure trend (measured as A1/A2 faults in Pressure System Database - PSDB). The measure is largely influenced by the ability of the FPD (slamshut) to operate within the required limits.

Other components within pressure reduction systems on above 7 bar PRS sites, have low failure occurrences and with the availablity of spares, repairs are straight forward, not requiring targeted capital investment.

A contributory factor to the reportable faults under PSSR regulations is the reliability of the Audco actuators. To illustrate pressure system performance over recent years the graph below has been produced and shows a steady increase in the percentage of PSSR faults reportable to Ofgem. Source: GDN Outputs – Operational Performance, Table 2.17O.

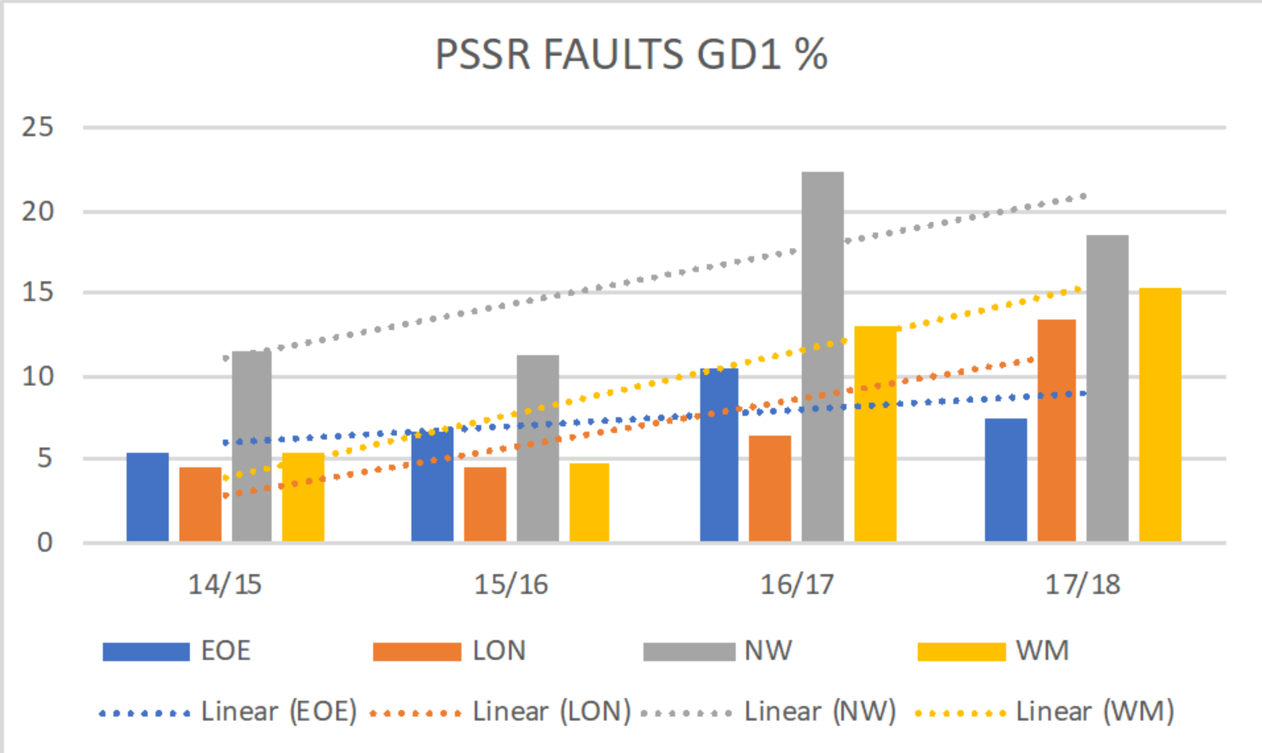


Figure 10: PSSR Faults

Fault modes

Within our risk models (developed using the NOMs methodology), the following failure modes (failure effects) are considered:

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 has not been used as it is covered by the capacity review investment area (Appendix 09.23 Capacity Upgrades - > 7 bar reinforcements (AGIs) - Base Case).
- **Release of Gas** – failure of a pressure-containing component on site can lead to an unconstrained release of gas within and, possibly, off the site.
- **High Outlet Pressure** – this relates to the failure of the pressure control system to control the pressure at least to within the Safe Operating Limit of the downstream system.
- **Low Outlet Pressure** – failure resulting in under pressurisation that can lead to a partial or total loss of downstream supplies.
- **General Failure** – this covers other failures that do not lead to the release of gas, low/high outlet temperature or capacity failures, but still require repair.

The following risk map shows how we have considered the above failure modes and failures effects to understand and quantify the consequences of failure in NARMs. These consequences are explained in the next section.

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 occur to drive these failure effects).

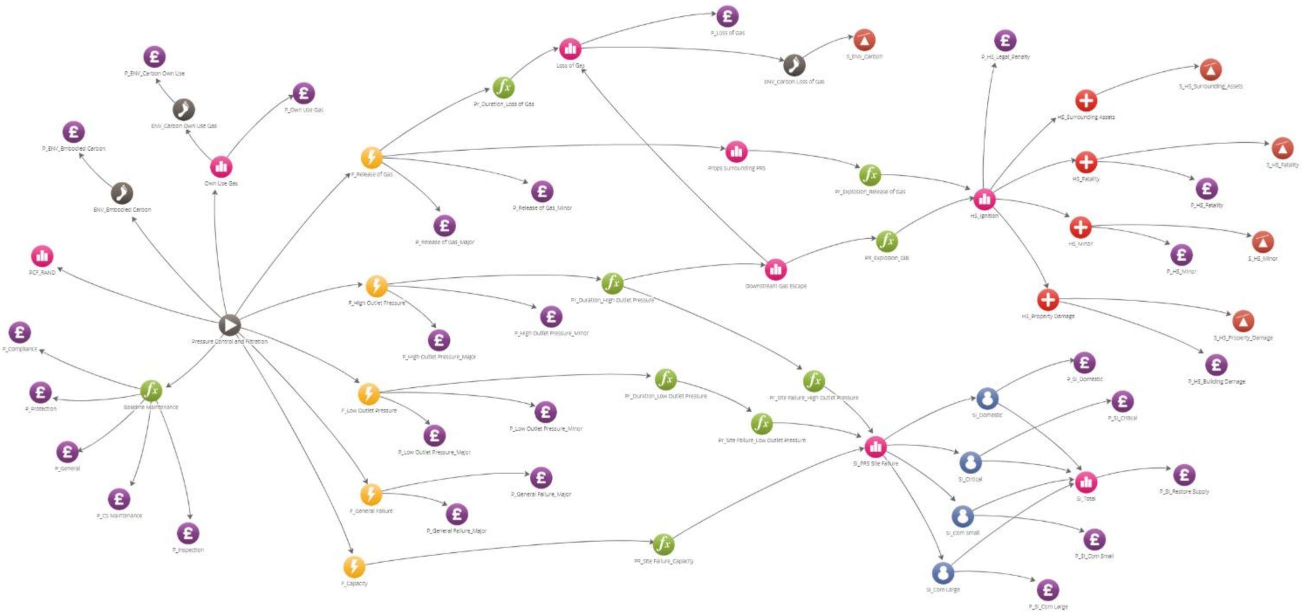


Figure 11: PRS and Offtakes Risk Map

For the four specific high failure rate components identified by Enzen, the historical fault data is summarised below:

Component	Key fault nature	% of total faults	Key fault causes	% of fault causes
Jetstream Regulator	Loss of control	35%	Aged/Worn	64%
	Worn	26%		
Fisher V25 Regulator	Loss of Control	25%	Aged/Worn	58%
	Leak	25%		
Audco Actuator	Poor Control	23%	Stiction - static friction cannot be overcome to enable motion of parts in contact	58%
	Failed Open	18%		
	Failed Closed	14%		
Bristol Controller	Loss of Control	26%	No causes have been documented	
	Worn	19%		

Table 4: Failure modes for the PRS components

For these specific asset components (makes and models identified above), Enzen also looked at the most probable failure modes. These are summarised below, and the consequences of these failures are discussed in Section 6:

Asset component	Most likely failure modes
Jetstream Regulator	Jetstream regulators contain a high-density rubber plug, which is prone to disintegration and failure.
Fisher V25 Regulator	These regulators are often operated in an automatic flow-control mode. The failure of the flow control valve is the item that causes significant consequences to the system.
Audco Actuator	There are no specific component failures; ultimately, the actuator will either fail open/closed or partially open, which means it will not operate as an automated flow control protection device.
Bristol Controller	There are lots of different sub-components that could fail, ultimately leading to the Bristol controller failing. The failsafe is that this specific stream will shut-down.

Table 5: Specific failure modes associated with the four high failure rate assets identified in the Enzen report

More information on the associated consequences of failure is discussed in Section 6.

5.1. Probability of Failure Data Assurance

The following key data sources have been used to derive the probability of failure data, with dates of extracts shown in brackets:

- The number of obsolete assets was derived from the SAP asset database on [2019-02-07]
- The asset data within the PRS and Offtake models was taken on [2019-02-07]
- The fault data was extracted from Mobile Data Capture (MDC) database on [2019-01-02]
- The PSSR failure trend was based on data from the Pressure Systems Database (PSDB) [2019-03-04], Condition Surveys [2018-04-18] and Operations Issue Log [2019-02-04].

Fault data and information have been collected around specific fault types, matched to the different PRS systems and components. We have made best use of this data to understand the probability of failure.

We have a good understanding of our asset numbers for the obsolete asset components; we also understand the volume of faults associated with the equipment.

6. Consequence of Failure

As stated earlier in this document, the variability of demand in future forecasts is small; our demand would have to change significantly to require a step-up or down in model-size of regulator and slamshut required. We have therefore only considered one supply-demand scenario.

Using the NOMs methodology, our monetised risk model links failure modes to the probability of failure and to their potential consequences.

The consequences of failure used within the model are:

Risk	Description
Safety Risk	Uncontrolled release of gas/ignition – either at the pressure station itself or in the downstream network
Interruptions to supply	Interruptions to customers in the network downstream of the pressure station
Environmental Risk	Loss of gas - arising from the pressure station itself or the downstream network
	Gas escape - that could result in increased Public Reported Escapes
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 6: Consequences of failure

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

Customer Driver	Data source
Environment – GHG emissions	UK Government. Value agreed with Ofgem. • *Increases from* **XXXX** *tCO2e in 2021 to* **XXXX** *tCO2e in 2071.*
Safety – injuries and deaths	UK Government (HSE). Value agreed with Ofgem. • **XXXX** • **XXXX**
Interruptions to supply – per property	WTP research. Independently assured. • *Range of values computed depending on duration and property type, e.g.* **XXXX** *per domestic property for up to 24 hours interruption.*
Other societal impacts	Our analysis includes wider impacts such as property damage and transport disruption.
Financial impact – cost of repairs (unit)	Company accounts.
Financial impact – cost of replacement (unit)	Company accounts.

Table 7: Sources of societal benefits

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 financial risk components for our above 7 bar PRS and Offtake slamshuts and regulators.

This shows that, for Offtakes and PRS sites, approximately 25% of the risk is financial. Environmental risk is greater for Offtakes (approx. 50%) compared to PRS sites (approx. 25%). In comparison, the PRS sites pose a higher safety risk (approx. 50%) compared to Offtakes (approx. 25%). This is due to PRS having a higher proportion of high pressure and release of gas faults, which both feed into safety.

Figure 12: Offtake and PRS sites (> 7 bar): consequence of failure from model

Enzen's more detailed engineering report, looked more specifically at the consequence of failure of the four identified components. A summary of these consequences is shown below:

Asset component	Discussion on consequence of failure
Jetstream Regulator	A plug-failure could cause damage to downstream assets. There are a number of fail-safes within the system, but a plug failure could cause loss of control, leading to over or under-pressurisation. Plug failures may also induce vibration, leading to possible failures of small diameter tappings. This type of failure will result in a significant release of high-pressure gas and significant cost to attend and repair.
Fisher V25 Regulator	If any of the flow control valves fail, then this regulator stream will fail 'closed'. Multiple stream-failures would lead to a supply interruption.
Audco Actuator	Actuators generally fail to open/close or can just fail to operate correctly. This means their associated FPD, known as a slamshut, would not operate correctly. This could lead to over-pressurisation of the downstream network and may result in explosion, fire and risk to the public, employees and contractors and significant cost to rectify. Failing-closed will result in loss of that working-stream; multiple failures would result in loss-of-supply. Actuation control loops can fail which can result in high-pressure leakage and loss of control of the actuator.
Bristol Controller	Controller failure causes that stream to fail 'closed', potentially causing loss of supply in the event of a multiple failure. An example of this is the significant near-miss in South Mimms in 2010 which could have disrupted supplies to 30% of the London network at that time (see real life example above).

Table 8: Consequences of failure from the four asset components discussed in the Enzen report

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.

Reactive interventions are discounted because of the need to comply with PSSR regulations. We have, however, developed a baseline scenario which excludes mandatory safety work in order to deliver an economic appraisal analysis. Including safety work in the base case would not allow us to value it.

We have used bottom up engineering assessments and our NOMs monetised risk model to develop and appraise investment options for our RIIO-2 plan, testing the volume of interventions that might be required in RIIO-2. These are summarised below and also includes secnarios considered as part of sensitivity testing and are used for comparison purposes:

Options	Description
0	Reactive only
1	**Engineering Volumes Option** Targeted investment programme to replace obsolete components. 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)** Used our monetised risk model to assess the minimum investment required to maintain total monetised risk on an annual basis until the end of RIIO-3. In this option the costs reflect the RIIO-2 investments only.
3	**Maximum Whole Life Benefits (RIIO-2 only)** The investment required to maximise the whole life benefits over RIIO-2 and RIIO-3, considering those investments that payback within 20 years of the end of RIIO-2. Costs reflect the RIIO-2 costs only.
4	**Minimum investment to maintain stable risk (RIIO-2 & RIIO-3)** Used our monetised risk model to assess the minimum investment required to maintain total monetised risk on an annual basis until the end of RIIO-3. In this option the costs reflect the RIIO-2 and RIIO-3 investments.
5	**Maximum Whole Life Benefits (RIIO-2 & RIIO-3)** The investment required to maximise the whole life benefits over RIIO-2 and RIIO-3, considering those investments that payback within 20 years of the end of RIIO-2. Costs reflect the RIIO-2 and RIIO-3 costs.
6	**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 whole life benefits. 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.
7	**Engineering Volumes Option excluding 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. *This option has not been described below because it has been used only as a sensitivity test for Option 1.*

Table 9: The Options Modelled

All options are compared to the baseline (Option 0), which involves reactive only investment, and the associated maintenance and repairs.

As part of our review of plausible intervention options we have considered whole system interventions and interventions of individual components within the PRS systems, with the targeted approach of components with the highest failure rates to provide the best balance between ensuring asset health is maintained, while being affordable and deliverable. See components within the PRS systems described earlier in section 3.

Option 1 has, looked at different solution options to derive the preferred investment programme. Option 1 has been developed working with an independent consultant to whom we provided all of our asset data. The resulting output recommends that we conduct replacements on obsolete components with high failure rates. For modelled Options 2 and 3, we have only considered a replacement option.

Our approach to modelling

We have used AIM to support the build of the RIIO-2 plan. AIM allows us to model different investment scenarios, produce optimised plans and test their cost-benefit. The CBA capability within AIM can find the solution to a problem 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.

It should be noted that the Bristol Controllers (**XXXX** 2018/19 prices) are not being modelled through the NARMs model, as they are not covered by the industry's NOMs methodology, and therefore have not been included in the CBA modelling analysis within AIM.

Our approach to CBA and options analysis

We have used CBA to assess 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 cost-benefit analysis. Costs and benefits are discounted and shown in present value (PV) terms, in line with Ofgem requirements and HM Treasury Green Book.

7.1. Option 1: Engineering option: replace obsolete asset components

This option has been derived from a detailed engineering assessment undertaken by Enzen between March and August 2019. The NPV has been derived using the AIM model for the regulators and slamshut actuators. Bristol controllers are not modelled and do not contribute to the PV and NPV calculations.

From the detailed SAP asset records held, the following table summarises the number and size of the four obsolete asset components identified.

	No.	Diameter of component							Earliest Date Installed
		50	100	150	200	250	300	Other	
Jetstream Regulator	176	12	30	68	65	-	1	-	1971
Fisher V25 Regulator	37	-	4	5	11	12	-	5	1960
Audco Actuator	658	Not Applicable							1969
Bristol Controller	75	Not Applicable							1980

Table 10: Asset stock by make, model, size and age

These assets were broken down by each of our four distribution networks to help inform the intervention costs for this targeted investment option:

Description	EoE	Lon	NW	WM	TOTAL
Offtake					
Jetstream Regulator	12	6	15	1	**34**
Fisher V25 Regulator	10	0	10	0	**20**
Audco Actuator[3]	28	2	15	11	**56**
Bristol Controller	18	5	11	10	**44**
Total	**68**	**13**	**51**	**22**	**154**
PRS					
Jetstream Regulator	92	10	40	0	**142**
Fisher V25 Regulator	1	6	0	10	**17**
Audco Actuator[4]	263	81	140	118	**602**
Bristol Controller	15	12	3	1	**31**
Total	**371**	**109**	**183**	**129**	**792**

Table 11: Total Asset populations by Network

Enzen, as part of its study, assessed the optimum intervention required in RIIO-2 for each of these asset components.

The Enzen report assessed two primary intervention options:

- Continue to maintain existing component
- Replace with a modern-day equivalent asset component

No wholesale rebuild options were considered, as much of the remaining PRS systems were deemed to be operating satisfactorily. This is an evolution from our RIIO-1 approach of full system replacement.

In summary, Enzen's report recommended the following:

Component	No. of RIIO-2 interventions	Reasons for preferred option
Jetstream Regulator	136	Jetstream regulators are now obsolete and spares are not readily available. It is suggested to undertake proactive replacement on critical sites and to retain a stock of serviceable units of each size range for emergency use until replacement.
Fisher V25 Regulator	33	Fisher V25s are now obsolete and spares are not readily available. It is suggested to undertake proactive replacement on critical sites and to retain a stock of serviceable units of each size range for emergency use until replacement.
Audco Actuator	238	P480 and P1700 actuators are now obsolete and spares are not readily available. It is suggested to undertake proactive replacement on critical sites and to retain a stock of serviceable units of each size range for emergency use until replacement.
Bristol Controller	34	Bristol 624 controllers are now obsolete, and spares are not readily available. It is suggested to undertake proactive replacement on critical sites and to retain a stock of serviceable units of each size range for emergency use until replacement. The replacement priority should be based on site criticality, fault history and sites with obsolete or unreliable FCVs.

Table 12: Preferred interventions for Option 1

[3] The regional split matches the split of pressure reduction systems in Table 1.
[4] The regional split matches the split of pressure reduction systems in Table 1.

The of replacements in RIIO-2, has been based on an assessment of critical sites and the volume needed to create an appropriate stock of critical spares, which is a feature of the sizes in use across the various sites. This has led to a slightly different volume of replacement as a percentage of the total asset stock.

Enzen also reviewed Cadent's historic costs for delivery of regulator and slamshut interventions to infer a reasonable unit price for each replacement in RIIO-2. A blended-average unit price for each component was calculated, see Section 7.8 for additional details.

Enzen's derived units costs, and the proposed RIIO-2 work volumes were multiplied together to obtain total RIIO-2 investment costs that are summarised in the following table for Option 1:

Asset Component	Volume of work in RIIO-2	Estimated unit-cost for replacement (£k) (pre-efficiency)	Total Intervention Cost for RIIO-2 (£m)
Jetstream Regulator	136	Redacted due to commercial sensitivity	
Fisher V25 Regulator	33		
Audco Actuator	238		
Bristol Controller	34		

Table 13: Proposed Volume and Cost for RIIO-2 for Option 1.

Proposed intervention and spend profile (with Bristol Controllers)

The proposed intervention and spend profile for this programme of work has then been smoothed out evenly throughout RIIO-2 and is shown below. Costs have been rounded to the nearest £1k. This work programme was then input into our monetised risk model, to assess the NPV of the proposed option. The results are summarised in Section 8.

	Volumes					
Region	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
Offtakes						
EoE	11	13	11	13	11	**59**
Lon	1	1	2	1	1	**6**
NW	8	7	7	7	8	**37**
WM	1	2	1	2	1	**7**
Total	**21**	**23**	**21**	**23**	**21**	**109**
PRS						
EoE	30	29	30	29	30	**148**
Lon*	10.6	11.6	10.6	11.6	10.6	**55**
NW	6	6	5	6	6	**29**
WM*	19.8	19.8	20.8	19.8	19.8	**100**
Total	**66.4**	**66.4**	**66.4**	**66.4**	**66.4**	**332**

Note: The PRS slamshut regulator interventions for Lon & WM have been smoothed across the RIIO-2 period.

Table 14: Proposed spread of Interventions throughout RIIO-2 for Option 1

The resulting capex spend is shown below:

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

Table 15: Proposed RIIO-2 spend profile for Option 1

Proposed intervention and spend profile (without Bristol Controllers)

	Volumes					
	2021/22	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
Offtakes						
EoE	10	11	10	11	10	**52**
Lon	1	1	2	1	1	**6**
NW	7	6	7	6	7	**33**
WM	1	2	1	2	1	**7**
Total	**19**	**20**	**20**	**20**	**19**	**98**
PRS						
EoE	27	26	27	26	27	**133**
Lon*	9.6	9.6	9.6	9.6	9.6	**48**
NW	6	6	5	6	6	**29**
WM*	19.8	19.8	19.8	19.8	19.8	**99**
Total	**62.4**	**61.4**	**61.4**	**61.4**	**62.4**	**309**

***** Note: The PRS slamshut regulator interventions for Lon & WM have been smoothed across the RIIO-2 period.***

Table 16: Proposed spread of Interventions throughout RIIO-2 for Option 1 (Without Bristol Controllers)

The resulting capex spend is shown below:

	£k / year					
Region	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 17: Proposed RIIO-2 spend profile for Option 1 (Without Bristol Controllers)

7.2. Option 2: Minimum investment to maintain stable risk (RIIO-2 only)

This option has been derived from our monetised risk model. The model has been used to assess interventions and capex spend needed to hold monetised risk flat within the model.

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

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Offtake						
EoE	0	0	0	0	0	**0**
Lon	0	0	0	0	0	**0**
NW	0	0	0	0	2	**2**
WM	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**0**	**2**	**2**
PRS						
EoE	4	2	2	6	3	**17**
Lon	2	2	0	2	0	**6**
NW	11	4	12	18	20	**65**
WM	9	4	0	7	4	**24**
Total	**26**	**12**	**14**	**33**	**27**	**112**

Table 18: Intervention volumes: Option 2

The resulting capex spend is:

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 19: Capex costs: Option 2 (£m)

7.3. Option 3: Maximum Whole Life Benefits (RIIO-2 only)

This option has been derived from our monetised risk model. The model has been used to assess interventions and capex spend needed while maximising whole life net benefit.

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

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Offtake						
EoE	4	19	12	0	4	**39**
Lon	0	2	0	0	0	**2**
NW	3	0	12	2	3	**20**
WM	2	2	4	0	0	**8**
Total	**9**	**23**	**28**	**2**	**7**	**69**
PRS						
EoE	81	55	54	51	59	**300**
Lon	28	41	35	50	35	**189**
NW	84	56	52	54	34	**280**
WM	47	43	57	45	30	**222**
Total	**240**	**195**	**198**	**200**	**158**	**991**

Table 20: Intervention volumes: Option 3

The resulting capex spend is:

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 21: Capex costs: Option 3 (£m)

7.4. Option 4: Minimum investment to maintain stable risk (RIIO-2 and RIIO-3)

This option has been derived from our monetised risk model. The model has been used to assess interventions and capex spend needed to hold risk flat within the model. For comparison purposes, we have also considered the impact over 10 years, through RIIO-2 and RIIO-3.

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

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Offtake						
EoE	0	0	0	0	0	**0**
Lon	0	0	0	0	0	**0**
NW	0	0	0	0	2	**2**
WM	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**0**	**2**	**2**
PRS						
EoE	4	2	2	6	3	**17**
Lon	2	2	0	2	0	**6**
NW	11	4	12	18	20	**65**
WM	9	4	0	7	4	**24**
Total	**26**	**12**	**14**	**33**	**27**	**112**

Table 22: Intervention volumes: Option 4

The resulting capex spend is:

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 23: Capex costs: Option 4 (£m)

7.5. Option 5: Maximum Whole Life Benefits (RIIO-2 and RIIO-3)

This option has been derived from our monetised risk model. The model has been used to assess interventions and capex spend needed while maximising whole life net benefit. For comparison purposes, we have also considered the impact over 10 years, through RIIO-2 and RIIO-3.

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

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Offtake						
EoE	4	19	12	0	4	**39**
Lon	0	2	0	0	0	**2**
NW	3	0	12	2	3	**20**
WM	2	2	4	0	0	**8**
Total	**9**	**23**	**28**	**2**	**7**	**69**
PRS						
EoE	81	55	54	51	59	**300**
Lon	28	41	35	50	35	**189**
NW	84	56	52	54	34	**280**
WM	47	43	57	45	30	**222**
Total	**240**	**195**	**198**	**200**	**158**	**991**

Table 24: Intervention volumes: Option 5

The resulting capex spend is:

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 25: Capex costs: Option 5 (£m)

7.6. Option 6: Engineering Volumes Option with Maximum Benefits

This scenario has been derived from our monetised risk model.

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.

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

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Offtake						
EoE	4	1	1	6	39	**51**
Lon	4	0	0	0	0	**4**
NW	2	0	0	6	25	**33**
WM	1	0	0	0	6	**7**
Total	**11**	**1**	**1**	**12**	**70**	**95**
PRS						
EoE	77	2	6	6	42	**133**
Lon	8	4	6	0	30	**48**
NW	28	0	0	0	1	**29**
WM	19	50	2	10	18	**99**
Total	**132**	**56**	**14**	**16**	**91**	**309**

Table 26: Intervention volumes: Option 6

The resulting capex spend is:

Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 27: Capex costs: Option 6 (£m)

Option 7 has the same volumes and capex spend as Option 1, and therefore has not been described below.

7.7. Options Technical Summary Table

Option	Option 1		Option 2	Option 3	Option 4	Option 5	Option 6
Description	Engineering option: replace obsolete asset components (Includes Bristol Controllers)	Engineering option: replace obsolete asset components (Without Bristol Controllers)	Minimum investment to maintain stable risk (RIIO-2 only) (Without Bristol Controllers)	Maximum Whole Life Benefits (RIIO-2 only) (Without Bristol Controllers)	Minimum investment to maintain stable risk (RIIO-2 & RIIO-3) (Without Bristol Controllers)	Maximum Whole Life Benefits (RIIO-2 & RIIO-3) (Without Bristol Controllers)	Engineering Volumes Option with Max Benefits (Without Bristol Controllers)
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	109 replacements: Offtake sites 332 replacements: PRS sites	98 replacements: Offtake sites 309 replacements: PRS sites	2 replacements: Offtake sites 112 replacements: PRS sites	69 replacements: Offtake sites 991 replacements: PRS sites	2 replacements: Offtake sites 112 replacements: PRS sites	69 replacements: Offtake sites 991 replacements: PRS sites	95[5] replacements: Offtake sites 309 replacements: PRS sites
Types of interventions	Replacements of specific asset components	Replacements of specific asset components	Slamshut / Regulator Replacements	Slamshut / Regulator Replacements	Slamshut / Regulator Replacements	Slamshut / Regulator Replacements	Slamshut / Regulator Replacements
Equipment design life	23 years	23 years	23 years	23 years	23 years	23 years	23 years
Total installed cost	Redacted due to commercial sensitivity						

Table 28: Options Technical Summary Table

[5] The model has focused investment on a smaller number of sites than our chosen engineering option.

7.8. Options Cost Summary Table

	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Option 1 (With Bristol Controllers)						
Option 1 (Without Bristol Controllers)						
Option 2			Redacted due to commercial sensitivity			
Option 3						
Option 4						
Option 5						
Option 6						

Table 29: Options Cost Summary Table (Capex in £m)

These costs form part of the CBA. The table above shows that a wide range of cost and intervention levels have been considered in our CBA.

Unit costs of slamshuts and regulators

All modelled options have used the following unit costs, which uses a weighted average cost of a regulator replacement:

Interventions	Unit cost £k (pre-efficiency)
Offtake & > 7 bar PRS Regulator System replacement	Redacted due to commercial sensitivity
Offtake & > 7 bar PRS Slamshut replacement	

Table 30: Unit costs used within our NOMs model

Our model does not differentiate between two different types of regulator with different unit costs. Therefore, a weighted average unit cost has been derived, taking account of the volumes and cost of interventions for each regulator design and obtaining the average of the total.

The individual regulator asset unit costs have been obtained through analysis conducted by Enzen to derive unit costs through the use of Complex Engineering Project Conceptual Design Study Reports plus Cadent finance data.

Our independent consultant has applied engineering judgement to these costed jobs due to these activities having wider work scopes than specifically the 4 components proposed only, and therefore adjusted accordingly.

Asset Component	Estimated unit-cost for replacement (£k) (pre-efficiency)
Jetstream Regulator	
Fisher V25 Regulator	Redacted due to commercial sensitivity
Audco Actuator	
Bristol Controller	

Table 31: Unit costs used within the Engineering Study

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 of 0.90% over 5 years. Commencing at 0.3% in first year raising to 1.50% in fifth year. All costs in this document are post efficiency, unless otherwise stated.

For 7 bar Offtakes and PRS Slamshut Regulators our confidence is defined as being within Detailed Design stage with a range of +/-10%.

We are also seeking to drive overal costs down by targeting components that require investment rather than whole complete systems.

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 the investment drivers and asset performance to customer impacts, making use of models to evaluate options using CBA.

The primary requirement of this investment is to meet safety legislation. We have however, utilised CBA to explore the economic value of safety work and give further insight around management of this asset group.

Our drivers for this investment case are discussed in detail in section 4 and are to ensure our pressure-reducing assets continue operating safely, efficiently and reliably in order to maintain the following:

- Safety, specifically compliance with PSSR Regulations
- Security of supply to customers
- Value for money: efficiently intervening in our assets to manage customers' bills.

The table below reviews the different options against the first two performance indicators with a simple RAG score.

Option No.	Option Description	Safety	Security of supply – Reliablity (Supply interruptions)
0	Reactive Only	R	R
1	Engineering Volumes Option (Chosen)	A	G
2	Minimum investment to maintain stable risk (RIIO-2 only)	A	R
3	Maximum Whole Life Benefit (RIIO-2 only)	G	G
4	Minimum investment to maintain stable risk (RIIO-2 and RIIO-3)	A	R
5	Maximum Whole Life Benefit (RIIO-2 and RIIO-3)	G	G
6	Engineering Volumes Option with Maximum Benefits	G	A
7	Engineering Volumes Option exc. WTP	As 1	As 1

Table 32: Linking options considered to investment drivers

Key:

R = Worse at 2025 than 2020;
A = little change from 2020 starting point – less than 5%;
G = improvement from 2020. Good reduction in monetsied risk £m.

Note:

The expectation is that reality will be between Option 1 and Option 6 as we will choose to prioritise investment on sites where there are asset health issues causing faults identified, while considering the criticality of sites requiring investment – a blend between the aim to minimise faults and minimise the consequences.

8.2. Business Case Summary

For our December submission, we have completed CBA for several options. We have improved our assessment since October, when we experienced some difficulties in representing the differences between component and system replacements in our models, particularly with regards to the performance of specific assets rather than cohorts of assets.

We are confident that our targeted approach should provide the best value for customers, we are replacing components, rather than full systems, and targeting the assets with the highest failure rates to manage costs compared to our RIIO-1 programme. Our CBA model has been reviewed and updated to ensure that we can assess our proposed interventions and to allow effective comparison between the options.

Note:

It should be noted that the Bristol Controllers are not being modelled through the NARMs model and therefore have also been excluded from the CBA modelling, these items are a small proportion of the overal submission.

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 present value of costs for each option to 2071. Costs and benefits are discounted and shown in present value (PV) terms, in line with Ofgem requirements and HM Treasury Green Book.

The table shows the present value of costs for each option. This shows five years of investment over RIIO-2, unless otherwise stated.

Option No.	Option Description	PV Expenditure & Costs (£m)	PV Environment (£m)	PV Safety (£m)	PV Reliability (£m)	PV Other (£m)	Total PV (£m)	NPV (relative to baseline) (£m)
0	Reactive Only							
1	Engineering Volumes Option (Chosen)							
2	Min investment to maintain stable risk (RIIO-2 only)							
3	Max Whole Life Benefit (RIIO-2 only)							

Redacted due to commercial sensitivity

Option No.	Option Description	PV Expenditure & Costs (£m)	PV Environment (£m)	PV Safety (£m)	PV Reliability (£m)	PV Other (£m)	Total PV (£m)	NPV (relative to baseline) (£m)
4	Min investment to maintain stable risk (RIIO-2 and RIIO-3)							
5	Max Whole Life Benefit (RIIO-2 and RIIO-3)							
6	Engineering Volumes Option with Max Benefits							
7	Engineering Volumes Option exc. WTP							

Redacted due to commercial sensitivity

Table 33: Present value of costs and benefits for the modelled scenarios – above 7 Bar Regulators / Slamshuts (£m)

The following text provides a guide on how to read and interpret the results in the above table

- NPV for each option is computed as the difference between the total PV for the option and the total PV for the baseline
- 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.
- Costs are presented as negative value. The total PV is the summation of the five categories of costs.
- 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 options deliver benefits across the monetised-risk categories: safety, environment, financial, and other. The key societal benefits centre on reductions in environmental risk associated with reduced leakage; safety benefits are also an important part of the reduction in risk that investment delivers.

The table below summarises the cost-benefit results for each option. This provides the NPV for the option (computed as the difference in total PV relative to the baseline) to show which options are cost-beneficial or not. We also include the payback period, the RIIO-2 (replacement and refurbishment only), and the ratio of NPV to RIIO-2 to understand how much NPV per pound spent in RIIO-2 the options generate.

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	RIIO-3 spend (Replace, Refurb) (£m)	Ratio NPV to RIIO-2 and RIIO-3 (Replace, Refurb) (£m)
0	Reactive Only	N/A	N/A	N/A	-	-	-	-
1	Engineering Volumes Option (Chosen)	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX
2	Min investment to maintain stable risk (RIIO-2 only)	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX
3	Max Whole Life Benefit (RIIO-2 only)	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX
4	Min investment to maintain stable risk (RIIO-2 and RIIO-3)	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX
5	Max Whole Life Benefit (RIIO-2 and RIIO-3)	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX
6	Engineering Volumes Option with Max Benefits	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX
7	Engineering Volumes Option exc. WTP	XXXX	Cost Beneficial	XXXX	XXXX	XXXX	XXXX	XXXX

Table 34: CBA for the modelled scenarios – above 7 Bar Regulators / Slamshuts

The following text provides a guide on how to read and interpret the results in the above table

- 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.

Option discussion

We have analysed 3 main options and 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 6, for comparative purposes - looks to deliver our chosen investment in a way that maximises value
  - Option 7 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)**
  - Option 4 extends the investment into RIIO-3 to see the resulting capex spend profile.
- **Maximum whole life benefits (Option 3)**
  - Option 5 extends the investment into RIIO-3 to see the resulting capex spend profile.

The following section discusses these three main options and how the supporting CBA scenarios have influenced our conclusions:

The table shows that the chosen option and all other options and scenarios considered are highly cost-beneficial. All options have very high NPVs as well as reasonable payback periods.

Our preferred option is **Option 1**. This targeted option in our CBA tables has an NPV of **XXXX** with Payback by **XXXX** is achieved, balancing the risk position of the assets and deliverability and affordability of the investment. The modelled option primarily focuses on reducing the number of faults occurring. The number of events with High Outlet pressure (which can be considered analogous to Fail open) are held flat and managed, with low outlet pressure (which can be considered analogous to Fail closed) events reduced, improving the reliability and reducing interruptions. Monetised risk over RIIO-2 will reduce with this option. This option is **chosen** because it meets safety, reliability and benefit criteria, while balancing affordability.

Option 2, minimum investment in maintaining stable monetised risk has the best ratio of NPV to RIIO2 spend, and aims to minimise the consequences of failure by targeting investment at the sites with the most benefit (in terms of monetised risk reductions). While overall reducing the safety risk. Howevere, high outlet pressure risk is allowed to increase over RIIO-2, along with an increase of probablity of failure events and supply interruptions. Due to these reasons the minimum investment to maintain stable risk is **rejected** as an option.

Despite being the most cost benefical and having the highest benefits of all the options, **Option 3** is **rejected** due to the large investment cost required – more than double the chosen Option 1, and deliverability challenges this would result in. While spend benefit ratio is greater than the chosen option, it is not high enough to justify the extra spend.

Option 4, looks to the RIIO-3 investment needed in addition to RIIO-2 investment in Option 2, and shows that an increase in minimum investment is required to maintain minimum stable risk. Again the same (safety and reliability) issues that occur in Option 2 for RIIO-2, occur here in this scenario and continue into RIIO-3. Therefore this option is **rejected**.

Option 5, looks to the RIIO-3 investment needed in addition to RIIO-2 investment in Option 3, and shows the very high level investment continued to deliver the highest benefits. Again the same affordability and deliverability issues that occur in Option 3 for RIIO-2, occur here in this scenario and continue into RIIO-3. Therefore this option is **rejected**.

Option 6 shows that the NPV for the engineering option (Option 1) could be as high as **XXXX** if the investment can be delivered to maximise benefits, as it would deliver further safety improvements. In this scenario we would not focus on minimising supply interruptions or fault count but would hold the probability of failures steady, whereas the chosen option 1 ensures that we make greater reductions in these performance indicators. Whilst we reject delivering the investment in line with Option 6, to ensure we manage faults appropriatley, we will deliver our chosen investment in a way that is value for money for our customers.

Across all our options, we have considered whether the options are cost beneficial, irrespective of the customer value for preventing interruptions. **Option 7** is a scenario which shows that this is not a key benefit of investment, with results very similar to Option 1.

These results are cost-beneficial across all four regions. The table below shows the results for the regions for the preferred option 1:

Region	NPV (£m)	Cost Beneficial	Payback	RIIO-2 spend (£m)
Offtakes				
EoE	XXXX	Cost Beneficial	XXXX	XXXX
Lon	XXXX	Cost Beneficial	XXXX	XXXX
NW	XXXX	Cost Beneficial	XXXX	XXXX
WM	XXXX	Cost Beneficial	XXXX	XXXX
Total	XXXX	**Cost Beneficial**	XXXX	XXXX
PRS				
EoE	XXXX	Cost Beneficial	XXXX	XXXX
Lon	XXXX	Cost Beneficial	XXXX	XXXX
NW	XXXX	Cost Beneficial	XXXX	XXXX
WM	XXXX	Cost Beneficial	XXXX	XXXX
Total	XXXX	**Cost Beneficial**	XXXX	XXXX
Combined Total				
EoE	XXXX	Cost Beneficial	XXXX	XXXX
Lon	XXXX	Cost Beneficial	XXXX	XXXX
NW	XXXX	Cost Beneficial	XXXX	XXXX
WM	XXXX	Cost Beneficial	XXXX	XXXX
Total	XXXX	**Cost Beneficial**	XXXX	XXXX

Table 35: CBA results by region for Option 1

The following diagram shows how the benefits and risk vary for all options assessed:

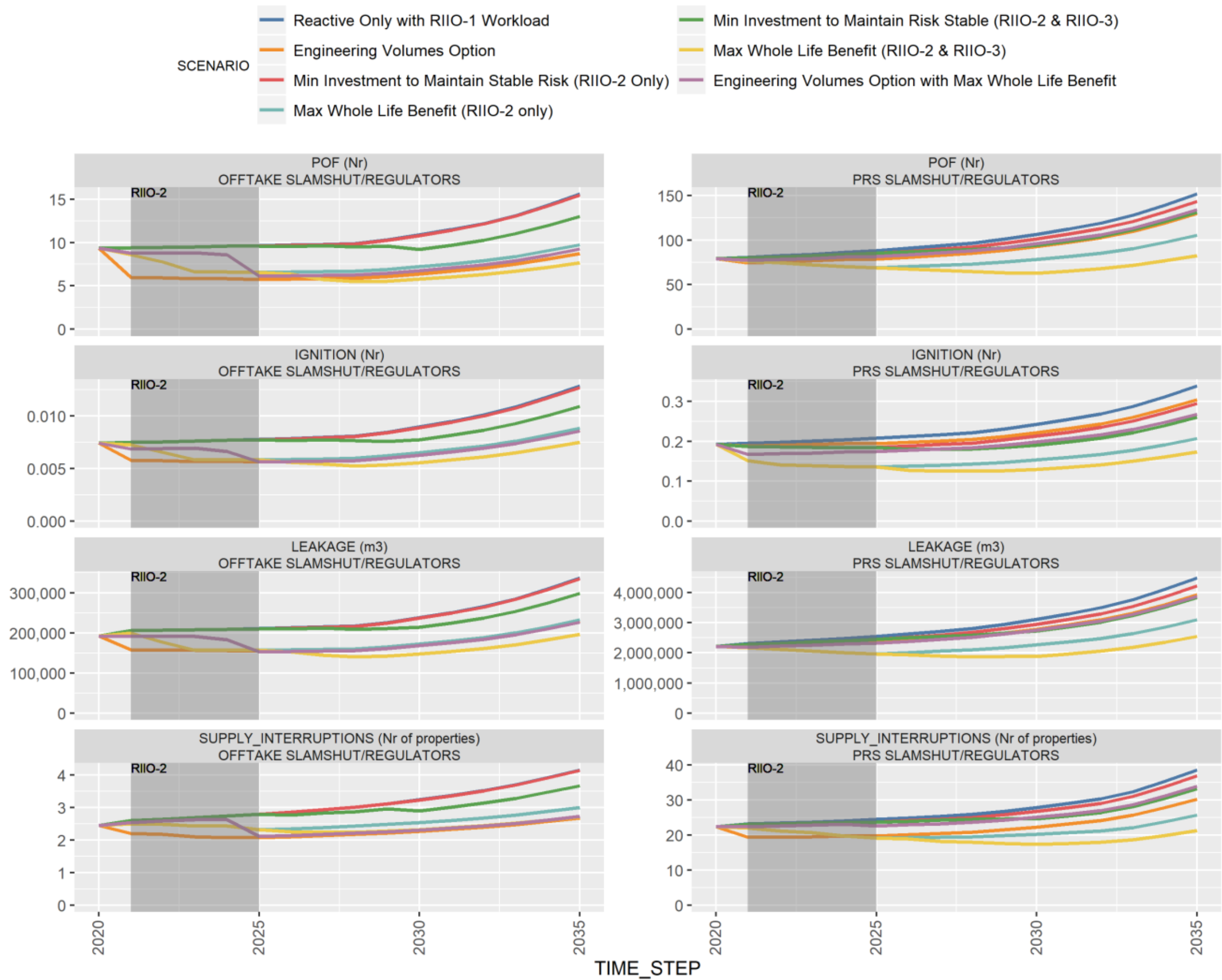


Figure 13: Key asset health and performance measures over time per asset category coloured by scenario (N.B. the Y-axis is independent for each plot)

This chart shows several varying scenarios of investment and risk that were investigated and compared to the reactive only scenario (blue line) for each asset category (Offtakes and PRS). All scenarios can be seen to either be near constant or reduce key performance measures over RIIO-2 (grey shaded box). All scenarios were assessed and compared against the final chosen scenario – based on engineering assessment of all options (Engineering Volumes Option Chosen – Option 1).

Benefits from the investment

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. The benefits are conservative, as described above.

Name	Asset Category	Scenario	2020	2025	2030	2035
POF (Events)	OFFTAKE SLAMSHUT/ REGULATORS	Reactive Only	9.36	9.64	10.87	15.59
		Chosen	9.36	5.76	6.38	8.73
	PRS SLAMSHUT/ REGULATORS	Reactive Only	79.28	88.27	106.33	151.49
		Chosen	79.28	78.80	92.84	129.60
IGNITION (Nr)	OFFTAKE SLAMSHUT/ REGULATORS	Reactive Only	0.01	0.01	0.01	0.01
		Chosen	0.01	0.01	0.01	0.01
	PRS SLAMSHUT/ REGULATORS	Reactive Only	0.19	0.21	0.24	0.34
		Chosen	0.19	0.19	0.22	0.30
LEAKAGE (m3)	OFFTAKE SLAMSHUT/ REGULATORS	Reactive Only	192,287	211,042	237,705	337,077
		Chosen	192,287	154,466	169,306	228,688
	PRS SLAMSHUT/ REGULATORS	Reactive Only	2,209,325	2,551,844	3,117,167	4,489,478
		Chosen	2,209,325	2,343,460	2,787,599	3,930,026
SUPPLY INTERRUPTIONS (Props)	OFFTAKE SLAMSHUT/ REGULATORS	Reactive Only	2.44	2.80	3.24	4.16
		Chosen	2.44	2.07	2.27	2.68
	PRS SLAMSHUT/ REGULATORS	Reactive Only	22.29	24.45	27.83	38.59
		Chosen	22.29	19.70	22.25	30.17

Table 36: Comparison of the performance improvements of Option 1 versus ‘Reactive only’

This is also shown in the following chart:

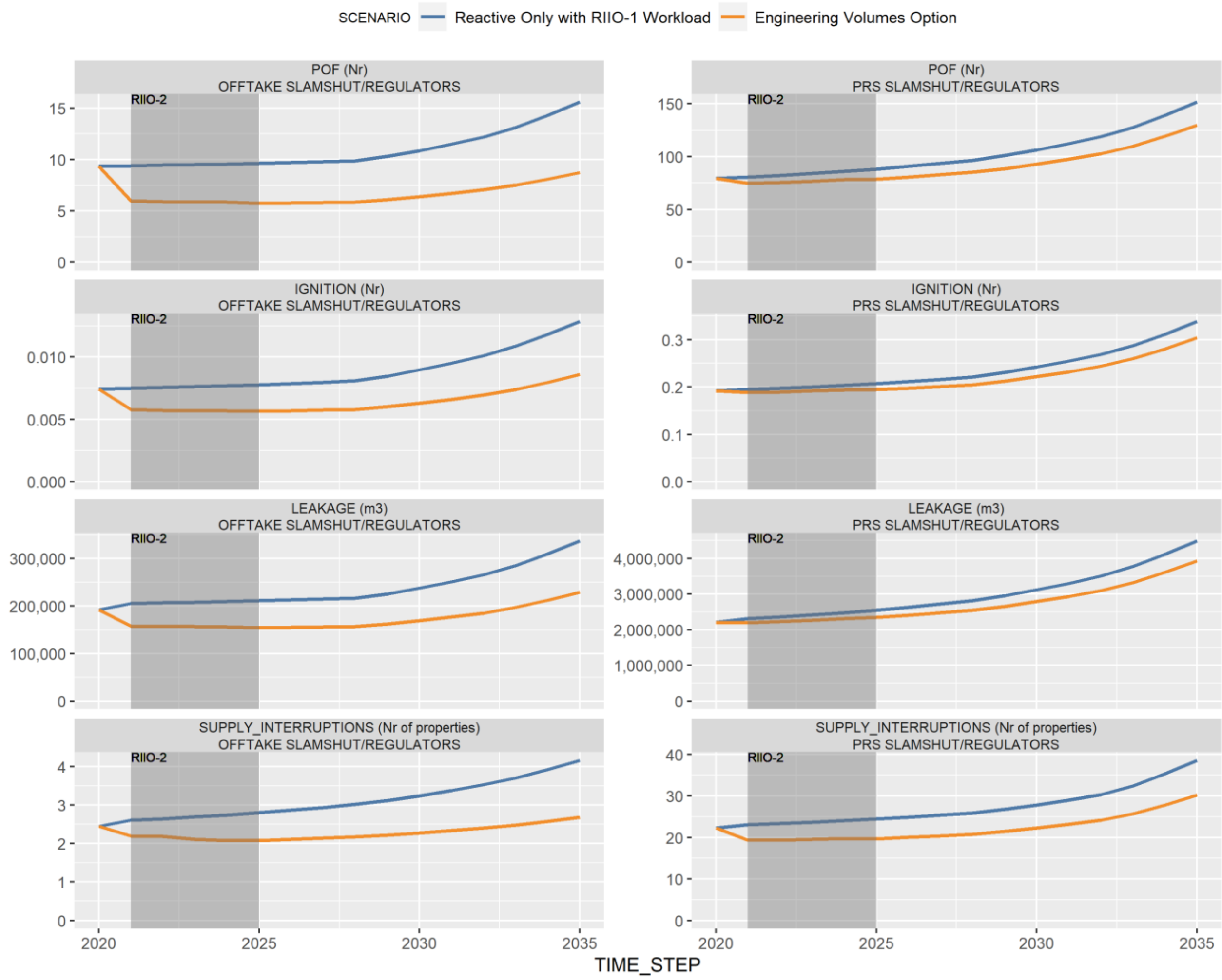


Figure 14: Summary of baseline versus the preferred Option 1
(N.B. the Y-axis is independent for each plot)

This chart shows a comparison of a 'reactive only' (no investment) approach compared directly to the chosen scenario for four key asset health and performance measures. The chosen scenario shows a flat or reducing risk position at the end of RIIO-2.

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

Our preferred option is Option 1 – Engineering Volumes Option.

While the chosen option does not have the highest NPV, this option balances investment to reduce the assets risk position whilst being affordable and deliverable.

Option 1

Based on the preferred option, the following table summarises the proposed intervention volumes for RIIO-2. A more detailed split of interventions by Offtakes and PRSs is in Section 7.

	Intervention Volumes					
Region	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
Offtake						
EoE	11	13	11	13	11	**59**
Lon	1	1	2	1	1	**6**
NW	8	7	7	7	8	**37**
WM	1	2	1	2	1	**7**
Total	**21**	**23**	**21**	**23**	**21**	**109**
PRS						
EoE	30	29	30	29	30	**148**
Lon	10.6	11.6	10.6	11.6	10.6	**55**
NW	6	6	5	6	6	**29**
WM	19.8	19.8	20.8	19.8	19.8	**100**
Total	**66.4**	**66.4**	**66.4**	**66.4**	**66.4**	**332**

***** Note: The PRS slamshut regulator interventions for Lon & WM have been smoothed across the RIIO-2 period.***

Table 37: Option 1 Total Intervention volumes in RIIO-2

9.2. Asset Spend Profile

We envisage that work delivery in RIIO-2 will be on a smoothed profile and broadly similar to that in RIIO-1, although variations year-to-year can be noted – especially on Offtakes where small volumes of interventions, make large differences in spend profile year-to-year.

The associated investment levels for RIIO-2, based on the above intervention volumes are set out below.

	Costs £m					
	2021/22	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
Offtakes						
EoE						
Lon						
NW						
WM						
Total						
PRS						
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 38: Option 1 Total Intervention Expenditure in RIIO-2 in £m

9.3 Investment Risk Discussions

Remediation on slamshuts and regulators are routine tasks undertaken by our operations team and our supply chain; as such, we do not foresee any material delivery risks associated with this investment case.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.07 - 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
09.07 - 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
09.07 - 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
09.07 - 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.
09.07 - 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.
09.07 - 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.
09.07 - 007	Lack of clarity on Regulator replacement components	Effect on pricing and delivery of availability to meet programme	Low	Ongoing research and market testing with supply chain

Table 39: Risk Table

9.4 Regulatory Treatment

The outputs from this investment will be included in the NARMs reporting mechanism.

With the exception of Bristol Controllers, which are less than **XXXX** of investment across our four networks, the workload will be reported through RRP and cost variance managed through the Totex Incentive Mechanism (TIM).

This investment is accounted for in the Business Plan Data Table 3.01 LTS, Storage & Entry, within the PRS and NTS Offtake Sub-Tables.

Appendix 1. Photographs showing examples of Regulators

Figure 1: Pressure-Regulating installation showing filters in the foreground, monitors and vented building behind

Figure 2: PRS (Stream A) with monitor and action regulators

Figure 3: PRS (Stream B) with monitor and action regulators

Figure 4: Associated Instruments (not in scope of this methodology)