Cadent
Your Gas Network

Appendix 09.14
Offtakes & PRS Filters
RIIO-2 Spend: XXXX

Investment Decision Pack Overview: Offtakes and PRS filters

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.

Overview

Filter systems are normally installed within an Offtake or PRS typically upstream of the pressure control system in order to remove dust or debris in the gas flow. This ensures a safe supply of clean gas to the downstream system and protects the regulators and control valves from damage.

The replacement of filters is a routine, low-cost, high-volume activity which results from a risk-based inspection programme. We need to invest in these assets to comply with Pressure System Safety Regulations (PSSR), 2000. As assets age and deteriorate they are more prone to failure, which can result in legal non-compliance and may lead to explosions which could cause injury as well as a loss of supply to customers.

Our investment programme is driven by safety requirements. We have also undertaken cost benefit analysis to assess the proposed level of investment. In the CBA, the baseline for our assessment is reactive investment only. We have undertaken a rigorous assessment of a range of intervention options:

- Intervention based on bottom-up engineering assessment of PSSR failures and faults from RIIO-1
- Intervention to maintain stable monetised risk (using NOMs model)
- Intervention to deliver maximum whole life benefits (using NOMs model)

Our analysis shows that these Options (and the additional scenarios) are all highly cost beneficial, delivering significant benefits in terms of reduced leakage and improved safety. Our preferred option is to continue to intervene based on bottom-up engineering assessment of PSSR failures and faults from RIIO-1. This option ensures sufficient investment to fully comply with PSSR regulations; our NOMs model does not fully represent this regulatory mandate to remediate filters for PSSR compliance. Our NOMs model underestimates the investment required to fully manage this risk.

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

Material Changes Since October Submission

There has been a reduction of XXXX of investment since October after calculations have been refined (a more specific calculation of asset risk), reducing the number of expected filter replacements that are to be undertaken in RIIO-2. The cost base for this document has been updated to 2018/19 prices.

Table of Contents

2. Introduction

The following Engineering Justification Paper (EJP) document covers the investment case methodology for high pressure (above 7 bar) filter replacements at Offtake and Pressure Reduction Systems (PRS) sites.

Filter systems are normally installed within an Offtake or PRS typically upstream of the pressure control system in order to filter out dust or debris in the gas flow. This ensures a safe supply of clean gas to the downstream system and protects the regulators and control valves from damage.

Filter replacement is a routine, low-cost, high-volume activity which results from a risk-based inspection programme. Filters are included in the NOMs reporting tool and, as such, we can report the risk benefit associated with these assets.

Signs of structural failure of the filter unit means that it is no longer safe to hold compressed gas – filters must hold gas between 7 and 75 barg - such filters are not compliant with the Pressure System Safety Regulations 2000 (PSSR).

To determine the replacement investment, two approaches have been developed. First, we have reviewed past failure rates to establish an average number of interventions following a known number of inspections. We apply the failure rate to the known inspection programme to produce a work volume. Second, we use a modelling framework to predict the volume of work needed to 'hold total monetised risk flat' for filter assets. The latter approach does not reflect the requirements of PSSR, but it does capture general condition and performance. We have compared these two approaches to confirm our final work volume.

This document sets out our approach in line with Ofgem's data template guidance. It also describes our approach to inspections as it relates to developing our inspection plans. The costs of inspection are opex and are recorded elsewhere.

Investment is shown in the Business Plan Data Tables (BPDT): LTS, storage and entry within NTS Offtake/PRS line.

The approach adopted reflects compliance with external codes and company management procedures. Our costs are efficient, and our proposed investments provide value for money and align with stakeholder requirements. We are therefore confident we have identified the right mix of interventions and investment for this asset type.

3. Equipment Summary

Data sources

Two data sources have provided the asset list and base data requirements.

- SAP Extract (February 2019) provides the hierarchy of assets, condition data, and other important attributes.
- The Pressure System Database (PSDB) is the repository of our safety data to demonstrate compliance with the Pressure System Safety Regulations 2000 (PSSR)

Filter systems

Filter systems comprise of two or more gas filters (units) are normally installed within an Offtake or PRS, typically upstream of the pressure control system. Filters ensure a supply of clean gas to the downstream system and protect the regulators or control valves from damage.

Filter assets of same size and type are installed across both Offtake and > 7 bar PRS sites with the same ageing and fault mode mechanisms, therefore have been delivered in one complete investment case. We have however split out the two elements for report in line with Ofgem guidance.

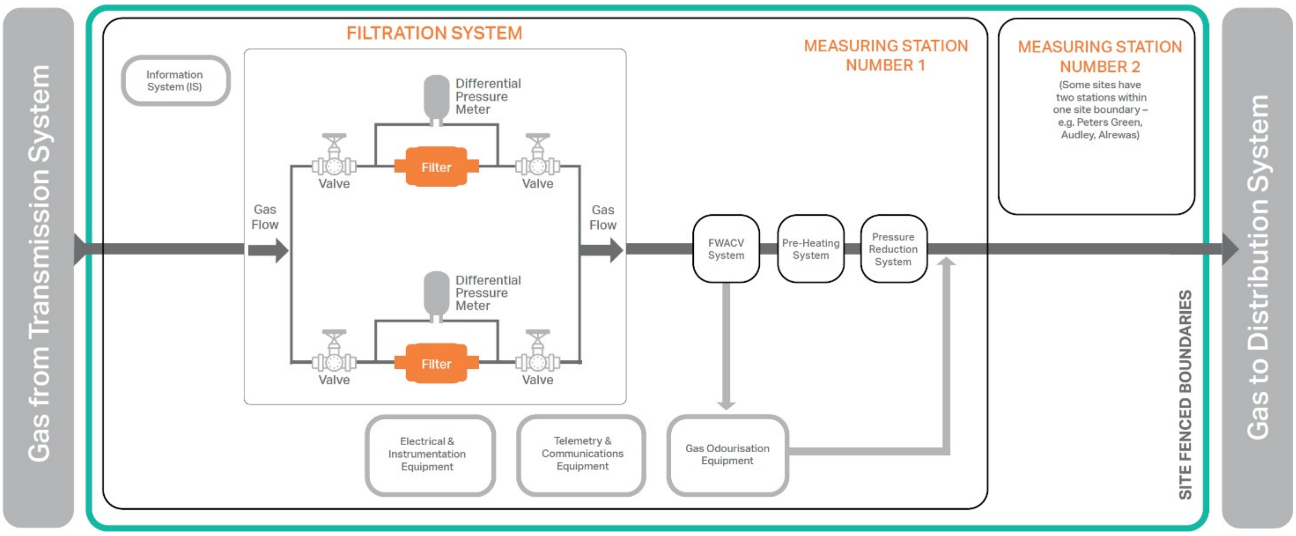


Figure 1: Typical Layout of an Offtake / Pressure Reduction Station with Filters

Our 1,570 high-pressure filters are of various sizes, ranging from 1" diameter up to 1,200mm; these are recorded in the Pressure System Data base (PSDB). Approximately 16% of asset stock is of 3" or less diameter (≤3"); with the remaining 84% being more than 3" in diameter (>3").

These assets remove particles and debris from the pipes, that may otherwise cause damage and blockages to downstream pipes and equipment, resulting in a potential risk of costly remediation.

Filter units may be arranged in parallel with common inlet and/or outlet pipework or within individual pressure reduction streams. Valves located on the inlet and outlet of each filter allows the isolation and removal of filter elements for cleaning or replacement.

Filters are categorised as ‘pressure vessels’ and are therefore covered by the Pressure Systems Safety Regulations (PSSR) 2000, which also detailed the relevant examinations required.

Figure 2: Filter

We hold the necessary asset and performance data for the filter assets to comply with PSSR reporting requirements.

Investment history

The current inspection methodology for RIIO-1 is a physical inspection by a specialist engineer with Magnetic Particle Inspection (MPI) non-destructive testing, to assess the condition of filters and non-compliance with PSSR. The same inspection methodology will be used going forward.

To maintain the performance and risk of the asset stock, through RIIO-1, we have delivered a rolling programme of inspection and replacements which are driven by legislative requirements.

Inspection frequency is based on the previous inspection result, with the duration between inspections adjusted accordingly to effectively manage any observations identified in previous inspections to ensure the filter remains fit for purpose.

We also conduct visual inspections and operational maintenance visits to our sites. These can lead to high-pressure filters being replaced in addition to those failing the planned PSSR inspection. Our data for replacements in the years 2018/19 and 2019/20 shows that 1.5% of asset stock is to be replaced in each network each year based on their condition, determined by networks.

Asset profile

A summary of the asset base for each network is shown in the following table, which has been refined since July's submission:

		Filter Size				
		≤3"	≤3" (Welded-in)	>3"	Other	Grand Total
	Offtakes	**18**	**0**	**143**	**0**	**161**
Network	East of England (EoE)	14	0	60	0	**74**
Network	North London (Lon)	0	0	16	0	**16**
Network	North West (NW)	4	0	35	0	**39**
Network	West Midlands (WM)	0	0	32	0	**32**
	Not Offtake - PRS	**212**	**14**	**1,182**	**1**	**1,409**
Network	East of England (EoE)	120	0	515	0	**635**
Network	North London (Lon)	12	0	204	1	**217**
Network	North West (NW)	44	14	227	0	**285**
Network	West Midlands (WM)	36	0	236	0	**272**
	Grand Total	**230**	**14**	**1,325**	**1**	**1,570**

Source: Pressure Systems Database (PSDB)

Table 1: Above 7 Bar Filters Asset Base

Note: Filters of diameter 80mm or less and 3" or less are deemed to be in the less than 3" group of filters and are referred to as ≤3" throughout this document.

The overall observed condition of our assets is shown below. This condition score is assessed through visual surveys, with clear criteria used to assign an asset to a condition band. Condition 1 assets are in very good condition, typically new or rehabilitated, with little or no evidence of deterioration. Condition 5 assets are in very poor condition, with the asset in unacceptable condition with widespread evidence of deterioration and potential for failure. This condition assessment is not linked to PSSR compliance criteria which would include Magnetic Particle Inspection (MPI).

We are intervening on the assets which are in poorest condition and reliability in RIIO-1 to manage risk. Assets will deteriorate over time and are monitored through risk-based inspections, until proactive intervention is needed.

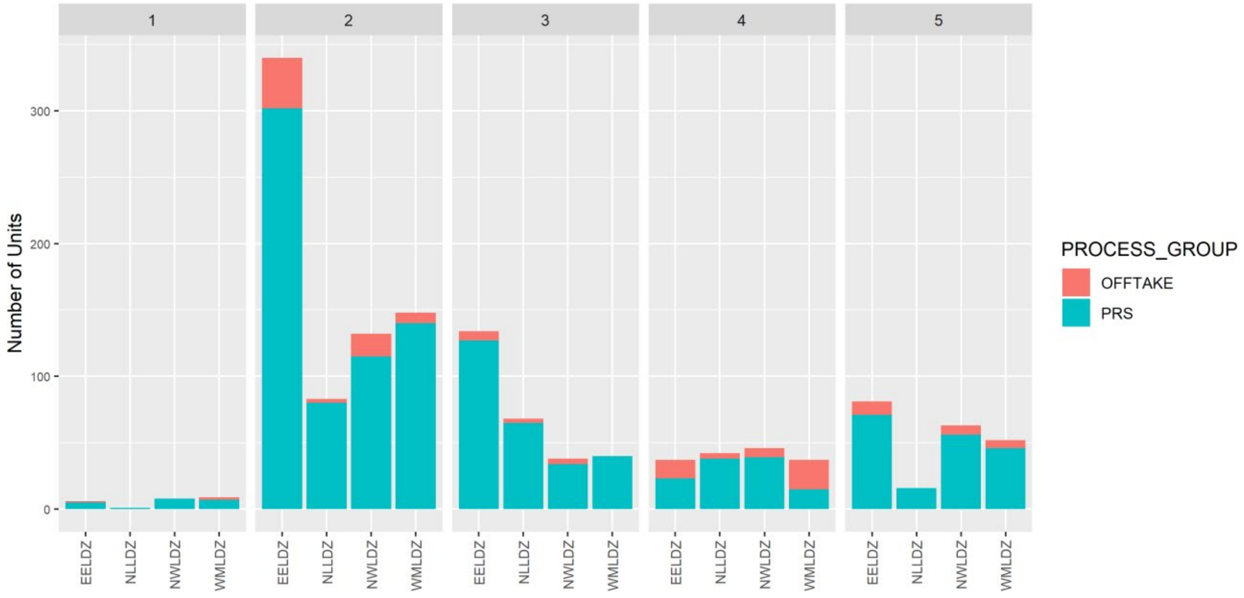


Figure 3: Condition Profile (SAP data – February 2019)

While we do not invest in these assets to improve observed condition *per se*, this is useful in showing that several assets are showing signs of ageing.

We have a good understanding of our filter asset base. We understand the condition and performance of these assets.

4. Problem Statement

We invest in these assets to comply with PSSR. As assets age and deteriorate they are more prone to failure, which can result in legal non-compliance and may lead to explosions which could cause injury as well as a loss of supply to customers. Compliance with PSSR is an absolute duty.

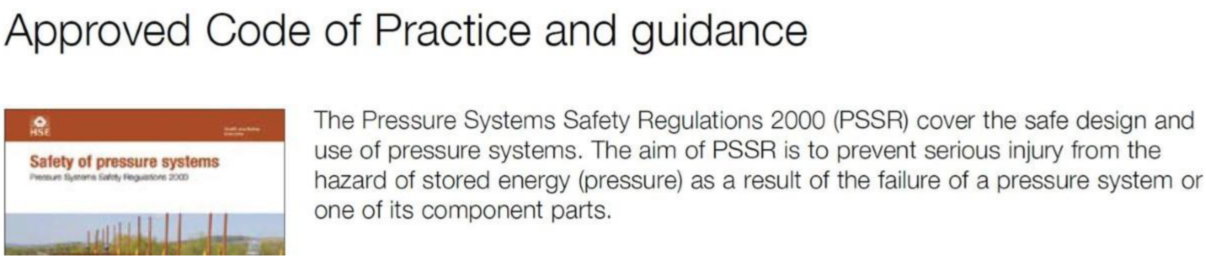


Figure 4: Approved Code of Practice

Our base case supply demand scenario for this investment case is our peak 1 in 20-year demand to comply with our Licence Obligations. A significant amount of investment in filters is repair and remediation, which is not impacted by small changes in supply demand scenario. 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 filters required, where a replacement filter is required, as such we have only considered one supply demand scenario.

Investment drivers

The investment drivers for filters are Safety (Legislative), Asset Condition (Performance) 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 in order to minimise customer bills.

Legislative

We have a duty to maintain a safe network and prevent gas leakage and the risk to the public and operational staff of an explosion from a pressure-vessel failure. All above 7 bar filters must comply with the Pressure Systems Safety Regulations (PSSR) 2000 and are inspected to assess filter condition and ensures the filter remains fit for purpose.

Performance condition

Investment is required in above 7 bar filters that require replacement, driven by asset condition and not by PSSR inspection results, (i.e. non-PSSR filter interventions). In these cases, an asset has not failed with regard to its ability to contain high-pressure gas but needs investment to improve its overall condition and functionality. This site condition-based replacement can be modelled by the NOMs reporting tool.

Interruptions to supply

A secondary driver for investment in filters is to prevent interruptions to supply. Filtration is essential to ensuring a supply of clean gas to the downstream system. Site failure can result in the loss of supply to all downstream domestic, commercial or industrial consumers.

Our current records show that we have few or no interruptions to supply due to these assets (although we do record faults on our pressure reduction equipment linked to poor filter performance); investment ensures we maintain the high levels of reliability of these assets.

However, our NOMs model does not forecast interruptions to supply, based on the allocation of failure modes to asset types on offtake and PRS sites and therefore we have not allocated any failures which lead to site failure and supply interruptions, for RIIO-2.

Impact of no investment

We can consider the impact of no investment through two lenses. First, failure to comply with safety legislation would lead to HSE enforcement and could also result in injuries, fatalities and interruptions to supply. Second, we can model the deterioration of the asset in our modelling tool, reflecting condition classes.

With no investment, the number of failures and the risk of consequences increases over time.

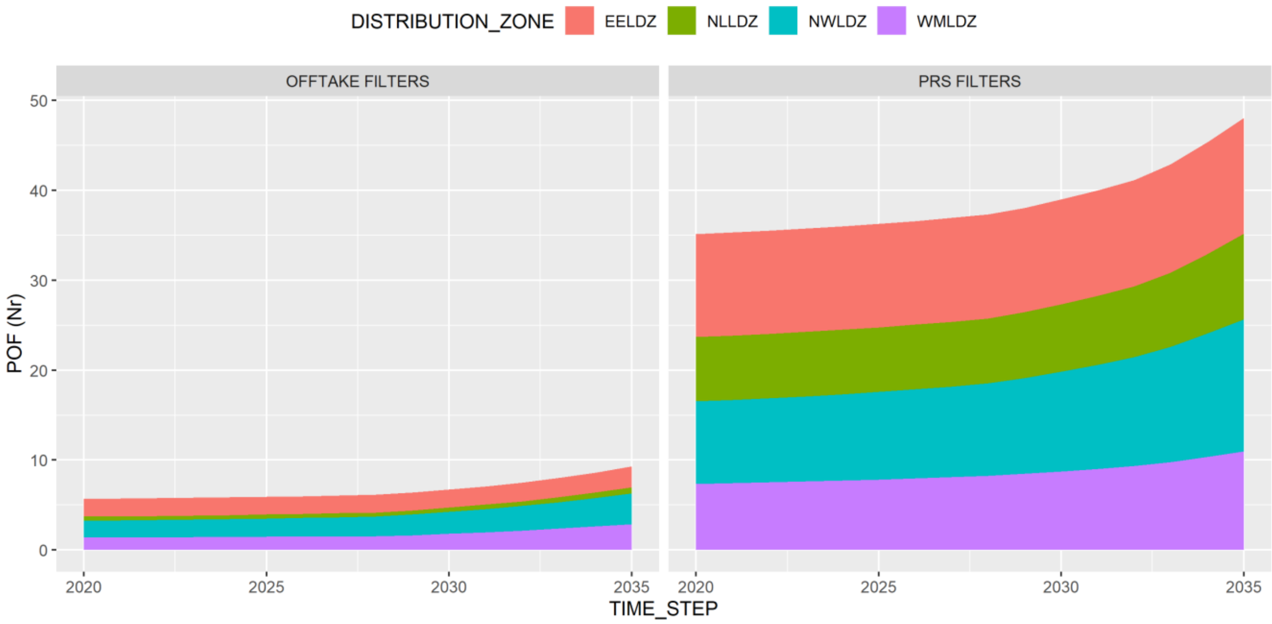


Figure 5: Probability of failure (POF – volume of failures) over time for reactive only (no investment) split by asset category coloured by distribution zone

The reactive only plot shows an increasing trend of POF (faults) across all networks with PRS Filters showing a greater absolute value due to a larger asset portfolio.

Required outcomes

We consider the do-nothing position (i.e. what happens if we do nothing) to be unacceptable. The do-nothing position does not ensure that we comply with PSSR and creates a material safety risk. Customers and stakeholders have consistently told us that worsening levels of reliability and network security is not in line with their preferences. Our approach to customer research is described in Chapter 5 of the Business Plan.

In summary, the required outcomes for this investment are a safe and reliable system. Success is measured by ensuring zero explosions and zero HSE enforcement for non-compliance.

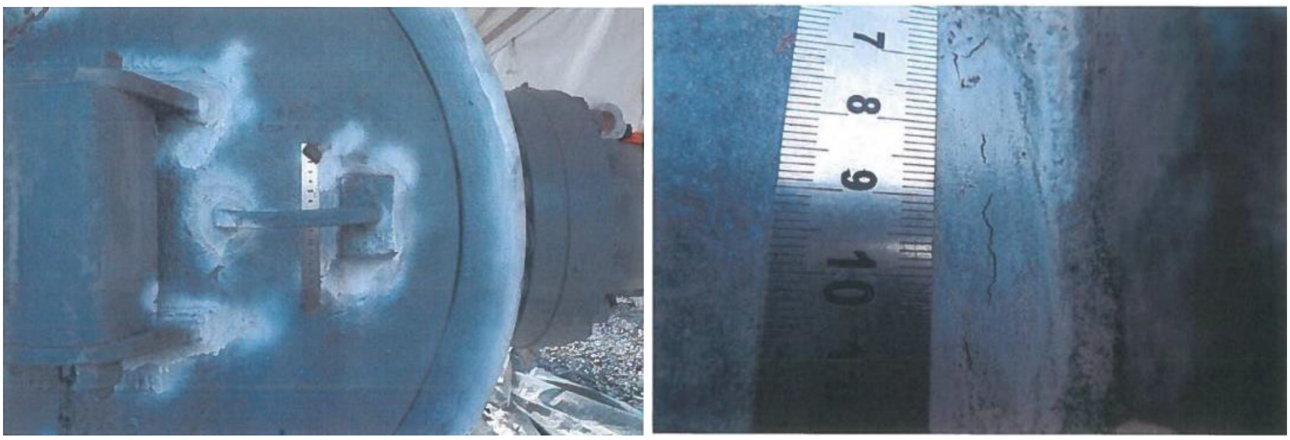
We will consider our investment plans to be acceptable and appropriate if and only if these outcomes are met.

4.1. Narrative Real-Life Example of Problem

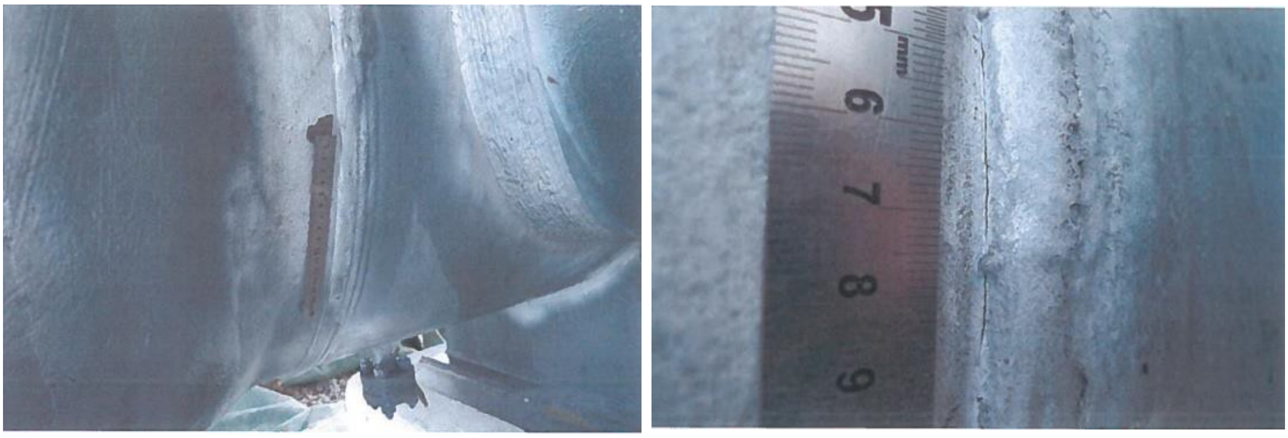
Pressure system: Alrewas Offtake, West Midlands network. Inspected: October 2018. Maximum Operating Pressure 70 barg.

Filter units run at high pressure and go through multiple pressure cycles, leading to deterioration of integrity. Small cracks identified can grow over time due to fatigue and corrosion and, if left unchecked, can grow to the point where the filter casing is unable to contain the pressurised gas within, resulting in failure of the filter, dangerous uncontrolled escape of gas and failure to supply the network downstream.

The inspection of this asset shows the types of defects and issues that can arise with filters and, therefore, compromise safe and compliant operation.



Cracks in the left-hand side of the door handle mounting block measuring 4-15mm in length



Multiple toe cracks throughout the front-end sub-arc girth weld. Cracks measured 2-122mm in length.

A 10mm crater crack in a longitudinal sub arc weld to the front end of a filter.

Figure 6: Alrewas (West Midlands) Inspection Results

These failures, resulting from operational wear and tear since the last inspection, compromise the structural integrity of the filter and render it non-compliant with PSSR. The filter may still be operating satisfactorily in terms of filtration but there is a significant fault that requires action quickly to prevent system failure (rupture) before the next inspection.

4.2. Spend Boundaries

We will only replace the filter unit; this includes the basket and door. We would not replace pipe supports or surrounding pipework as part of this intervention.

This paper covers replacement. Minor operation interventions, such as filter cleaning, are picked up through opex and are not included in this investment case.

This case does not include filter valves – valves are included in the Valves investment case.

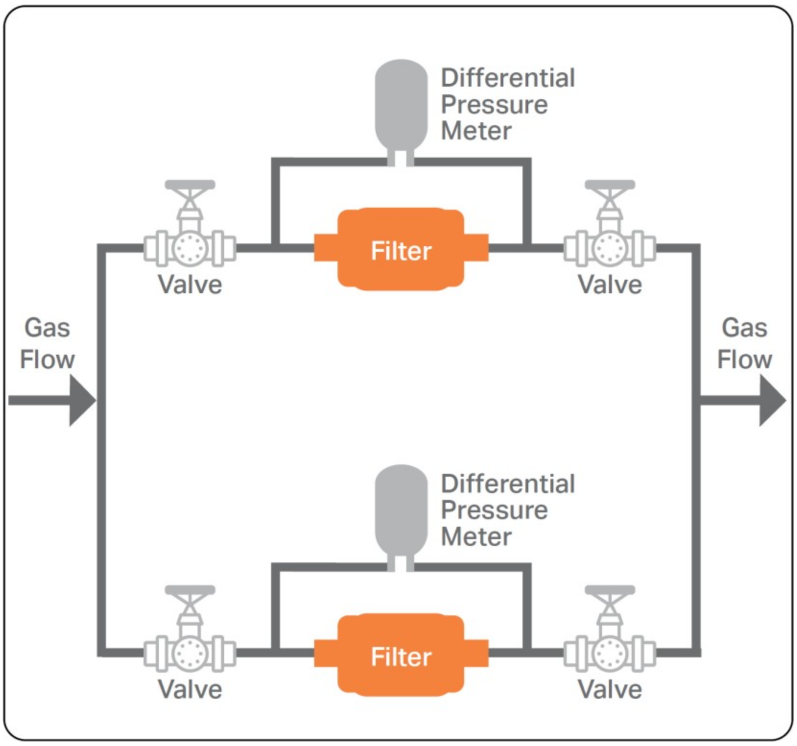


Figure 7: HP Filter Investment Case Spend Boundaries, the orange filters is the only element of the system included

5. Probability of Failure

We have considered the probability of failure in two ways. First, we have reviewed past PSSR failure rates to establish an average number of interventions following inspection. Given the future risk-based inspection programme is known, we can apply the failure rate to the inspection programme to produce a work volume.

Second, we have examined age-based deterioration as calculated by the Network Output Measures (NOMs) model, which we can run forward. The issue with this approach is that it does not capture failures against PSSR, such as those identified in Section 4.1. The failure mode is a structural integrity failure – a crack – which compromises a filter's ability to hold gas under pressure.

This section, therefore, discusses the probability of failure based on our model as well as the learning from a more detailed review of our PSSR failure rates (from a review of our filter inspection reports).

Probability of failure within our Model

In NOMs we have modelled five failure effects:

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.

Low Outlet Pressure – failure of the filter, such as a blockage of all filters due to upstream contamination, can lead to a partial or total loss of downstream supplies.

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. This would typically require the concurrent failure of the regulators and the slamshut (failure to operate) within one pressure control stream. Such concurrent failures are rare, but the probability of failure may be inferred through available data associated with individual component faults.

Capacity – this is where the system, due to failure, has insufficient capacity to meet a forecast 1:20 peak day downstream demand.

General Failure – this covers other failures that do not lead to the release of gas, low/high outlet temperature or capacity failures, such as failure of the instrumentation or telemetry system.

However, these effects do not drive the required investment, and we have estimated RIIO-2 failure rates based on our past inspection failures.

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.

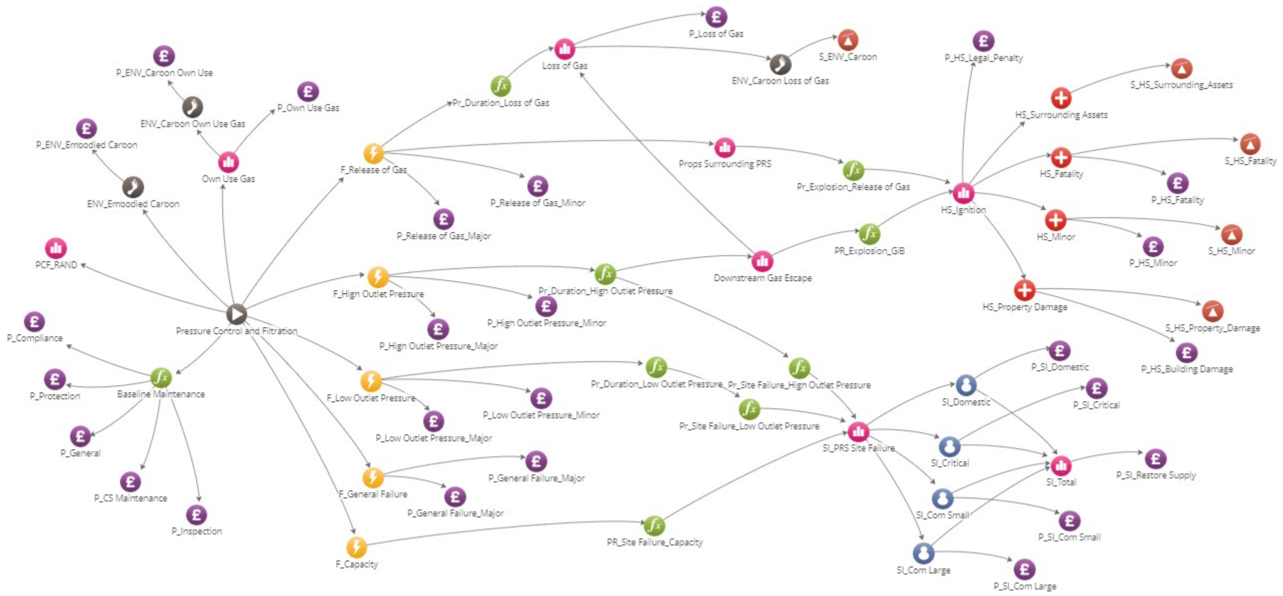


Figure 8: Filter Risk Map

This risk map also shows the consequence 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.

The following graph shows the performance of the filters over time with no investment, for each of the key risks.

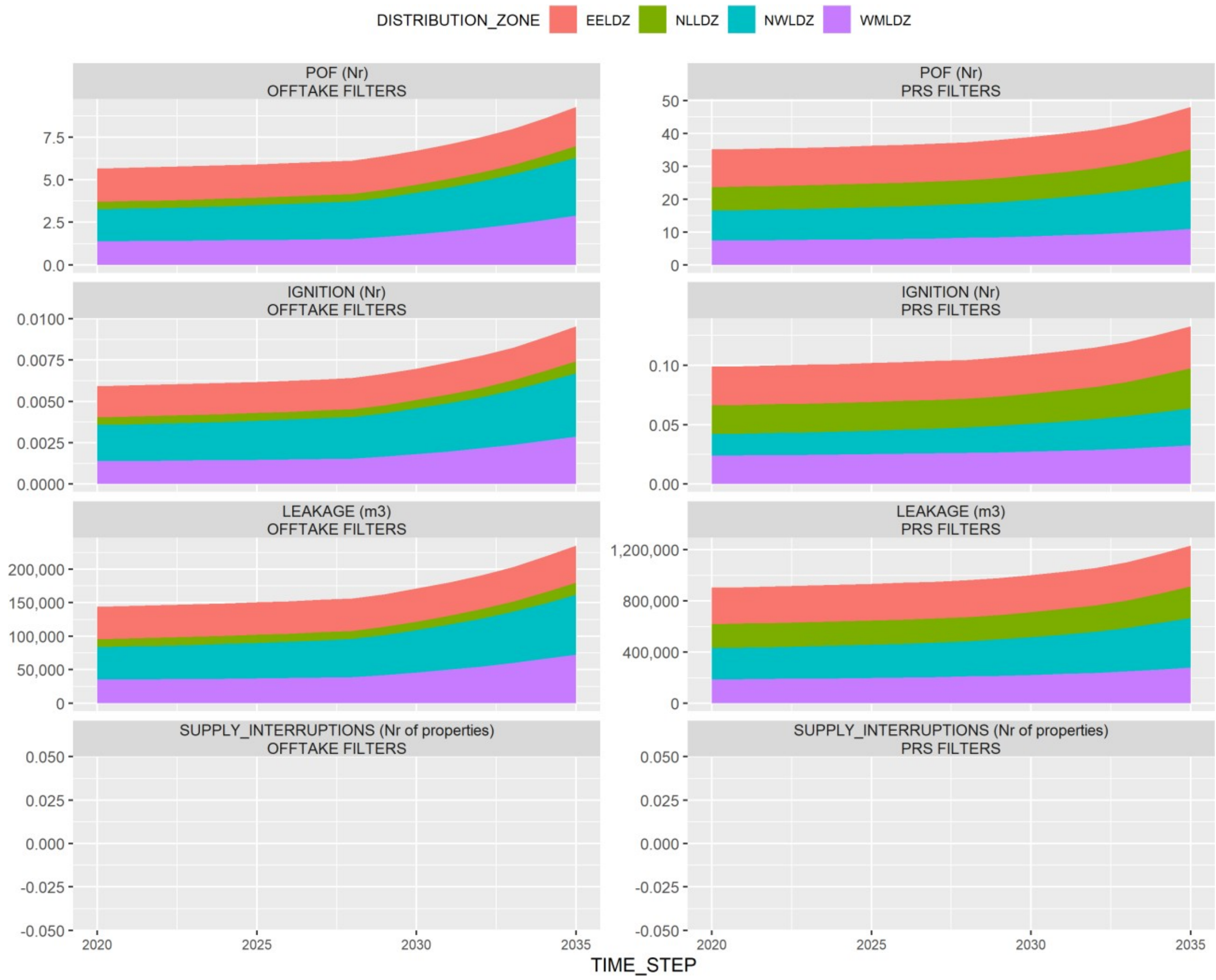


Figure 9: Key risks over time for reactive only (no investment) split by asset category coloured by distribution zone.

The key asset health and performance measures reactive only plot shows an increasing trend across all networks with North London proportionally larger in PRS compared to Offtakes. Filters are not associated with supply interruptions risk in the NOMs model, hence there are no performance data in the chart above.

RIIO-2 fault rates based on Filter inspection data

As part of our targeted engineering assessment of filter performance (the basis of our Option 1), we reviewed our filter inspections results and analysed the failure rates. Failure, in this context, is defined as a serious deficiency or risk that requires an intervention to comply with PSSR. The RIIO-2 failure rates for PSSR, and therefore the required intervention volumes, have been set based on the ratio of inspections to interventions recorded in RIIO-1. This provides a predicted volume of interventions across all filters of different sizes above 3".

For filters ≤ 3" in diameter, Cadent doesn't carry out an inspection to identify faults, with a subsequent follow-up visit to rectify any deficiencies. The cost of ≤ 3" filters is less than XXXX, and it was shown during RIIO-1 that a proactive replacement of these ≤ 3" filters, to align with the 12-year inspection frequency for PSSR compliance, provided the best value (i.e. cheaper than paying for an inspection and then paying for a replacement of a portion of the stock). For this reason, we do not have the corresponding failure rates for ≤ 3" filters. Further details on this approach are outlined below.

When defects are identified, these are assessed in accordance with the Defect Management Procedure T/PM/DAM/1, based on industry standards, to determine if they are within Cadent's allowable defect size limits, which results in either increased monitoring, grinding repair, weld repair, hydrotest revalidation or replacement. T/PM/DAM/1 determines whether a filter requires replacement (and would feed into this investment programme) or requires refurbishment via an opex/maintenance intervention.

The PDSB data also captures information on the type of a fault and its severity.

The severity of faults is identified as part of an inspection. The different fault reporting categories are as follows:

A1 – Imminent Danger Fault – Immediate action is required

A2 – Significant Fault – shall not give rise to immediate danger but where action is required to prevent system failure prior to the date of next inspection

B – Category Fault – where the component is not in the condition it should be, but not judged to be dangerous. Action or assessment is to be conducted to ensure the fault shall not deteriorate into an A2 fault by the next inspection

C – Category Report – represents a satisfactory condition

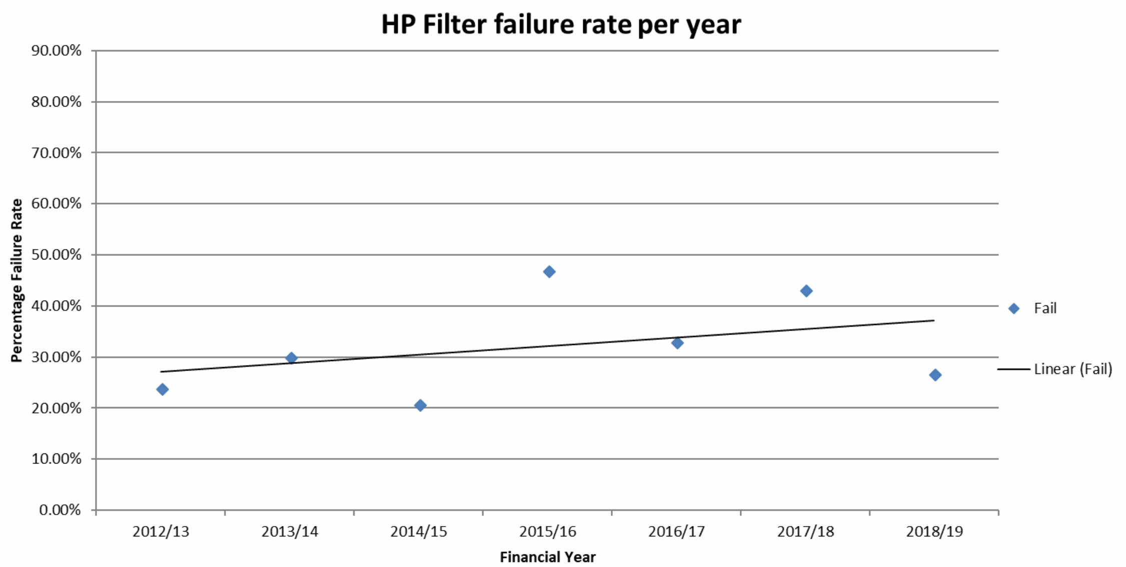
During RIIO-1, interventions were completed on filters with fault categories A1, A2 and B.

PSDB filter inspections during RIIO-1 have been analysed to determine filter design failure rates. A total of 33.25% of filters inspected had an identified risk of non-compliance with PSSR through GD/PM/PS/3 in accordance with T/PM/DAM/1 (i.e. an A or B fault).

When the failure rate is reviewed in each year of RIIO-1 it is seen that the failure rate is variable year to year, with a small overall rise in the trendline (Figure 10). We are not extrapolating this trend into our investment case for RIIO-2. Rather, we have selected the average rate throughout the whole assessed period, a **failure rate of 33.25%** and applied to all filter sizes. By combining our regional data in to a single data set (Figure 10) we have a larger and therefore more representative sample of filter failure of inspection rates.

The failure rate derived is for filters only and is different from the RRP data reported for all PSSR device faults.

Categories A1, A2 and B are considered as a 'Fail'. Category C is considered as a 'Pass'. Defect acceptance limits are defined in specification document GD/SP/PV/15.



No. of inspections	25	63	154	136	151	132	127

Figure 10: HP Filter failure rate percentages by year

In RIIO-2, we intend to continue to invest in faults of a similar severity (A1, A2 and B) and, therefore, keep the risk profile consistent with that in RIIO-1. This is to ensure Cadent remain compliant with PSSR requirements and effectively manage asset health risk of filters as part of pressure reduction systems as a whole. We have implemented a 1-year phase shift from inspections to interventions, to allow for the lead time to purchase and install the filter. Year 8 of RIIO-1 inspections impact on interventions in year 1 of RIIO-2. This 1-year offset shift is taken forward throughout the RIIO-2 period.

It has been assumed that any asset that attracts an A1 or A2 fault severity poses a risk of gas leakage, explosion, damage to other assets or people, and loss of supply, i.e. it is not PSSR compliant. An asset with a B fault has an impending breach of legislation, if no action is taken, i.e. filter not being fit for purpose. As such, no further prioritisation of fault rectification has been completed as action is required on all faults.

A review of the most prevalent fault modes has been conducted, with cracks being most significant and surface defects also being notable.

On this basis, with the 33.25% fault rate applied, Cadent estimates the following number of filters to fail inspections and require replacement per network per year throughout RIIO-2 is shown below:

Expected volume of Inspections to inform RIIO-2 interventions:

Network	2020/21	2021/22	2022/23	2023/24	2024/25	Total
EoE	30	34	33	32	48	**177**
Lon	14	8	5	20	21	**68**
NW	4	5	1	9	6	**25**
WM	17	6	21	14	26	**84**
Total	**65**	**53**	**60**	**75**	**101**	**354**

Table 2: Future >3" Filter Inspection volumes per Network per Year

Expected volume of subsequent Interventions in RIIO-2:

Network	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	10	11	11	11	16	**59**
Lon	4	3	2	6	8	**23**
NW	2	2	1	3	1	**9**
WM	6	2	6	5	9	**28**
Total	**22**	**18**	**20**	**25**	**34**	**119**

Table 3: Future >3" Filter Intervention volumes per Network per Year

5.1. Probability of Failure Data Assurance

Our records are part of the Pressure Systems Database (PSDB). The PSDB is audited on a regular basis (monthly) by a Competent Person representative. It has also been audited by HSE when PSSR was part of its routine audit. As such, the data is well controlled.

6. Consequence of Failure

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 size of filter unit, as such we have only considered one supply demand scenario.

Linking failures to consequences

Failure to intervene means non-compliance with our absolute duty in PSSR to ensure filters remain fit for purpose. If we do not replace deteriorated assets, the likelihood of an explosion is high, affecting safety. Loss of a supply through a large offtake can impact thousands of customers.

Within NOMs, each failure mode and probability of failure has been assessed in terms of its potential consequence. The consequences of failures are:

Consequences of failure	Description
Safety Risk	Ignition – an explosion at the filters and pressure control asset or in the downstream network
Environmental Risk	Downstream gas escape – caused by low outlet temperatures
	Loss of gas – from the filters and pressure control asset or the downstream network

N.B. filters are not associated with supply interruptions risk in the NOMs model and therefore are not included in the table above.

Table 4: Consequences of failure

Each potential consequence has been expressed as monetary values 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 5: Sources of societal benefits

These benefits have been estimated using a range of sources, including our own willingness to pay research with our consumers as well as published government values for carbon, risk of fatality, and non-fatal injuries as per the agreed industry methodology.

We have also included the financial consequences associated with fixing faults as they occur (e.g. repair costs) and remedying the consequences of failures (e.g. clean up and compensation).

The plot below shows the percentage contribution of financial risk components:

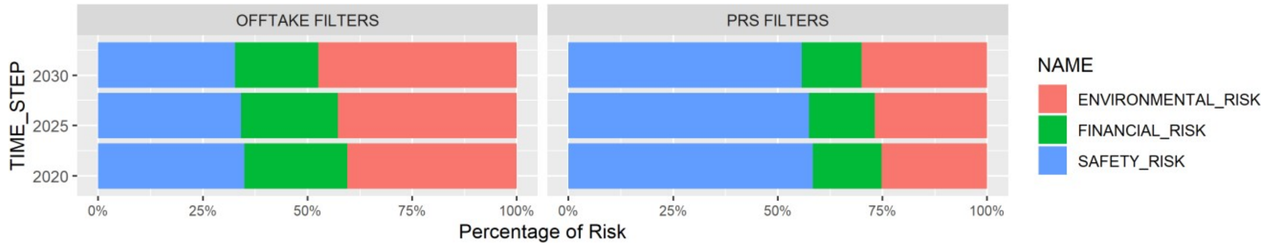


Figure 11: Proportion of risk components over time split by asset class

This plot shows the proportion of key risk components for each asset category over time. This shows that as assets age without intervention there is an increase in risk of leakage and safety risk.

7. Options Considered

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 and legislative requirements.

Replacement must be delivered within 12 months of a fault being identified. We are confident that replacement is the right intervention, given that our inspection regime uses Magnetic Particle Inspection (MPI) to identify failures – a well-established and well-understood process.

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 identified that the inspection costs for ≤3" filters are comparable with replacement costs. As such, for these assets, we do not inspect, but replace the asset. This is the lowest whole-life cost option for small filters.

From our analysis for the 56 ≤3" inspections planned for RIIO-2, 19 filters would require replacement which would cost at an extra XXXX compared to simply replacing all of the 56 filters and not paying for inspections. Although this is a small cost saving it does not include benefits in administration, mobilisation effort and filter replacement lead time.

For the considered options, each filter size has costs applied to them using information shown in Section 7.8.

We have therefore considered the following options within this paper, testing the volume of interventions that might be required in RIIO-2:

- Option 1: Bottom-up engineering assessment of PSSR failures and faults from RIIO-1
- Option 2: Maintain stable monetised risk (using NOMs model)
- Option 3: Maximum Whole Life Benefits (using NOMs model)

We have also considered the option of delivering cost beneficial investment only.

For comparison purposes, we have also included additional scenarios to understand the cost benefit of our plans as well as considering the maximum whole life benefits, excluding the use of customer interruption willingness to pay data, as part of our sensitivity analysis. It should be noted that these scenarios may not guarantee that our PSSR requirements are fulfilled to intervene upon filters where a 'crack' has been identified as the CBA model balances these risks against other factors such as environmental risks.

In RIIO-1 we have invested in the software tool AIM to allow us to build asset management capability using the NOMs approach. AIM includes an optimisation capability which allows us to model different investment scenarios and produce optimised plans and test their cost benefit. The cost-benefit analysis (CBA) capability within AIM can find the solution to a problem with many restrictions and potentially millions of potential solutions (options).

AIM has been used to model filters. This has involved 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 (these are performance failures not PSSR failures). Our model has been applied in RIIO-2 at the level of individual filter units – meaning that individual assets and their performance can be modelled, producing precise results for the plan.

The full scenario options list is below:

Option	Description
0	Reactive only
1	**Engineering Volumes Option (Chosen)** Bottom up engineering assessment of PSSR inspections, faults & asset health from RIIO-1. As set out above in RIIO-2 fault rates based on Filter inspection data
2	**Minimum investment to maintain stable risk (RIIO-2 only)** Used our monetised risk model to assess interventions and capex spend needed to hold monetised risk flat until the end of RIIO-2.
3	**Maximum Whole Life Benefits (RIIO-2 only)** We have used our monetised risk model to assess interventions whilst maximising whole life net benefit.
4	**Minimum investment to maintain stable risk (RIIO-2 & RIIO-3)** For comparison purposes, we have also considered the option to continue to maintain stable risk to the end of RIIO-3, to understand the RIIO-3 cost of this option.
5	**Maximum Whole Life Benefits (RIIO-2 & RIIO-3)** For comparison purposes, we have also shown the RIIO-3 expenditure associated with maximising whole life net benefits.
6	**Engineering Volumes Option with Max 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.
7	**Engineering Volumes Option excluding 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 as it has been used as a sensitivity test for Option 1.*

Table 6: Filter Options considered

Our approach to options analysis:

For any scenario, we have understood the year-on-year opex and capex costs, together with monetised risk impacts in a CBA. The results of the analysis over RIIO-2 are shown in Section 7 for Cadent as a whole (network-specific CBAs have been submitted alongside this document).

Costs and benefits are discounted and shown in present value (PV) terms in line with Ofgem requirements and HM Treasury Green Book. The net present value (NPV) is the overall summation of all discounted costs and benefits.

7.1. Option 1: Bottom-up engineering assessment of PSSR failures

This option assesses the level of intervention required to comply with our PSSR compliance, and thus achieve a safe and compliant asset base. The bottom-up engineering assessment of PSSR failures and intervention volumes uses past RIIO-1 fault data, to estimate a likely failure rate for RIIO-2.

We have a different PSSR inspection and maintenance approach for our filter asset stock, based on size:

- **Filter Interventions (≤ 3" diameter):** For Filters ≤ 3", we have assumed that these filters are replaced at the same time as the 12 yearly PSSR inspection must be conducted. We have therefore used our forward inspection programme and our RIIO-1 unit costs, applied to each filter size using the table in Section 7.8 below, to estimate our investment levels.
- **Filters Interventions (>3" diameter):** We carry out inspections and then proactively remediate the high-risk failures.

7.1.1. Option 1a: Filter Interventions ≤ 3"

We will need to replace 69 filters of size ≤ 3" in RIIO-2.

The variations in volumes are generated by the natural variation in inspection frequencies produced by the current inspection or replacement intervals (12 years); with an increase in replacement volumes in RIIO-3 as a result.

For the asset health driven replacements, we have used data for replacements in 2018/19 and 2019/20 which shows 1.5% of asset stock is replaced on condition in each network each year. Given this is based on a small sample size, our RIIO-2 investment case conservatively assumes we will need to intervene on 1% of our filter asset stock as a result of non-PSSR findings.

As we cannot predict the size of the filters within the ≤ 3" filter population that are affected due to asset health (non-PSSR) a blended average of ≤ 3" filter sizes and costs in RIIO-1 has been used to establish an estimated unit cost per network, which has been multiplied by the estimated 1% volumes in each network.

The following table summarises the volume of ≤ 3" filter interventions volumes for RIIO-2 and 3, by region and year, driven by **PSSR compliance**:

	Financial Year											
Network	2021/ 22	2022/ 23	2023/ 24	2024/ 25	2025/ 26	2026/ 27	2027/ 28	2028/ 29	2029/ 30	2030/ 31	2031/ 32	Grand Total
EoE	3	16	4	11	4	17	21	22	19	6	6	**129**
Lon	0	0	0	2	0	0	2	4	0	4	0	**12**
NW	0	0	2	2	6	11	5	8	9	9	3	**55**
WM	0	0	6	0	0	2	0	4	4	17	3	**36**
Grand Total	**3**	**16**	**12**	**15**	**10**	**30**	**28**	**38**	**32**	**36**	**12**	**232**
Invest Period Total			**56**					**164**			**12**	**232**

Table 7: Future ≤3" filter replacement volumes per network per year (PSSR compliance)

Non-PSSR driven ≤ 3" filter replacements due in RIIO-2 and 3, per network per year, are summarised below:

	Financial Year											
Network	2021/ 22	2022/ 23	2023/ 24	2024/ 25	2025/ 26	2026/ 27	2027/ 28	2028/ 29	2029/ 30	2030/ 31	2031/ 32	Grand Total
EoE	1	1	2	1	2	0	1	2	2	2	1	**15**
Lon	0	1	0	0	0	1	0	0	0	0	1	**3**
NW	1	1	1	0	0	0	1	1	1	0	1	**7**
WM	1	1	0	0	0	1	1	0	0	0	1	**5**
Grand Total	**3**	**4**	**3**	**1**	**2**	**2**	**3**	**3**	**3**	**2**	**4**	**30**
Invest Period Total			**13**					**13**			**4**	**30**

Table 8: Future ≤3" Non-PSSR driven filter replacement volumes per network per year

The volumes of each filter size replacement (PSSR and Non-PSSR) are multiplied by the respective unit cost and summated to establish a total cost for each network for each year. The table below is the investment for ≤3" filter replacements for RIIO-2, to the nearest XXXX:

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

Table 9: RIIO-2 costs for ≤ 3" filter interventions by Network for all drivers

7.1.2. Option 1b: Filter Interventions (>3" diameter)

For filters above 3", we estimated the number of faults likely to emerge in RIIO-2, based on the forward inspection programme, using the fault data from RIIO-1. We then assessed the volumes of A1, A2 and B faults from PSSR inspections and calculated the costs of a replacement filter with these faults, for each filter size. The unit costs for each filter size is contained within the table of costs in Section 7.8 of this document. These unit costs have been multiplied to the volume of filter interventions proposed in order to establish intervention costs per network per year.

To continue with this approach means we will ensure compliance with PSSR and undertake a deliverable workload that improves the asset stock's overall health.

For the asset health driven replacements, we have used data for replacements in 2018/19 and 2019/20 which shows 1.5% of asset stock is replaced on condition in each network each year. Given this is based on a small sample size, our RIIO-2 investment case conservatively assumes we will need to intervene on 1% of our filter asset stock as a result of non-PSSR findings.

As we cannot predict the size of the filters within the > 3" filter population that are affected due to asset health (non-PSSR) a blended average of > 3" filter sizes and costs in RIIO-1 has been used to establish an estimated unit cost per network, which has been multiplied by the estimated 1% volumes in each network.

In total we will need to replace 186 filters of size > 3" in RIIO-2.

- 119 of these failures are because of PSSR non-compliance identified following surveys
- 67 are filters that have severe asset health faults, identified between surveys

The following table summarises the filter interventions volumes for RIIO-2 and 3, by region and year, driven by **PSSR compliance**.

	Financial Year											
Network	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**Grand Total**
EoE	10	11	11	11	16	18	29	27	19	32	19	**203**
Lon	4	3	2	6	8	7	9	10	11	17	12	**89**
NW	2	2	1	3	1	7	12	14	13	15	13	**83**
WM	6	2	6	5	9	8	7	7	10	14	8	**82**
Grand Total	**22**	**18**	**20**	**25**	**34**	**40**	**57**	**58**	**53**	**78**	**52**	**457**
Invest Period Total			**119**					**286**			**52**	**457**

Table 9: *Future >3" filter intervention volumes per network per year (PSSR compliance)*

Non-PSSR driven **>3" filter replacements** due in RIIO-2 and 3, per network per year, are summarised below:

	Financial Year											
Network	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**Grand Total**
EoE	6	6	7	5	5	5	6	7	5	6	6	**64**
Lon	2	3	2	2	2	2	3	2	2	2	3	**25**
NW	2	3	3	3	2	2	3	3	3	3	2	**29**
WM	3	3	3	2	3	3	3	3	2	3	3	**31**
Grand Total	**13**	**15**	**15**	**12**	**12**	**12**	**15**	**15**	**12**	**14**	**14**	**149**
Invest Period Total			**67**					**68**			**14**	**149**

Table 100: Future >3" Non-PSSR driven filter replacement volumes per network per year

Applying unit costs to the estimated PSSR and Non-PSSR remediation or replacement volumes, the following investment for >3" filter interventions for RIIO-2 by network are summarised in the following table, to the nearest £1,000:

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

Table 11: RIIO-2 costs for > 3" filter interventions by Network

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 over RIIO-2.

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
EoE	1	0	0	1	1	**3**
Lon	2	0	0	0	2	**4**
NW	2	1	1	2	1	**7**
WM	1	0	0	0	1	**2**
Total	**6**	**1**	**1**	**3**	**5**	**16**

Table 12: Intervention volumes: Option 2

The resulting capex spend is (costs in £m):

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

Table 13: Capex costs: Option 2

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
EoE	81	75	52	70	56	**334**
Lon	24	17	23	21	20	**105**
NW	43	42	29	27	18	**159**
WM	36	44	35	27	22	**164**
Total	**184**	**178**	**139**	**145**	**116**	**762**

Table 14: Intervention volumes: Option 3

The resulting capex spend is (costs in £m):

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

Table 15: Capex costs: Option 3

7.4. Option 4: Minimum investment to maintain stable risk (RIIO-2 & 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 monetised 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
EoE	1	0	0	1	1	**3**
Lon	2	0	0	0	2	**4**
NW	2	1	1	2	1	**7**
WM	1	0	0	0	1	**2**
Total	**6**	**1**	**1**	**3**	**5**	**16**

Table 16: Intervention volumes: Option 4

The resulting capex spend is (costs in £m):

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

Redacted due to commercial sensitivity

Table 17: Capex costs: Option 4

7.5. Option 5: Maximum whole life benefits (RIIO-2 & 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
EoE	81	75	52	70	56	**334**
Lon	24	17	23	21	20	**105**
NW	43	42	29	27	18	**159**
WM	36	44	35	27	22	**164**
Total	**184**	**178**	**139**	**145**	**116**	**762**

Table 18: Intervention volumes: Option 5

The resulting capex spend is (costs in £m):

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 5

7.6. Option 6: Engineering Volumes Option with Maximum Benefits

This option 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 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. That is if PSSR driven work co-insides with risk monetisation benefits.

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
EoE	20	34	24	28	25	**131**
Lon	6	6	4	10	10	**36**
NW	5	6	7	8	9	**35**
WM	10	6	15	7	12	**50**
Total	**41**	**52**	**50**	**53**	**56**	**252**

Table 20: Intervention volumes: Option 6

The resulting capex spend is (costs in £m):

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

Table 21: Capex costs: Option 6

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

7.7. Options Technical Summary

	Option 0: Reactive	Option 1: Engineering assessment	Option 2: min investment to maintain stable risk (RIIO-2)	Option 3: Max whole life benefits (RIIO-2)	Option 4: min investment to maintain stable risk (RIIO-2 & 3)	Option 5: Max whole life benefits (RIIO2 & 3)	Option 6: Engineering Volume with Max Benefits[1]
Description	Reactive only, fix on failure	Engineering assessment of asset health and trial proposal.	Used our monetised risk model to assess interventions and capex spend needed to hold risk flat within the model.	Used our monetised risk model to assess interventions whilst maximising whole life net benefit.	For comparison purposes, we have also considered the inclusion of RIIO-3, to see if the option is still value for money.	For comparison purposes, we have also considered the inclusion of RIIO-3, to see if the option is still value for money.	For comparison purposes, we have also considered the engineering volumes with the assets that deliver the maximum benefits
First year of spend	2021/22	2021/22	2021/22	2021/22	2021/22	2021/22	2021/22
Last year of spend	2025/26	2025/26	2025/26	2025/26	2025/26	2025/26	2025/26
Intervention Volumes - Offtakes	0 interventions	26 interventions	0 interventions	82 interventions	0 interventions	82 interventions	24 interventions
Intervention Volumes - PRS	0 interventions	229 interventions	16 interventions	680 interventions	16 interventions	680 interventions	228 interventions
Design life	23 years	23 years	23 years	23 years	23 years	23 years	23 years
Total installed cost (RIIO-2)	Redacted due to commercial sensitivity						

Table 22: Technical Summary Table

Option 7 is the same as Option 1 in the table above and has been used to test the sensitivity of the chosen result by choosing the engineering volumes option with the removal of willingness to pay. It is shown in our economic analysis below.

Note that Option 6 value is slightly different to Option 1 due to the monetised risk model selecting different filters with different unit costs to obtain the maximum risk monetisation benefits.

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

7.8. Option Cost Summary Table

The following table compares all options (costs in £m):

	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Baseline						
Option 1						
Option 2						
Option 3						
Option 4						
Option 5						
Option 6						

Table 23: Option Cost summary table

These costs form part of the CBA and show that a range of cost profiles have been considered in our CBA.

Unit costs of filter interventions

The list of unit costs for intervention types used are summarised below:

Our unit costs for filter replacements are seen as efficient as we have built up unit costs from our historic experience in RIIO-1, using 3 years' worth of data, baselined to 2017/18 prices and then uplifted to 2018/19 prices. Work is delivered within our compounds where there is little variation in cost activity except in the sizes of filters.

Variations in costs between regions are due to differences in filter models which have been installed historically, different filter designs and as a result of different requirements of accompanying works. That is to say variation is driven by design differences between regions.

A summary of the unit costs used for RIIO-2 are set out below; they are derived from RIIO-1 actual costs:

Filter Size	EA	EM	Lon	NW	WM
1"					
1.5"					
2"					
3"					
Non-PSSR ≤ 3"					
4"					
6"		Redacted due to commercial sensitivity			
8"					
10"					
12"					
14"					
16"					
18"					
20"					
24"					
47"					
Non-PSSR > 3"					

Table 24: Unit Costs from RIIO-1, used as a basis for RIIO-2 filter replacement investments

It should be noted that there are different costs for East Anglia (EA) and East Midlands (EM) Local Distribution Zones (LDZ) within the East of England network, and these costs have been applied to volumes of filter interventions in the respective LDZs.

Greyed out cells are where there are no filters of that size highlighted for replacement and therefore have had no unit cost derived.

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 of average efficiency of 0.90% over 5 years for filter interventions. This commences at 0.3% in first year rising to 1.50% in fifth year. A 0% efficiency has been applied to our PSSR filter inspection works. All costs in this document are post efficiency.

For Offtakes & PRS Filters our confidence is defined as being at Construction stage with a range of +/-5%.

8. Business Case Outline and Discussion

8.1. Key Business Case Drivers Description

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. In developing the RIIO-2 plan we have defined distinct programmes of work as detailed in the table below:

Title	Investment Driver Summary
HP Filter PSSR Interventions & HP Filter Non-PSSR Interventions (≤3")	• A proactive replacement of these filters at the same time as the mandatory 12 yearly PSSR inspections. • The health of the assets
HP Filter PSSR Interventions & HP Filter Non-PSSR Interventions (>3")	Replacement of filters which have failed inspection, taking into consideration: • Compliance with our PSSR regulations • The health of the assets • The risks associated with failure of the assets

Table 25: Investment Drivers

Despite there being two distinct programmes of work for filters, we have taken a single approach to develop the plan. The CBA process has allowed us to consider each of the investment drivers listed above in a unified approach enabling the most efficient and coherent plan to be developed.

We have used our monetised risk model to assess the risk drivers. Monetised risk reductions are delivered primarily through a reduction in environmental risk, which results from preventing leakage which causes emissions. Additional risk reductions stem from the reduction in safety risk and financial risk. These insights help us to better articulate the benefits of investment, however, the fundamental need to comply is the mandatory driver of this work. The table below reviews the different options against safety performance indicator with a simple RAG score.

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

Table 26: 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 monetised safety risk £m.

8.2. Business Case Summary

CBA Results: Options analysis

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

The table below shows the 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 - 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				
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 Selection exc. WTP							

Table 27: PV and NPV for scenarios

Table Notes

- 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.
- In addition, it should be noted that the NOMs model does not value supply interruptions per the allocation of failure modes discussed in section 4.

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 for PRS and Offtake filters combined. 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 £ 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							
1	Engineering Volumes Option (Chosen)							
2	Min investment to maintain stable risk (RIIO-2 only)							
3	Max Whole Life Benefit (RIIO-2 only)							
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 Selection exc. WTP							

Redacted due to commercial sensitivity

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 alsoshown.
- 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 (Table 27).

Options Discussion

We have analysed 3 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 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 options we have considered for this asset are all cost beneficial. This is demonstrated through the excellent payback and very high ratio of NPV to RIIO-2 spend.

Our **chosen option (Option 1)** guarantees compliance with PSSR regulations, ensuring that filters are fit for purpose. Investment conducted in RIIO-2 is cost beneficial for the filter asset stock.

Option 2 shows the costs needed to maintain stable monetised risk. This shows that we only need to spend a small amount of money to maintain stable monetised risk over RIIO-2. However, maintaining stable monetised risk is not sufficient to manage the safety risk and maintain PSSR compliance. **Option 4** shows that a low amount of investment is also needed in RIIO-3 to continue to maintain stable monetised risk. In spending this low amount of money (c. XXXX across RIIO-2 and RIIO-3), the model chooses the assets with the highest NPV gain per £ spent (i.e. the most cost beneficial) resulting in a very high NPV ratio for this investment. We note that in this option, the interventions are on PRS filters only.

Our chosen option to invest more than this Option 2 means that we will be improving the monetised risk position over RIIO-2, which will help to manage future investment requirements.

Option 3 is the most cost beneficial option, delivering maximum whole life benefits. This shows that there is cost beneficial investment above that needed to maintain stable monetised risk and meet our obligations. **Option 5** shows the RIIO-3 cost beneficial investment associated with this option. Under this option the NPV ratio is less than for Option 2, as the additional cost beneficial of investment is less cost beneficial than what is selected in Option 2.

While the most beneficial investment in monetary terms is Option 3, the NPV to the RIIO-2 spend is not as beneficial as our chosen option. Moreover, in the interests of affordability, we believe we can manage our risks with the level of investment needed to meet our obligations and defer additional investment to be considered in RIIO-3. This is especially so as the chosen option will improve our overall monetised risk position of the assets over RIIO-2. At this time, we do not consider the significant additional investment (more than double) associated with this option to be in the best interests of our customers.

Option 6 is a useful comparative scenario. This shows that if PSSR failures occur on assets which show other risk monetisation benefits the NPV of our chosen option may be even higher.

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

Overall the CBA results have been useful in confirming our engineering assessment of the minimum investment to meet our obligations is the right level of investment. This will reduce the overall monetised risk of these assets to the benefit of our customers. Further cost beneficial investment does exist, but we recognise that we can defer this to RIIO-3 whilst still delivering value for money investment in RIIO-2 for our customers.

These results are similar across all four regions, with similar payback years. The table below shows the results for the regions for the preferred Option 1:

Network	NPV (£m)	Cost Beneficial	Payback	RIIO-2 spend (£m)
		PRS Filters		
EoE		Redacted due to commercial sensitivity		
Lon				
NW				
WM				
Total				
		Offtake Filters		
EoE		Redacted due to commercial sensitivity		
Lon				
NW				
WM				
Total				
		Combined Total		
EoE		Redacted due to commercial sensitivity		
Lon				
NW				
WM				
Total				

Table 29: Cost benefit summary for the chosen scenario by region

These results are shown in the figure below:

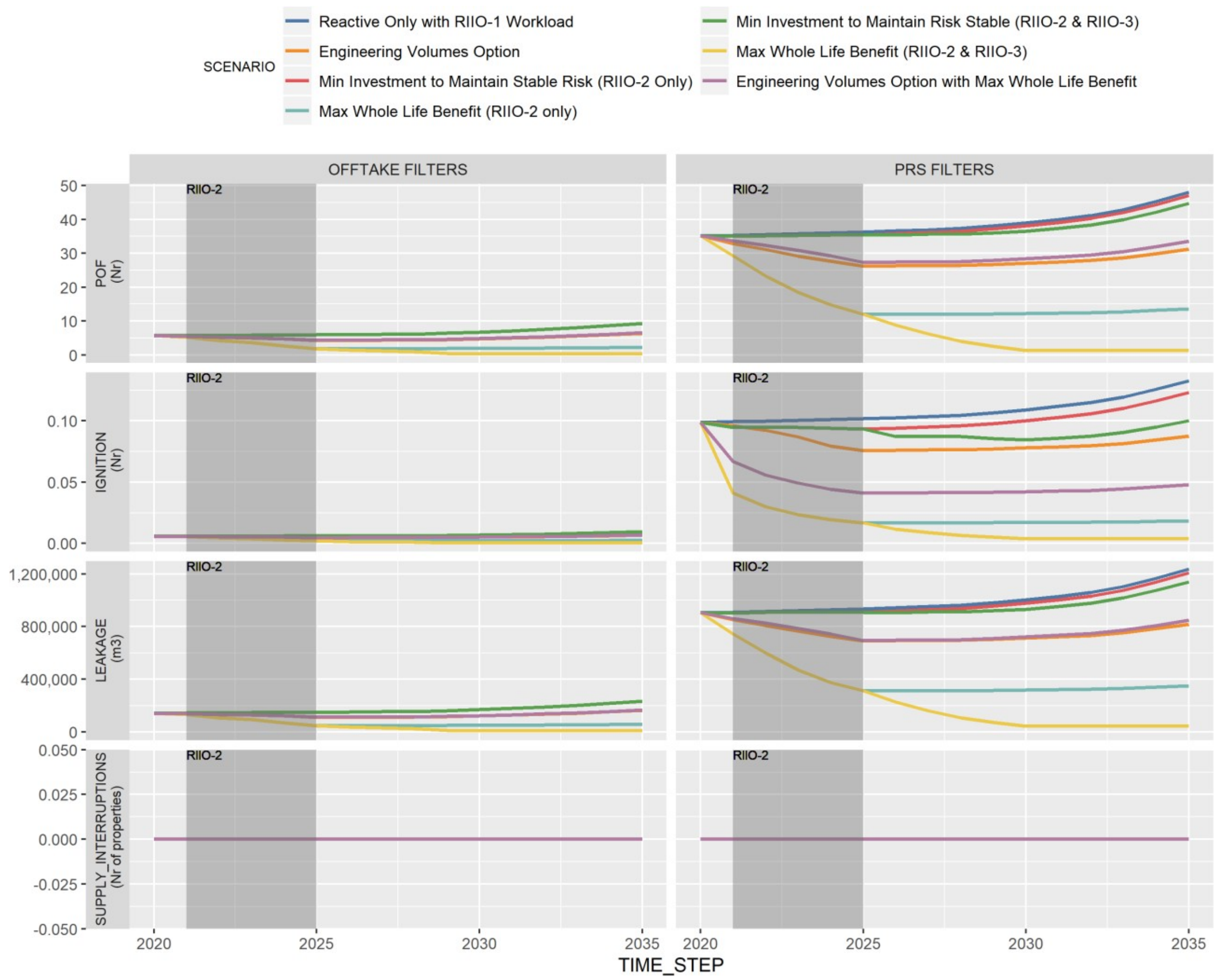


Figure 12: Key asset health and performance measures over time per asset category coloured by scenario (N.B. the Y-axis is independent for each plot).

This 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 (Offtakes and PRS). The majority of scenarios can be seen to either hold constant or reduce key performance measures over RIIO-2 (grey shaded box). Only Min Investment to Maintain Risk Stable scenario (green line) has notable rises in 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).

The conclusions for each option are further summarised below. This is for Options 1 and 3. We have not included Options 4-7 which are for comparison purposes only, as part of our sensitivity analysis.

Option	Conclusions
1	Maintains PSSR requirements and improves our overall monetised risk position over RIIO-2. The option involves higher costs than Option 2 but delivers higher NPV benefits.
2	This modelled option is low cost; however, it does not ensure we comply with our legal requirements. It provides insight into condition deterioration.
3	The cost beneficial investment level is more expensive than our chosen option. Less affordable, and less well targeted, than our preferred option.

Table 30: Conclusions of each option

Option 1 is the preferred option for our RIIO-2 investment case, as it is the only option that would ensure compliance with our PSSR regulations. In Section 9 the summary of the volumes and costs for option 1 is set out.

Benefits from investment: preferred scenario

The improvements in monetised risk performance as a result of the investment in filters is provided in the section below.

Name	Asset Category	Scenario	2020	2025	2030	2035
POF (Events)	OFFTAKE FILTERS	Reactive Only	5.7	5.9	6.7	9.3
		Chosen	5.7	4.2	4.7	6.4
	PRS FILTERS	Reactive Only	35.1	36.3	39.0	48.1
		Chosen	35.1	26.2	27.1	31.2
IGNITION (Nr)	OFFTAKE FILTERS	Reactive Only	0.01	0.01	0.01	0.01
		Chosen	0.01	0.00	0.01	0.01
	PRS FILTERS	Reactive Only	0.10	0.10	0.11	0.13
		Chosen	0.10	0.08	0.08	0.09
LEAKAGE (m3)	OFFTAKE FILTERS	Reactive Only	144,053	150,569	171,100	235,482
		Chosen	144,053	110,355	122,601	165,137
	PRS FILTERS	Reactive Only	904,867	934,591	1,003,930	1,234,863
		Chosen	904,867	692,104	712,916	818,667

Table 31: Performance under preferred scenario compared to reactive only

The selected investment option meets the PSSR requirements and monetised risk is reduced to acceptable and compliant levels.

This is illustrated in the figure below:

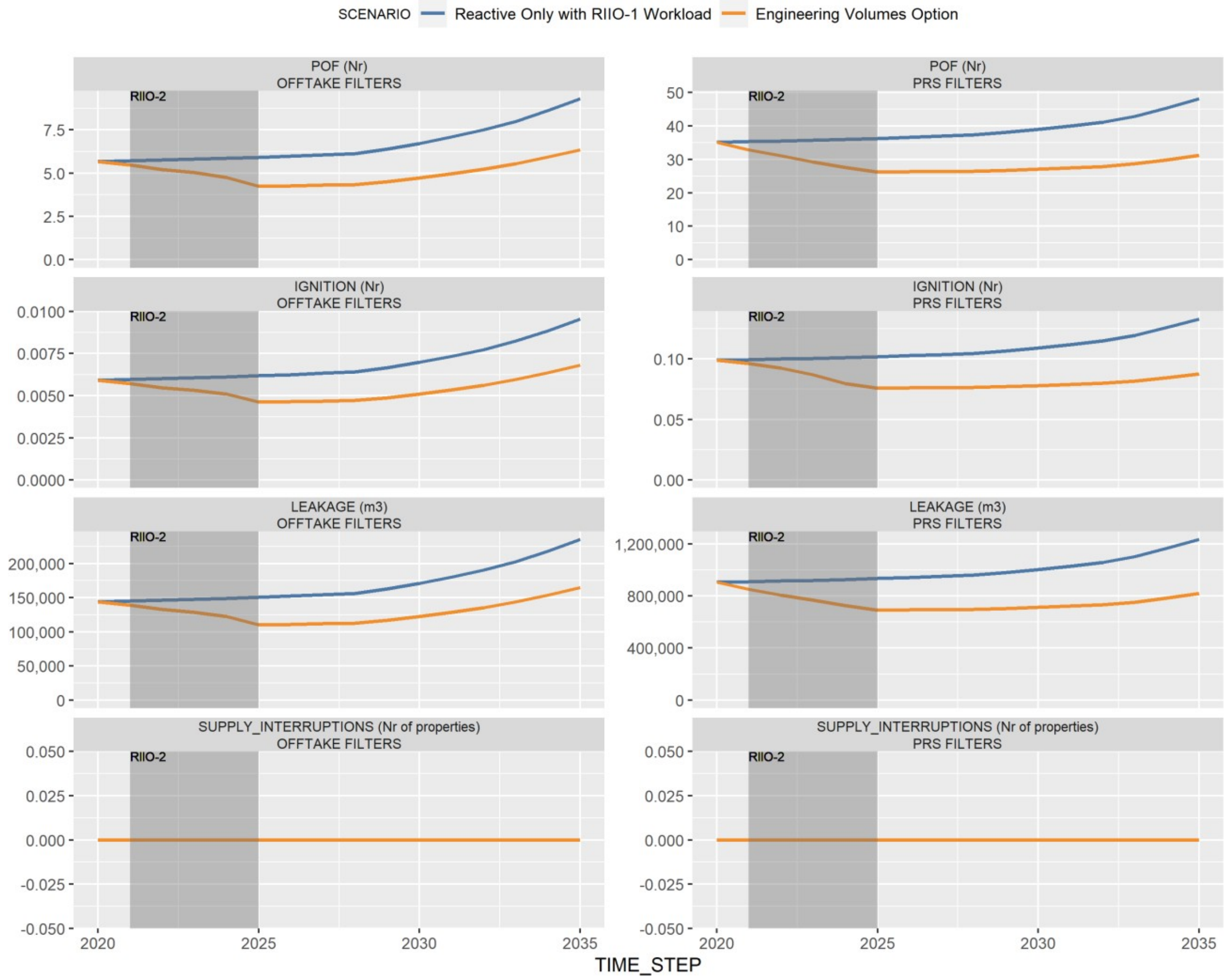


Figure 13: Key asset health and performance measures over time per asset category for reactive only and the final chosen scenario (N.B. the Y-axis is independent for each plot).

This figure shows the reactive only position (no investment) compared directly to the chosen scenario for four key asset health and performance measures. The chosen scenario shows a stable or reducing risk position whilst maintaining compliance with all legal obligations.

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

Our preferred option is Option 1, which also ensures we meet PSSR requirements. This, in turn, drives monetised risks to acceptable and compliant levels.

Option 1: Filter Interventions (≤ 3" diameter)

Based on the preferred option 1, we will need to replace 69 filters of size ≤ 3" in RIIO-2.

- 56 of these failures are because of PSSR non-compliance identified following surveys
- 13 are filters that have severe asset health faults, identified between surveys

Applying unit costs to the estimated replacement volumes, the following table shows investment for ≤3" filter replacements for RIIO-2, to the nearest £1,000:

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

Table 32: RIIO-2 costs for ≤ 3" filter interventions by Network

Option 1: Filter Interventions (>3" diameter)

Based on the preferred Option 1, we will need to replace 186 filters of size >3" in RIIO-2.

- 119 of these failures are because of PSSR non-compliance identified following surveys
- 67 are filters that have severe asset health faults, identified between surveys

Applying unit costs to the estimated PSSR and Non-PSSR remediation and replacement volumes, the following investment for >3" filter interventions for RIIO-2, by network, are estimated and summarised in the following table, to the nearest £1,000:

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

Table 33: RIIO-2 costs for > 3" filter interventions by Network

9.2. Asset Spend Profile

The proposed RIIO-2 programme of work and costs is shown in the table below:

Filter size	£k / year					
	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Filters ≤ 3"						
Filters > 3"			Redacted due to commercial sensitivity			
Total						

Table 34: Proposed asset health spend (£k))

The investment is at a similar level to that in RIIO-1, this is a rolling programme of work we understand and routinely deliver.

We have a total investment cost confidence of +/- 5% for this expenditure of high volume, low cost work with a robust understanding of our unit costs.

9.3. Investment Risk Discussion

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.14 - 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
09.14 - 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
09.14 - 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
09.14 - 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.
09.14 - 005	Unexpected / uncommunicated obsolescence during RIIO-2 period of	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 /

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
	equipment components			replacements become at risk.
09.14 - 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.
09.14 - 007	Supply chain changes for units / components	Increased unit costs and supply challenges affecting programme delivery	Low	Supply chain engagement and testing to ensure the correct selection of equipment and procurement strategy

Table 35: Risk Register

9.4. Regulatory Treatment

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

This investment is accounted for in the Business Plan Data Table 3.01 LTS, Storage & Entry within the NTS Offtakes Sub Table and the PRS Sub Table under the Filters lines.