Preheating Replacement Programme

Engineering Justification Paper (SGN-GD3-EJP-LTS-007)

Final Version 1.0

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Transmission Asset Management SGN

SGN

Your gas. Our network.

Contents

1 Summary Table

Table 1: Ofgem Project Summary Table

Name of Project	Preheating Replacement Programme EJP		
Scheme Reference	SGN-GD3-EJP-LTS-007		
Primary Investment Driver	Asset Health		
Project Initiation Year	2026/27		
Project Close Out Year	2031/32		
Total Installed Cost Estimate (£)	£22.07m		
Cost Estimate Accuracy (%)	25%		
Project Spend to date (£)	£52,212 (RIIO – GD/2 Feasibility Spend)		
Current Project Stage Gate	Feasibility Study		
Reporting Table Ref	LTS Storage and Entry 5.01		
Outputs included in RIIO-GD2 Business Plan	No		
Spend apportionment (£m)	GD2	GD3	GD4
	£0.05	£22.07	£0

All expenditure above 23/24 prices

2 Executive Summary

1 This investment paper outlines a strategic investment plan to replace pre-heating systems at 18 sites supplying more than 3 million customers. These replacements are being carried out on both Boiler systems in addition to Water Bath Heaters. It is a programme with multiple different assets and multiple different drivers with a total capital cost of £22.07m in RIIO GD/3.

2 The drivers for the Boiler System replacements are the integrity and reliability of their internal Aluminium Heat Exchangers in addition to other integrity related drivers. The primary driver for the Water Bath Heater replacements relates to their inefficiency and the introduction of additional legislation on emissions.

3 Cost benefit analysis has been undertaken for this proposal, the net present value of the preferred option at a 16-year assessment point from the start of the model (2043) is £16.81m in the Scotland Network and £48.92m in the Southern Network.

4 The delivery profile as visible in the 'Forecast Volume' row in Table 2 shows the commissioning years for each of the pre-heating replacement projects. No projects will be delivered in year 1 due to the lead time for design and material procurement.

Table 2: GD3 Project Expenditure Profile in 23/24 Prices (for both networks)

Year	26/27	27/28	28/29	29/30	30/31	Total
Forecast Cost (£m)	2.73	8.07	7.79	2.45	1.02	22.07
Forecast Volume	0	4	7	6	1	18

5 By comparing Table 2 and Table 3 it can be observed that the average cost for a pre-heating replacement intervention has gone up from £0.85m per site to £1.22m per site. The average cost has been increased by the inclusion of larger duty sites and Water Bath Heater replacements when compared to the 3 boiler replacement projects undertaken in RIIO-GD/2.

Table 3: GD2 FD Allowances and Volumes in 23/24 Prices (for both networks)

Year	21/22	22/23	23/24	24/25	25/26	Total
FD Allowance (£m)	0.31	1.06	1.06	0.14	0.00	2.57
FD Volume	0	0	1	2	0	3

6 As we look to form our plans and develop our strategy for the next price control GD3, we have engaged with support from our Independent Stakeholder Group (ISG) with a wide range of our customers and stakeholders to better understand what their needs are and what they expect from us. We have responded, challenging ourselves to focus on the projects that prioritise safety and resilience, while delivering most value to our customers. This document should be read in conjunction with our GD3 Business plan, section C2 Customer and Stakeholder priorities. This section provides a greater level of detail of our approach to customer and stakeholder engagement.

3 Introduction

7 Within the Local Transmission System (LTS), many Pressure Reduction Stations (PRS) and Offtakes are required to regulate the flow of gas from a Higher Pressure to a Lower Pressure System. When Natural Gas is reduced in pressure the 'Joule-Thomson Effect' results in a proportionate decrease of temperature (generally 0.5 oC for every bar). Sub-zero temperature would represent a risk to the operation of pressure control equipment in addition to the potential for damage to outlet pipework or the conveyance of cold gas to customers.

8 Where the cut is significant (generally 15 bar and above)1 a Pre-Heating System is Installed which will heat the flow of gas before the pressure cut preventing sub-zero temperatures at the outlet. The required size and duty of the pre-heating system required depends on the size of the pressure cut and peak demand flow through the site. For larger sites two types of pre-heating systems make up the majority of SGN's Asset Population:

- Water Bath Heaters: An older less efficient technology used on many sites that have not had replacement since site construction. These operate using a natural gas burner which heats a large static 'water bath'. The main flow of gas is conveyed through a pipe within the bath allowing it to be pre-heated.
- Boilers and Heat Exchangers: The more contemporary technology used on sites constructed in the last thirty years or where assets have already been replaced. These generally use a closed loop pressurised loop of circulating water, pairing a modular boiler system with shell and tube heat exchangers to pre-heat the gas.
- The outlet temperature of the gas flow through a site will generally be maintained at $0^{o}C$ through the operation of a pre-heat system.

9 This engineering justification paper aims to present a thorough analysis of problems and options to resolve issues associated with the integrity, safety, reliability and sustainability of Pre-Heat Systems throughout the Network. This submission mostly represents a replacement programme focused on Water Bath Heaters and Boiler/Heat Exchanger Systems with varying drivers. The primary drivers can be summarised as:

- The reliability of Aluminium Heat Exchangers
- The efficiency of Water Bath Heaters and impending regulation (Medium Combustion Plant Directive)
- Safety of Boilers associated with Delayed Ignition
- TD/13 compliance and the lack of 100% parallel redundancy

10 More than 3 million customers[2] over Scotland and the South of England are supplied by gas which are pre-heated by assets included in this replacement programme. The pre-heating systems are on sites that supply at network pressure ranging from High Pressure (up to 85barg) down to Medium Pressure (<= 2 barg).

11 By assessing these drivers and demonstrating the benefits of replacements, this paper aims to justify a construction programme of Pre-Heating Systems. By optimising the operation of Pre-Heating across the Gas Distribution Network it will deliver increased security of supply, safety and security of supply for customers in RIIO-GD/3.

[1] IGEM TD/13 Edition 3, clause 7.6
[2] Includes figures from integrated networks where systems are fed by more than one site

Figure 1: Water bath Heater at Aberdeen Offtake (Scotland Network)

Figure 2: Shell and Tube Heat Exchangers Hardwick Offtake

Figure 3: Boilers At Hardwick Offtake (Southern Network)

12 Figures 1, 2 & 3 show heating systems on Aberdeen Offtake and Hardwick Offtake respectively. Both represent large pre-heating systems on critical sites that require intervention in RIIO-GD/3.

4 Equipment Summary

13 The deliverable for these projects is the replacement of pre-heating systems. Their operation is briefly explained in this section for both Boiler and Heat Exchanger Systems and Water Bath Heater Systems.

14 Water Bath Heaters operate by heating a large volume of water which pre-heats the main process flow of gas which is routed through the bath within a coiled pipe. They are typically situated on older Offtakes and PRSs and connected at the inlet section of the site which operates at High Pressure. Consequently, the supply for the fuel gas is routed through the bath so it can also be pre-heated ahead of its own pressure reduction. The fuel gas then flows through a pressure control system ultimately feeding the burner at a pressure typically between 0.5 barg and 2 barg dependent on the size of the heater. The burner flame and exhaust gasses heat the water bath through a u-shaped 'fire tube', the exhaust ultimately exits through a chimney on top of the heater.

15 The flow of the fuel gas to the burner is controlled by various control valves in series to ensure the system operates safely. These operate as follows:

a. To control the heat supplied as influenced by the outlet temperature of the site

b. To maintain the water within the water bath heater at an appropriate temperature

c. To shut off the flow to the gas burner should the water level be too low or the pilot flame fail

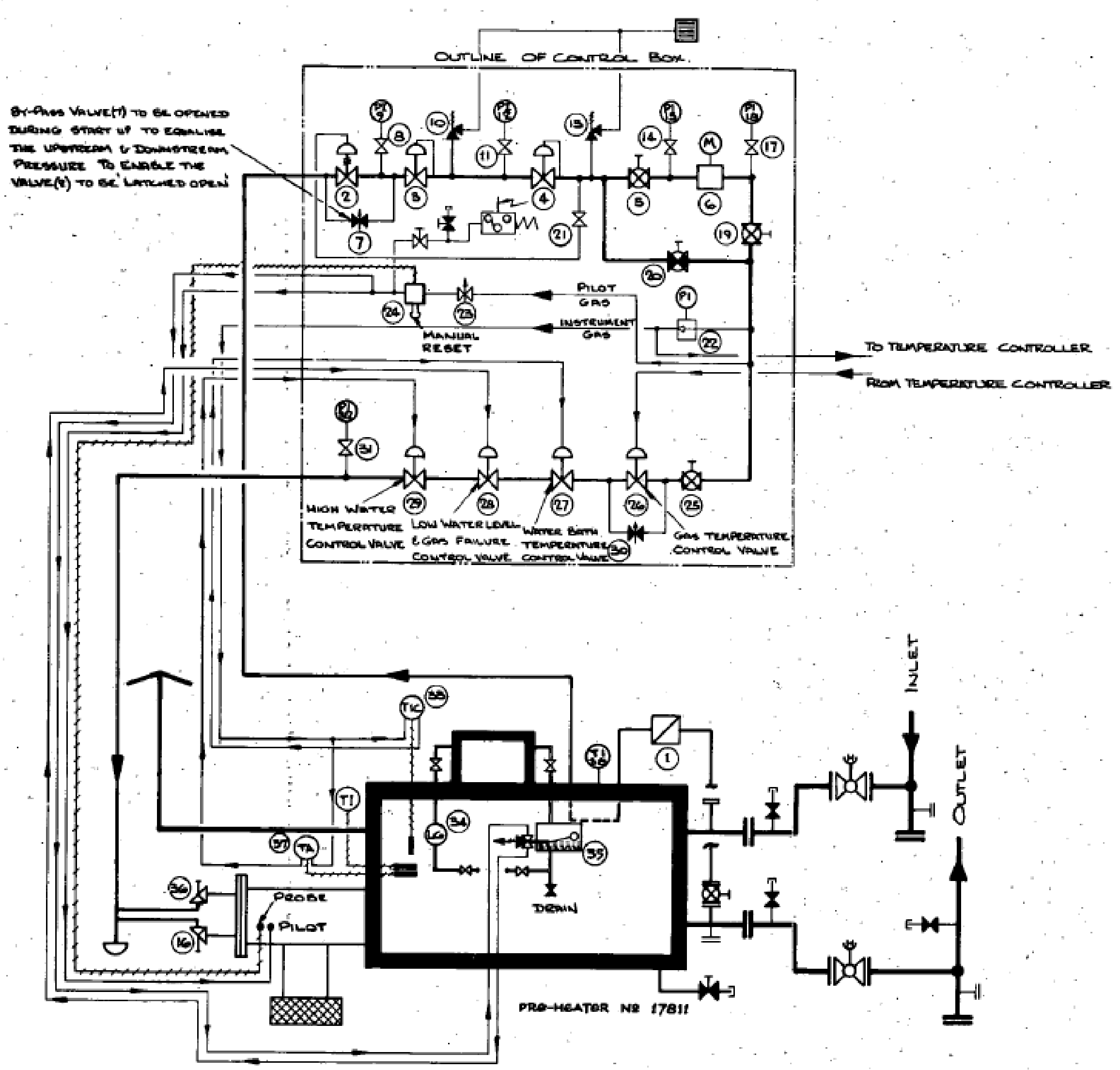
d. To shut off the flow to the gas burner should the water temperature get too high

16 Due to the high temperature operation of the water bath heaters, they generally operate at a low efficiency when compared to boilers and heat exchangers. One study on a small Water Bath Heater on Lochmaben PRS found a Water Bath Heater to have a Burner Efficiency of 67%, Thermal Efficiency of 57% and overall System Efficiency of 57%.[3]

17 Water Bath Heaters typically operate with 100% parallel redundancy, allowing sufficient pre-heating if one of the water bath heaters were to fail. This also allows the heaters to be taken out of service for maintenance.

[3] Project closure report, Immersion Tube pre-heating, NIA_SGN0002, 15/06/2016

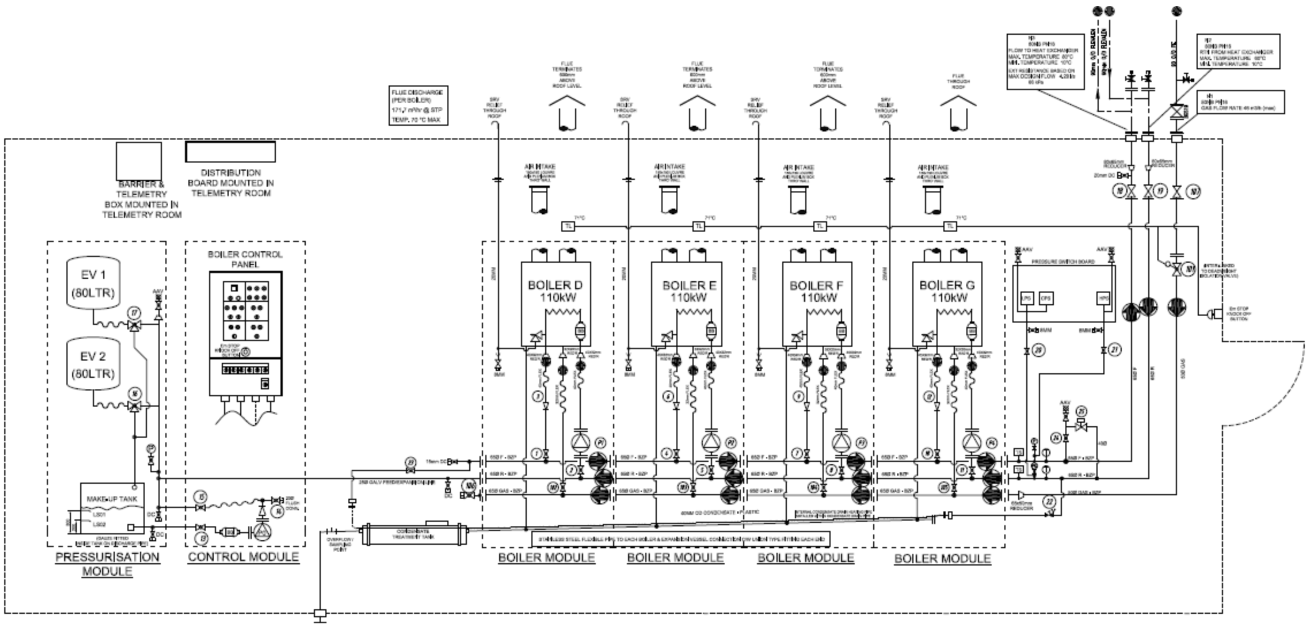
Figure 4: Schematic of a Water Bath Heater and the associated fuel gas control system



18 Boilers and Shell and Tube Heat Exchangers operate in conjunction using a closed loop circulation system to pre-heat the gas flow. The boilers operate through the same principle as domestic condensing units but are connected in parallel within a ‘modular’ boiler house

19 The modular arrangement allows the control system to change the quantity of boilers turned on dependent on the heat requirement at the time. The control system does this by sensing the outlet temperature of the gas flow on site in addition to the temperature of the circulating water. There is also telemetry utilised to report boilers that have gone into fault conditions. These systems operate with parallel redundancy, where at least one boiler can be lost while supplying the peak heat demand.

Figure 5: Example of a Boiler Schematic



20 Within the shell and tube heat exchangers the main process flow of gas is split through dozens of thin wall tubes to merge again at the outlet. Simultaneously, the hot water is flowing through the outer ‘shell’ so that heat is exchanged at the surface of the thin wall tubes allowing for efficient heat transfer. To avoid the risk of over pressurising the water system from a failed tube, bursting disks are installed on top of the heat exchangers on the shell side. The maintenance of these disks is a requirement under PSSR.[4]

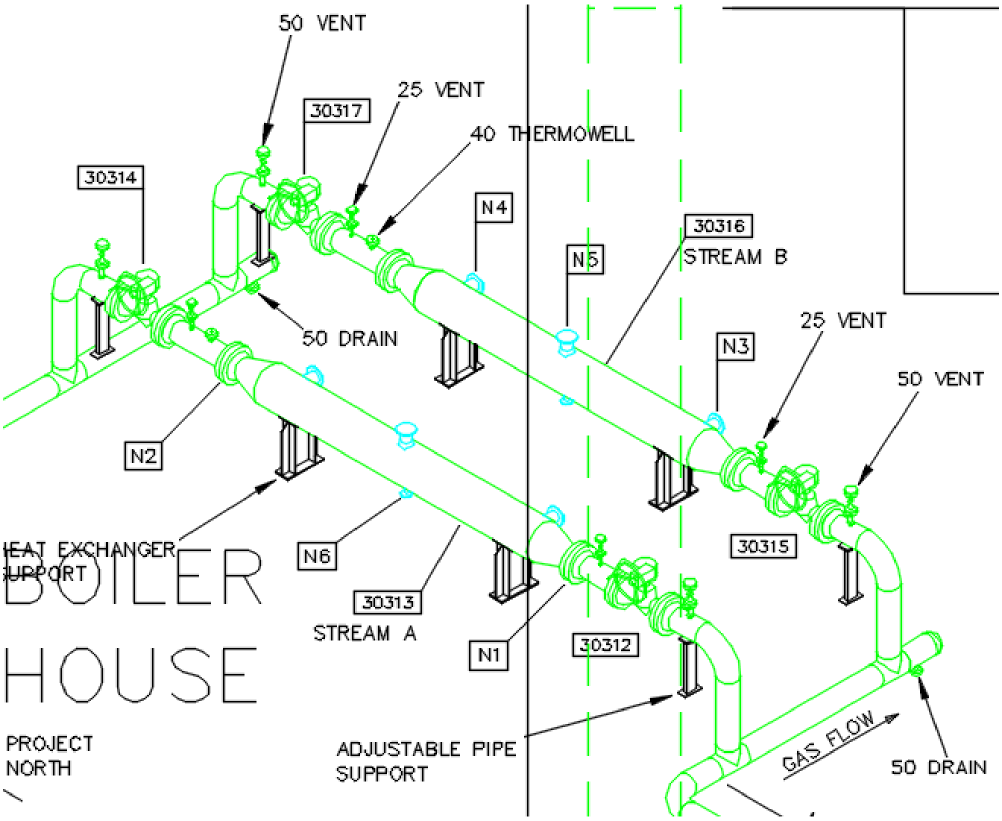
21 Heat Exchangers typically operate with 100% parallel redundancy, allowing sufficient pre-heating if one of the heat exchangers were to fail. This also allows the heat exchangers to be taken out of service for maintenance.

22 Condensing Boiler Systems run at much higher efficiencies, typically between 90-99%.

Figure 6: The end plate of a shell and tube heat exchanger

[4] Pressure Systems Safety Regulations 2000

Figure 7: Shell and Tube Heat Exchanger Skid Drawing



23 Appendix C "Equipment Summary" provide equipment summaries for this Preheating Replacement Programme in addition to global summaries across both Scotland and Southern Network. This will give some context for the high quantity and diversity of pre-heating assets that are required to operate the Gas Networks in Scotland and the South of England.

5 Problem/Opportunity Statement

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

Problem 1 – Failing boiler heat exchangers

24 The aluminium boiler heat exchangers in our heating systems are experiencing accelerated failure rates due to the accumulation of aluminium salt deposits. These deposits form on the surfaces of the heat exchangers over time, leading to several critical issues that compromise the efficiency, safety, and longevity of the boilers.

25 The primary problem stems from the buildup of these deposits, which significantly increases the back pressure within the combustion chamber. This increased back pressure disrupts the optimal flow of exhaust gases, resulting in inefficient combustion processes. Consequently, the boilers exhibit reduced thermal efficiency, higher fuel consumption, and elevated emissions, undermining their performance and environmental performance. Furthermore, the elevated combustion chamber back pressure can lead to combustion product spillage into the boiler houses, posing a safety risk.

26 Moreover, the persistent presence of aluminium deposits accelerates the corrosion of the heat exchanger surfaces. This corrosion weakens the structural integrity of the heat exchangers, leading to frequent breakdowns and costly repairs. The shortened lifespan of these components not only escalates maintenance expense but also causes unplanned downtime, disrupting the preheating system, potentially affecting customer supply.

27 In summary, the accelerated failure of aluminium boiler heat exchangers and the resultant increase in combustion chamber back pressure presents a significant operational challenge. Addressing this issue is crucial to enhancing the reliability, efficiency, and sustainability of our heating systems.

28 Figure 8 and 9 show photos of corroded internal heat exchangers from a boiler on a pre-heating system. These specific heat exchangers were later remediated.

Figure 8: Image showing internal deterioration of aluminium heat exchanger.

Figure 9: Image showing internal deterioration of aluminium heat exchanger.

Problem 2 – Water Bath Heaters and Medium Combustion Plant Directive Compliance

29 The Medium Combustion Plant Directive is a piece of EU legislation which was originally introduced under 'MCPD- Directive (EU) 2015/2193' on the 25th of November 2015. Environmental Regulations have been amended in both Scotland and England to include these requirements.[5] Consequently, the requirements apply to SGN's Combustion Pre-Heating Equipment in both Scotland Network and Southern Network.

30 The goal of the regulation is to improve air quality by regulating the emission of certain pollutants into the air. It was introduced to address the gap in regulation for any medium sized plant between 1 and 50MW. There are 4 sites in SGN (all in Scotland Network) which operate with Water Bath Heaters with Net Rated Thermal Inputs more than 1 MW. Without replacement, these units will need to comply with the regulations during RIIO-GD/3.

31 The 4 sites are subject to the following deadlines:

Table 4: Registration deadlines in The Pollution Prevention and Control (Scotland) Regulations 2012

Requirement	Deadline
Must have applied for a permit	30 June 2028
Must comply with the Emission Limit Values set in the permit	1 January 2030

32 It is likely that specialist support will be needed to obtain perimetry based on previous experience with environmental regulation. The permits will require periodic monitoring (at least every 3 years) so that emission levels can be reported. Plants must be monitored for Sulphur Dioxide, Nitrogen Oxides, dust and Carbon Monoxide.

33 The detection of unacceptable emission values may require the Plant to be modified to achieve compliance. However, if practical this is likely to be very costly given the age of the relevant Water Bath

[5] https://www.sepa.org.uk/regulations/pollution-prevention-and-control/medium-combustion-plant/#Legislation

Heaters. If this cannot be achieved, this would eventually result in SGN being served enforcement notices by SEPA.

34 As described previously, Water Bath Heaters have a low overall system efficiency of 57%. The Water Bath Heaters in question have largest thermal inputs in Scotland Network. Therefore, their replacement would result in the greatest reduction of carbon emissions from OUG (Own Use Gas) when compared to any other heaters on the network.

Problem 3 –Lack of standby provision and Obsolescence

35 The design of effective pre-heating systems requires consideration of the sizing of the pre-heating units in addition to the requirement for standby. Inclusion of standby capacity allows for pre-heating to continue to operate even when there is partial failure. Industry guidance within TD/13 recommends the provision of standby by considering:

- Criticality of the station and its requirement for pre-heating
- The probability of the failure of a unit occurring simultaneously with a period of extreme demand.[6]

36 Three sites in this programme, do not have full standby provisions consistent with this requirement. The arrangement of one of these three sites is explained in more detail below:

- Petersfield Durford Rd PRS only has a singular boiler with no standby provision. It feeds with an inlet pressure of 26.2barg and outlet pressure of 1.5barg. This would result in an approximately 12 degrees drop in temperature without pre-heating. The ground temperature and therefore inlet gas temperature is expected to be below 12°C for half of the year[7]. Failure of the pre-heating system and subzero temperatures is also a credible risk.

37 The availability of spares is a critical element of the maintainability of any system. Boiler maintenance requires the replacement of bespoke components that cannot be sourced generically when no longer manufactured.

38 For example, in this replacement programme there are two of the boiler systems without standby will be more than thirty years old at the beginning of RIIO-GD/3. Both systems have obsolete boilers with limited availability of spares. For example, the Petersfield (Durford Road) PRS boilers were installed in 1995 (Model: Chappee XG 16.00 CS)

39 Without spares, there is no expedient way to easily repair a fault that requires a replacement component. Failure on one of these sites would result in an extended period of sub-zero temperatures at the outlet of the station. Consequently, there is an elevated safety risk from a failure in addition to the potential to compromise the security of supply.

40 Replacement of the pre-heating systems in this programme will resolve the current risks present from a lack of standby and obsolescence.

Problem 4 – Delayed Ignition

41 A specific additional risk at one of the sites in this replacement programme (Bucklebury PRS) is delayed ignition. This is caused by a fault within the burners where ignition does not occur at the appropriate time, instead only happening once excessive gas has entered the boiler. Consequently, there is a small detonation within the boilers which results in an over pressurisation event. No spare can be sourced for the burner that would have rectified the issue.

42 Delayed ignition in turn causes the following risks:

- Boiler Damage: The boiler can be damaged by the over-pressure event. For example, there is a risk of cracking occurring on the internal heat exchanger or the movement/vibration of loose components.

[6] IGEM TD/13 Edition 3, clause 7.6.6
[7] https://www.researchgate.net/figure/Annual-soil-temperature-profile-for-South-East-UK_fig1_225874880

- Safety Risks: In an extreme scenario, delayed ignition could result in total boiler failure and a fire risk.
- Carbon Monoxide Poisoning: Delayed ignition can result in improper combustion, which can not only result in inefficiencies, but also the risk of the leaking of carbon monoxide into the boiler house. This is a potential severe risk to personnel.

What is the outcome that we want to achieve?

43 The outcome we want to achieve is to deliver the pre-heater replacement programme on 18 sites in GD/3. In doing this, SGN will improve the reliability, safety and efficiency of its pre-heating fleet in both Scotland Network and Southern Network.

44 The outcome must also ultimately include benefit to the customer base. Examples of how these positive outcomes will materialise are detailed below:

a. Improved security of supply through improved reliability of the pre-heating fleet, particularly though the reduced prevalence of internal Boiler Aluminium Heat Exchangers.

b. Improved safety on the network through a reduced probability of failure of the pre-heating system for the reasons described above.

c. Lower environmental impact to the public from the decommissioning of the largest Water Bath Heaters on the network.

How will we understand if the spend has been successful?

45 The implementation of the replacement programme will be managed and tracked within SGN through the Plant/1[8] process. The primary indicator of success will be the commissioning of the replacement pre-heating systems on the 18 sites in GD/3. This will result in the previously described problems being eliminated or reduced as applicable. It will be possible to track this through monitoring the fault data for the sites.

46 Substantial cost savings in maintenance are expected in the replacement of boiler systems that use Aluminium Heat Exchangers with ones using Stainless Steel Units. The baseline option would require additional maintenance of the Aluminium Heat Exchangers over a 10-year period including their ultimate replacement. The savings in carrying out this maintenance are estimated at £426,897 in Scotland Network alone.

47 Specifically for the Water Bath Heaters, decommissioning of the 8 largest Water Bath Heaters (over 4 sites) will negate all requirements under the Medium Combustion Plant Directive. The additional requirements would have included applying for the necessary perimetry in addition to monitoring and servicing the units every 3 years to maintain compliance. The savings are forecast as £7,712 of one-off costs and £24,878 every 3 years.

5.1 Narrative Real-Life Example of Problem

Boilers – Aluminium Heat Exchangers

48 Aberdeen Craibstone is a PRS on the outskirts of Aberdeen which supplies approximately 50,000 customers. This site provides gas preheating by utilising six 252kW boilers with aluminium heat exchangers, which were manufactured and installed in 2005.

49 These boilers have been found to have combustion chamber to flue differential pressure greater than the manufacturer determined critical pressure of 2.7mbar. These heat exchangers were removed from service and pressure washed to remove deposits of aluminium salts, however this did not fully remediate the excessive differential pressure and following reinstatement the heat exchanger continued to deteriorate, exhibiting accelerated corrosion. Affected boilers were rendered as inoperable which subsequently decreased the operating capacity of the modular boiler preheating system. In 2021, the boilers were

[8] SGN/WI/PLANT/1 Work Instruction for the Delivery of Plant Projects

replaced with similar capacity modules housing stainless steel heat exchangers. This allowed the site to operate reliably without similar issues on Boiler Heat Exchanger Deterioration.

50 Similar issues have been experienced at 7 other PRS', with a total of 18 boilers affected and subsequently replaced or remediated. Internal Aluminium Heat Exchanger failure continues to be a risk for the Network.

5.2 Project Boundaries

51 The deliverable for this project is to replace the heating systems on 18 sites in RIIO-GD/3 with new Pre-Heating Systems utilising Boilers and Heat Exchangers. These new systems will:

- Be substantially more efficient than Water Bath Heaters or non-condensing boilers
- Will utilise Stainless Steel Heat Exchangers rather than Aluminium
- Will have full spares support and standby provision in accordance with TD/13

Table 5: Overview of the primary interventions within the Preheating Replacement Programme

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Description of Primary Intervention
Replacement of WBHs with Boiler and Heat Exchanger Systems	4	Decommissioning and removal of the largest Water Bath Heater Units in Scotland Network Installation of replacement Boiler and Heat Exchanger Systems with inclusion of standby capacity for TD/13 compliance.
Replacement of Al Hex Boilers with Stainless Steel Boilers	10	Decommissioning and removal of the existing pre-heating systems on these sites. Installation of replacement Boiler and Heat Exchanger Systems with inclusion of standby capacity for TD/13 compliance.
Upgrade of sites that do not currently have standby capacity	3	
Replacement of Boiler System with Delayed Ignition	1	

52 These costs do not cover any provision for the replacement of any other systems on the relevant PRSs or Offtakes, for example Filtration, Metering or Pressure Control. They do however include supporting E&I Works and some ancillary civil works on site. These are being included within the package of works to increase the benefit of the investment.

6 Probability of Failure

53 Probability of failure is a key component of the NARM model and has been robustly produced from either industry guidance or from datasets that SGN hold. Sensitivity analysis on key components within the CBA has been undertaken to test if the overall investment is still warranted. However, it must be noted that testing of this type is performed holistically and does not consider specific drivers.

54 When considering the possible failure modes that could occur across targeted sites, there are a several different categories in which these failure types can be grouped. The most credible forms of failure are discussed below:

Low Outlet Temperature:

55 **Preheating equipment failure:** As discussed in the problem statement, this failure mode is caused by accumulation of aluminium salt deposits within the heat exchangers of the boiler modules. This causes the boilers to exhibit a reduced thermal conductivity and accelerated corrosion leading to failures becoming more frequent, putting additional cyclic thermal stress on the remaining operational boilers within the heating system. These events raise the risk of unacceptably low temperatures on outlet pipework and failure through brittle fracture. These factors are worsened on sites with obsolescence or a lack of standby which would greatly debilitate the ability to recover quickly.

Figure 10: Example of the effect on outlet pipework on a site without pre-heating

56 This site feeds from 19barg to 75mbarg and was replaced with a skid including pre-heating in RIIO-GD/2.

Low/High Outlet Pressure:

57 **Malfunction of Pressure Control Equipment:** As previously described, pre-heating doesn't only protect the downstream network but also protects the pressure control equipment on the site. The correct operation of pressure control systems depends on the mechanical operation and movement of pilots and regulators. This function depends on the unrestricted motion of the internal components. In addition to the primary regulators, gas flows through the pilots and is cut in pressure. Without pre-heating, the pilots and impulse pipework would be subject to significant freezing on the plant and impulse lines. If there were to be water ingress within the breather of the pilots this could lead to the incorrect function of the control equipment. Depending on the mechanism of failure this could lead to high or low outlet pressure.

Release of Gas:

58 **Failure of the outlet pipework due to failure of pre-heating:** Sustained sub-zero temperatures following a failure of pre-heating equipment increases the chance of the failure of outlet pipework. The physical characteristics of the outlet pipeline materials are adversely affected by cold conditions. This is worse for Polyethylene which becomes significantly more brittle at colder temperatures. These risks are exacerbated if the heating outage is lengthy and the demands in the system are high, extending the duration and overall length exposed to cold temperatures.

59 **Failure of boiler due to delayed ignition:** The delayed ignition on Bucklebury PRS is a consistent issue when the boiler is turned on. Every occurrence increases the risk of total boiler failure. A failure event could result of release of gas within the boiler house itself, in addition to the risks associated with the lack of pre-heating as described above.

Failure Rates

60 The NARMs modelled PRS & Offtake failure rates assumed for each failure mode are provided in Appendix E.

6.1 Probability of Failure Data Assurance

61 The key factors affecting the NARM failure rate on a transmission asset are:

a. The asset type (preheating, pressure control, Filter, Odorant, Meter), which sets out the deterioration curve. For preheating there are separate curves for Boilers, Water Bath Heater and Electrical heating systems.

b. The condition score (between 1 and 5 where 5 is the worst condition), which provides the ‘Effective Age’ and therefore the point on the deterioration curve used.

62 Due to limitations on fault data availability across the GDN’s, an elicitation process was undertaken to estimate system failure rates and condition grade transitions, as described below, they were used to:

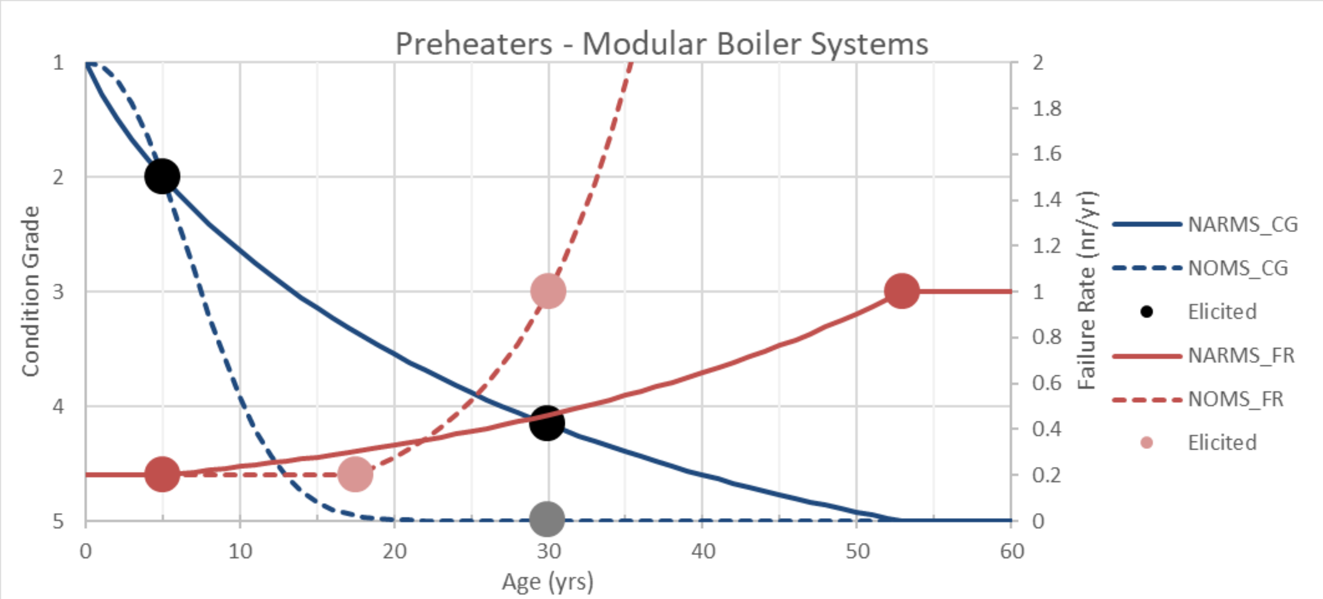
a. Develop a relationship between true asset age and condition adjusted (or effective) age, which is used within the PRS and Offtake asset deterioration curves.

b. Create deterioration curves using assigned condition grades, starting at the gamma age (now aligned with Condition Grade 2). NB: The age at which the asset starts to show a noticeable increase in failures is also referred to as “Gamma”.

c. The mean time between failure (or repairs, MTBF) at Condition Grade 5 is now used as a cap on possible failure rates, per asset. This ensures that the model does not predict failure rates beyond what could practically be repaired, whereby the asset would either be replaced or mothballed (pending replacement).

63 Our robust methodology provides confidence that our investment is aligned to address the probability of failure highlighted in this paper.

Figure 11: The updated elicitation in moving from the GD1/GD2 NOMs methodology to the GD3 NARMs methodology. Note the MTBF Cap at 1 from an 'Effective age' of 55



7 Consequence of Failure

64 When assessing the credible failure modes for targeted sites within this paper, there are several categories of consequences to consider. These failure modes will impact one or more of the following consequences:

- Loss of supply to customers
- Safety impact of failure
- Environmental impact

65 The below matrix plots the credible failure modes against the severity of the consequences.

Table 6: Potential failure consequences against different failure modes

	Failure Consequence		
Failure Mode	**Loss of Supply to Customers**	**Safety Impact**	**Environmental Impact**
Malfunction of Pressure Control Equipment	If malfunction causes the outlet pressure to deviate unacceptably out of tolerance, there would be a high risk of site failure and the loss of supply to customers. In combination the 18 sites feed more than three million customers.	Safety Impact if pressure control equipment malfunction results in over-pressurisation of the outlet network. This could result in injury to the public from network failure.	Carbon emissions proportionate to the volume of the escape in an over pressurisation scenario.
Failure of the outlet pipework due to failure of pre-heating	Failure of the outlet pipework represents a high risk of the loss of supply to customers. Whether failure occurs is dependent on the severity of the escape.	Safety Impact from the gas escape caused by the failure of the outlet network.	Carbon emissions proportionate to the volume of the escape caused by failure of the outlet network.
Failure of boiler due to delayed ignition	Moderate risk of the loss of supply of customers from the knock-on effects of losing pre-heating.	Risk to SGN personnel from malfunctioning or failed boiler. Potential of the escape of gas or Carbon Monoxide Poisoning.	Minor Impact, Carbon emissions proportionate to the volume of the escape from failed Boiler.

Loss of supply to customers

66 Even if a loss of supply is due to a failure mode that can be easily remedied and SGN invokes a customer self-isolation & restoration, thousands of customers, dependent upon the specific site, will be without a gas supply for days. This outage will have significant financial and operational repercussions.

67 The period of a loss of supply is greatly variable dependent on the failure mode that occurs. The malfunction of pressure control may take less than a day to resolve, while a major escape on the outlet system may take several days.

68 The immediate impact of losing supply from these sites is that thousands of customers will be left without gas for their heating, cooking, and other needs. This loss of service can cause considerable inconvenience and potential health and safety issues, particularly if it occurs during cold weather.

69 Beyond the financial penalties, SGN must also consider the broader implications of customer dissatisfaction and potential damage to its reputation. Therefore, ensuring a continuous and reliable gas supply is crucial to avoid these significant penalties and maintain customer trust.

70 For a loss of supply scenario, example incident durations and failure to supply gas payments are shown for the smallest site in Table 7. These costs do not account for the incident response and failure remediation. However, it puts into perspective the potential financial impact when security of supply is compromised. The smallest site is being used as an example of the minimum impact from a failure to supply. The impact for larger sites will depend on the resilience of the downstream network but could potentially result in the failure to supply orders of magnitude additional customers.

Table 7: Examples of penalties associated with supply cessation.

	Customers	Incident Duration (SGN Isolation and Restoration)	Associated failure to supply gas payments	Incident Duration (Customer Isolation and Restoration)	Associated failure to supply gas payments
Smallest site	6,400	3 days	£1,344,000	2 days	£896,000

Safety impact of failure

71 Pipe failure or fracture from a loss of pre-heating presents serious safety risks. The primary concern includes the potential for loss of containment of natural gas. If it escapes due to damaged infrastructure, it can form an explosive mixture with air and have safety implications on anyone in proximity. The primary safety risks include:

a. Fire hazards: even a small spark can ignite the escaping gas, leading to fires which risk burning personnel or members of public.

b. Explosions: in confined spaces or areas with poor ventilation, gas can accumulate and cause explosions if ignited or released. This presents a risk of injury to people or damage to property from dangerous release of energy.

c. Health risks: inhaling high concentrations of natural gas can cause health issues, including dizziness, nausea and even asphyxiation from natural gas depleting the oxygen in the environment.

72 SGN has obligations to protect members of the public from the risk of harm caused by failure of infrastructure. There is a risk of an escape of gas as caused by the previously discussed control issues that could occur on site. The potential for severe harm will vary significantly dependent on the pressure, volume, and location of the escape.

Environmental impact

73 From an environmental perspective, the key concerns are related to methane emissions. Natural gas primarily contains methane, a potent greenhouse gas. Any loss of containment can have several environmental impacts:

a. Climate Change: methane has a much higher global warming potential than carbon dioxide (28 times higher), making its release particularly concerning for climate change.

b. Air Quality: leaking natural gas can contribute to air pollution, impacting both local air quality and contributing to broader atmospheric changes.

c. Soil and water contamination: escaping gas can seep into the soil and water, contaminating local ecosystems and harming wildlife.

d. Vegetation damage: gas leaks can damage plant life, disrupting local flora and potentially leading to longer term ecological imbalances.

74 The cost of carbon has been included within the monetised risk modelling within the accompanying CBA.

8 Options Considered

75 Our Monetised Risk model has only just been aligned with the new long term risk view and as such is not included within this EJP. For more information on the monetised risk delivered through our interventions please see the CBA benefits and NARM BPDT's.

76 We have spent time to cost up options where we feel there will be value added to the decision making process. Where options are less likely to be pursued we have chosen to present higher level costs, without the breakdown, based on some broadly similar assumptions which allows a comparison within the CBA.

8.1 Preferred Option

The technical detail of the option i.e. capacity, system rating, availability etc.

77 This is the preferred option to carry out the Preheating Replacement Programme proposed in this paper on 18 sites at a cost of £22.07m within RIIO-GD/3.

a. 4 of the sites require the replacement of Water Bath Heater Systems with Boiler and Heat Exchanger based systems. The 4 sites selected are the only Pre-Heating Units in SGN large enough to fall under the Medium Combustion Plant Directive.

b. 10 of the sites require the replacement of Boilers due to the high failure rate of the Aluminium Heat Exchangers in use. The 10 sites selected are the higher duty pre-heating systems which would have the most severe consequence if failure were to occur.

c. 3 of the sites require the replacement of the existing Preheating Systems due to a lack of standby capacity which has been assessed as non-compliant with IGEM TD/13. The 3 sites selected have the least redundancy within the Preheating Fleet.

d. 1 of the sites requires its boilers replaced due to the risks associated with delayed ignition

78 Table 8 gives some technical detail for the pre-heating replacement programmes for the preferred option. This includes data on the customer numbers and heating capacity for the sites. This is to put some perspective on the size and criticality of the equipment requiring replacement.

Table 8: Technical Detail of Pre-Heating Replacement Programme for preferred option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Total Heating Capacity (kW)	Average Heating Capacity Per Site (kW)	Total Customer Numbers	Average Customer Numbers per Site
Replacement of WBHs with Boiler and Heat Exchanger Systems	4	9706	2427	308110	77028
Replacement of Al Hex Boilers with Stainless Steel Boilers	10	33719	3372	3745568	374557
Upgrade of sites that do not currently have standby capacity	3	146	49	24500	8167
Replacement of Boiler System with Delayed Ignition	1	695	695	74800	695

Note: The basis for the cost estimate/unit cost

Table 9: Preheating Replacement Programme Costs for Preferred Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Total Contingency		Total Cost including Contingency	Delivery Price Control
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]
[redacted]				[redacted]	
		[redacted]		**£22,060,775.00**	

79 The costs for these replacement works have been estimated by the Major Projects department using high-level scopes to determine Desktop Costs. £52,212 has been spent in RIIO-GD/2 on feasibility costs to support the production of these estimates.

80 Similar pre-heating upgrade projects have been delivered within previous price controls. The costs have been produced with a combination of known costs from previously delivering similar projects in addition to investigating market rates.

The perceived benefits of the option

a. Identified as the option with the highest Net Present Value following an assessment of the Cost Benefit Analysis

b. Goes beyond a minimum level of compliance, also minimising risk and ongoing maintenance expenditure for the sites.

c. Improves the thermal efficiency of the usage of Own Use Gas in the Pre-heating Fleet

d. Removes the requirement for compliance with the Medium Combustion Plant Directive

e. Reduces the safety risk from the context of boiler reliability and the subsequent effect on the Network from the risk of Cold Temperatures.

f. Improves the Security of Supply to the Networks for the same reason

Delivery timescales

Table 10: Delivery year for the projects within the Preheating Replacement Programme for the Preferred Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume 26/27	Volume 27/28	Volume 28/29	Volume 29/30	Volume 30/31
Replacement of WBHs with Boiler and Heat Exchanger Systems	0	0	2	2	0
Replacement of Al Hex Boilers with Stainless Steel Boilers	0	2	4	4	0
Upgrade of sites that do not currently have standby capacity	0	1	1	0	1
Replacement of Boiler System with Delayed Ignition	0	1	0	0	0

81 Table 10 shows the planned delivery volume for the Preheating Replacement Programme within RIIO-GD/3.

Key assumptions made

82 It has been assumed for the boiler replacement projects that both the flow/return pipework and the existing boiler houses will be repurposed.

83 It has been assumed that where Pre-Heating Units are being replaced that it will be possible to do this without extensive pipework modification.

84 It has been assumed it will be possible to procure the necessary materials from the marketplace, in addition to competent resource for design and construction.

Any other items that differentiate the option from the others considered.

85 This is the only preferred option

86 This is the option that minimises maintenance costs with a proportionate capital delivery programme in RIIO-GD/3

8.2 Do More

The technical detail of the option i.e. capacity, system rating, availability etc.

87 The 'Do More' option retains the delivery package within the 'Preferred Option' but also includes additional workload with similar drivers.

88 An additional 4 Water Bath Heater replacement projects have been included with the similar drivers to the Preferred Interventions. The meaningful difference with these 4 is that they are not large enough units to require MCPD compliance. Their replacement would however improve the efficiency of the Pre-Heater Fleet by reducing the use of Own Use Gas.

89 An additional 4 Boiler replacement projects have been included with the same drivers to the Preferred Interventions. These Boiler Packages have a lower overall duty but still utilise Aluminium Heat Exchangers so suffer from the same shortcomings. The consequence of failure for these systems would however be lower as the extent of cold temperatures would not be as severe.

90 An additional 10 Pre-Heating Projects have been included within the Southern Network package of works for the 'Do More' option. These sites (Boiler and Heat Exchangers) do not have the fundamental lack of standby issues but do use extensive obsolete components that can be difficult to source following failure. The package also includes the replacement of sites where 'open-systems' are utilised rather than closed -systems. Closed systems are generally more efficient and less susceptible to internal corrosion due to lower oxygen ingress.

The basis for the cost estimate/unit cost

Table 11: Preheating Replacement Programme Costs for 'Do More' Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Total Contingency	Total Cost including Contingency	Delivery Price Control
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			[redacted]	
		[redacted]	**£37,415,110.00**	

91 Table 11 gives a breakdown of the Preheating Replacement Programme for the 'Do More' Option. The costs have been derived in the same method for the 'Preferred Interventions'. The costings for the additional interventions have been estimated from similar projects.

The perceived benefits of the option

a. Goes far beyond a minimum level of compliance, also minimising risk and ongoing maintenance expenditure for the sites.

b. Greatly improves the thermal efficiency of the usage of Own Use Gas in the Pre-heating Fleet

c. Removes the requirement for compliance with the Medium Combustion Plant Directive

d. Reduces the safety risk from the context of boiler reliability and the subsequent effect on the Network from the risk of Cold Temperatures at a large volume of sites.

e. Improves the Security of Supply to the Networks for the same reason

Delivery timescales

Table 12: Delivery Phasing for the Preferred Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume 26/27	Volume 27/28	Volume 28/29	Volume 29/30	Volume 30/31
Replacement of WBHs with Boiler and Heat Exchanger Systems	0	0	4	4	0
Replacement of Al Hex Boilers with Stainless Steel Boilers	0	4	5	5	0
Upgrade of sites that do not currently have standby capacity	0	1	1	0	1
Replacement of Boiler System with Delayed Ignition	0	1	0	0	0

Key assumptions made

92 It has been assumed for the boiler replacement projects that both the flow/return pipework and the existing boiler houses will be repurposed.

93 It has been assumed that where Pre-Heating Units are being replaced that it will be possible to do this without extensive pipework modification.

94 It has been assumed it will be possible to procure the necessary materials from the marketplace, in addition to competent resource for design and construction. The 'Do More' Option will also require sufficient resource within SGN to manage the project. This will be more challenging when compared to the 'Do More' Option.

Any other items that differentiate the option from the others considered.

95 This is the option for the largest programme of interventions in RIIO-GD/3.

96 This is the option with the highest risk reduction in RIIO-GD/3

97 This is the option which will be the most challenging to deliver in RIIO-GD/3

8.3 Do Minimum & Defer to GD4

The technical detail of the option i.e. capacity, system rating, availability etc.

98 The "Do Minimum & Defer to GD4" Option involves the deferral of most of the pre-heating replacement programme to RIIO-GD/4.

99 Deferring most of the pre-heat replacement projects to RIIO-GD/4 will still result in necessary costs being incurred in RIIO-GD/3. These include costs required to ensure the sites remain compliant and functional.

100 The "Do Minimum & Defer to GD4" option still requires 3 sites to undergo upgrades of their pre-heating systems in GD/3. They do not currently have an adequate level of standby provision to cope with a heater failure without the unacceptable risks associated with sub-zero gas occurring. The upgrades on these sites are therefore considered a part of the baseline for IGEM/TD/13 compliance.

101 The decision not to replace the sites with Aluminium Heat Exchanger Boilers will result in further failures in RIIO-GD/3. Spares, where available will need purchased for these sites. In addition, costs will be incurred undertaking the reactive replacements following any boiler failures.

102 Retaining the Water Bath Heaters that will be affected by the Medium Combustion Plant Directive will result in additional requirements for those sites. These include registering the sites for permits before 30th June 2028. There will also be ongoing emission monitoring and limits which will need adhered to for regulatory compliance. The operating expenditure with MCPD has been modelled in the accompanying CBA.

103 There will be a general increase of risk of extended downtime of Pre-heating for sites with a lack of standby or issues with obsolescence during RIIO-GD/3. The risks associated with the site with delayed ignition will also remain present.

104 The technical details for the remaining projects to be delivered in GD/4 are identical to the details described in the 'Preferred Option'. The only difference is the phasing.

The basis for the cost estimate/unit cost

Table 13: Capex within RIIO-GD/3 for the 'Do Minimum & Defer to GD4' Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Total Contingency	Total Cost including Contingency	Delivery Price Control
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			[redacted]	[redacted]
[redacted]			[redacted]	[redacted]
[redacted]			[redacted]	
		[redacted]	**£8,415,075.00**	

Table 14: Major Projects within RIIO-GD/4 for the 'Do Minimum & Defer to GD4' Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Total Contingency	Total Cost including Contingency	Delivery Price Control
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			[redacted]	[redacted]
		[redacted]	**£13,928,700.00**	

105 In addition to the costs for the major projects as detailed in Table 14 above, there are additional costs (Table 13) incurred because of not carrying out the other projects within the 'Preferred Option' within RIIO-GD/3.

106 The costs for Boiler Heat Exchanger Remediation are based on known previously quoted prices for pressure washing heat exchangers. This remediation is a lower cost measure than replacement which can be used to

temporarily restore operability following partial corrosion. It can clean heat exchangers so that the back pressure being produced during combustion is compliant. The continued degradation of the heat exchangers will eventually necessitate replacement. It has been assumed that every Aluminium Heat Exchanger within the boilers will need remediated once over the next 10 years.

107 The costs for replacing Aluminium Heat Exchangers are based on quotes for replacement units and the associated costs of installation. When the degradation of the Heat Exchangers has reached a certain stage, it is no longer possible to remediate through pressure washing. It has been assumed that every Aluminium Heat Exchanger within the boilers will need replaced once over the next 10 years.

108 Retaining the Water Bath Heaters will require permits to be obtained for all 4 sites under the Medium Combustion Plant Directive. Based on previous experience obtaining perimetry from SEPA requires expert support to correctly apply for the license. The accompanying CBA includes the operation expenditure for obtaining the supporting work to apply for the site permits in addition to the application fees to SEPA.

109 In addition to obtaining the permits, it will be necessary to monitor the sites every 3 years for emissions. The costs for emission monitoring have been based on previous quotations for carrying out this monitoring. Additional costs have been included for servicing and cleaning at the time of testing.

110 Table 14 gives a breakdown of the remainder of the Preheating Replacement Programme which are to be delivered in RIIO-GD/4. The costs have been derived in the same method for the 'Preferred Interventions'. The costings for the additional interventions have been estimated from similar projects.

The perceived benefits of the option

a. Reduces the upfront capital costs by deferring most of the projects into RIIO-GD/4.

b. The minimum level of compliance is still achieved by delivery the projects required to meet TD/13 standby requirements

Delivery timescales

Table 15: Delivery year for the projects within the Preheating Replacement Programme for the "Do Less" Intervention

RIIO-GD3 Capex "Do Less" Intervention	Volume 26/27	Volume 27/28	Volume 28/29	Volume 29/30	Volume 30/31	RIIO-GD/4
Replacement of WBHs with Boiler and Heat Exchanger Systems	0	0	0	0	0	4
Replacement of Al Hex Boilers with Stainless Steel Boilers	0	0	0	0	0	10
Upgrade of sites that do not currently have standby capacity	0	1	1	0	1	0
Replacement of Boiler System with Delayed Ignition	0	0	0	0	0	1

Key assumptions made

111 Assuming that the costs will be allowed and that SGN will have the capacity to deliver these projects in RIIO-GD/4.

Any other items that differentiate the option from the others considered.

112 This is the only option which sets out a programme of interventions for RIIO-GD/4. It therefore has a high degree of uncertainty as it sets out a capital delivery programme with little progress made in RIIO-GD/3. The associated benefit will therefore also be deferred.

8.4 Do Less (Do Minimum)

The technical detail of the option i.e. capacity, system rating, availability etc.

113 The "Do Less" Option is to only carry out the minimum required works in RIIO-GD/3 with no follow up capital investment programme for the pre-heating in RIIO-GD/4.

114 The technical details for "Do Less" are identical to the technical details for the GD/3 works in the "Do Minimum & Defer to GD4" Option.

The basis for the cost estimate/unit cost

Table 16: Intervention Costs within RIIO-GD/3 Associated with the Do Less Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	Total Contingency	Total Cost including Contingency	Delivery Price Control
Upgrade of sites that do not currently have standby capacity	3	£375,405.00	£3,282,075.00	RIIO-GD/3
Ongoing remediation and replacement of Aluminium Heat Exchangers in Scotland Network			£213,000.00	RIIO-GD/3
Ongoing remediation of Boilers Southern Network			£70,000.00	RIIO-GD/3
Total Overheads for 'Do Less' Option			£4,850,000.00	
		£375,405.00	**£8,415,075.00**	

115 The basis for the capital cost estimates is identical to the GD/3 works in the "Do Minimum & Defer to GD4" Option.

The perceived benefits of the option

a. This option will have a lower upfront cost associated with capital investment.

b. Lower Major Projects delivery workload

c. The expenditure required to achieve a minimum level of compliance has been included

Delivery timescales

116 MCPD Permitry requires registered by 30th June 2028 with the associated monitoring required at least every 3 years following.

117 The Boiler Aluminium Heat Exchanger Remediation and Repairs will be as required based on when failure occurs

118 Table 17 shows the delivery timescales for the interventions that remain within the Baseline option in RIIO-GD/3.

Table 17: Delivery Timescales within RIIO-GD/3 for the 'Do Less' Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume 26/27	Volume 27/28	Volume 28/29	Volume 29/30	Volume 30/31
Upgrade of sites that do not currently have standby capacity	0	1	1	0	1
Registration of Water Bath Heater Sites required as associated with the MCPD	0	0	4	0	0

Key assumptions made

a. Aluminium Heat Exchanger Failure Rate estimated based on the current failure rate of the units

b. MCPD costs based on similar work as no units have been previously registered

c. Major Project costs have been derived in the same way as for the preferred option.

Any other items that differentiate the option from the others considered.

119 This is the option that has the lowest upfront capital investment

120 This is the only option that requires consideration of the Medium Combustion Plant Directive Requirements

121 This is the option with the highest overall maintenance costs into the future

8.5 Do Nothing

The technical detail of the option i.e. capacity, system rating, availability etc.

122 This is the option to undertake no proactive or reactive interventions in relation to the Preheating Systems relevant to this EJP. This includes no replacement programme, nor reactive repairs or replacements to failures. It also doesn't include any actions taken to comply with the Medium Combustion Plant Directive. The decision to 'Do Nothing' would result in near certain network failure in addition to regulatory non-compliance with Environmental legislation.

The basis for the cost estimate/unit cost

123 Since this is the 'Do Nothing' option, the associated intervention cost is 'Nil'

The perceived benefits of the option

124 The only perceived benefit for the 'Do Nothing' Option is that the initial Capital Investment is nil.

Delivery timescales

125 Not applicable for the 'Do Nothing' Option

Key assumptions made

126 It is assumed that while routine maintenance would be conducted, no additional investment would be made to address the issues described within this EJP.

Any other items that differentiate the option from the others considered.

127 This option is wholly unacceptable and has only been included for the purposes of comparison.

8.6 Options Technical Summary Table

Table 18: Options Technical Summary Table for the Pre-heating Replacement Programme

	Preferred	Do More	Do Minimum + Defer remainder of preferred option to GD4	Do Less	Do Nothing
First year of spend	FY 26/27	FY 26/27	FY 26/27	FY 26/27	n/a
Final year of spend	FY 29/30	FY 30/31	FY 35/36	Ongoing	n/a
Volume of Interventions (within RIIO-GD/3)	18	36	3	3	None
Design Life (within RIIO-GD/3)	40 Years	40 Years	40 Years for sites with interventions, 10 years for sites without	10 Years	< 1 Year
Benefits	High Levels of Risk Reduction with realistic Capital Costs and Delivery	The greatest risk reduction within RIIO-GD/3	Defers much of the Capital Intervention Cost	Low Capital Intervention Cost	Lowest Capital Intervention Cost
Risks	Some deliverability risk from market conditions	The greatest Capital Intervention Cost with High Deliverability Challenges	Greater Failure Rate in RIIO-GD/3 and greater workload in RIIO-GD/4	Greater Failure Rate in RIIO-GD/3 with no plan for mitigation in RIIO-GD/4	Very High Failure Rate in RIIO-GD/3 with no mitigation of the consequences
Total Cost (RIIO-GD/3 cost only)	£22.07m	£37.4m	£8.4m (plus £13.9m in RIIO GD/4)	£8.4m	Nil

8.7 Options Cost Summary Table

Table 19: Pre-Heating Replacement Programme, Cost Summary Table, Intervention Capital Costs RIIO GD/3

	Preferred	Do More	Do Minimum + Defer remainder of preferred option to GD4	Do Less	Do Nothing
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]		[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
Total Cost (RIIO-GD/3 cost only)	£22.07m	£37.4m	£8.4m (plus £13.9m in RIIO GD/4)	£8.4m	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	

128 Table 19 gives a cost comparison of the four options presented in this EJP for the Pre-Heating Replacement Programme.

9 Business Case Outline and Discussion

9.1 Key Business Case Drivers Description

129 Our objective of this business case is to build an asset intervention plan which best reflects customer and stakeholder expectations and meets the required outcomes of the proposed investment. This has been achieved through development of a methodology which links investment drivers and asset health and performance to customer impacts, using CBA models to evaluate the options described in this EJP.

130 The primary requirement of this investment is to meet safety legislation and ensure adherence with our Gas Transporters Licence. The CBA developed has been utilised to explore economic and environmental value of this investment.

131 Our drivers for this investment are to ensure our pressure reduction and preheating assets continue to operate reliably and safely to maintain the following:

- Operational and personnel safety.
- Security of gas supply to customers.
- Environmental commitments to reduce methane emissions.
- Value for money – efficiently intervening in our assets to maximise pass through benefit to our customers.

9.2 CBA Outputs

132 Outputs from the CBAs for the options considered in this EJP are shown in table 20 to 23 below.

Table 20: CBA Output Summary (Southern Network)

Option Name	Included in this CBA? (Y/N)	Preferred Option (Y/N)	NPV (2043 PV, £m)	Company view
Do Minimum	Y	N	N/A	This option is not preferred. While the minimum level of intervention will be carried out to comply and it requires a lower capital investment in the short term, customers will be exposed to a greater risk of network failure and more environmental emissions.
Preferred option	Y	Y	48.92	SGN's view is that this is the optimal option. This option targets interventions to improve the integrity and efficiency of the fleet of pre-heating systems in Scotland Network. This will be beneficial to the customers and the assets from both increased reliability and lower environmental emissions.
Do Minimum + Defer remainder of Preferred Option to GD4	Y	N	30.34	This option is not preferred. While the minimum level of intervention will be carried out to comply and it requires a lower capital investment in the short term, customers will be exposed to a greater risk of network failure and more environmental emissions. Greater intervention will likely be required in GD4 to respond to further asset deterioration.

Do more	Y	N	42.35	This option requires greater investment but would also deliver the greatest risk reduction. However, this option would be more challenging to resource and may not be deliverable with the current resources available.
Do nothing	N	N	N/A	SGN's view is that this option is not viable. It would likely result in network failure and regulatory non-compliance. This would not provide customer or asset benefit, but would instead expose both to significant risk of supply loss. This option has not been included in the CBA as it is a non-compliant option and is therefore not possible to justify.

Table 21: CBA Output – Sensitivity Analysis (Southern Network)

NPV (2043 PV, £m)	Low CO2 Cost	Central CO2 Cost	High CO2 Cost
Capex - Low	49.92	49.93	49.93
Capex - Central	48.91	48.92	48.93
Capex - High	47.90	47.91	47.92

Table 22: CBA Output Summary (Scotland Network)

Option Name	Included in this CBA? (Y/N)	Preferred Option (Y/N)	NPV (2043 PV, £m)	Company view
Do Minimum	Y	N	N/A	SGN's view is that while the minimum level of intervention will be carried out, it exposes the network to a greater risk of failure in addition to the requirement to comply with the MCPD. While this requires a lower capital investment in the short term, customers will be exposed to a greater risk of network failure and more environmental emissions.
Preferred Option	Y	Y	16.81	SGN's view is that this is the optimal option and targets interventions to improve the integrity and efficiency of the fleet of pre-heating systems in Scotland Network. This will be beneficial to the customers and the assets from both increased reliability and lower environmental emissions.
Do Minimum + Defer remainder of Preferred Option to GD4	Y	N	12.09	SGN's view is that while the proposed interventions will eventually be carried out in GD4, it increases the network risk within GD3. In addition, it decreases the company's

				capacity to deliver other interventions in GD4. This only defers capital investment, and customers will be exposed to a greater risk of network failure and more environmental emissions.
Do More	Y	N	23.43	The Company's view is that while this option would result in a greater level of risk reduction, it would also require greater Capital Investment and would be more challenging to resource. The customers would be required to fund more works which are not as targeted as the preferred option.
Do Nothing	N	N	N/A	SGN's view is that this option is not viable. It would likely result in network failure and regulatory non-compliance. This would not provide customer or asset benefit but would instead expose both to significant risk of supply loss. This option has not been included in the CBA as it is a non-compliant option and is therefore not possible to justify.

Table 23: CBA Output – Sensitivity Analysis (Scotland Network)

NPV (2043 PV, £m)	Low CO2 Cost	Central CO2 Cost	High CO2 Cost
Capex - Low	18.19	19.01	19.83
Capex - Central	16.00	16.81	17.63
Capex - High	13.80	14.61	15.43

9.3 Business Case Summary

133 Table 24 below summarises the options and compares them against the impact on risk reduction as associated with Safety, Security of Supply and Environmental Impacts.

Table 20: Business Case Summary for the Preheating Replacement Programme

Option Description	Safety	Security of Supply (Reliability)	Environmental
Preferred Option	Mitigates a High Level of Safety and Security of Supply Risk as associated with the risk of failure from Pre-Heating Systems.		Reduces Carbon Emissions through the reduced risk of network failure in addition to lower use of OUG on Water Bath Heater Sites.
Do More	Mitigates the Highest Level of Safety and Security of Supply Risk from an extensive Pre-Heating Replacement Programme		Further reduction of Carbon Emissions, particularly through increased WBH Replacement Workload
Do Minimum + Defer remainder of preferred option to GD4	Only partial reduction of Safety and Security of Supply Risk from delivery of replacement of Systems which do not have Standby Provision, with remaining reduction deferred to GD/4.		Does not meaningfully mitigate Carbon Emissions in RIIO-GD/3 but will in RIIO-GD/4.
Do Less	Only partial reduction of the Safety and Security of Supply and Risk from delivery of replacement of Systems which do not have Standby Provision		Does not meaningfully mitigate Carbon Emissions in RIIO-GD/3 or RIIO-GD/4.
Do Nothing	No reduction in risk, instead an unacceptable increase of risk from undertaking no proactive or reactive works		No mitigation to carbon emissions in addition to a failure to comply with Environmental Regulations (MCPD)

10 Preferred Option Scope and Project Plan

10.1 Preferred Option

134 The preferred option is to carry out the Preheating Replacement Programme on 18 sites in RIIO-GD/3 at a total Capital Investment Value of £22.07m.

10.2 Asset Health Spend Profile

135 Table 25 below gives the cost phasing for the preferred option in £m.

Table 25: Cost Phasing for the Preferred Option in RIIO GD/3

RIIO-GD3 Capex "Preferred Option" Intervention	Volume	26/27	27/28	28/29	29/30	30/31
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total (£m)	18	2.73	8.07	7.79	2.45	1.02

10.3 Investment Risk Discussion

136 Table 26 gives a breakdown of the top 3 Investment Risks associated with the Preferred Option. These Risks and the necessary mitigations have been considered within the costings. The remainder of the risks are detailed in 'Appendix D Expanded Risk Register'.

Table 26 21: Investment Risks for the Preheating Replacement Programme

Risk Description	Impact	Likelihood	Mitigation/Controls	Comments
Lack of Availability of Main Works Contractors	Negative Impact on Timing and Expenditure	20% - 40%	Procurement Strategy to group similar Projects to improve offering and reduce costs. Competitive Tender to the available market.	
Availability of Materials, Market Volatility	Negative Impact on Timing and Expenditure	20% - 40%	Prompt procurement of materials to account for lead times and risk. Competitive Tender to the available market.	Can be impacted by international events

Difficulty obtaining Discharge Consents for Condensate from Boiler houses	Negative Impact on Timing and Expenditure	40% - 60%	Resource to support obtaining environmental perimetry	

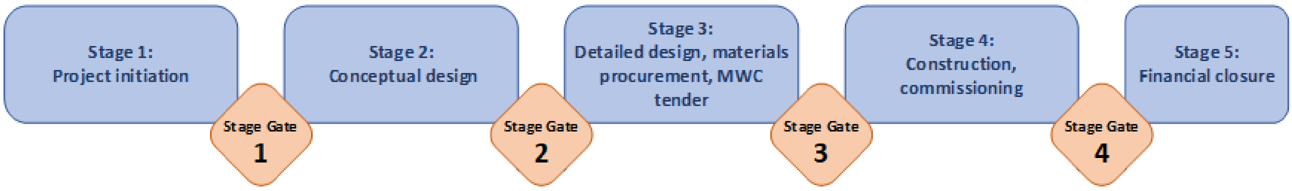
10.4 Project Plan

137 We have indicated below our process for managing this project through appropriate project management stage gates. However, we haven't currently detailed this for our submission as it is still being produced. We have, however, produced an indicative phasing of the works based on our assessment of resource availability.

138 Our project governance that is applied to High Value Capital Transmission Investments is the 'Stage Gate Process'. This is a process where projects are only given approval to proceed to a certain 'gate' so that there is a regular review of the project's progress, expenditure and planned scope. This has been implemented for projects in RIIO-GD/2 and has been valuable in ensuring that projects remain on track from cradle to grave.

139 Figure 12 shows a summary of the stage gate process. This will process will be utilised for the Preheating Replacement Programme in RIIO-GD/3. The projects within the Preheating Replacement Programme will generally require 12 months lead time for materials procurement ahead of commencing construction. The length of time between Project Initiation to Financial Closure for these projects will generally be 24-36 months.

Figure 12: Summary of the Stage Gate Process



140 Table 27 gives the planned commissioning years and volumes as a part of the Preferred Option for the Preheating Replacement Programme.

Table 22: Delivery Phasing for the Preferred Option

RIIO-GD3 Capex "Preferred Option" Intervention	Volume 26/27	Volume 27/28	Volume 28/29	Volume 29/30	Volume 30/31
Replacement of WBHs with Boiler and Heat Exchanger Systems	0	0	2	2	0
Replacement of Al Hex Boilers with Stainless Steel Boilers	0	2	4	4	0
Upgrade of sites that do not currently have standby capacity	0	1	1	0	1
Replacement of Boiler System with Delayed Ignition	0	1	0	0	0

10.5 Key Business Risks and Opportunities

141 There is no risk of a demand scenario that will change the requirement for these interventions. The drivers are principally driven by integrity issues. Provided the infrastructure is required, the need for these interventions will remain. Other business risks are detailed in 'Appendix D Expanded Risk Register'.

10.6 Outputs included in RIIO-GD2 Plans

142 None of the proposed interventions within the Preheating Replacement Programme were Outputs included within the RIIO-GD/2

Appendix A – Acronyms

Acronym	Meaning	Description
CBA	Cost Benefit Analysis	The assessment undertaken to compare the cost benefits of the different intervention options
E&I	Electrical and Instrumentation	The discipline associated with electrical installations and on-site instruments
LTS	Local Transmission System	The >7barg Network operated by the Gas Distribution Networks
MCPD	Medium Combustion Plant Directive	European legislation which regulates combustion systems which has been adopted within UK law
OUG	Own Use Gas	Gas consumed by the Gas Distribution Networks for their own use (e.g. pre-heating)
PRS	Pressure Reduction Station	An Above Ground Installation Where High-Pressure Gas is reduced to a lower pressure
SEPA	Scottish Environment Protection Agency	The Environmental Regulator within Scotland
WBH	Water Bath Heaters	Pre-Heating Systems utilised on older sites

Appendix B – References

Pressure System Safety Regulations (PSSR) (2000).

The Medium Combustion Plant Directive.

IGEM/TD/13-E3 – Pressure Regulating Installations for Natural Gas, Liquefied Petroleum Gas and Liquefied Petroleum Gas/Air (2023)

SGN/WI/PLANT/1 –Work Instruction for the Delivery of Plant Projects

Appendix C – Equipment Summary

Table 23: Boilers within this Pre-heating Replacement Programme including manufacturer and Heat Exchanger Material

Boiler Models/ Heat Exchanger Material	Quantity of Boilers
Aluminium	**82**
EC Two 500X	24
Potterton - EC Plus 200	8
Potterton - EC Plus 250	14
Potterton - Eurocondense Two 250	8
Potterton - Eurocondense Two 500	4
Sirius FS 525	24
Cast Iron	**4**
Derwent 3a Prestige	4
Grand Total	**86**

Table 24: Global Equipment Summary for all Boilers across both Scotland and Southern Network

Boiler Manufacturers and Models	Quantity of Boilers
BAXI	**9**
100HE	6
Solo 30HE	3
Brotje Heizung	**8**
EctoTherm Plus WGB 15 C	4
EctoTherm Plus WGB 20 C	4
Buderus	**2**
GE224 L	2
Chappee	**1**
XG 16.00 CS	1
Ideal	**15**
Concord CXA40H	3
Concord CXA50H	7
Ideal Vogue S18 GEN2	3
Vogue S15	2
MHS Boilers	**3**
MHS Boilers - Regency Slimline SG200/80	3
Mikrofill	**112**
Ethos 110	31
Ethos 130	51
Ethos 50	3
Ethos 70	10
Ethos 90	13
Ethos RS 550	4
Potterton	**468**
Derwent Compact 4/50	3
Derwent 20/315	3
Derwent 3a Prestige	4
Derwent Compact 4/50	3

Derwent Compact 5/66	3
Derwent Compact 8/116	4
Derwent Compact Plus5	1
Derwent Premier 9	3
EC Plus 200	8
EC Plus 250	14
EC Two 500X	45
Eurocondense EC3 300kW	5
Eurocondense Two 250	13
Eurocondense Two 500	15
Paramount 40	4
Paramount 60	15
Paramount 80	13
Paramount Two 115	3
Paramount Two 30	11
Paramount Two 40	11
Paramount Two 60	27
Paramount Two 80	41
Paramount Two WGB15	2
Paramount Two WGB20	2
Sirius FS 525	48
Sirius Three WH70	2
Sirius Two FS 400	4
Sirius Two WH110	53
Sirius Two WH50	6
Sirius Two WH70	6
Sirius Two WH80	2
Sirius Two WH90	17
Sirius WH110	58
Sirius WH50	2
Sirius WH60	2
Sirius WH90	15
Seagold	**2**
1HE	2
Unknown	**1**
Unknown	1
Grand Total	**621**

Table 30: Global Equipment Summary, Pre-Heating System Types and Manufacturer

Preheating Type & Manufacturer	Quantity of Heat Transfer Units
ELEC (direct)	**37**
Eltron	22
EXHEAT Ltd	14
Thielmann	1
Heat Exchanger	**346**
Andre Engineering	9
Buckley & Taylor	8
EB	2

Heat Transfer Ltd	4
Himex Engineering	5
Holbrook Engineering	2
Holden & Brooke	11
Int. Combustion Ltd	29
Megga-Gaz	8
Motherwell Bridge Ltd	4
None	2
Paul & Loughren	202
R. Lord & Sons	7
Serck	4
Simmons & Hawker	2
Swinney	5
Thermo Engineers	5
Thew Engineering	3
Unknown	34
Proheat	**6**
ProHeat Systems Limited	6
Water Bath Heater	**135**
Forcom	2
Hygrotherm	4
Kenward Heaters	50
Lanemark	5
Natco - WBH	0
Robert Jenkins & Co	69
Unknown	5
Water Bath Heater (Electric)	**2**
Ireland Welding	2
Grand Total	**526**

Table 31: Global Equipment Summary of Pre-Heating System Types in Scotland and Southern Network

Preheating Type	Number of Sites
ELEC (direct)	25
Boilers and Heat Exchangers	174
None	53
Proheat	3
Water Bath Heater	68
Water Bath Heater (Electric)	2
Grand Total	**325**

Appendix D – Expanded Risk Register

Table 32: Expanded Risk Register

Risk Description	Impact	Likelihood	Mitigation/Controls	Comments
Lack of availability of Designers	Negative Impact on Timing and Expenditure	20% - 40%	Competitive Tender to the available market.	
Lack of Availability of Main Works Contractors	Negative Impact on Timing and Expenditure	20% - 40%	Procurement Strategy to group similar Projects to improve offering and reduce costs. Competitive Tender to the available market.	
Availability of Materials, Market Volatility	Negative Impact on Timing and Expenditure	20% - 40%	Prompt procurement of materials to account for lead times and risk. Competitive Tender to the available market.	Can be impacted by international events
Bats found in existing buildings following Bat Surveys	Negative Impact on Timing and Expenditure	< 20%	Undertake Bat Surveys early in programme. Replacement Boiler house could be required	
Difficulty obtaining Discharge Consents for Condensate from Boiler houses	Negative Impact on Timing and Expenditure	40% - 60%	Resource to support obtaining environmental perimetry	
Change of Legislation, Medium Combustion Plant Directive	Impact on drivers for the project	< 20%	Other drivers including reduction in Own Use Gas	Not considered a credible risk

Appendix E – NARMs modelled failures

Table 33: NARMs modelled PRS & Offtake asset failure rates (no. per asset per year)

Network	General Failure	High Outlet Pressure	Low Outlet Pressure	Release of Gas	High Outlet Temp	Low Outlet Temp
SC	1.14	0.00	0.00	1.28E-01	0.02	1.20
SO	1.06	0.00	0.00	1.41E-01	0.02	1.26

The modelled failure rates are forecast values for financial year 2026/27. These are forecast using the NARM methodology deterioration rates.