Cadent
Your Gas Network

Appendix 09.05

Offtakes and PRS Pre-Heating

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.

Pre-heating is the facility to heat gas prior to reducing its pressure to mitigate the effect of low outlet temperature. Gas pre-heating is required to avoid the freezing of downstream equipment and the potential for asset damage and/or failure. We have 884 gas pre-heating units (spread over 413 sites). This includes electrical heaters, modular boilers and Water Bath Heaters (WBH).

We have modelled the performance of our preheating units, including forecast failures, performance and operating costs. This shows we will need to continue to invest in these assets in order to manage ongoing issues such as: poor performance linked to asset deterioration; compliance with environmental legislation (MCPD); environmental input; efficiency; compliance with PSSR; and potential interruptions to supply in the event of failures. If we do not invest, the risk of failures and other services impacts (e.g. supply interruptions, leakage and ignitions) will rise quickly.

Our investment for pre-heaters is comprised of three key elements. Two of these elements are mandatory – compliance with MCPD emission standards and completion of PSSR inspections and resulting maintenance. For the third element – managing the reliability of pre-heater assets – we have undertaken CBA to evaluate the preferred investment option.

We evaluated multiple scenarios in the CBA. For example, we considered the level of investment which would maximise whole life benefits (over the short and long term); the minimum investment to maintain a stable level of risk; the minimum investment to lower risk by 10%, etc. Our analysis shows that all of these scenarios are cost beneficial.

Our preferred option is to set investment in order to maximise whole life benefits within a 15 to 20-year payback period. This option delivers more benefits than most of the options (in terms of supply interruptions, avoided opex, etc) and requires less overall investment to deliver. Giving a strong expenditure/benefit ratio.

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

<u>Material Changes Since October.</u>

Following refinement of the options considered within the CBA, this has led to a *XXXX* spend reduction in replacement of Pre-heat units whilst improving our investment metrics (Cost/NPV ratio & Payback).
The costs in the document have also been uplifted to the 2018/19 price base.

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2. Introduction

This document covers the investment case methodology for Pre-heaters. Offtake and Pressure Reduction System (PRS) heaters are included in this case but itemised separately. Our investment scenario is based on the probability and consequence of failure of individual heater units regardless of their Offtake/PRS classification.

Pre-heating is the facility to heat gas prior to reducing its pressure to mitigate the effect of low outlet temperature. Gas pre-heating is required to avoid the freezing of downstream equipment and the potential for asset damage and/or failure.

We have 884 gas pre-heating units (spread over 413 sites). This includes electrical heaters, modular boilers and Water Bath Heaters (WBH).

To understand the investment needs of these assets we have used a robust and consistent analytical framework (aligned to the NARMs approach and assured by Lloyds Register, see Appendix 09.00 Overview: how we have developed our investment plan for details), which allows us to model the preheating units we own and how they operate individually. The models allow us to forecast failures, performance and operating costs and assess the potential effects of investment. More detail on the modelling approach used can be found in section 7.

This approach has been coupled with a bottom-up engineering assessment of work mandated by the Medium Combustion Plant Directive (MCPD) requirements. The approach adopted complies with external codes, company management procedures, and best practice. 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 used for our asset base

Two data sources provided the asset list and base-data.

- SAP Extract (February 2019) provides the hierarchy of assets, condition data and other important attributes.
- NOMS Offtakes base data is the NOMS formatted dataset baselined for RIIO-2 purposes. This dataset provided the basis for consequence values and infill for attributes that could not be derived from the SAP extract.

These sources have been reconciled within our Asset Data Manager (ADM) software.

Our pre-heater asset stock

This section sets out the different pre-heater technology in use, provides a summary of the number of each type of heater by region, and then gives a summary of the current condition of this asset stock.

Our pre-heater assets are used on our above 7 bar networks at our pressure regulating sites and our offtakes. They typically operate during the winter months. This enables maintenance to be completed on these assets during summer. Most sites have a duty/standby arrangement, providing some level of resilience.

Heater assets can be found at both offtake and PRS sites at which they perform the same function. Although PRS sites are generally smaller than Offtakes, our modelling approach considers the specific risks associated with each heater regardless of their location.

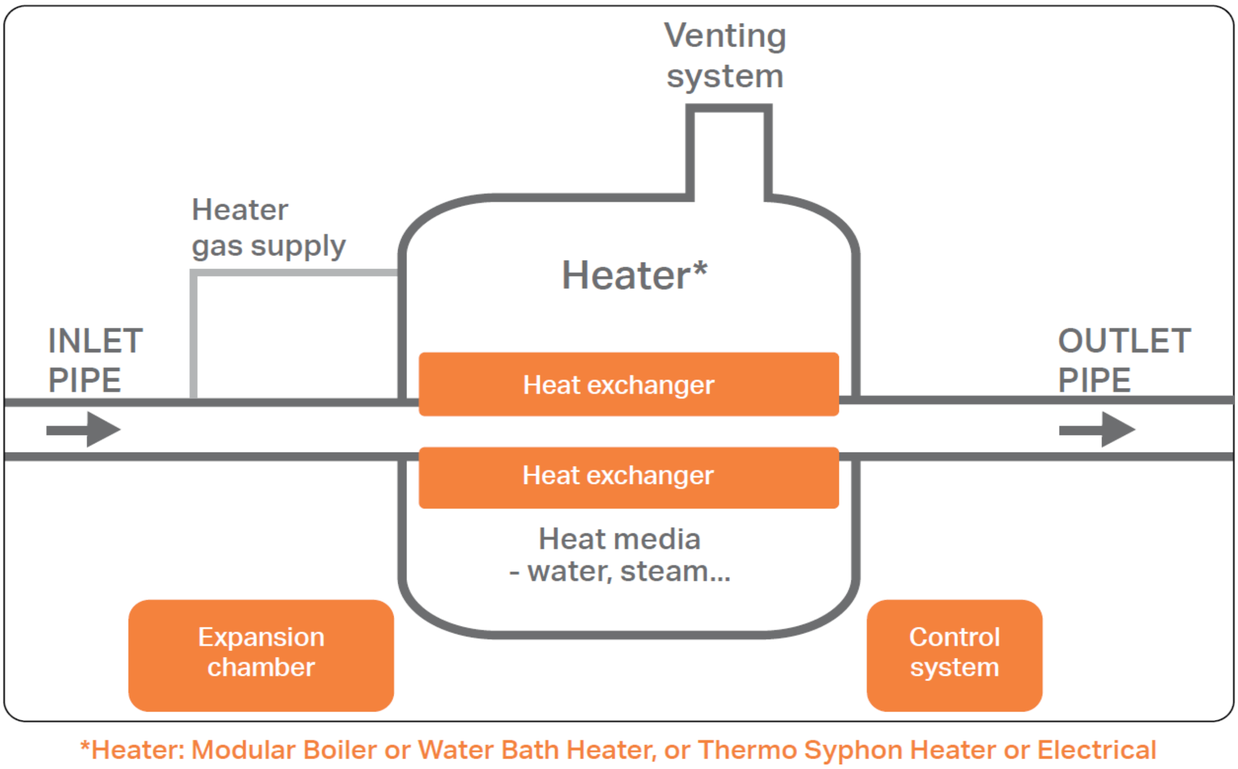


Figure 1: typical layout of an Offtake / Pressure Reduction Station pre-heating system (NB a site may have more than 1 system, and multiple units).

The different types of pre-heater technology in use

The purpose of pre-heaters on the network is to ensure gas is heated prior to the pressure reduction process, to guard against excessively cold gas leaving the pressure-reducing facility. Depending on demand requirements of each site, four asset options can be used (volumes by type are given in Figure 6).

Water bath heaters (WBHs) are a simple method of pre-heating gas. The pipes pass through a bath of heated water with antifreeze and corrosion-inhibitor properties. Gas burners heat this thermal medium (water) to transfer heat to the gas pipeline. Exhaust gases are released through a flue stack that must be sized and maintained, along with the air intake, to ensure efficiency of the system.

These are the oldest and least efficient systems, with older units having an estimated overall efficiency of approximately 50%. New water bath heaters provide a greater efficiency. Issues with these installations include obsolescence of spares, reliability issues, inefficiency, safety issues and risks to the environment from flue emissions and chemical leaks.

Figure 2 – Water bath heaters.

Modular Boiler (MB) systems are comprised of gas-fired boilers coupled to a hot water system. Water is pumped to the heat exchanger(s) where the available heat is transferred to the gas via high-pressure gas tubes prior to the pressure-reduction process.

MB systems offer an increased efficiency compared to water bath heaters. Although these systems are more efficient, they can prove to be less reliable than water bath heating systems due to the increased complexity of the technology in the boiler equipment and the Programmable Logic Controller (PLC) system.

The control system is a short-life (Electrical & Instrumentation) asset, and the boilers also have a much shorter asset life than a WBH.

Figure 3 – modular boiler system.

Electrical Heater Systems provide gas heating through immersion heaters. These systems are reliable due to the simplicity of the heating delivery and control system. They are generally used on installations with low gas-heating requirements as lower amounts of heat transfer are possible. They are limited because they need a substantial power supply which cannot be provided by standard mains power.

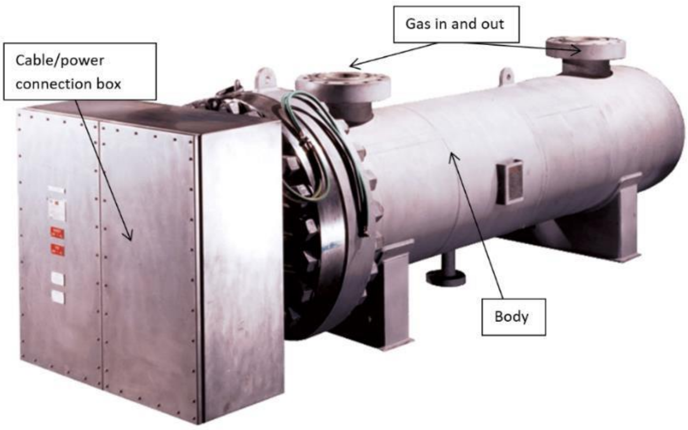


Figure 4– electrical heater system.

Thermosyphon Pre-heating is a more efficient, but more complex, variation on WBH. It consists of an airtight container of liquid under vacuum which is heated by a gas flame; this heats the liquid that turns to steam at much lower temperatures, as it is in vacuum. The units run around 95% efficiency. The whole life cost of the technology is comparable to legacy WBH. They have a higher upfront cost but will last for an anticipated 30 years compared with 8-12 years for a MB system.

Innovative thermosyphon pre-heating was trialled by Cadent in RIIO-1 and approved for use in 2018/19. We have some thermosyphon heating units in scope for installation during the remainder of the RIIO-1 period. Currently, these are planned for 'non-critical' sites only; while we learn more about these assets, their performance and any possible risks. This means that appraising these assets may not provide a true reflection of their value (e.g. in a cost benefit analysis).

Figure 5 - thermosyphon pre-heating.

Current asset-stock of pre-heaters by type

We have 884 gas pre-heating units. Below is a summary of the number of Pre-heaters installed on the asset base split across each of the Networks and by type.

Distribution Zone	Heater type model	Offtake	PRS	Total
East of England	Electric heater	1	8	9
	Modular boiler	60	146	206
	Water bath heater	24	85	109
North London	Electric heater	-	9	9
	Modular boiler	-	92	92
	Water bath heater	7	15	22
North West	Electric heater	-	9	9
	Modular boiler	16	210	226
	Water bath heater	17	49	66
West Midlands	Electric heater	-	8	8
	Modular boiler	11	69	80
	Water bath heater	11	37	48
Total	Electric heater	1	34	35
	Modular boiler	87	517	604
	Water bath heater	59	186	245
	Total Units	**147**	**737**	**884**

Table 1: Asset Stock April 2019 (source SAP) – Number of Units.

Cadent also have thermosyphon heating and HotCat installations. The thermosyphon heating units are included in the figures discussed above, but there is no distinction for this technology in SAP and in the RIIO-1 risk model. The HotCat system is not in SAP and therefore not in Cadent's RIIO-1 dataset – they are located at Moore village, Scawby & Woodhouses. There is also a Vacuum Steam Heater at Aylestone Road, which is classified as a Water Bath Heater in SAP.

Asset condition

Through GD PCR1 and RIIO-1, we have delivered a rolling programme of risk-based heater replacement to maintain the performance of our asset stock. For smaller sites, we have favoured replacement of WBHs with modular boilers. Therefore, MBs now form a larger portion of our asset base than they did 10 years ago.

In line with our previous replacement profile, most pre-heaters are in condition[1] grade 2 and above, but an increasing number are in grade 3 and above. This is shown in the chart below.

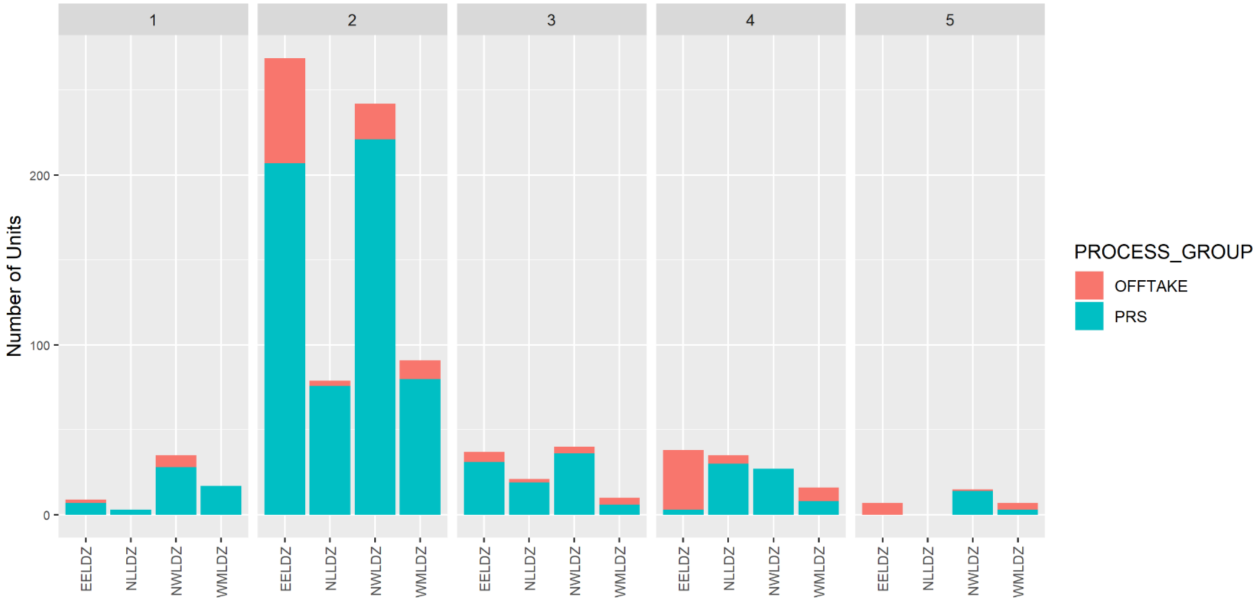


Figure 6 - Condition profile of Pre-heating Units by Distribution Zone and function (Offtake/PRS)

(source SAP extract 2019).

Investment in the last two years of RIIO-1 will improve this condition profile but will still leave some assets in the worst condition bands.

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

[1] Condition 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 imminent failure.

4. Problem Statement

Our preheating systems are a critical asset at our pressure reduction sites and offtakes; they ensure that gas is heated to prevent freezing and associated damage to equipment caused by these pressure changes.

By the end of RIIO-1, approximately 50% of our pre-heating assets will be > 15 years old. Based on our AIM model, by the end of RIIO-1 20% of our PRS heating systems will be condition grade 3 to 5, 34.6% of our offtake heating systems will have a condition grade of 3 to 5.

It is crucial that we develop a cost-effective way to manage and maintain these assets, through effective inspection, repair and replacement. Customers have also been clear that they want a balanced investment that generates environmental, safety and reliability benefits. Asset deterioration causes poor performance and possible failures. This in turn could lead to supply interruptions, gas-leaks, environmental impacts and associated fire and explosion risks to employees and customers.

We also have a legal mandate to inspect and maintain these assets to comply with the Pressure Systems Safety Regulations.

The Medium Combustion Plant Directive (Directive (EU) 2015/2193), is enforced within the UK through the following regulations; The Environmental Permitting (England and Wales) (Amendment) Regulations 2018. These regulations have put additional responsibilities on Cadent to permit, monitor and manage emissions from thermal plan between 1MW & 50MW output.

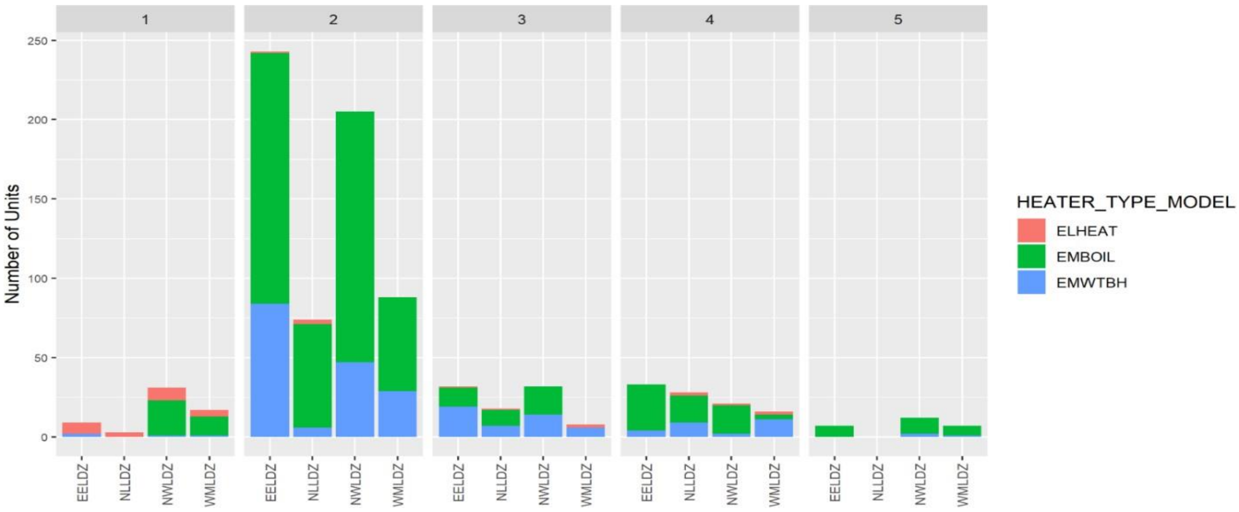
We have discussed the following key points in more detail below:

- Asset deterioration: the condition of our asset stock and the impact this has on reliability and safety
- Compliance with the MCPD Directive; there are clear requirements that we must achieve during RIIO2
- Efficiency: How we have considered the efficiency of each heating system to inform our investment case.
- Pressure Systems Safety Regulations: this sets out our obligations for inspections and maintenance
- Interruptions to Supply: the ultimate impact if our preheating systems fail.

Asset deterioration

As our assets age and deteriorate they are more prone to failures, which in turn affect the ability of these assets to meet safety and reliability requirements.

The graph below shows the current (2019) condition of the pre-heaters by type, across our four networks. A large proportion of the assets are in condition grade 3 and will deteriorate further throughout RIIO-2.



Note: ELHEAT = Electric Heaters; EMBOIL = Modular Boiler Heaters; EMWTBH = water bath Heaters

Figure 7 - Pre-heating condition by Distribution Zone and Type (source SAP extract 2019).

The figure below shows the expected condition grade population at the end of RIIO-1:

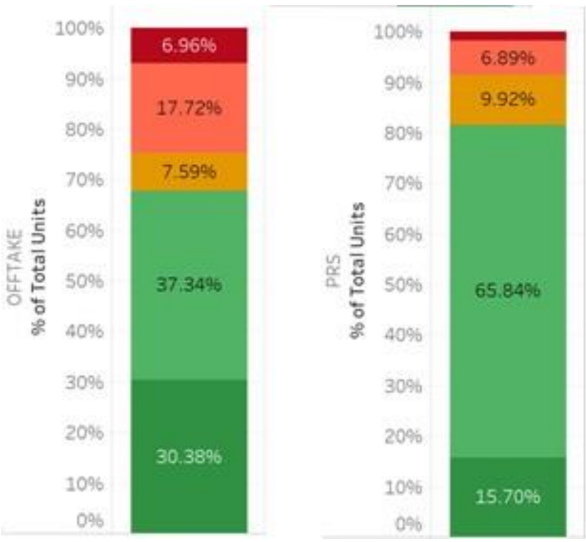


Figure 8 – RIIO-2 starting position of Pre-heating unit condition

Reliability: Despite the replacement programme during RIIO-1, the increase in age and running hours are leading to a deterioration of condition. This in turn is leading to an increase in failures, maintenance and emissions. For example, heater fault data from January 2017-April 2019 provided by the Distribution Network Control Centre shows that there was a fault on our heater assets every two hours regarding Low/High temperatures and low-water alarms.

Modular Boiler systems are more efficient than WBHs; however, experience shows that they can prove to be less reliable due to the complexity of the technology. In addition, the control systems become obsolete (in relation to our benchmark of asset life) within 8 years, and this means that considerable rework or replacement is required after 10 years.

Safety: Heat Exchangers are subject to PSSR regulations and must be examined and revalidated according to a written scheme of examination. Any corrosion on these must be remediated in accordance with this written scheme. This is further detailed in Section 4.1.

Compliance with Environmental legislation

There are requirements to comply with the Medium Combustion Plant Directive (MCPD) as enacted in UK Legislation through the Environmental Permitting Regulations 2018. This applies to all thermal plant with an input thermal rating of 1 MW to 50MW that run for more than 500 hours per year. The MCPD requires Cadent to ensure that Environmental Permits and robust monitoring of stack emissions are in place by certain dates. Emissions from all thermal plant shall also comply with certain limits within the timescales stated below:

Thermal input of thermal plant	Due date for environmental permit	Due date for monitoring of stack emissions	Compliance of emissions
5MW to 50MW	1 Jan 2024	1 Jan 2025	1 Jan 2025
1MW to 5MW	1 Jan 2029	1 Jan 2030	1 Jan 2030

Table 2: MCPD implementation dates.

Currently, all pre-heaters are compliant, but we will have one site (with four units) that will become non-compliant during RIIO-2, with further units becoming non-compliant in RIIO-3 unless we invest.

Efficiency

New units will be more efficient than the units they replace: in particular modular boilers and thermosyphon pre-heating claim higher standards of efficiency. Detailed assessment of efficiency is hampered by the absence of own-use gas meters at our sites.

Own use gas (consumption by heaters and losses through operational venting) is 0.011% of Cadent's annual demand, this has not been deemed significant enough to justify installation of meters on pre-heating sites.

Safety legislation

We have a duty to maintain a safe and compliant network, underpinned by statutory instruments:

Instruments	Main legislative drivers
Pressure Systems Safety Regulations 2000 (PSSR)	We have a mandated programme of works to conform with Pressure Systems Safety Regulations, 2000. Shell tube heat exchangers require a written scheme of examination and examinations undertaken in accordance with these written schemes (known as an F-Schedule validation). The revalidation work is designed to ensure the integrity and functionality of the heaters and identify any corrosion. **These are included in our modelling framework in this justification document.**

Table 3: Main Safety Legislative Driver.

Interruptions to supply

NTS Offtakes and PRS are critical to the security of supply of the network and can impact supplies to hundreds of thousands of customers. A failure of the heating system will reduce the volume of gas that a site can process, or even lead to the site being shut down.

When gas is expanded there is a corresponding cooling effect – this is known as the Joule Thompson effect. If gas is allowed to cool below freezing point, the following consequences could occur:

- Embrittlement of the pipeline material, leading to potential fracture as a result of impact or ground forces
- Formation of ice around the pipe, leading to ground-heave, subsidence, structural damage, potential stresses on pipes resulting in potential fracture
- 'Freezing' of regulator components, leading to potential loss of supply to end users (our pressure management fault data shows multiple failures linked to heating issues in RIIO-1)
- Water or hydrocarbon dew point issues which may interfere with the operation of regulating equipment

Gas is therefore heated prior to the pressure reduction process in order to guard against excessively cold gas leaving the pressure-reducing facility. Without operational heating; the site will be compromised, and its output reduced or removed.

Impact of no investment

We need to invest in these assets to ensure a continuous and safe supply of gas to our customers.

In order to understand the investment requirements fully, our analyses have begun by considering the impact of 'no investment' on these assets. In this scenario, we continue to meet our legal obligations to inspect these assets without intervening to deal with any defects or arising issues.

We have used robust estimates of the probability of failure and consequence of failure to understand this position, as summarised in Sections 5 and 6.

Under the no-investment scenario, the failure and risk from these assets quickly rises. Associated with these failures are service impacts: supply interruptions, leakage and ignitions. Increased leakage is linked to increased carbon emissions. Increased ignitions are linked to increased health and safety risk.

The impact of no-investment scenarios on these service impacts are shown in the figure below:

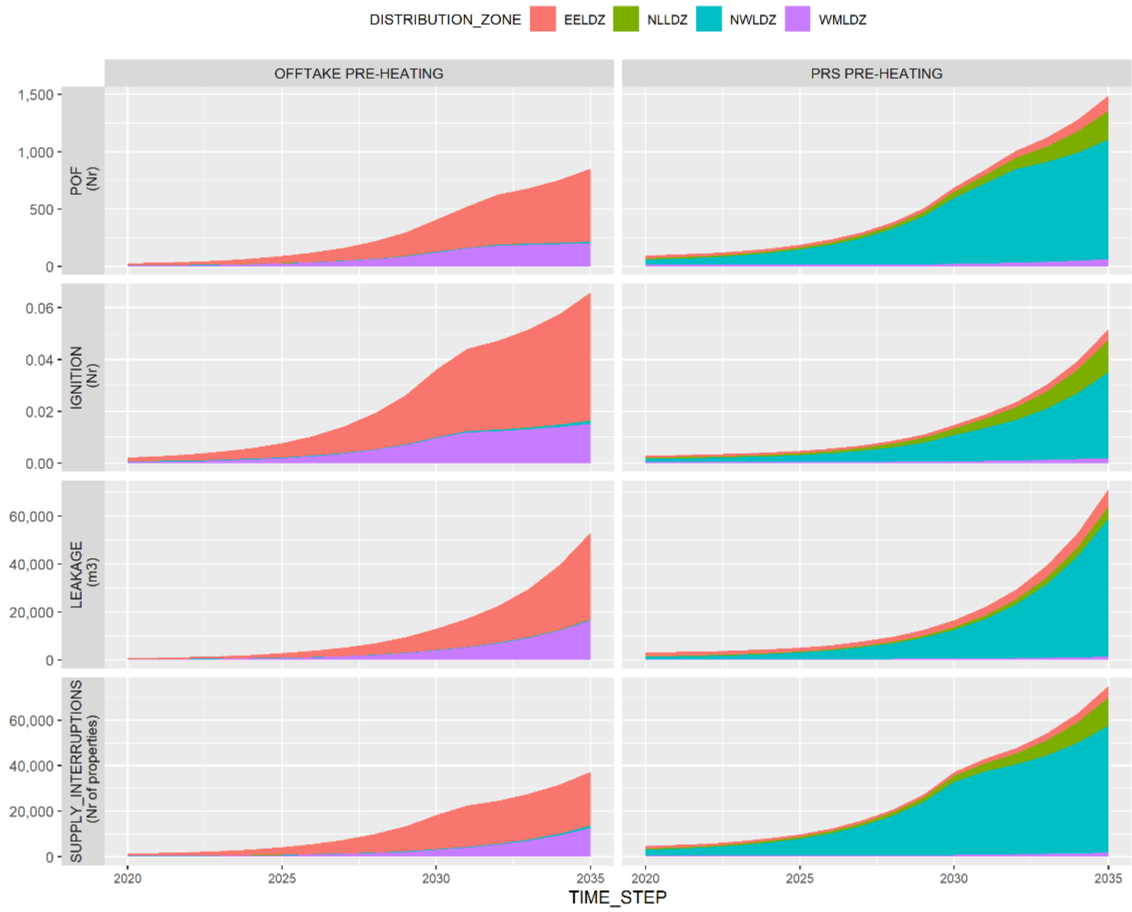


Figure 9 : Service impact risk over time for reactive only (no investment) split by asset category coloured by distribution zone.

The ignition and leakage reactive only plots show an increasing trend across all networks with East of England and West Midlands having a greater proportion in Offtakes, and North West greater in PRS. This is due to a combination of asset volumes, and asset volumes in higher/worse condition grades.

We consider the no-investment position to be unacceptable. It does not ensure that we comply with PSSR and MCPD. Compliance with these regulations is important to our customers and stakeholders. In addition, customers and stakeholders have consistently told us that worsening levels of interruptions are not in line with their expectations.

Required outcomes

In summary, the required outcomes for this investment are:

- Ensuring continued compliance with PSSR and MCPD and other legislative requirements.
- Managing and remediating the deterioration of assets to ensure they do not present a safety risk to the public and do not impact the reliability of gas supplies to our consumers.

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

Figure 10 : ice forming following failure of heating asset.

The image shows a pipe within the West Midlands following failure of the heater tube within a pre-heat system, which led to cold gas being run for over 24 hours. A film of ice has formed around the pipework and pressure management equipment. Without repair or reducing gas flows, accretion of this ice film would have continued, applying pressure to surrounding pipework and ultimately leading to fracture.

4.2. Spend Boundaries

The costs included are for the pipework and replacement of the pre-heater unit. There are no costs included for housing and buildings. Furthermore, the costs do not include upsizing driven by growth in demand.

Investment to comply with PSSR relating to inspections is included in this investment case.

5. Probability of Failure

The NOMs methodology, developed with Ofgem, 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 and consequence of failure estimates for pre-heating assets. This is summarised below and in Section 5.

Failure modes

A range of different failure modes can occur for a pre-heater system, and these will lead to five key failure effects, summarised below:

Release of Gas – failure of a pressure containing component on site leading to an unconstrained release of gas within and possibly off the site. Such component failures include defects, corrosion and interference damage.

Low Outlet Temperature – failure of the pre-heating system to provide the correct heat input for the associated site gas-flow rate, causing low outlet temperatures.

High Outlet Temperature – failure of the pre-heating system to provide the correct heat input for that associated site gas flow rate resulting in high outlet temperatures.

Loss of Capacity – where the system due to failure has insufficient capacity to meet a forecast 1:20 peak day downstream demand. This is not a driver for investment in this investment paper.

General Failure – other failures that do not lead to release of gas, low/high outlet temperature or capacity failures, such as heater water-level alarms, burner and exhaust/flue adjustments and PLC control system resets.

These failure effects have been used in our risk map within our AIMs model, this is discussed further below.

5.1. Probability of Failure Data Assurance

Our assessment of the probability of failure is part of our development of the end-to-end analytical framework for these assets, within our AIM software. We have applied a consistent framework, as shown in the risk map below. The yellow nodes show the five failure effects introduced above.

[2] NOMS, March 2016, Appendix E

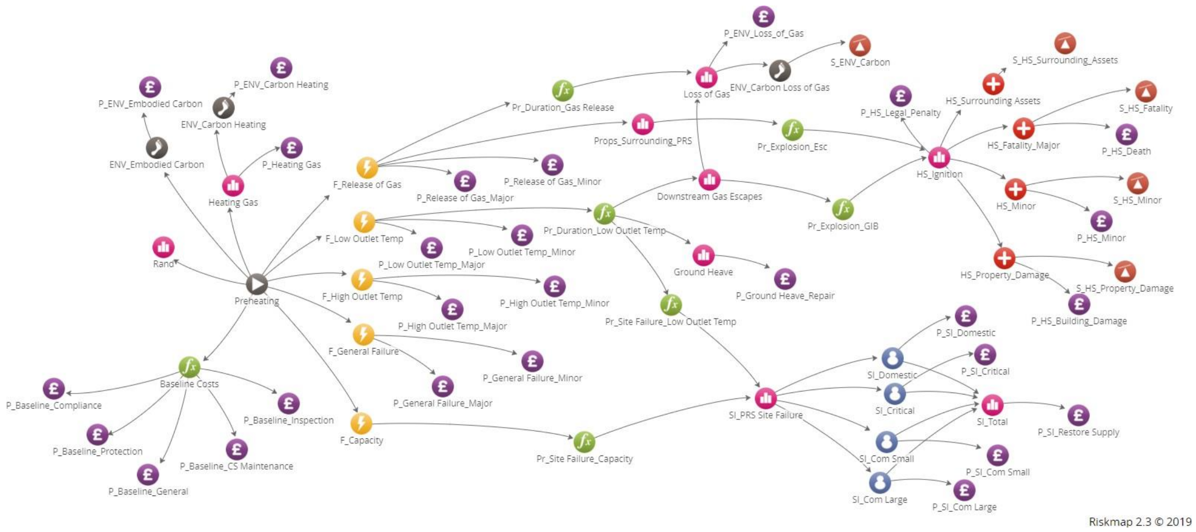


Figure 11 : pre-heating risk map.

This risk map also shows the consequences of failure, which is explained in the next section. Please refer to Appendix 09.00 for a further explanation of the risk map.

The current probabilities for these failure effects, which have been used within the model, are summarised in Figure 12 below. N.B. Probability is calculated from incidents per year.

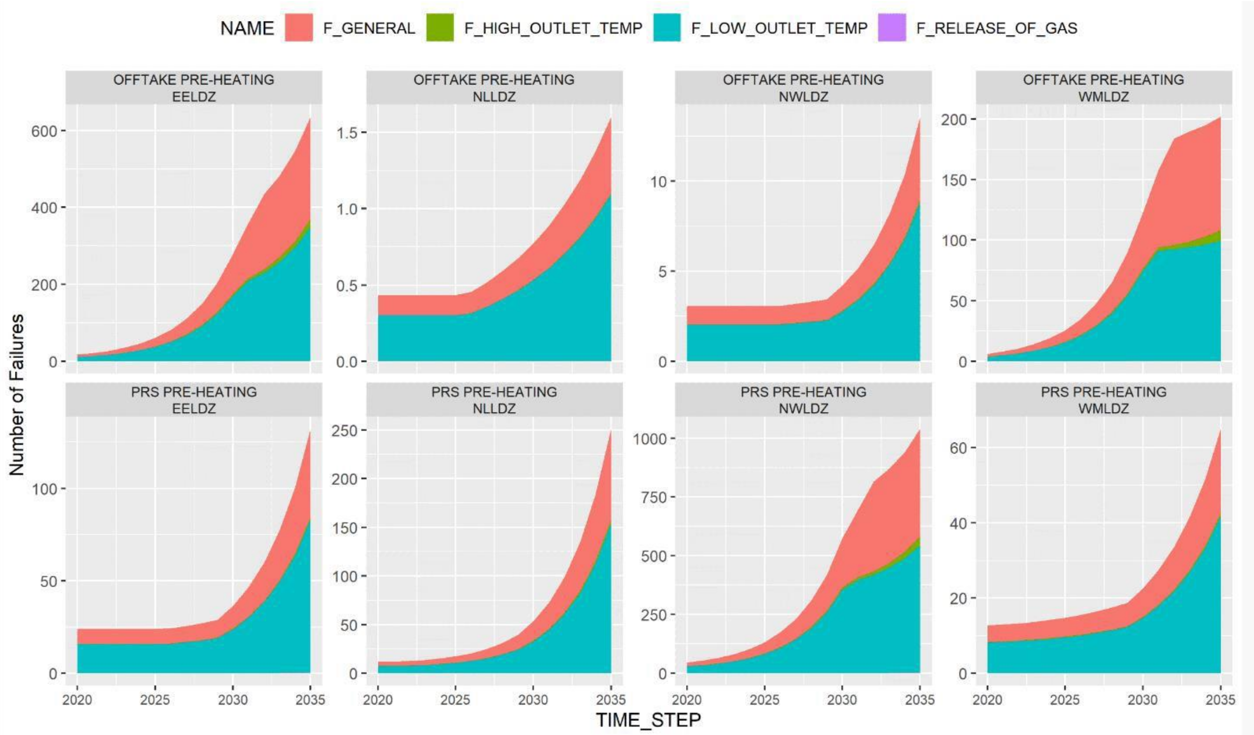


Figure 12 : Pressure heater failures by failure effect.

The failure effects for each network show a very steep trend in East of England (Offtakes) and North West (PRS) for general and low outlet temperature failures. This is representative of the bathtub deterioration model that is driven off the condition grades.

Applying the failure models to our asset base gives the following predictions of failures over time. Without investment there is a sharp increase in failures, especially low outlet temperature failures and general failures, more so for PRS than Offtakes.

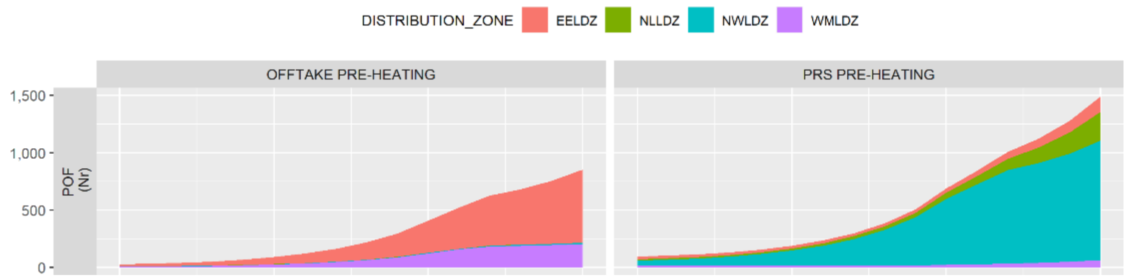


Figure 13 : Probability of failure (POF) over time for reactive only (no investment) split by asset category coloured by distribution zone.

This plot shows an increasing trend of failures across all networks with East of England and West Midlands a greater proportion in Offtakes, and North West greater in PRS. Again, due to a combination of asset volumes, and asset volumes in higher/worse condition grades.

How we have validated our failure data

These five failure models are taken from the NOMs methodology. We have applied these models to our asset base. Asset base data is sourced from SAP and NOMS as described in Section 3.1. The temporal range for the failure data set is 7.6 years and includes approximately 2000 fault records relating to preheating.

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

- Do the predicted total failure counts each year align with historical data and in line with expert judgement?
- Are the actual failure counts by equipment type aligned with historical data and in line with expert judgement?

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

6. Consequence of Failure

Our base case supply demand scenario for this investment case is our peak 1 in 20 year demand to comply with our Licence Obligations. The variability of demand in future forecasts is small; our demand would have to change significantly to require a step-up or down in model-size of preheater unit, as such we have only considered one supply demand scenario.

Linking failures to consequences

Each failure mode and probability of failure has been assessed in terms of its potential consequence. The consequences of failures are:

Failure Mode	Consequence of Failure
Safety Risk	Ignition – an explosion at the filters and pressure control asset or in the downstream network
Interruptions to supply	PRS Site Failure – a site failure impacting consumer supplies
Other	Ground Heave – resulting in damage to structures, roads and other assets due to low outlet temperatures
Environmental Risk	Downstream gas escape – caused by low outlet temperatures
	Loss of gas – from the filters and pressure control asset or the downstream network

Table 4: Consequences of failure.

Each potential consequence has been expressed as monetary values using the agreed industry 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. - *Cost per Fatality XXXX* - *Cost per Non-Fatal injury 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.*
Financial impact – cost of repairs (unit)	Company accounts.
Financial impact – cost of replacement (unit)	Company accounts.

Table 5: Sources of economic benefits.

These 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.

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

All of these consequences can be seen in Figure 11: pre-heating 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

The chart below shows the percentage contribution of financial risk components.

Redacted due to commercial sensitivity

Figure 14 : 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 and their risk value. An increasing proportion of system risk (purple) can be seen – this relates to increased fault repairs.

7. Options Considered

Introduction

Our investment for pre-heaters is comprised of three key elements, as summarised below:

1. **Completion of PSSR inspections and subsequent Pre-heater maintenance resulting from inspections,** to ensure the pre-heaters comply with the PSSR
2. **Compliance with MCPD emission standards**
3. **Replacement of our pre-heaters** to manage asset health and asset reliability

Items 1 and 2 are mandatory, required by legislation, so we have not assessed any options for these areas of investment. That is to say we have not considered options which are non-compliant. However, in this section, we have summarised our approach to calculating our investment levels for these and ensuring that we deliver compliance efficiently. The intervention rates and costs for PSSR inspection and MCPD replacement work has been input into the model to derive a total investment cost.

Background to our Modelling Approach: In RIIO-1 we have invested in the software tool, AIM, to allow us to build asset management capability using the NOMs approach. AIM has been used to support the construction of the RIIO-2 plan. The software includes an optimisation capability which allows us to model different investment scenarios, produce optimised plans and test their cost benefit. The CBA capability enables us to find the solution to a problem with many restrictions and potentially millions of potential solutions (options).

AIM has been used to model pre-heating assets. 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. Our model has been applied in RIIO-2 at the level of pre-heater units (i.e. individual assets and their performance have been modelled, producing precise results for the plan).

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, The HM Treasury Green Book, and is also embedded within AIM.

Mandatory PSSR inspections

To comply with PSSR, we must carry out PSSR inspections and validations; Shell Tube Heat Exchangers require a written scheme of examination and revalidations.

The frequency of maintenance examinations for WBH and shell and tube heat exchangers are risk based: determined by the previous three annual water-chemistry analyses but have a ten-year maximum period between inspections.

Applying this approach, the following inspection volumes have been derived for the future:

Network	Financial Year										
	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29	29/30	30/31	31/ 32
EoE	13	21	58	7	20	8	13	27	58	5	20
Lon	9	7	7	3	2	12	10	11	7	3	2
NW	8	12	11	9	9	4	6	6	11	13	11
WM	0	9	16	8	8	8	0	7	14	4	7
Total	**30**	**49**	**92**	**27**	**39**	**32**	**29**	**51**	**90**	**25**	**40**

Table 6 : Annual inspection volumes derived via bottom up risk-based approach.

We have also used the model to predict inspections costs. Both approaches give very similar results; we have therefore concluded that the model is adequately tuned and have used it to forecast PSSR inspections.

Compliance with MCPD emission standards

At the end of RIIO-1, Cadent will have one site that is over 5MW thermal input and over fifty years of age. Therefore, we have recognised it will not meet MCPD standards and will require replacement in RIIO-2.

We have used the model to test how MCPD-mandated works impact optimisation for other benefits. The MCPD heaters would not necessarily be picked by the model as part of an optimised solution to deliver other benefits (e.g. in respect of safety or interruptions). They will, however, contribute to improved performance in these areas. Running the model to identify the optimal solution and then adding the MCPD work on top would be over investment. Instead, the MPCD is built into the model as mandatory work and optimisations are then run to find the right level of additional investment. We have run multiple scenarios to explore this overlap of work.

Managing the reliability of our pre-heater assets

To develop an optimum investment plan, we have looked at a number of investment scenarios and options assessing the following criteria:

- The interaction of MCPD mandated work with optimised monetised risk removal - running the models with and without MCPD to understand overlaps
- The impact of thermosyphon heating - this new technology is promising but not fully tested. We want to see how the model uses it, but we will use engineering judgement to set limits on its application (the model has been constrained to not recommend thermosyphon heating at more than 60% of locations).
- The maintenance of total monetised risk – both private costs and societal costs.
- Cost options through time - how we deliver minimum whole-life costs. These scenarios looked at spreading risk or cost through time.
- Maintaining or improving current asset health, characterised by faults.

The options considered

Our investment case for managing the asset health of our pre-heaters has considered a range of options using a methodology which links asset performance to customer impacts, making use of our monetised risk models and AIM to evaluate options using cost benefit analysis (CBA).

We began our options development process by running ‘standard options’ (no investment, hold the current level of service, invest at the same rate as RIIO-1 and maximise benefits over the life of the model). These options help establish boundaries within which further options can be developed.

Hold service (monetised risk) flat examines what investment we would need to make to ensure no deterioration (or improvement) in service. The invest at the same rate as RIIO-1 option identifies what impact the current investment strategy would have if continued into the new period. Maximise whole life benefits will give the best theoretical investment plan for the period balancing investment and benefits through time to maximise NPV in the long term.

For our July submission we explored options which focused on improving safety, interruptions or environmental features. However, through our Business options testing (See Appendix 09.02 Distribution Mains and Associated Services (Iron, PE, Steel & Other) internal Appendix 7) we identified that customers had a preference for a ‘balanced plan’ and we did not continue these areas of optioneering.

The maximum whole life net benefit run identified that there was considerably more customer benefit that could be released than simply delivering a ‘hold monetised risk flat option’. However, the run itself (although producing a very high NPV) came at a significant cost to customers. We therefore sort to identify an option which generated greater customer benefit than holding risk flat but was not as expensive as maximum whole life net benefit.

For October, we developed a maximum whole life benefit over a 20-year period option. Following receiving stakeholder feedback, for December, we have challenged ourselves with subject matter experts to ensure we are addressing our worst performing assets and delivering the best benefits

Workshops were undertaken to fully understand and clarify the scenarios and remove the scenarios that we do not think are valid. We have therefore developed an enhanced option based on asset condition and a maximise benefit over 15 years. A good range of spend profiles and drivers have been considered.

We are therefore confident we have the right list of options, and scenarios around the options.

	Option
0	**Reactive only**
1	**Max whole life benefits (Focus on poor condition short payback) (Chosen)** Maximise whole life net benefit (CBA) over 15 years; limited to 60% of pre-heating units replaced with thermosyphon heating, with a flat yearly capex limit. Plus, selecting all condition grade 5 assets plus the grade 3 and above conditioned assets with 20-year payback.
2	**Minimum investment to maintain stable monetised risk** Minimise investment (capex spend) to keep monetised risk flat until 2030; limited to 60% pre-heating systems replaced with thermosyphon heating with capex equalised between price control periods (RIIO-2 and RIIO-3)
3	**Maximise whole life benefits next 20 years (option selected for October's plan)** Maximise whole life net benefits (CBA) over 20 years; limited to 60% of pre-heating units replaced with thermosyphon heating, with a flat yearly capex limit.
4	**Minimum investment to maintain stable monetised risk 10 year** The minimum investment required to maintain total monetised risk on an annual basis until the end of RIIO-3.
5	**Maximise whole life benefits next 20 years - 10 years** The investment required to maximise whole life benefits over RIIO-2 and RIIO-3, considering those investments that payback must be within 20 years of the end of RIIO-2.
6	**Continue RIIO-1 volumes in RIIO-2** Maximise whole-life net benefit (CBA) over 45 years, limited to 60% of pre-heating systems replaced with thermosyphon heating with a flat yearly capex limit based on RIIO-1 spend
7	**Reduce Risk 10% at least cost** Minimise investment (capex spend) to reduce monetised risk by 10 percent by 2025 and hold at that level until 2030. Limited to 60% pre-heating systems replaced with thermosyphon heating, with capex equalised between price control periods (RIIO-2 and RIIO-3)
8	**Chosen scenario (1) excluding WTP**

Table 7 : The Options Modelled.

All options ran include the mandated MCPD work and are seeking to deliver their target at lowest cost.

7.1 Option 1: Max whole life benefits (focus on poor condition and short payback)

This option has used the AIM model to maximise whole life net benefit (CBA) over 15 years; limited to 60% of pre-heating units replaced with thermosyphon heating, with a flat yearly capex limit. Plus, selecting all condition grade 5 assets plus the grade 3 and above conditioned assets with 15-year payback. This run combined short payback investments with poor condition grade investments

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

Volumes of interventions / year						
Region	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EoE	2	2	2	2	2	**10**
Lon	1	1	1	1	2	**6**
NW	2	2	2	3	2	**11**
WM	2		1		1	**4**
Total	**7**	**5**	**6**	**6**	**7**	**31**

Table 8: Proposed RIIO-2 volume profile for Option 1

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

Table 9: Proposed RIIO-2 spend profile for Option 1

7.2 Option 2: Minimum investment to maintain stable monetised risk

This option has used the AIM model to minimise investment (capex spend) to keep monetised risk flat until 2030; limited to 60% pre-heating systems replaced with thermosyphon heating with capex equalised between price control periods (RIIO-2 and RIIO-3).

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

Volumes of interventions / year						
Region	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EoE	1	0	0	0	0	**1**
Lon	1	0	0	1	0	**2**
NW	1	0	1	0	2	**4**
WM	1	0	1	0	0	**2**
Total	**4**	**0**	**2**	**1**	**2**	**9**

Table 10: Proposed RIIO-2 volume profile for Option 2.

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

Table 11: Proposed RIIO-2 spend profile for Option 2.

7.3 Option 3: Maximise whole life benefits next 20 years

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

Volumes of interventions / year						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	2	4	4	4	1	**15**
Lon	1	2	2	2	2	**9**
NW	5	4	5	5	5	**24**
WM	0	1	1	1	1	**4**
Total	**8**	**11**	**12**	**12**	**9**	**52**

Table 12: Proposed RIIO-2 volume profile for Option 3.

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

Table 13: Proposed RIIO-2 spend profile for Option 3.

7.4 Option 4: Min investment to maintain stable monetised risk 10 years

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

Volumes of interventions / year						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	1	0	0	0	0	**1**
Lon	1	0	0	1	0	**2**
NW	1	0	1	0	2	**4**
WM	1	0	1	0	0	**2**
Total	**4**	**0**	**2**	**1**	**2**	**9**

Table 14: Proposed RIIO-2 volume profile for Option 4

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

Table 15: Proposed RIIO-2 spend profile for Option 4.

7.5 Option 5: Maximise whole life benefits next 20 years - 10 years

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

Volumes of interventions / year						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	2	4	4	4	1	**15**
Lon	1	2	2	2	2	**9**
NW	5	4	5	5	5	**24**
WM	0	1	1	1	1	**4**
Total	**8**	**11**	**12**	**12**	**9**	**52**

Table 16: Proposed RIIO-2 volume profile for Option 5.

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

Table 17: Proposed RIIO-2 spend profile for Option 5.

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

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

Volumes of interventions / year						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	6	6	7	7	7	**33**
Lon	1	1	1	1	1	**5**
NW	3	3	3	3	3	**15**
WM	3	3	3	3	3	**15**
Total	**13**	**13**	**14**	**14**	**14**	**68**

Table 18: Proposed RIIO-2 volume profile for Option 6.

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

Table 19: Proposed RIIO-2 spend profile for Option 6.

7.7 Option 7: Reduce Risk 10% at least costs

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

Volumes of interventions / year						
Region	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	1	0	0	1	1	**3**
Lon	1	1	1	1	1	**5**
NW	1	1	0	0	3	**5**
WM	1	1	0	1	2	**5**
Total	**4**	**3**	**1**	**3**	**7**	**18**

Table20: Proposed RIIO-2 volume profile for Option 7.

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

Table 21: Proposed RIIO-2 spend profile for Option 7.

Option 8 has the same cost and volumes as option 1 but is not discussed in detail as it is only included for comparative reasons.

7.8 Options Technical Summary Table

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

Option	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7
Description	Max whole life benefits (15 year payback)	Minimum investment to maintain stable risk	Max whole life benefits next 20 years	Min investment to maintain stable risk 10 years	Max whole life benefits next 20 years -10 years	Continue RIIO-1 volumes in RIIO-2	Reduce Risk 10% at least costs
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 replacements	11 Offtake 20 PRS	5 Offtake 4 PRS	12 Offtake 40 PRS	5 Offtake 4 PRS	12 Offtake 40 PRS	13 Offtake 55 PRS	6 Offtake 12 PRS
Costs of replacements (£)			Redacted due to commercial sensitivity				
Costs of inspections & repairs (£)							
Equipment design life	23 Years	23 Years	23 Years	23 Years	23 Years	23 Years	23 Years
Total Capex (£)							
Total Opex (£)							

Table 22: Options Technical Summary Table.

7.9 Options Cost Summary Table

The following table provides a cost summary table for all modelled options. It explains the total RIIO-2 expenditure by intervention type. The model has chosen a volume of work to replace (renew) the current preheaters, and it has estimated a sum of money to continue to maintain and repair the existing heaters, this includes the costs preheater inspections.

These costs form part of the CBA (as discussed in section 8); they demonstrate that we have considered a good range of scenarios from spending small sums of money to significant sums of money, so we can understand the right level of investment for these assets.

Description of Option	Total RIIO-2 Forecast Expenditure (£)			
	Replacement	Maintenance & Repair	Other	Total
0. Reactive Only (none compliant)				
1. Max whole life benefits to customer within 15-year payback plus engineering rules.				
2. Minimum investment to maintain stable risk				
3. Max whole life benefits next 20 years		Redacted due to commercial sensitivity		
4. Minimum investment to maintain stable risk 10 year				
5. Max whole life benefits next 20 years - 10 years				
6. Continue RIIO-1 volumes in RIIO-2				
7. Reduce Risk 10% at least cost				
8. Chosen scenario (1) excluding WTP				

Table 23 : Intervention option costs (as computed in the Ofgem CBA templates).

We have also shown the capex cost profiles by year for each option. This capex investment is the total to deliver all required preheater replacements.

	21/22	22/23	23/24	24/25	25/26	Total
Option 1						
Option 2						
Option 3						
Option 4			Redacted due to commercial sensitivity			
Option 5						
Option 6						
Option 7						

Table 24: Options Cost Summary Table. (Capex-profile) £

Deriving our unit costs for this investment case

These modelled scenarios have been derived from a comprehensive review of unit costs to apply for each preheater replacement, repair and inspection, based on historic costs and a recent tendering exercise:

	Unit Cost Replace with same type	Unit Cost Replace with Thermosyphon heating	Probability of Electrical Upgrade
Electric Heater			
Waterbath		Redacted due to commercial sensitivity	
Modular Boiler			
Thermosyphon Heater			

Table 25: Preheater replacement costs.

Our 2017/18 unit costs are used for the basis of our plan, with the 2018/19 price base uplift applied. We have developed cost models based on our recent experience in the RIIO-1 period. The basis of these costs has been current, known unit-replacement costs within Engineering Delivery Services and Asset Strategy. Costain have undertaken an audit on the costs used for this investment; further detail on our costing approach can be found in Appendix 09.00. Further detail can be found in the tables below;

Total cost is calculated as the sum of the unit cost of the intervention either replace or thermosyphon heating replacement, plus the cost of a potential electrical upgrade (cost is weighted by the probability of that upgrade happening, 50% for offtakes and 16% for PRS).

	Maintenance Cost	Inspection Rate	Yearly Approximation
Electric Heater		N/A	
Waterbath		Redacted due to commercial sensitivity	
Modular Boiler		7 yearly	
Thermosyphon Heater		10 yearly	

Table 26: Preheater maintenance costs.

The PSSR inspection costs are smoothed into yearly values, as the exact scheduled years are not known in the model.

In March 2018, a tender event was concluded for the maintenance services.

37 suppliers were initially sent the tender document, with 3 suppliers returning their interest. A Request for Proposal was then issued to the 3 suppliers, with 2 continuing to the next stage. An analysis including

technical competence, innovation and pricing was then completed, as well as the benefits per supplier being identified.

The final recommendation was to award one network (North West) to the Tudor Group as the Primary supplier, with Armstrong in place as the secondary supplier for the North West for all Maintenance work. All other Networks to be awarded to Armstrong Integrated as the Primary Supplier, with the Tudor Group given the opportunity to act as the Secondary for those networks.

By Awarding as per the above recommendation, Cadent will achieve a saving of 79% in the North West for the remainder or RIIO-1. With Armstrong Integrated awarded the other Networks, there will be an overall saving of 38% against current rates.

The costs in Table 25 and Table 26 have been factored in to the model for each unit/work type highlighted.

For Offtakes and PRS Pre-Heating we are at various stages of cost confidence. We have extensive experience of installing PSSR, Modular Boilers, WBH and Electrics heaters throughout RIIO-1 and have assigned a high +/-5% confidence for these elements. For pro-heat costs are based on having less experience, and as such, our confidence is at Conceptual Design stage. When applying a weighted position our cost confidence is at +/-14%.

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 efficiency Average of 0.90% over 5 years for Other Units PRS and Offtakes. 0.3% in first year raising to 1.50% in 5th year, 0% on 2.04 Maintenance PRS Preheating, in this investment area. All costs in this document are post efficiency.

8. Business Case Outline and Discussion

8.1. Key Business Case Drivers Description

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

In developing the RIIO-2 plan, we have defined distinct programmes of work as detailed in the table below. Each of these programmes of work has a different investment driver and scope of investment.

Title	Investment Driver Summary
PSSR Inspections and remediations	▪ Mandated programme of works to conform with Pressure Systems Safety Regulations 2000.
Interventions on Pre-heating Systems	▪ Highlighting a proactive replacement programme of works, taking into consideration; ➢ The health of the assets ➢ The risks associated with failure of the assets ➢ Ongoing maintenance costs ➢ Cost benefits
Medium Combustion Plant Directive (MCPD) Compliancy	▪ Ensuring Cadent take the steps to ensure pre-heating assets are compliant with MCPD. This includes ensuring all new pre-heating assets which have a rated thermal input of 1MW to 50MW (aggregated total for sites with more than one pre-heating unit) will comply.

Table 27 : Business driver summary.

8.2. Business Case Summary

As outlined in Section 7, there are three key elements to our pre-heater investments for RIIO-2:

1. **Completion of PSSR inspections and resulting pre-heater maintenance** to ensure the pre-heaters comply with the Pressure Systems Safety Regulations
2. **Compliance with MCPD emission standards**
3. **Replacement of our pre-heaters** to manage asset health and asset reliability.

No options have been considered for inspections and MCPD compliance (elements 1 & 2); a full options analysis has however been completed for replacement and asset maintenance of our pre-heater asset stock.

We have considered whether to invest and replace with Thermosyphon Heating or continue with alternative/previous methods. All options consider investing in Thermosyphon Heating, but at different intervention rates.

Business case summary for PSSR inspections

This is a mandated programme of works to conform with PSSR, 2000.

XXXX is estimated to be spent on PSSR Inspections over RIIO-2.

Year						
	2021/22	2022/23	2023/24	2024/25	2025/26	Grand Total
PSSR Pre-heating Systems Inspections (£) **PRS**						
PSSR Pre-heating Systems Inspections (£) **Offtake**		Redacted due to commercial sensitivity				
Grand Total (£)						

Table 28 : Annual inspection costs derived (rounded to nearest £) split Offtakes/PRS.

Business case summary to comply with MCPD

The MPCD is built into the model as mandatory work and optimisations are then run to find the right level of additional investment. The replacement work shown below is included within the chosen option for RIIO-2.

	MCPD pre-heater upgrades to meet emission standards
Intervention volumes during RIIO-2	4 units - 1 site (NW – Weston Point)
Intervention volumes RIIO-3	Redacted due to commercial sensitivity
RIIO-2 costs	
RIIO-3 costs	

Table 29 : Investment summary

We have not yet assessed the impact of the 2030 standard, which is likely to require significant further investment in RIIO-3.

Business case summary for Pre-heater replacements / interventions

Options analysis for pre-heater asset health

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

Table 30 below shows the present value of costs for each option. This shows 5 years of investment over RIIO-2, unless stated otherwise.

Option No.	Option description	PV Expenditure & Costs (£)	PV Environment (£)	PV Safety (£)	PV Reliability (£)	PV Other (£)	Total PV (£)	NPV (£)
0	Reactive Only							
1	Max whole life benefits (15 year payback plus Cat 5) (Chosen)							
2	Minimum investment to maintain stable risk							
3	Max Whole life benefits next 20 years		Redacted due to commercial sensitivity					
4	Minimum investment to maintain stable risk 10 year							
5	Max Whole life benefits next 20 years - 10 years							
6	Continue RIIO-1 volumes in RIIO-2							
7	Reduce Risk 10% at least cost							
8	Engineering Volumes Selection exc. WTP							

Table 30: PV and NPV for all options

- Costs are presented as negative value. The total PV is the summation of the five categories of costs.
- PV expenditure and costs shows discounted sum of proactive investment (replacement or refurbishment costs), maintenance, repairs and other ongoing opex costs. Proactive investment has been considered over RIIO-2, although we have included some scenarios that consider 10 years of investment: RIIO-2 and RIIO-3. All other financial costs are considered over the full period to 2050. All financial costs are discounted using the Spackman approach.
- PV environment shows the discounted sum of leakage and shrinkage, using the base case cost of carbon.
- PV safety shows the discounted sum of the risk of fatalities and injuries, as valued using the Ofgem stated costs per Fatality and cost per non-fatal injury.
- PV reliability shows the discounted sum of interruption risk, as valued using our own valuation research (e.g. the willingness to pay study into the cost of interruptions to homes and businesses).
- PV other shows the discounted sum of any other impacts, as valued using our research into the cost of property damage and transport disruption.
- The baseline has been specified as the minimum investment position. The NPV for each option is computed as the difference between the total PV for each option and the total PV for the baseline. A positive NPV means an option has less costs associated with it relative to the baseline and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial of the options considered.

Option No.	Option description	NPV - Relative to baseline	Cost beneficial	Payback Year	RIIO-2 spend (Replace)	Ratio NPV to RIIO-2 replace/ refurb spend	RIIO-3 spend (Replace)	Ratio NPV to RIIO-2 and RIIO-3 (Replace)
0	Reactive Only							
1	Max whole life benefits (15 year payback plus Cat 5) (Chosen)							
2	Minimum investment to maintain stable risk							
3	Max whole life benefits next 20 years							
4	Minimum investment to maintain stable risk 10 year							
5	Max whole life benefits next 20 years - 10 year							
6	Continue RIIO-1 volumes in RIIO-2							
7	Reduce Risk 10% at least cost							
8	Engineering Volumes Selection exc. WTP							

Redacted due to commercial sensitivity

Table 31 : Present value of costs and benefits for the modelled scenarios (£)

The table above shows CBA results

- 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.

The options deliver benefits across the monetised risk categories: safety, environment, financial, and customer interruptions.

The table above shows that all options we have considered are highly cost beneficial, showing that proactive investment in these assets is beneficial to our customers.

Our chosen option has been developed through consultation with our stakeholders. Our October plan for these assets focused on delivering investment that would ensure we are compliant with all our legislative requirements, as well as delivering cost beneficial investment to our customers.

Our stakeholders challenged whether this was the best option for our customers, as they recognised that this is an area where the CBA is an important part of the decision-making process, and that if we were meeting our obligations, delivering our requirements and deferring some of the slightly longer pay back; it could reduce asset stranding risk and deliver high value for customer.

As a result of this challenge, we have sought to defer some investment.

Our preferred option is therefore not the most cost beneficial option. Option 3 is the most cost beneficial and is associated with significant investment in RIIO-2 and RIIO-3 (as demonstrated in Option 5). However, it also requires a more significant level of investment (and has a smaller investment/benefit ratio).

Option 2 is the option that maintains stable monetised risk to the end of RIIO-2. Option 4 shows the additional expenditure required in RIIO-3 to maintain risk to the end of RIIO-3. This option does offer low cost with a good investment/benefit ratio. However, it falls short in two areas. It has a low NPV when compared with other options, meaning that customers are losing benefits of improved reliability, safety and reduced environmental emissions (the latter becomes more material as environmental standards tighten post 2020). Secondly, the option does not provide the funding to remove all condition grade 5 assets from our network. Although overall monetised risk can be held flat by interventions in other assets, this option allows risks on or worst condition sites to rise. As such it concentrates risks at certain localities. This is both unequitable and potentially unsafe. Simply maintaining stable monetised risk has therefore been dismissed as an option.

The graphs below show a concentrated safety and reliability risk in our condition 5 graded assets under the hold monetised risk flat option, which is not acceptable:

Redacted due to commercial sensitivity

Figure 15: risk per heater by condition grade.

In developing our chosen option, we have selected investments in our assets that:

- Ensures we meet our legal obligations
- Are highly cost beneficial, with a short payback period and therefore low chance of asset stranding
- Are in poor condition (condition 5) and present an imminent or unacceptable level of risk to service now and over RIIO-2.

Our overall level of monetised risk will improve for preheating assets, although we will not be undertaking all cost beneficial investment in the RIIO-2 to reduce bill impacts.

Option 6 is included for comparative purposes and shows we can deliver the investment outcomes with less volumes in RIIO-2 than in RIIO-1. This shows that our proposed investment is targeted to deliver the most value for our customers.

Option 7 is also included for comparative purposes and shows that reducing risk is cost beneficial for our customers. This further supports the view that maintaining stable risk is not in line with our customer and stakeholder requirements.

Option 8 demonstrates that whilst preventing interruptions is an important part of the reason to invest in these assets, our chosen option is cost beneficial even excluding the value of reducing reliability risk.

The costs and benefits of each option is also summarised below:

Redacted due to commercial sensitivity

Figure 16 : key asset health and performance measures over time per asset category coloured by scenario.

This plot shows the several varying scenarios of investment and risk that were investigated and compared to the reactive only scenario (blue line) for each asset category (Offtakes vs PRS). All scenarios can be seen to either hold constant or improve key performance measures over RIIO-2 (grey shaded box). All scenarios were assessed and compared against the final chosen scenario (Engineering Volumes Option) - based on maximising whole life benefits smoothed over RIIO-2, Max Whole Life Benefit. These results are similar across all four regions.

The table below shows the results for the regions for the preferred option:

	NPV	Cost beneficial	Payback	RIIO-2 spend	Ratio NPV to RIIO-2 replace/ refurb spend
EoE					
Lon			Redacted due to commercial sensitivity		
NW					
WM					
Total					

Table 32 : cost benefit results for chosen option by region.

The results show that all options have a short payback period. Therefore, the risk of stranded assets is low. In addition, if changes in the network were to occur, pre-heating of alternative gas' would still be required.

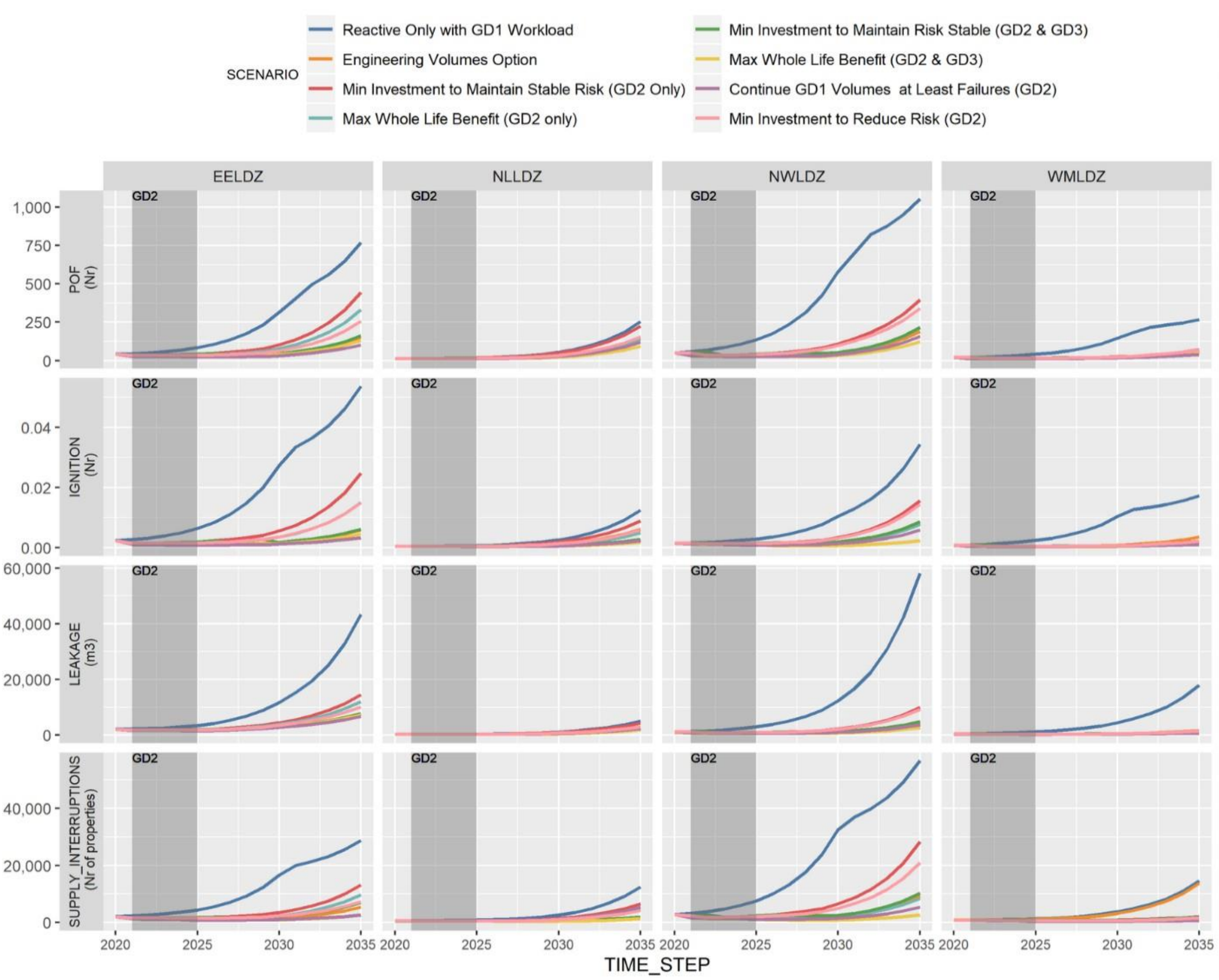


Figure 17 : key asset health and performance measures over time per network coloured by scenario.

This plot shows several varying scenarios of investment and risk that were investigated and compared to the reactive only scenario (blue line) for each network. East of England and North West show higher values of risk for the reactive only scenario. All scenarios can be seen to either hold constant or improve key performance measures over RIIO-2 (grey shaded box) for all networks. All scenarios were assessed and compared against the final chosen scenario based on maximise whole life benefits smoothed over RIIO-2 (Max Whole Life Benefit).

Preferred asset health investment option:

As discussed in section 8.2, Option 1 has been developed through consultation with our stakeholders and is the option we have chosen to take forward in to RIIO-2.

Holding risk stable does not maximise whole life benefits. We therefore explored Whole Life Cost (WLC) over 45 years, but this would increase customer bills materially in the short term. WLC with a shorter payback period of 15 years is more acceptable.

Option 1 also predominately replaces the worst conditioned assets, reducing the level of risk to service now and over RIIO-2.

On this basis, our preferred investment programme to manage the reliability and safety of the pre-heaters, to reduce failures and any resulting supply interruptions, together with providing a cost-effective programme that manages health and safety is set out in the tables below.

It is worth noting that the NARM's modelling has been produced for up to the end of RIIO-3, however, these figures may change depending on the development of the approach in RIIO-2.

	Volumes									
Network	2021/22		2022/23		2023/24		2024/25		2025/26	
	Offtake	PRS	Offtake	PRS	Offtake	PRS	Offtake	PRS	Offtake	PRS
EoE	1	1	2	0	2	0	2	0	1	1
Lon	0	1	0	1	0	1	0	1	0	2
NW	0	2	0	2	0	2	2	1	0	2
WM	0	2	0	0	1	0	0	0	0	1

Table 33: RIIO-2 volumes for pre-heat interventions by network.

Network	Costs									
	2021/22		2022/23		2023/24		2024/25		2025/26	
	Offtake	PRS	Offtake	PRS	Offtake	PRS	Offtake	PRS	Offtake	PRS
EoE										
Lon										
NW										
WM										

Redacted due to commercial sensitivity

Table 34: RIIO-2 costs for pre-heat interventions by network.

31 Pre-heat units will be replaced over RIIO-2 at a cost of *XXXX*. The units selected have the poorest condition ratings and are high risk to the network. There are other units that would also be cost beneficial to replace, but we are confident we can manage the risk.

The average annual costs between RIIO-1 and RIIO-2 are similar and RIIO-2 should see a stable delivery profile with achievable workload targets. The main regional variance appears within West Midlands, due to a lower workload. The unit replacement cost across all regions is consistent.

Benefits of the preferred investment case

The improvements in performance as a result of the investment in pre-heaters are provided in the sections below.

Name	Scenario	2020	2025	2030	2035
POF (Events)					
IGNITION (Nr)			Redacted due to commercial sensitivity		
LEAKAGE (m3)					
SUPPLY_INTERRUPTIONS (Props)					

Table 35: Performance under preferred scenario.

The figure below shows this comparison of reactive only (no investment) directly to the chosen scenario for four key asset health and performance measures. The chosen scenario shows a stable or reducing risk position.

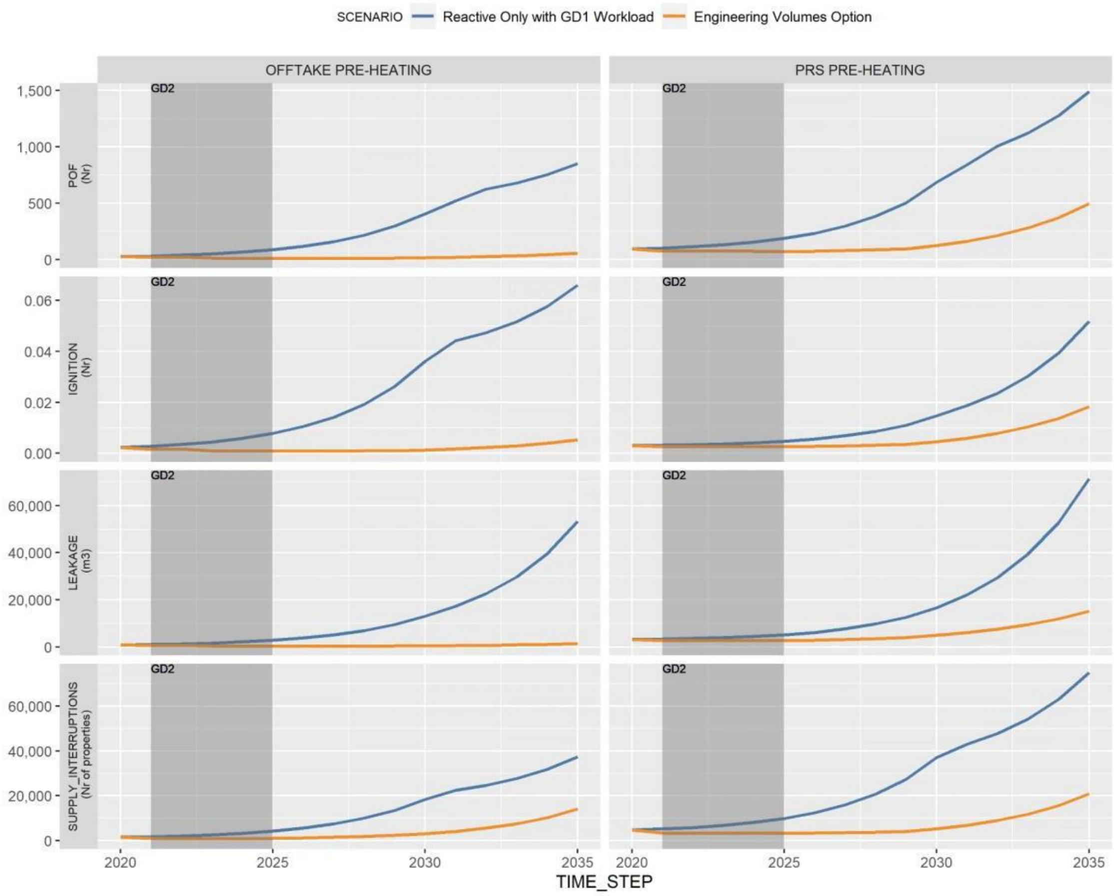


Figure 18: Key asset health and performance measures over time per asset category for reactive only and the final chosen scenario

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

Our preferred option for our RIIO-2 investment programme is comprised of the following:

- PSSR inspections to manage compliance against regulations.
- Pre-heater replacements to comply with MCPD and manage pre-heater asset health

Our proposed pre-heater replacement volumes are shown below:

Volume of pre-heater replacements	RIIO-2
Offtake Pre-heating	11
PRS Pre-heating	20
Total	**31**

Table 36: RIIO-2 Volumes of pre-heater replacements (asset health and MCPD compliance).

Heater Type	No. to be installed	% of total volume
Thermosyphon Heating	18	58.06%
Water Bath Heater	9	29.03%
Modular Boiler	2	6.45%
Electric Heater	2	6.45%

Table 37: volumes of heater types.

9.2. Asset Spend Profile

Our asset health spend is given below:

	Financial Year					
	21/ 22	22/ 23	23/ 24	24/ 25	25/ 26	Total
Total						

Table 38: RIIO-2 replacement costs.

For completeness, we have included the spend profile for the PSSR inspections below.

	Financial Year					
	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Total						

Table 39: PSSR Inspection RIIO-2 spend profile.

Delivery will be broadly in line with the first 6 years of RIIO-1 and we have strong delivery mechanisms in place.

9.3. Investment Risk Discussion

- RIIO-2 will involve a stable delivery profile with achievable workload targets.
- The work volume will be lower than during RIIO-1, although there will be challenges of using new technology. This will not require a material change in headcount. The main regional variance is within the West Midlands, which has a slightly lower workload. Therefore, there are no material delivery risks.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.05.01	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
09.05.02	Stretching efficiency targets may not be deliverable (unit costs increase)	Outturn costs are not met increasing overall programme costs.	Low	Established market place - ability to manage the known commodity market
09.05.03	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
09.05.04	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.

09.05.05	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.
09.05.06	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.
09.05.07	Performance and Availability of new heater technology does not meet programme requirements	Unit cost and delivery timescales impact upon Cadent safety requirements	Med	Supply chain engagement and testing regimes followed to prove equipment - Standards for equipment already proven.

Table 40: Risk Register

9.4. Regulatory Treatment

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

This investment is accounted for in the Business Plan Data Tables 2.04 (Non-Routine Maintenance) and 3.01 LTS, Storage & Entry, within the PRS and NTS Offtake Sub Tables under the heaters lines.