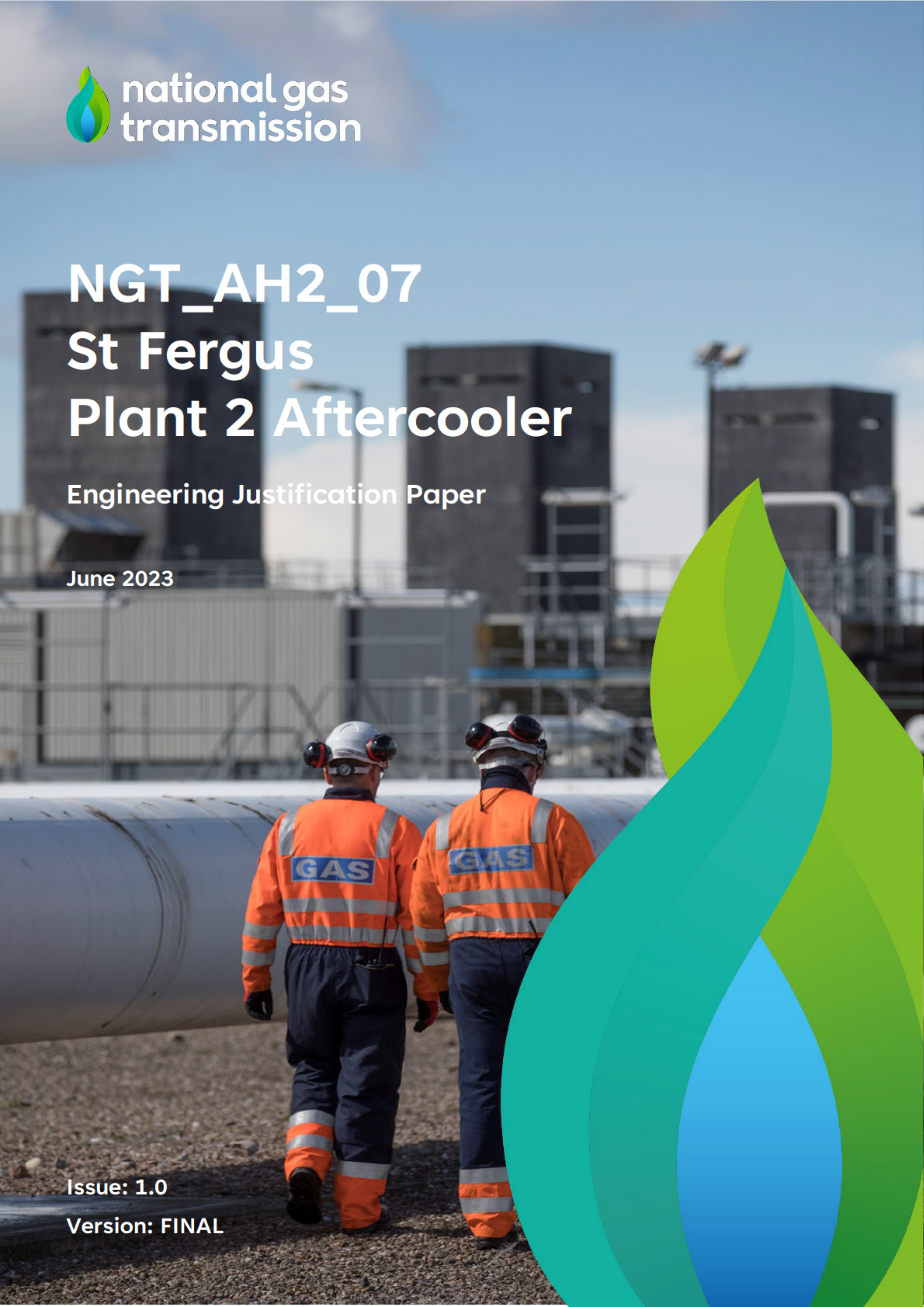
national gas transmission

NGT_AH2_07 St Fergus Plant 2 Aftercooler

Engineering Justification Paper

June 2023



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1. Executive Summary

1. National Gas Transmission (hereafter referred to as 'NGT'), are submitting this needs case in accordance with the RIIO-T2 Engineering Justification Paper Guidance v2 document. The purpose of this stage of the process is to justify the project need, set out the different options considered along with the preferred strategic options, and request funding for the preferred option justified within this paper. This Engineering Justification Paper (EJP) details the investment for Plant 2 Aftercooler at the St Fergus Gas Terminal.
2. This EJP details the investment for several works associated with the Plant 2 Aftercooler, an air-cooled aftercooler system at St Fergus Terminal. Specifically, replacement of condemned civil structures and all Aftercooler assets such as frames, Fin Tubes, motors and Fans. This paper also focusses on the need to upgrade the Aftercooler for it to handle contractual peak gas flows which is a current limitation. A project summary, included in Appendix A, provides key information on this project.
3. This is part of a suite of documents, shown in Figure 1, and should particularly be read in conjunction with the St Fergus Site Strategy and its appendices. The St Fergus Site Strategy describes the gas terminal's function, its criticality to the network and the proposed investments in line with the site strategy.

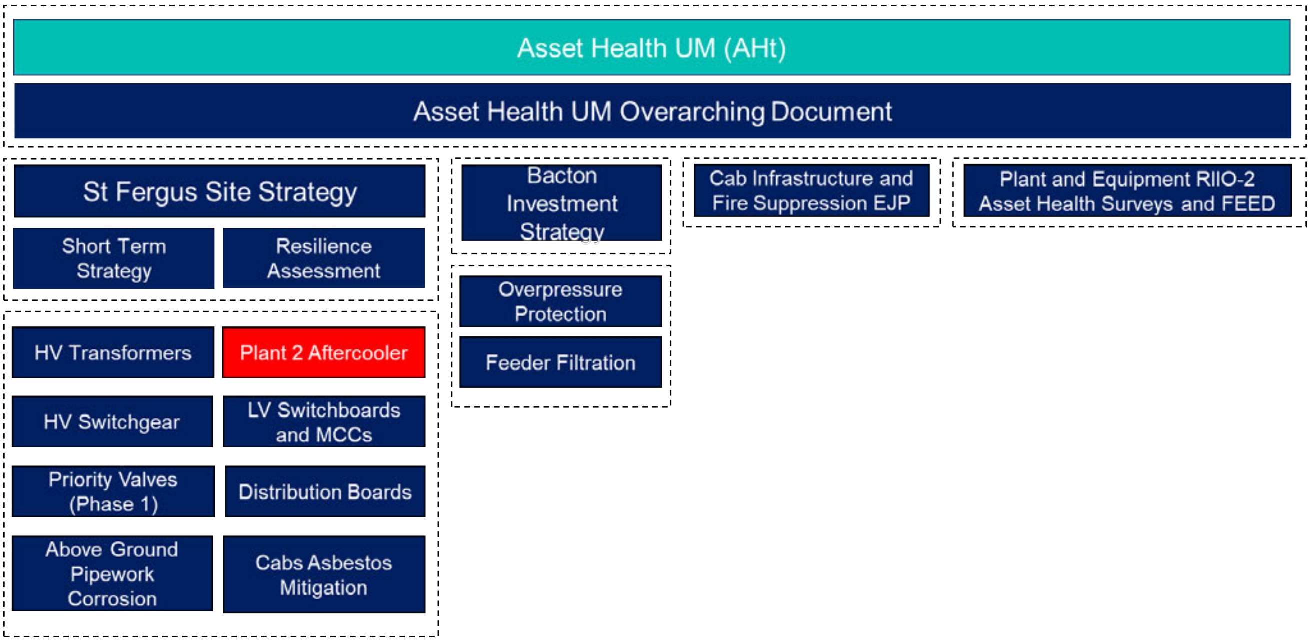

Figure 1: St Fergus Submission Documents Structure

4. The St Fergus Gas Terminal handles between 25% and 50% of the UK's gas supplies, dependent on supply and demand patterns. The site has been in continuous operation for over 45 years and is now moving beyond the design life of the critical original assets. The site is one of two upper tier COMAH sites on our network and as such is a major accident hazard site, subject to regular HSE and SEPA inspections and significant health, safety, and environmental legislation.
5. The St Fergus Short-Term Strategy confirms the requirement for investing in Plant 2 Aftercooler associated with compressor units required until 2030. This is because the assets in this scope

have been found to have asset health issues posing failure risks. Failure of these assets would result in the unavailability of essential compressor units and prolonged downtime depending on the nature of failure.

6. The current aftercooler assets at the site were installed at the time of terminal construction and have since this time been operated to provide the necessary gas cooling. In contrast, the Original Equipment Manufacture's (OEM) design life expectancy of these aftercoolers is 25 years. Gas cooling is required to prevent downstream asset integrity issues within the St Fergus buried pipework and our downstream feeder mains pipelines. Plant 2 and Plant 1 aftercoolers are used interchangeably, and they can both cool gas from any of the three compressor plants (Plants 1, 2 and 3).

7. The St Fergus Site Strategy provides certainty on the terminal's operation requirements, including minimum compression across Plant 1 and 2, for operation out to 2030. This baselines the aftercooling requirements at the site. As St Fergus is a 24/7/365 operation there is a need to ensure a good asset health level and redundancy in the aftercooling.

8. Plant 1 Aftercooler assets, which are not part of this justification paper, had numerous integrity defects and funding has already been requested via a January 2023 submission which is pending funding decision. The project for replacement of the Plant 1 Aftercooler has commenced in advance due to its urgency, as a result of discovering more significant integrity issues than anticipated. It is expected to be commissioned this year (2023). Meanwhile, the required gas cooling is solely provided by Plant 2 which is currently available. However, the Plant 2 aftercooler is exhibiting similar integrity defects as Plant 1. Section 4 highlights specific evidence of the dilapidated condition of Plant 2 aftercooler assets which are now posing operational risk. It is therefore prudent for the required interventions to be planned for proactively.

9. The scope of this investment includes all Plant 2 Aftercooler assets from their mechanical, electrical, instrumentation and supporting civil structures perspective. Surveys have been carried out utilising a range of inspection techniques such as Near Field Testing (NFT) and Internal Rotary Inspection System (IRIS). The surveys were undertaken by independent contractors, as guided by the detailed project scope document, prepared by NGT engineers. The most recent survey was undertaken by a contractor who has revealed several asset health defects which need attention as detailed in the final report in Appendix B.

10. Despite the already known asset health and safety issues is very important to note that Plant 1 Aftercooler has been out of service for more than 4 years now. It then follows that Plant 2 Aftercooler has been singly supporting gas cooling at St Fergus and could not be availed for further surveys which require it to be fully isolated. As a result, other surveys could only be limited to visual.

11. NGT is submitting this investment proposal in the June asset health submission window as funding is needed immediately to ensure safe and continued operation of the site in the short-term out to 2030.

12. The options considered for the Plant 2 Aftercooler are:

- Do nothing
- Replace like-for-like
- Replace with new design

13. The recommended option is to replace Plant 2 Aftercooler with a new design. The primary benefits of this investment are:

- Provision of individual bank isolation valves for maintenance.
- Restoring capacity to cool peak gas flows.
- Elimination of the current age-related defects.
- Capitalising on the best technologies in upgrading the old Aftercooler.

14. The indicative cost of this investment is [redacted] (18/19 price base). The estimated RIIO-T2 cost profile is shown in the Table 1. This project is at Stage 4.2 in the ND500 process: Option Selection. Therefore, the cost accuracy is estimated at +30/-15% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

Table 1 Current estimated RIIO-T2 spend profile

£m 18/19	FY2023	FY2024	FY2025	FY2026	Total	Comments
Plant 2 Aftercooler	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	

15. NGT are making this funding application for the Plant 2 Aftercooler replacement RIIO-T2 investment costs through the Asset Health Re-opener, in line with Special Condition 3.14, requesting an adjustment to the value of the NARMAHOt term for costs incurred in RIIO-T2.

16. This is summarised, along with other investments, within the Asset Health Overarching Document provided as Product 1 of the June 2023 Asset Health Re-opener Submission.

2. Introduction

17. This paper provides the justification for the intervention on the Plant 2 Aftercooler at the St Fergus Gas Terminal.

18. In developing our investment programmes at St Fergus since the RIIO-T2 Final Determinations, we have adopted a two-phase strategy to ensure clarity between short-term asset health and long-term site operating strategy.

19. Our St Fergus Site Strategy provides certainty on the terminal operation requirements, including minimum compression across Plant 1 and 2, for operation out to 2030. The long-term strategy will deliver the enduring terminal solution, including gas compression, required for operation beyond 2030. The aftercoolers are used in conjunction with both the gas and electric compressors and will be needed for as long as the site continues to compress gas.

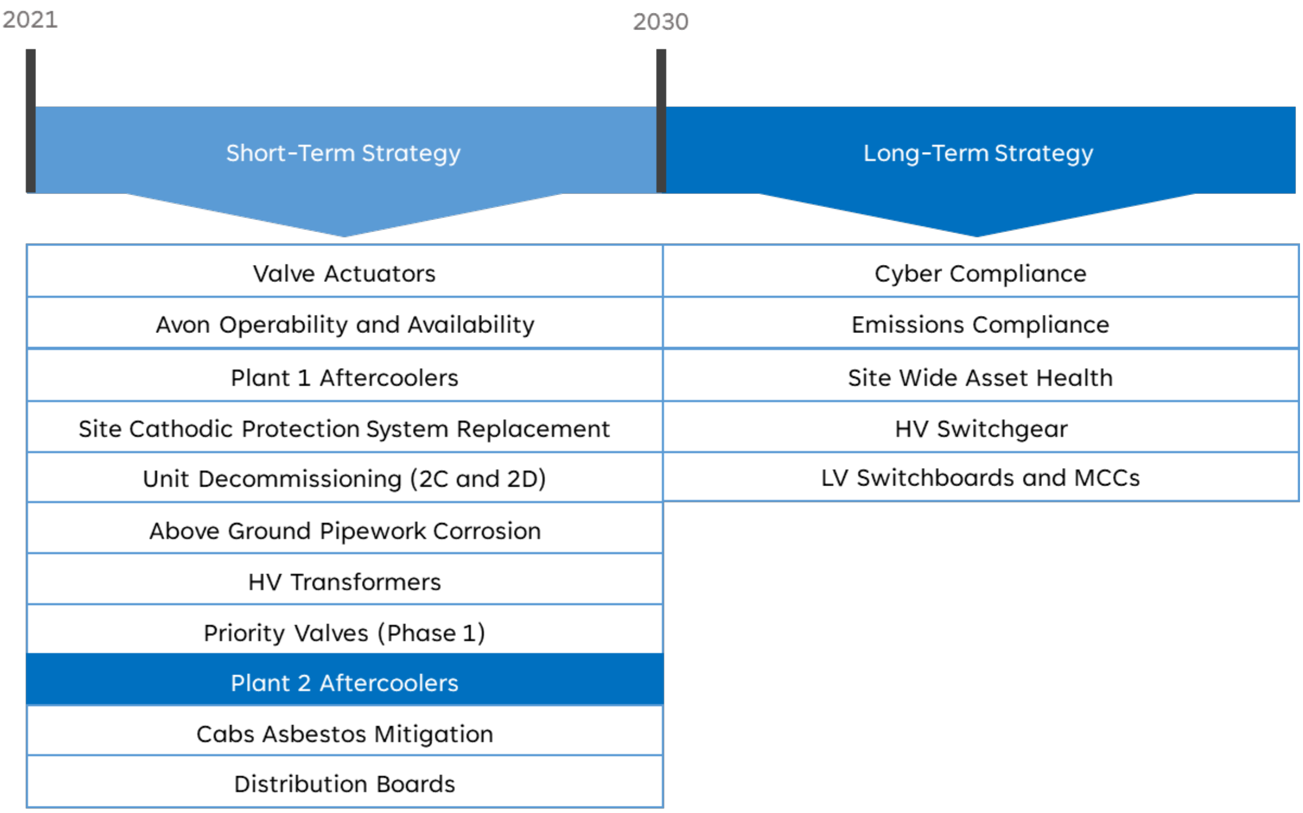

Figure 2: St Fergus Site Strategies Summary

20. The St Fergus short-term strategy supports the decision to rationalise the compression units across Plant 1 and 2 to four Avon units (1A, 1B, 1D and 2B) and maintain these in operation to at least 2030. That recommendation is fundamental to the proposals in this paper, therefore, it is important that these two documents are considered in parallel.

21. Due to the criticality of gas cooling at site, without a managed programme of investment, Plant 2 Aftercooler could rapidly become a major risk to the continued safe and efficient operation of St Fergus Site.

22. The investment outlined in this justification paper concerns Plant 2 Aftercooler system at the site which, along with Plant 1 Aftercooler, is fundamental to the safe and reliable operation of the St Fergus terminal and downstream sites on the National Transmission System (NTS).

23. The condition of the Plant 2 Aftercooler system presents significant operational and safety risks to site operations. Currently Bank D of the Aftercooler is isolated due to gas leaks being detected, therefore the asset is operating on three of its four cooling banks. This has resulted in sub-optimal cooling capability and flow volume limitations. Sub-optimal cooling poses a risk of downstream assets overheating.

24. Upon implementation of the proposed investment, the risk of failure and associated safety risks will be reduced to As Low As Reasonably Practicable (ALARP). This is a requirement aligned with the Health and Safety Executive (HSE) guidance which states the need to make sure risks are reduced to ALARP through weighing the risk against the sacrifice needed to further reduce it.

25. Not investing on the Plant 2 Aftercoolers would gradually increase the safety risk to site personnel as the probability of natural gas leaks is elevated. Natural gas leaks through corroded Aftercooler tubes have the potential to cause an explosion which impacts on the safety of people. The St Fergus Quantitative Risk Assessment (QRA) details the explosion hazards of which Plant 2 Aftercooler presents the highest risk. A summary of explosion calculations carried out as part of the QRA are presented in Table 2. The risk is highest on the Plant 2 Aftercooler region with the highest hazard distance.

Table 2: Summary of Explosions for Regions Full of Natural Gas

Region	Gas Concentration	Source overpressure (mbar)	Hazard Distances (m)	
			200 mbar	40 mbar
Electric-driven compressor cabs	Lean	91	-	20
	Stoichiometric	293	4	53
	Rich	112	-	28
Gas-driven compressor cabs	Lean	55	-	4
	Stoichiometric	495	7	54
	Rich	118	-	18
Plant 1 Aftercoolers	Lean	71	-	13
	Stoichiometric	1,405	82	323
	Rich	59	-	8
Plant 2 Aftercoolers	Lean	80	-	18
	Stoichiometric	1,621	94	370
	Rich	66	-	12

26. It also significantly impacts the site's resilience and increases the risk on security of supply as there is an increased risk of long plant outages should there be a major failure resulting in loss of compression capacity.

3. Equipment Summary

27. Comprehensive background information about the St Fergus Gas Terminal is available in the St Fergus Site Strategy.

28. There are two aftercoolers at St Fergus which were constructed in 1977. These are known as Plant 1 and Plant 2 Aftercoolers and their location on site is shown in Figure 3.

[redacted]

Figure 3: Aerial Photograph of the St Fergus Terminal Highlighting Different Plant Areas

29. Plant 1 Aftercooler has a smaller capacity as compared to Plant 2 Aftercooler and the two aftercoolers can only provide redundancy for each other if the gas flows are within the capacity of Plant 1 Aftercoolers.

30. The scope in this justification paper only covers Plant 2 Aftercooler since the justification for Plant 1 Aftercooler was submitted in January 2023.

<u>Gas Compression</u>

31. As explained in the St Fergus Site Strategy, compression is provided to increase the pressure of gas supplied from NSMP to the same pressure (70Barg) as gas from other suppliers (Shell and Ancala) before mixing.

<u>Gas Temperature Increase</u>

32. The compression process causes the temperature of natural gas to increase, due to the Joule-Thompson effect. The Joule-Thompson effect states that pressure increase during the compression process results in approximately 0.5 °C change in temperature for every 1 bar change in pressure. There is therefore significant gas temperature rise resulting in the need for aftercoolers to cool the compressed gas to the required exit temperature (approximately 30 °C).

Importance of cooling

33. High gas exit temperatures pose an integrity risk to local below ground pipework on site and downstream NTS feeders. Several of the feeders between St Fergus and Aberdeen Compressor Station are coal-tar coated to prevent them from below ground corrosion. The upper maximum operating temperature for these pipes is 38 °C, above which the coal-tar wrapping will get damaged and expose the pipes to corrosion. The aftercoolers are therefore used to maintain the gas temperature within the required range.

General Construction

34. The Plant 2 Aftercooler consists of:

- A concrete piled slab foundation and fan support plinths.
- A steel I frame with horizontal and vertical members, anchor bolted to the foundation.
- Main Girders, which run along the length of the structure and directly support the aftercooler units.
- Secondary girders which run across the width of the installations.
- Overhead Manifold Pipework and Header boxes
- Fin Tube assemblies, with circa 400 tubes per assembly
- Cooling Fans (Blades, shafts, and motors)

35. The image in Figure 4 shows a general diagram of an aftercooler bank arrangement.

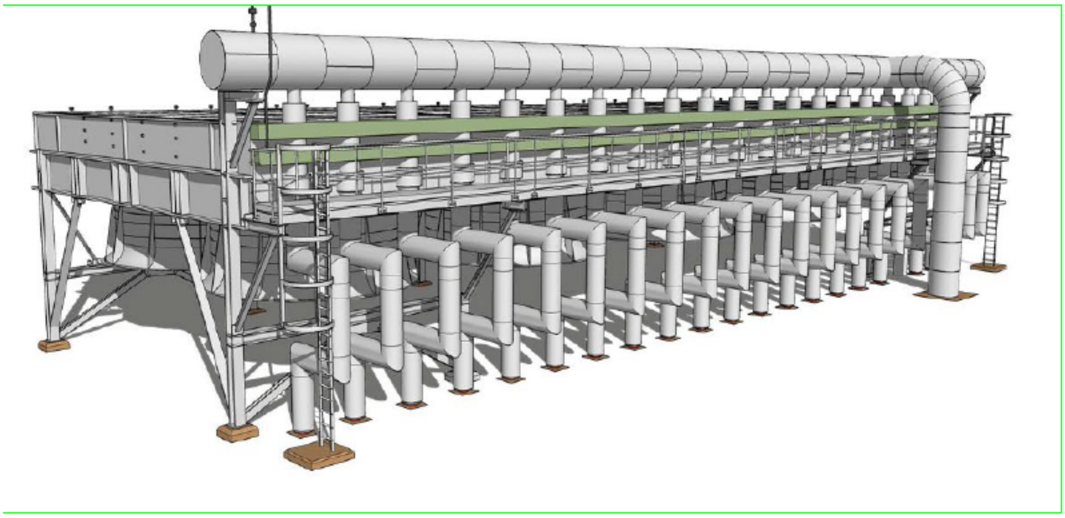

Figure 4: Typical Aftercooler Set-up

36. On the inlet side of the aftercooler, gas travels across the fin tube assemblies where the cooling fans located within the frame are used to reduce the temperature of the gas, before it exits the plant via another manifold on the outlet.

37. The Plant 2 Aftercooler consists of four banks of fin tubes (Banks A-D) each with four rows of fin tube assemblies (A1-A4, B1-B4 etc). Each bank of fin tubes consists of tubes, header boxes,

local support frame and flanged gas pipework connections. These fin tube assemblies are then air-cooled utilising the 36 electrically driven fans within the structure.

38. Figure 5 shows the header and fin tube arrangement of a single group of fin tubes.

Figure 5: Fin tube assembly with header connection

39. Figure 6 shows the Plant 2 Aftercooler exit side. The four outlet pipes (white pipework in foreground) leave the aftercooler system from the four banks enroute to the mixing plant.

Figure 6: Plant 2 Aftercooler Outlet

4. Problem Statement

40. The Plant 2 Aftercooler at St Fergus is a deeply aged asset, having been installed at the time the site was originally constructed. Whilst the St Fergus terminal has been operated and maintained for over 45 years with minimal disruption to its upstream and downstream customers, this is a testament to the original design and to the capability of the maintenance and operations teams. Nevertheless, ageing mechanisms of corrosion and fatigue have acted upon the facility's equipment and now the risk from those degraded equipment items and systems is intolerably high. The Plant 2 Aftercooler should be able to sufficiently cool gas to between 30°C and 35°C from the compressor outlet or aftercooler inlet temperature of approximately 75°C at the contractual flow rate of 72mcm/d.

41. Of the four banks, it is of paramount importance to note that Bank D has already deteriorated beyond repair. The failure mode of Bank D is characterised by leaks on the header box plugs with corrosion overtime as the major root cause. It has thus been isolated leaving Banks A, B and C in operation, thereby compromising the cooling effect of the whole aftercooler. This means the design cooling capacity of the whole aftercooler has reduced and will not be able to sufficiently cool gas if it is delivered at the peak contractual flow rate. Although the site is currently operating in this state because of reduced gas flows, the risk of the site failing to handle gas flows at contractual flow rate remains to be mitigated though this investment.

42. There is a pertinent requirement to modify inlet pipework and install inlet isolation valves as was undertaken on Plant 1 Aftercooler. This enables local isolations of banks for inspections and maintenance works without isolating the whole cooler.

43. The other Plant 2 Aftercooler sub-assets which have been identified to have significant degradation through surveys are:
    - Tube bundles and headers.
    - Cooling fans and associated equipment
    - The concrete plinths supporting the fans have been visually inspected and have significant degradation.
    - The steel supporting frame has some areas of severe corrosion however a significant part of the structure (girders) cannot be inspected in full until the aftercoolers are removed.
    - The piled slab foundations have not been surveyed in full yet and will form part of the next phase of this project.
    - Main inlet/outlet pipework and manifolds and the primary, secondary and tertiary structures.

44. The magnitude of deterioration on these units poses additional risk on site due to the increased chance of loss of containment. So, it is the responsibility of NGT under the HASAW Act to do necessary intervention works, especially considering that the site is a Major Accident COMAH

site and hence bound by law to undertake all measures necessary to prevent major accidents and the consequences of such.

45. The Aftercoolers are our most congested region within the whole terminal and as such are our highest major accident hazard risk in terms of a gas leak causing a vapour cloud explosion. As detailed in the QRA, explosion contours for this failure mode or Major Accidents Hazard have the largest overpressure hazard contour distances of any other scenario. There is therefore a need to comply with the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR). DSEAR puts duties on employers to protect people from fire, explosion and corrosion of metal risks in the workplace and to members of the public who may be put at risk by work activity. Explosion contours for this failure mode / MAH have the largest overpressure hazard contour distances of any other scenario.

46. From an operational perspective, there is a need to increase the level of isolation on individual cooler banks with the addition of isolation valve on the individual inlet/outlet manifolds. This is to allow full isolation of a cooler without isolating the full set of aftercoolers to assist with inspection and PSSR requirements.

47. Maintenance and minimum interventions have been unable to keep up with the growing number and severity of defects. The open defects currently are 52 open defects and 94 CM/4 defects. This is partly because the range and complexity of the issues being experienced on the asset require long term solutions. The fact that isolation of the entire plant is required for maintenance purposes has also hampered maintenance activities, particularly with the current unavailability of Plant 1 Aftercoolers. With 24/7/365 operation, redundancy is critical to avoid disruption to operation of the terminal.

48. A range of interventions have been undertaken on both Plant 1 and Plant 2 Aftercooler banks to continue the operation of these deteriorated assets and extend the life of the current installation. However, these efforts did not provide the required availability and reliability for Plant 1 Aftercooler resulting in spending at risk. As highlighted earlier, Plant 1 is already under a major investment program.

49. Annual aftercooler inspections have occurred throughout the life of the asset, involving visual inspections as per T/PM/MAINT/6 and gas detection testing to investigate leakage from the asset. A detailed condition survey was carried out by [redacted] in 2021 and further Asset Health surveys have been carried out by another contractor. Earlier surveys backdating to the year 2016 were also done by [redacted] as can be shown in a typical inspection report (Appendix D).

<u>Frames and plinths</u>

50. Fan support plinths on Plant 2 Aftercooler have been observed to require significant repair. Many of these concrete support plinths are cracked and crumbling at the four corners where the main anchor point plates are connected to the concrete plinth, providing little stability to the fan assembly. Figure 7 illustrates the extent of degradation on sample structures.

Figure 7: Plant 2 Aftercooler fan concrete support plinths: cracking, corrosion and loss of section

51. Corrosion is present across all the fan shafts and the main anchor points are severely corroded. All fans have four main anchor bolts, with most of these fans having one or two of the bolts being completely corroded, as shown in Figure 8.

Figure 8: Corroded anchor bolts and steel mounts

52. The structural steel columns, holding down bolts and girders have areas of corrosion ranging from minor to severe. Figure 9 shows column bulging due to severe corrosion.

53. It should be noted that large areas of the structural steel cannot be inspected and assessed fully, until the Aftercoolers are dismantled and removed. It is therefore not possible, at this stage, to form an opinion on the condition and suitability of the structural steelwork. Although, it is anticipated that the condition will be similar to that of the Plant 1 Aftercooler structural steelwork thus requiring complete replacement.

Figure 9: Steelwork column bulging (at 2/3rds height) due to severe corrosion.

<u>Electric Motors</u>

54. The electrical assets particularly motors as well as associated control stations and junction boxes, are badly corroded and need replacement. Figure 10 shows examples of corroded motors.

Figure 10: Plant 2 Aftercooler motors

<u>Fin Fans</u>

55. At the time of survey, 17 of the 54 installed fin fans were not available due to a range of defects. The most prominent failure modes are:

- Burnt drive motors
- Broken drive belts
- Broken spindles
- Sheared drive shafts

56. This is an indication of the motor failures being experienced. Although this 68% availability of fans may not impact operation at low gas throughput, it becomes a major constraint at high gas flows.

5. Probability of Failure

57. Excessive degradation was found on the Plant 1 Aftercooler upon its outage. Since the two aftercoolers operate under the same environmental conditions and are of similar design and age the condition of the Plant 1 aftercooler serves as a clear baseline of the level of damage likely to be found on Plant 2 Aftercooler.

58. The existing Plant 2 Aftercooler has 94 CM/4 corrosion defects and 52 other defects recorded against it. It has been operating well past its 25-year design life, having been commissioned in 1977.

59. A visual survey of the Plant 2 Aftercooler civil and structural works was carried out in October 2022. The failure mode of the support plinths, as seen in Figure 7 is widespread throughout this location and indicates a systemic failure. Anchor bolts are failing through corrosion whilst concrete integrity is failing due to cracking and disintegration.

60. As highlighted under the problem statement, Bank D on Plant 2 Aftercooler has already been isolated. Therefore, the scale of the defects and the observed failures at less than operational pressure evidence a high probability of failure under live scenarios.

61. Given the remaining three banks are exposed to the same environmental and operational conditions, the probability of the remaining banks failing is high.

62. The severity and prevalence of defects coupled with third party condition assessments shows that asset failure has already occurred.

63. Some of the major findings indicating that failure has occurred are:

    - The sampled tubes (10%) which were inspected using the IRIS method in 2016 showed a maximum wall loss of 15%. This could have worsened considering the period the aftercooler has been in use since this inspection. In addition, more detailed inspection if the aftercooler is reinspected can reveal further wall loss and other damages.
    - Ultrasonic Thickness and visual inspections of the 2" x 600 RTJ welded flange fitting nozzle on the inlet header box vent was found to be below minimum acceptable.
    - The header boxes are suffering from light localised corrosion on all exchangers, this is predominantly on the underside and on the endplates.
    - Concrete bases anchor bolts severely corroded and base plates have extensive thinning due to corrosion, concrete is broken and cracked in vicinity of the holding down bolts.

64. Figure 11 shows the typical corrosion deposit that have already been experienced on both inlet and outlet header plug sheets.

Figure 11: Header plug sheet corrosion

65. Although, the Plant 2 Aftercooler has been in service since the last inspection, continuing to defer major interventions proposed in this justification means increased probability of failure which is not desirable in view of the consequence of failure.

66. As a lesson learnt from Plant 1 Aftercooler, due to accessibility and safety challenges some of the major defects were discovered after the plant was fully isolated and dismantled. It is therefore anticipated that similar defects will be discovered as the Plant 2 Aftercooler is dismantled.

6. Consequence of Failure

67. Whilst the Plant 1 and Plant 2 Aftercoolers ordinarily provide redundancy for each other if both are available, the need to frequently intervene on Plant 2 due to defects results in a single point of failure for the Plant 1 Aftercooler. Most importantly, the Plant 2 Aftercooler has a bigger consequence as it has a higher capacity as compared to Plant 1 Aftercooler. However, because Plant 1 was in more deplorable state across all the banks, it was more logical to invest in the Plant 1 Aftercooler first.

68. The unavailability of Plant 2 Aftercooler becomes more critical when flows are above Plant 1 Aftercooler's rated capability, especially if the site is receiving peak gas flows. As evidenced in the problem statement there are numerous asset risks associated with the operation of this plant. The resulting loss of this asset would be significant from a financial, safety and reputational perspective.

69. Should Plant 2 Aftercooler fail and the site is receiving gas flows above the capacity of Plant 1 Aftercooler, compensation costs to Shippers would run into millions per day, upstream oil production would cease leading to significant venting/flaring, UK gas security of supply would be compromised, Scottish distribution pressures could become unmanageable under most demand scenarios and the reputational impact could result in significant limitations for NGT's ability to operate, notwithstanding the risk to site personnel. Quantifying these high impact and compounding risks is not straightforward, but it can be safely assumed that any failure as described below would result in costs outweighing any of the investment options outlined in this paper.

70. Through wall defects on the header boxes or the interface between the fin tubes and the header boxes would result in the shutting down of the entire aftercooler bank or the entire aftercooler plant. Return to service for a failure of this kind is not quick to resolve, tubes need to be manufactured through milling processes. In addition, structures, pipework configuration and valve replacement will have to be worked on. Should the Plant 1 Aftercooler also require an outage then no NSMP flows could be accommodated at the terminal resulting in the expected daily cost of constraint.

71. The worst-case failure mode will be the rapture of aftercooler pipework resulting in the release of natural gas at high flow rate as detailed in the QRA. This results in full-bore rupture of the aftercooler pipe bundles and headers at a pressure of 70 barg. Due to the larger number of small diameter pipework, these rupture scenarios are modelled conservatively as partial Emergency Shut Down (ESD), where a continuous release is maintained for 10 minutes prior to manual shutdown similar to large leaks in larger pipelines.

72. The maximum dispersion distance to Lower Flammability Limit (LFL) is predicted to be 190 m, and within this distance, ignition would result in a flash fire extending throughout the flammable cloud and burning back to the release point. The maximum dispersion distance to ½ LFL is predicted to be 355 m, and within this distance, ignition would result in a localised flash fire. The escape distance for people outdoors extends up to 151 m and secondary fires would occur

up to 149 m from the release point. These hazard distances are plotted on a site plan in Figure 12.

[redacted]

Figure 12: Maximum Hazard Ranges for rapture of Aftercooler pipework

73. It is recognised that explosions can occur in congested regions such as the Aftercooler areas, however, these are not limited to occurrence from Aftercooler area ruptures and leaks. Natural gas releases from neighbouring plant equipment and pipework have the potential to disperse into these areas and result in explosions.

74. Gas emissions caused by a pipework rupture also have a huge environmental impact.

7. Options Considered

75. Three options have been considered for this investment. Of the three options, one of them is immediately discounted as it is not viable for compliance and other reasons outlined below. Options 2 and 3 are then expanded upon by outlining the pros and cons of different designs to support the final option.

76. It is of paramount importance at this stage to note that the investment on Plant 2 aftercoolers requires a redesign of the units, as opposed to a like-for-like replacement as undertaken for Plant 1. This is intended to provide better flexibility in line with future planned throughput and requirements for maintenance and / or inspection interventions. A key part of the new design is to include the ability to isolate individual aftercooler banks, rather than requiring a whole plant shutdown to perform any maintenance on a single cooler. In addition, a new design would allow a more optimal approach to the gas cooling capability of the coolers to be implemented on site.

77. Refurbishment of Plant 2 Aftercooler was initially considered but had to be discounted owing to major lessons learnt on the Plant 1 Aftercooler project. This approach was attempted on Plant 1 to keep costs down which ultimately ended up with a piecemeal replacement and an increased project cost. With the knowledge now available in terms of viability and implementation challenges in this option, to control project costs and timeframes, replacement options are preferred.

78. The intent is also to capitalise on new technology. As part of the new design process, several vendors have been contacted to provide design solutions to improve the existing system at St Fergus and these will be reviewed.

<u>**Option Discounted**</u>

Option 1: Do nothing

79. This option entails retaining the Plant 2 Aftercoolers and continuing in the current operation and maintenance mode, irrespective of the risks identified during the inspections. This would result in the site reliably operating with just Plant 1 Aftercoolers since Plant 2 Aftercoolers will have increasing defects identified over time.

80. This option is not viable due to requirements to operate safe plant in compliance with PSSR, COMAH and other safety regulations. In addition, it would not meet the expectations set out by the HSE.

81. In the long run, there will be no redundancy to provide cooling to the NSMP gas flows in the event of an outage being required on Plant 1 Aftercooler. Also in the short term, the need to cool gas at contractual peak flows will not be accommodated.

Do nothing was deemed not viable and therefore not costed. This is because it presents significant limitations that do not address the major investment drivers and would also not guarantee long term reliability of the aftercooler to 2050.

Option Progressed

Option 2: Replacement Like-for-like

82. This option involves the replacement of the existing Plant 2 Aftercooler and the decommissioning of the old system, providing a like for like replacement of the cooling ability of the system.

83. This option will provide life extension to the identified assets and minimise defects.

84. However, it will not incorporate a critical identified operational need to upgrade the Plant 2 Aftercooler.

85. This requirement is motivated by the need for the aftercooler to cool peak gas flows of 72mcm/d to the required temperature whilst maintaining redundancy between both Plant 1 and Plant 2 Aftercoolers.

86. With this option, both Plant 1 and Plant 2 Aftercoolers will be put in service for effective cooling of gas at contractual peak flows.

Option 3: Replacement - New design

87. This entails replacing Plant 2 Aftercoolers with a new design which focuses on the following key improvements as compared to the existing coolers:

    - Ability to sufficiently cool gas to between 30°C and 35°C from the compressor outlet or aftercooler inlet temperature of approximately 75°C at the contractual gas flow rate of 72mcm/d.

      Currently the cooling of gas at peak flows requires both Plant 1 and Plant 2 coolers to be in service which presents a single point of failure at that instance. An operating envelope comparison to demonstrate the differences in gas cooling between the existing aftercooler and the proposed new design is shown in Section 9.

    - Must be able to isolate individual banks of the aftercooler for intrusive maintenance without the need to shut down the whole cooler. This improves flexibility and the ability to allow online maintenance of a single aftercooler bank. Currently, the available single isolation point only enables depressurising individual banks to have them out of service but will not be safe for intrusive online maintenance. This is the case with Bank D which is isolated, but cannot be maintained for safety reasons.

    - Must aim to decrease the Operating Expenditure (opex) costs. For instance, a 3-bank design may have less maintainable equipment as compared to the current 4-bank design. However, this should only be considered alongside other factors such as suitability, reliability, operability, and capex investment.

88. The ultimate number of banks will be determined after detailed design considerations as guided by the maximum gas flow requirement and the inlet temperature.

89. There are several lessons learnt from the Plant 1 Aftercooler project which will be taken advantage of in this option. For instance, modifying or replacing the current aftercooler with like-for-like has proved to be a major challenge to service providers.

90. Despite the advantages discussed above, this will be the portion with the highest immediate cost.

Options Cost Details

Options	Programme element	Unit costs (£m) (18/19prices)	Volume	Investment value (£m) (18/19prices)
Option 1	Do nothing			
Option 2	Replacement Like-for-like	[redacted]	[redacted]	[redacted]
Option 3	Replace with new design	[redacted]	[redacted]	[redacted]

91. The 15.7% price difference between like-for-like and new design replacement, with the latter being higher is broadly attributed to new design requirements. Some of the major drivers of cost variation are listed below:

- The new design involves consultancy expertise to achieve the specified cooling capacity.
- To achieve the requirement to isolate individual banks for maintenance, the header bank needs to be redesigned and aligned for the purpose. It also follows that there will be an increased number of valves.
- The pre-works supporting the repair or replacement of concrete plinths including evaluations of existing foundations for re-use.
- A design change from an induced draft arrangement as opposed to a forced draft arrangement.
- A new gantry design will be designed and installed to support the new plant.
- The existing fan blades were confirmed to be inefficient and needs redesigning.
- Design and construction of new plinths are required.

8. Option analysis and selection

92. Considering the above rationale and options assessment, Table 3 provides a summary of the options considered for the Plant 2 Aftercooler. The table also highlights the recommended option.

Table 3: Summary of considered options

Solution considerations		Option 1	Option 2	Option 3
		Do Nothing	Replace Like-for-like	Replace with New Design
Cost		Not Costed	High cost-margina y cheaper than option 3	Higher cost in short term, but onger term efficiencies
Compliance	DSEAR	Non-Comp iant as deteriorated tubes a ready giving in	Comp iant	Comp iant
	PSSR	Non-Comp iant as deteriorated tubes a ready giving in	Comp iant	Comp iant
Environmental Impact		Medium impact increased tube fai ures a ow natura gas to eak into the atmosphere	Low impact	Low impact
Maintenance	Ongoing OPEX	High cost - continued deterioration and defects requiring OPEX interventions	Low cost	Low cost
	Flexibility	None repair of eaks on y possib e with the who e aftercoo er iso ated	None repair of eaks on y possib e with the who e aftercoo er iso ated	Avai ab e Aftercoo er banks can be iso ated individua y
	Risk	High risk - risk of p inths co apsing and tubes continuous y fai ing	Low risk Recurring defects are reso ved through this intervention	Low risk Recurring defects are reso ved through this intervention
Operational Resilience	Single Point of Failure	High risk -When on y P ant 1 Aftercoo er assets are avai ab e due to a high number of P ant 2 Aftercoo er defects	Medium risk Improves the avai abi ity and re iabi ity of the aftercoo er	Lowest risk due to improved avai abi ity and re iabi ity as compared to option 2
	Security of Supply	Continuous maintenance activities wou d require outages on the p ant,	Medium- addresses a corrosion and age-re ated defects, but does not have capacity to hand e peak gas f ows	Low - addresses a corrosion and age-re ated defects and provides capacity to hand e peak gas f ows

Solution considerations		Option 1 Do Nothing	Option 2 Replace Like-for-like	Option 3 Replace with New Design
		resu ting in no redundancy for P ant 1 Aftercoo er		
Overall viability		Not viable	Viable	Viable

9. Preferred Option Scope and Project Plan

93. The assessments outlined in this paper and the associated discounting and costing of options demonstrates that the most viable, cost effective and logical option to take forward is the replacement of the Plant 2 Aftercooler with an upgraded design. This would have the capacity to cool natural gas at peak flow rates to the desired exit temperature and also incorporate the provision to isolate individual banks.

94. Focus is therefore on ensuring Aftercooler assets of the Best Available Techniques (BAT) are procured, and the investment is delivered at the lowest overall cost.

Project Scope

95. The following is a summary of the project scope deliverables:

- Destruction and removal of existing Plant 2 Aftercoolers.
- Demolition and removal of existing plinths and structural steel frame/rack including temporary works.
- Installation of new plinths and services including temporary works.
- Design, procurement, installation, and commissioning of new aftercooler units.

96. In an endeavour to give more detail on the need for upgraded Plant 2 Aftercooler as well as to have an indication of the required design, a preliminary design has been completed using [redacted] and the relevant specification sheets in Appendix C. This allows for an approximate comparison between the original and new designs. It should however be noted that this approach is high-level and vendor designs and cost estimates should be obtained at the stage of detailed design consideration.

97. The input data assumed for the EDR model is below.

- Design capacity = 72 mcm/d (peak gas flow)
- Inlet Pressure = 70 bar gauge
- Process inlet temperature = 40°C to 80°C
- Process outlet temperature (target / maximum allowable) = 30°C / 36°C

98. Two design options consisting of 3-bank and 4-bank aftercooler units were developed and compared with the existing units. The resultant operating envelopes for all three designs for an aftercooler inlet temperature of 80°C (with a 5°C safety factor) is shown in Figure 13. Both new designs offer significant improvements to the existing units in achieving the target temperatures.

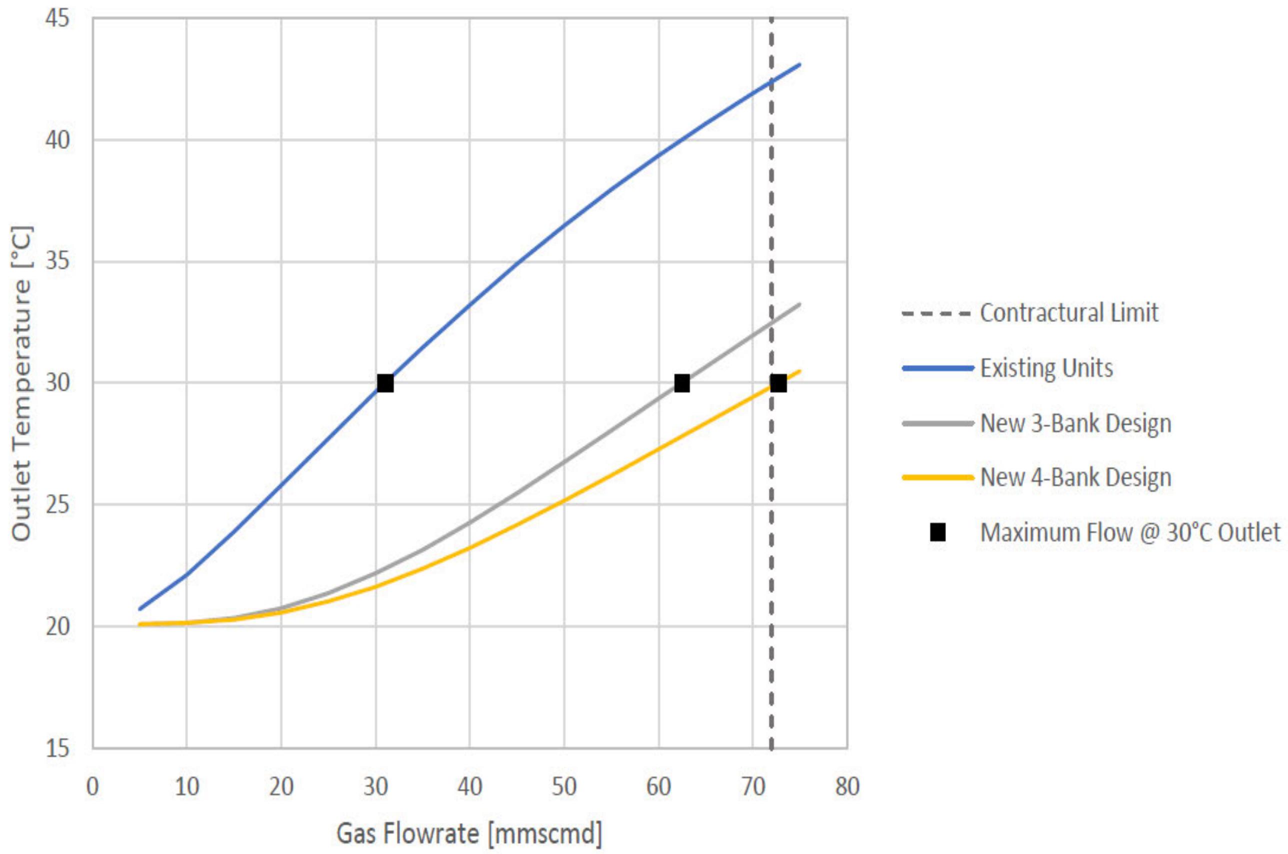

Figure 13: Operating envelope comparison

99. The expected 30°C - 35°C gas exit temperatures from the Plant 2 Aftercooler is achievable with the 3-bank and 4-Bank new design cases at the maximum flow of 72mcm/d. Therefore, consideration should be made for 3-Bank and 4-Bank designs as part of future phases. It should be noted that both designs are very close to the footprint limits for the area and will be considered during the detailed design stage.

100. The survey undertaken by [redacted] Appendix E, on the piled foundations was a visual inspection on the top surface of the slab only and no visible signs of distress were noted. However, further testing will be required to determine the integrity of the concrete and reinforcement to inform the likely residual working life of these foundations. This will determine the suitability of the foundation to support the new Aftercooler for at least a design life of 25 years. Based on the report, the scope of this option excludes the replacement of piled foundations and only covers the complete replacement of plinths. However, the same report recommends further suitable testing to establish the remaining life of the pile caps, which will be carried out in the next design stage.

Final Cost and program

101. Table 4 provides a breakdown of the final costs (to be finalised) for the project split by several categories.

Table 4: Preferred Option Final Costs

	Cost Category	Outturn Costs (£m)	Costs (£m) 2018/19 Price Base
	OEM costs	[redacted]	[redacted]
Direct	EPC Estimate	[redacted]	[redacted]
Indirect	EPC PM	[redacted]	[redacted]
Direct	EPC Site Establishment	[redacted]	[redacted]
Direct	NGT Direct Company Costs	[redacted]	[redacted]
Indirect	NGT Indirect Company Costs	[redacted]	[redacted]
	Contractor Risk	[redacted]	[redacted]
Direct	NGT Project Risk	[redacted]	[redacted]
	FEED	[redacted]	[redacted]
	Development / Optioneering	[redacted]	[redacted]
	Land / Easements	[redacted]	[redacted]
	TOTAL	[redacted]	[redacted]
		[redacted]	[redacted]
	Direct	[redacted]	[redacted]
	Indirect	[redacted]	[redacted]

Asset Health Spend Profile

102. Table 5 shows the spend profile for our preferred option in 2018/19 pricing.

Table 5: Spend Profile of preferred option

£m 18/19	FY2023	FY2024	FY2025	FY2026	Total	Comments
Plant 2 Aftercooler replacement	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	

RIIO-T2 Volume UIDS

103. Costs associated with this project have been assigned against the RIIO-T2 Unique Identifier (UID) A22.22.5.6 - ST FERGUS TERMINAL – Aftercooler Replacement. Table 6 provides a summary of the UIDs and associated funding for the scope of works proposed in this paper.

Table 6: UID Details

UID	Baseline volume of Intervention (By PP) (by unit of measure)	Baseline total funding available (£ 18/19)	Current volume of intervention (by unit of measure)	ECC total funding required (£m 18/19)	Output Year	UID funding requested through UM (£m)
[redacted] ST FERGUS TERMINAL – Aftercooler Replacement	[redacted]	[redacted]	[redacted]	[redacted]	2026	[redacted]

104. The cost accuracy at this stage of the project is estimated at +30/-15% in accordance with the Infrastructure and Projects Authority (IPA) cost estimating guidance.

NARMS Benefit

105. Following discussions with Ofgem in the NARM Development Monthly Meetings, it is proposed that for simplicity all the investments that arise from the UMs are collated and one NARMs update is provided after the Plant & Equipment submission.

106. For further details and a summary of UIDs please see the Asset Health UM Overarching document.

Conclusion

107. This report has explained the asset health and compliance shortcomings of the Plant 2 Aftercooler at St Fergus and their implications to the safe and reliable operation of the terminal. The condition of the units has been found to be consistent with its aging, with varying degrees of degradation.

108. Upon conducting thermal analysis of the existing Plant 2 Aftercoolers in [redacted] EDR, a new design has been recommended. The new design presented is like the original, with an optimised tube and fan layout to ensure efficient cooling of the gas at the expected maximum flow and inlet temperature. A high-level cost estimate has been provided based on the new units replacing the existing, with the addition of new double block and bleed valves on the inlet/outlet of each bank to allow single isolations without shutting down all banks.

109. Due to the maturity of the design at this stage, civil/structural costing has been based on the replacement of the existing units and plinths foundations, excluding pile foundations. The new units may occupy less footprint and be lighter than the existing, with different mechanical loadings. As such the civil/structural works should be revisited when a more developed design. However, a finalised position will be determined at in the next design stage. The total cost expected, including a 30% contingency is [redacted] in 18/19 price base

8 Appendices

Appendix A – Project Summary

Table 7 summarises the key information on the project.

Table 7: Project Summary

Name of project	T2_St Fergus_2021_St Fergus RIIO-2 Asset Health Programme		
Scheme reference	[redacted]		
Primary investment driver	Asset Deterioration		
Project initiation year	2023		
Project close out year	2026		
Total installed cost estimate 18/19	[redacted]		
Cost Estimate accuracy (%)	+30/-15		
Project spend to date Outturn	[redacted] (all St Fergus T2 AH UM development)		
Current project stage gate	F2		
Reporting table ref	RRP Table 6.3 (Asset Health) and Table 6.4 (Asset Health Projects)		
Outputs included in RIIO-T1 business plan	No		
Spend apportionment 18/19	T1	T2	T3
	[redacted]	[redacted]	[redacted]

Appendix B – [redacted] Report

File: 5210385-001-PR-REP-019, 19-Plant 2 Aftercoolers, [redacted] Rev 3.0, 2023

national gas transmission

Appendix C – [redacted] Exchanger Design and Rating Specification Sheets.

[redacted]

national gas
transmission

[redacted]

Appendix D – Plant 2 Aftercooler [redacted] Inspection REV 3

File: 16-1010-A2, Plant 2 Aftercooler [redacted] Inspection Report, Tutis, Issue 3.0, 2016

Appendix E – [redacted] Inspection Report

File: 1002-000665, Plant 2 and 3 Aftercooler: Desk Study and Condition SURVEY, [redacted] Rev 3.0, 2021

national gas transmission