Engineering Justification Paper: EJP15

Preheat on Offtakes & PRS

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CADENT - CONFIDENTIAL

1 Summary Table

Name of Programme	Offtakes and PRS Preheating Replacements
Programme Reference	EJP15
Primary Investment Driver	Asset Health – Reliability
Programme Initiation Year	2027
Programme Close Out Year	2031
Total Installed Cost Estimate (£)	[cost data redacted]
Cost Estimate Accuracy (%)	+/- 10%
Project Spend to date (£)	RIIO-2 spend to date is [cost data redacted] RIIO-3 spend to date is [cost data redacted]
Current Project Stage Gate	Rolling programme of investment
Reporting Table Ref	5.01 LTS storage and entry
Outputs included in RIIO-3 Business Plan	Yes
Spend apportionment (RIIO-3)	[cost data redacted]
Proposed Regulatory treatment for RIIO-3 workplan	Managed via NARMs (network asset risk metric)

Table 1: Summary Table

Note: Unless otherwise stated, all prices are pre-efficiency and are in a 23/24 price base throughout this document

This investment case does not satisfy the criteria for late competition or early competition and pursuing these activities would not be in the interests of the customer. We recognise the benefits that competition can bring to customers through efficiency and innovation. We continue to challenge ourselves as a business to ensure that we are harnessing competitive forces where they can provide these benefits. For specific detail on how we have assessed competition, please see Chapter 6 of the Workforce and Supply Chain Strategy (Appendix 17).

2 Executive Summary

Preheating is the facility to heat gas prior to reducing its pressure, to mitigate the effect of low outlet temperature. Gas preheating is required to avoid the freezing of downstream equipment and the potential for asset damage or failure or both.

The primary driver for investing in our preheat systems is asset health. Ensuring that we invest in our oldest systems, our systems in the worst condition, and those with the highest fault rates and criticality in way of number of customers supplied. This will also ensure resilience in the network and improve our environmental impact by way of MCPD (Medium Combustion Plant Directive). The environmental benefit is not a primary investment driver; however, it is a consideration through our CBA and is in line with ours and the UK's wider ambitions to reduce emissions.

We have modelled the performance of our preheating units including failures, risk to supply and condition by using our standard investment methodology supported by our models[1]. We need to continue to invest in these assets to manage ongoing issues such as poor performance linked to asset deterioration; compliance with environmental legislation (MCPD); environmental input; efficiency; compliance with PSSR (Pressure System Safety Regulations 2000); and potential interruptions to supply in the event of failures. If we do not invest, the risk of the number of failures and other service impacts (e.g. supply interruptions, leakage, and ignitions) will rise quickly.

We have used our asset model to derive a range of programme options based on different goals. Our proposed strategy for RIIO-3 is consistent with RIIO-2, in that we will invest in our most aged, poorest condition systems. In RIIO-3, there will be a mixture of interventions which are detailed in section 8.2.

In RIIO-2 our final determination included the allowance of [cost data redacted] to replace [volume data redacted]. We are forecasting a spend below this allowance to meet this replacement programme. Our preferred option will invest [cost data redacted] to replace [sensitive information redacted] preheat systems - a mixture of full systems and boiler-only in preheater systems. The below table shows our predicted RIIO-2 spend, and our proposed investment spend for RIIO-3 and RIIO-4.

Commercially Sensitive Information redacted

Table 2: Spend across regulatory periods

Spend to date in our preheating systems across the four networks is:

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Table 3: Spend across networks

3 Introduction

This document covers the engineering justification for preheaters at offtakes and pressure reduction system (PRS) sites. Preheating is the facility to heat gas prior to reducing its pressure to mitigate the effect of low outlet temperature because of the Joules-Thomson effect. Gas preheating is required to avoid the freezing of downstream equipment and the potential for asset damage or failure or both. Our investment scenario is based on the probability and consequence of failure at system level, regardless of their offtake/PRS classification. Systems operationally are the same whether they are on an offtake or PRS and therefore the failure modes and consequences of failure are the same. However, the impact of a failure on an offtake could be much more significant in terms of supply interruptions, compared to a failure on a PRS.

The investment expenditure and volumes discussed in this paper have been derived from our investment methodology - this is discussed in more detail in our RIIO-3 Network Asset Management Strategy (NAMS) - through the assignment of health scores per equipment, asset criticality and service risk metrics. By developing standardised investment scenarios, we can demonstrate an optimised programme to manage asset risk and maximise investment benefit. This has looked at actual fault rates and has calculated consequence of failure for each fault to derive a monetised risk value.

4 Equipment Summary

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

4.1 Overview of the assets

	Summary information
Location on the network	These are typically located on the network at points where the pressure decreases by more than 10 Bar. Predominantly PRS (Pressure Reduction Stations) and Offtakes.
Normal operating modes	Preheaters typically work together as a system. For water bath heaters (WBHs), each unit is sized to handle the full site load. Additional WBH units are typically installed for resiliency purposes, with a set point above the first unit, so that they only operate if the primary unit is faulty or too slow to react to demand spikes. Modular boiler/heat exchanger systems, depending on the heat requirement to increase the gas temperature, can operate in various modes, offering greater flexibility for modulating the number of units providing heat at any time. For example, only one boiler/heat exchanger may be required for small heat increases, whereas all units could operate if a greater increase is needed.
Redundancy architecture	We design the network to a N+1, where N = the total number of heaters required to maintain designed heating capacity. If a site is deemed low criticality from the heating criticality matrix set out in our internal engineering procedures, then these systems do not require a standby. Where the sites are identified as high criticality, then these systems would need to be N+1 independent heater.

	Summary information
Global equipment count.	Across our four networks we have a total of [sensitive information redacted] boilers, [sensitive information redacted] heat exchangers and [sensitive information redacted] water bath heaters, [sensitive information redacted] thermosyphon units and [sensitive information redacted] electrical heaters.
Breakdown of manufacturers / models	• [sensitive information redacted] • [sensitive information redacted] • [sensitive information redacted]

Table 4: Summary of operating modes, redundancy architecture and global equipment count.

The following section sets out the different approved preheat solution options that can be used.

4.1.1 Legacy Water bath heaters (WBHs)

These are a simple method of preheating 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.

Whilst these assets historically have posed efficiency challenges (due to latent heat) they are largely reliable. New water bath heaters provide a greater efficiency and are being explored through trial investment in RIIO-2. Issues with the older installations include obsolescence of spares, reliability issues, inefficiency, and risks to the environment from flue emissions and chemical leaks.

Commercially Sensitive Information redacted

Figure 1: water bath heaters

4.1.2 Modern Water Bath Heaters

Similar in design and operation to a legacy WBH but instead of a natural draft system, they are forced draft and have a more complex burner system with solenoid valves controlling the gas supply. This results in increased efficiency.

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Figure 2: Modern water bath heater on trial in NW

4.1.3 Modular Boiler (MB) systems

Modular Boiler (MB) systems are comprised of gas-fired boilers and heat exchanger(s). Heat exchangers are safeguarded by bursting discs (BDs) to relieve pressure in the event of tube failure. BDs require replacement at the same time as the heat exchanger PSSR examination.

MB systems offer an increased efficiency compared to water bath heaters. Although these systems are more efficient, they have been proven 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 boilers have a much shorter asset life than a WBH. Our modelled life expectancy is 5-15 years for aluminium MBs (which are prohibited for new installation but an ageing population requiring investment) and 10-20 years for stainless steel MBs. Heat exchangers are however comparable to the WBH and modelled at 60 years.

Commercially Sensitive Information redacted

Figure 3: modular boiler system.

4.1.4 Electrical Heater Systems

These provide gas heating through elements inserted directly into gas process stream. These systems are reliable due to the simplicity of the heating delivery and control system. Their maximum heating output is limited by the power that can be supplied by the site's electrical capacity. Typically, these require a 3-phase power supply and so an electrical capacity upgrade may be required.

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Figure 4: electrical heater system

4.1.5 Thermosyphon Preheating

Thermosyphon heaters consist of an airtight container of liquid under vacuum which is heated by a gas flame; this heats the liquid to steam at lower temperatures than a WBH due to the nature of a vacuum. The whole life cost is comparable to a WBH. They have a higher capital outlay, but this is paid back through operational reliability and performance.

It should be noted that the UK supply chain for these systems is currently mothballed and would need significant commitment from us to support any re-mobilisation.

Commercially Sensitive Information redacted

Figure 5: thermosyphon preheating

4.1.6 Other heating systems

Catalytic heaters – Over RIIO-2, we have also trialled catalytic heaters. Large catalytic heaters were not seen as a preferred replacement to conventional preheat systems, however smaller units with a small electrical power requirement are currently on trial on smaller sites.

Vortex – We also completed a trial through RIIO-2 on vortex heaters; however, these were not a favoured solution due to operational impacts. Due to their design, they would provide warm gas into the pressure reduction stream, to ensure no freezing or loss of control, however, sending even colder gas downstream leads to freezing and other asset health issues.

4.2 Detailed equipment summary

We have [sensitive information redacted] (incl. heat exchangers) gas preheating units. Table 5 is a summary of the number of preheaters installed on the asset base split across each of the Networks and by type.

Commercially Sensitive Information redacted

Table 5: Asset Stock – Number of units (asset model – extracted November 2024)

The following table sets out a view of this asset class, these assets typically start to show elevated fault rates at around [sensitive information redacted] from installation (for boilers) and [sensitive information redacted] for heat exchangers and water bath heaters

What the following table shows, is that 90% of our boilers [sensitive information redacted] and [sensitive information redacted], which we are increasingly observing performance issues and increased fault rates. See section 7 for more information on fault rates.

The table also shows that 75% of our water bath heaters [sensitive information redacted] and 42% [sensitive information redacted]. Like boilers, we are increasingly observing performance issues with these assets and a decline in available spares. This increases the likelihood of asset downtime in the event of a failure. This downtime impacts the downstream supply, which impacts our customers.

Commercially Sensitive Information redacted

Figure 6: Percentage distribution of asset age for all Networks (Asset Model – extracted November 2024)

These assets have a rolling maintenance and inspection regime. This provides insight to asset condition. Our condition data is coupled with fault data which provides an overview on the health of an asset, and it is the metric that is modelled to determine the need for investment. The following table shows todays average health score of these assets split by Network and a Cadent average.

Commercially Sensitive Information redacted

Table 6: Average health score, by Network and as Cadent average (Asset Model – extracted November 2024)

Health scores range from 1-5, 1 being excellent condition and 5 being very poor. See NAMS (Network Asset Management Strategy) document for methodology on how these health scores are derived.

5 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. The investment driver for these assets is to mitigate the risk of supply interruptions caused by asset deterioration and failure. We have a statutory obligation per Licence Condition 16, to ensure security of supply to meet our peak 1 in 20 demand. It is crucial that we develop a cost-effective way to manage and maintain these assets, through effective inspection, repair, and replacement. Asset deterioration causes poor performance and possible failures.

At the start of RIIO-3, our modelling informs us that [sensitive information redacted] of our PRS heating systems will have a [sensitive information redacted], and [sensitive information redacted] of our offtake heating systems will have a [sensitive information redacted]

Our strategy is to hold asset health stable and ensure security of supply to our customers, whilst removing some systems that have a health score greater than 3. Our investment seeks to mitigate the risks posed by poorer performing assets and those with a decline of spares that are required through routine maintenance and failure of soft parts (the internal components of the asset). Due to newer more efficient technologies, this investment will also help reduce our carbon emissions.

5.1 What happens if we do nothing

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 following summarises the risks if we do nothing:

- Safety: We must comply with PSSR (2000) Regulation 8 (written scheme of examination for inspections) together with intervention, as required, in relation to Regulation 12 (repair). We have an obligation to prevent serious injury from the hazard of stored energy because of the failure of a preheat system or one of its component parts. We have a robust maintenance regime for our preheating systems, however due to the unreliability of some systems with no available spares, we are seeing an increased frequency of ad hoc works being carried out to ensure operation. Without this maintenance regime on our preheat systems, this poses a safety risk, due to the fire and explosion risk from a leak, following a failure. The consequences modelled in our AIM model are fatalities and minor injuries following ignition.

- Environmental: Loss of containment will result in an uncontrolled gas release to atmosphere, resulting in an impact to carbon emissions. We have a target to reduce our emissions, therefore an option that undermines our environmental commitments is not favourable.

- Regulatory compliance: We have a legal obligation to inspect and maintain these assets under the Pressure Systems Safety Regulations (2000). We also must ensure the mechanical integrity of our assets via the provision of pre heat, to maintain safe operational temperatures. Those systems that fail to comply within the allowable tolerances, would need intervention to remain compliant and ultimately ensure resilience in the network.

- Security of Supply: We have a duty to comply with the terms of our gas transporter licence, specifically Condition 16 (Pipeline System Security Standards) to manage our network to meet the demand of connected customers by supplying to meet the peak aggregate daily demand. Any option that prohibits us meeting this condition is not acceptable. Preheating system failures could cause asset or site outage, resulting in customer supply interruptions. Depending on the configuration of the network and the size of the site, this could result in a significant number of customers being impacted.

- Financial: Any preheater failure will have resulting costs to respond and mitigate the failure, to re-establish operation, repair and restore service and repair of any ground heave due to high outlet temperatures. Repair costs also increase with the life of all preheating assets. Options that negatively impact the customer bill or result in penalties through fines is not favourable.

- Customer Interruptions: Safety and resilience are non-negotiable. Customers place a high premium on the safety and resilience of the network. Therefore, any investment must focus on minimising and mitigating risks to prevent customer interruptions, ensuring a continuous, safe and dependable gas supply.

5.2 Key outcomes and understanding success

[Commercially sensitive information – section redacted]

5.3 Narrative real-life example of problem

[Commercially sensitive information – section redacted]

Commercially Sensitive Information redacted

Figure 7: Example of iced pipe following failure of heater tube within a preheat system

Commercially Sensitive Information redacted

Figure 8: Iron Oxide build up within a modular boiler

5.4 Project Boundaries

6 Probability of Failure

[Commercially sensitive information – section redacted]

6.1 Failure modes

Commercially Sensitive Information redacted

Table 7: Failure modes and consequences

6.2 Failure rates for each failure mode

Commercially Sensitive Information redacted

Figure 9: Failure rates over time for reactive only, which is our baseline do nothing option (Asset Model - extracted November 2024)

6.3 Probability of Failure Data Assurance

[Commercially sensitive information – section redacted]

7 Consequence of Failure

[Commercially sensitive information – section redacted]

Commercially Sensitive Information redacted

Table 8: Consequence of Failure

8 Options Considered

[Commercially sensitive information – section redacted]

8.1 How we have structured this section

[Commercially sensitive information – section redacted]

8.2 Modes of Intervention

[Commercially sensitive information – section redacted]

Commercially Sensitive Information redacted

Table 9: Intervention modes used in programme options

8.2.1 Intervention mode 1: Repair of preheating systems

Commercially Sensitive Information redacted

Table 10: Intervention mode 1: reactive repair

8.2.2 Intervention Mode 2: Minor refurbishment of preheating systems

Commercially Sensitive Information redacted

Table 11: Intervention mode 2: Minor refurbishment

8.2.3 Intervention Mode 3: Major refurbishment of preheating systems

Commercially Sensitive Information redacted

Table 12: Intervention mode 3: Major refurbishment

8.2.4 Intervention Mode 4: Full system replacement of preheating system

Commercially Sensitive Information redacted

Table 13: Intervention mode 4: Full replacement

8.3 Timing choices

[Commercially sensitive information – section redacted]

8.4 Options

Commercially Sensitive Information redacted

Table 14: Intervention modes against timing choices

8.5 Programme Options

Commercially Sensitive Information redacted

Table 15: Programme options considered

8.6 Technical Summary Table: Programme Scenarios

Commercially Sensitive Information redacted

Table 16: Summary of Programme options

Commercially Sensitive Information redacted

Figure 10: Condition score of each programme option (Asset Model – extracted November 2024).

9 Business Case Outline and Discussion

[Commercially sensitive information – section redacted]

9.1 Key Business Case Drivers Description

[Commercially sensitive information – section redacted]

9.2 Business Case Summary

Commercially Sensitive Information redacted

Table 17: Programme options comparison

9.3 Discussion of results

9.3.1 Risk removal

Commercially Sensitive Information redacted

Figure 11: Monetised risk (£m) per year for preheat customer interruptions

9.3.2 Cost Benefit Analysis

Commercially Sensitive Information redacted

Table 18: CBA outputs for Options 3 and 5

Commercially Sensitive Information redacted

Table 19: CBA outputs for options 2 and 9

9.3.3 Customer views

[Commercially sensitive information – section redacted]

9.3.4 Deliverability

[Commercially sensitive information – section redacted]

9.4 Conclusions

[Commercially sensitive information – section redacted]

9.5 Sensitivity analysis

Commercially Sensitive Information redacted

Table 20: Sensitivity testing

10 Preferred Option Scope and Project Plan

[Commercially sensitive information – section redacted]

10.1 Preferred Option

Commercially Sensitive Information redacted

Table 21: RIIO-3 Volumes of preheater replacements

Commercially Sensitive Information redacted

Table 22: Volumes of heater types to be installed.

Commercially Sensitive Information redacted

Table 23: Programme of heater replacements by PRS / Offtake site

10.2 Asset Health Spend Profile

Commercially Sensitive Information redacted

Table 24: Spend profile for preheat interventions.

10.3 Investment Risk Discussion

Commercially Sensitive Information redacted

Table 25: Risks

10.4 Project Plan

[Commercially sensitive information – section redacted]

10.5 Key business risks and opportunities

[Commercially sensitive information – section redacted]

10.6 Outputs included in RIIO-2 Plan

[Commercially sensitive information – section redacted]

11 Regulatory Treatment

[Commercially sensitive information – section redacted]

12 Glossary

Term	Definition
AIM	Asset Investment Manager
CBA	Cost Benefit Analysis
EJP	Engineering Justification Paper
FES	Future Energy Scenarios
NAMS	Network Asset Management Strategy
NARM	Network Asset Risk Metric
PSSR	Pressure Systems Safety Regulations

Table 26: Glossary Table