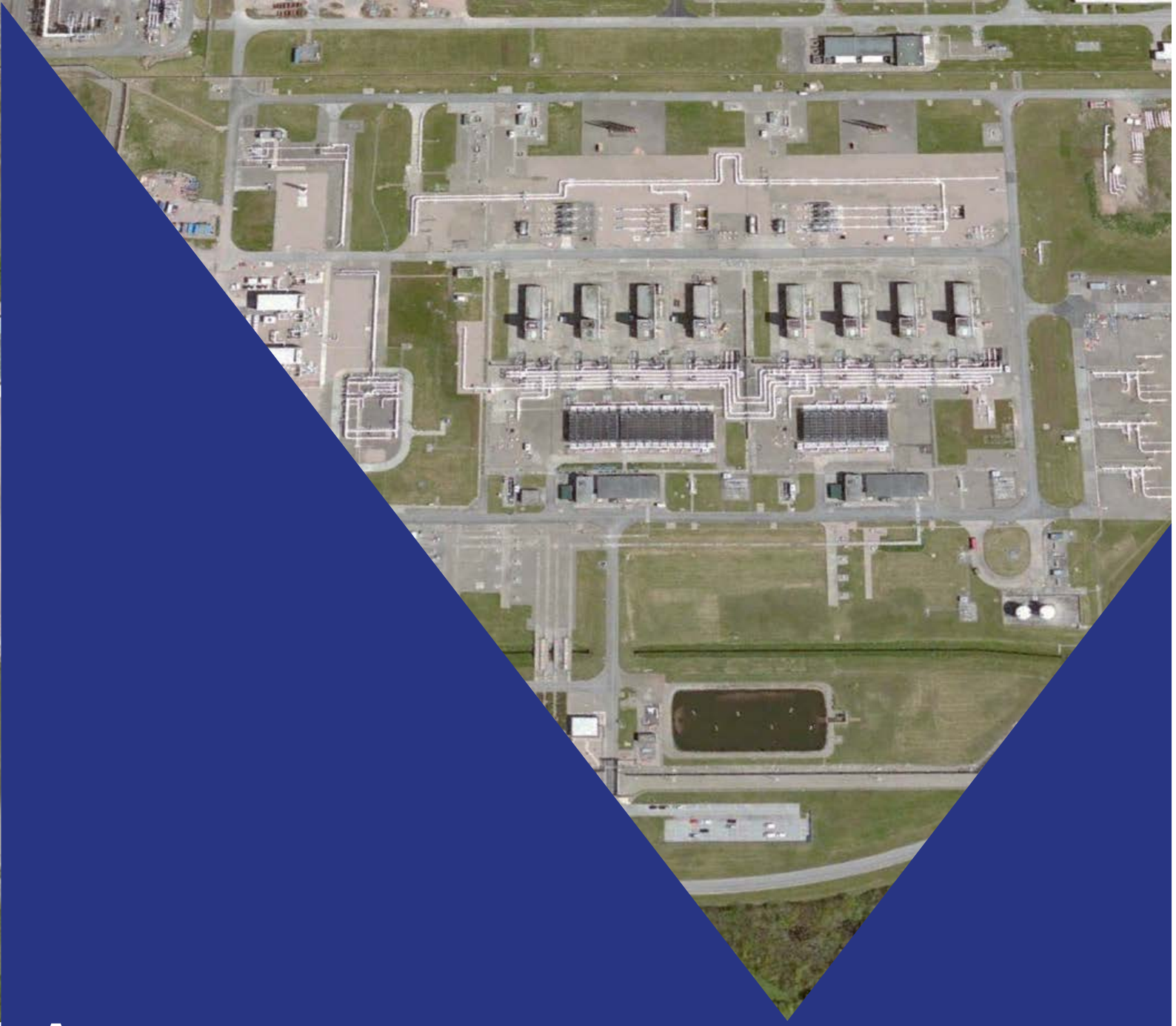

Annex

A16.16 St Fergus Investment Programme Engineering Justification Paper

December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

Table of Contents

1. Project Status and Request Summary 5
2. Problem/Opportunity Statement 7
3. Project Definition 15
4. Options Considered 22
5. Business Case Outline and Discussion 49
6. Preferred Option Scope and Project Plan 54
7. Project Plan 55
8. Key Business Risks and Opportunities 56
9. Appendix A Acronyms 58
10. Appendix B – St Fergus Stakeholder Engagement 59
11. Appendix C – FEED Scope 61
12. Appendix D - NSMP Entry Capability 63

Executive Summary

This paper provides an overview of our RIIO-2 and RIIO-3 investment proposals at the St Fergus Gas Terminal to ensure that we continue to meet stakeholder requirements. It is one of the most strategically important sites for the National Gas Transmission Network, as well as for the wider energy system of the UK. Our proposal delivers sufficient compression to meet the needs of our customers, whilst also complying with emissions legislation (Large and Medium Combustion Plant Directives (LCPD & MCPD)) and addressing the significant asset health issues at the site.

This justification supports the high level proposals in chapters 14 and 16 of the our business plan "I want to take gas on and off the Network where and when I want" and "I want to care for the environment and communities". This Justification Paper should be read in conjunction with the Compressor Emissions Compliance Strategy (CECS) in Annex A16.05 and the Asset Health Justification Papers Annexes (Cabs: A14.08, Compressors: A14.10, Plant & Equipment: A14.12, Valves: A14.14, Pipelines: A14.16, Civils: A14.18 and Electrical: A14.20).

The National Grid 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 40 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 (the other being Bacton terminal) and as such is a major accident hazard site, subject to regular HSE and SEPA inspections and significant health, safety and environmental legislation. It has the highest emissions of any site on our Network.

The terminal receives gas from three sub-terminals (currently owned by Ancala, Shell and North Sea Midstream Partners/Gassco). Uniquely on the NTS, National Grid provides 24/7/365 compression services for gas received from the NSMP terminal under the terms of the Network Entry Agreement (NEA). This is a legacy arrangement dating from when British Gas was privatised and cannot be changed unilaterally by National Grid.

The analysis was carried out in all four scenarios in FES 2018 indicates there is a compression requirement at St Fergus to 2040 and beyond. The expected flow range for NSMP is large, between 10 mcm/d and 68 mcm/d across the four different FES scenarios. Overall, the predicted flows show a slight decline over the next 10 years, with older gas field decline being largely offset by an increase in flows as new West of Shetland fields connect.

Gas from the NSMP sub-terminal enters the St. Fergus terminal at a pressure of approximately 40 barg. The gas then flows through scrubbers and meter streams before passing through the compression plants, where the gas pressure is raised, typically to between 60 and 65 barg. The gas is then cooled in the aftercoolers to remove the heat of compression before joining gas from the Ancala and Shell sub-terminals. The gas then enters the NTS pipelines flowing south towards Aberdeen.

There are nine units across three current compressor plants at St Fergus. The bulk of the compression is provided by 2 electric variable speed drive (VSD) compressor units which were commissioned in 2015. The remaining 7 are gas powered compressors from the original site (commissioned in 1978) on Plants 1 and 2 and are not compliant with emissions legislation. These compressors currently provide: the low flow capability, back up to the VSDs bulk flow and high capability when used with the VSD compressors. Compression continues to be required to maintain service to the customer; therefore a solution to address the environmental non-compliance on these gas units is required.

In May 2018 we submitted a request to Ofgem for an allowance to comply with the LCPD, effective in 2023 and impacting two compressors at St Fergus. This submission also addressed the IPPC legislations drivers onsite. Our July business plan proposals assumed this request was successful. Ofgem's minded-to position in their September 2019 consultation did not support the need to construct any new compressor units at St Fergus, with SEPA now recommending considering both MCP (effective 2030) and LCP compliance together for the site. Our interpretation of the minded to position is that we can continue to operate the Avon units on our current permitted basis until 2030.

In response to the minded-to outcome, we have reviewed a wider range of investment options for the site from a combined asset health and emissions compliance perspective against current and future site requirements. A Cost Benefit Analysis (CBA) compared the costs of proposed compressor units (installation and maintenance costs for new or existing units), the asset health investment required and estimates of constraint costs associated with the differing levels of capability and availability, to arrive at the lowest overall cost to consumers, see the CBA cost table below.

Costs over 25 years CBA (FY 2022-2047) £million

No.	Option Title	Operating Cost (fuel)	Constraints	CapEx (AH, Installed costs + Decommissioning)	Actual NPV NPV [1]
0	Derogate 4 Avons (plant 1 only).				-£2180.8 m
1	Derogate 5 Avons (plant 1 and 2)				-£1554.1 m
2a	Existing plant 2: 2 new units and 1x derogated Avon				-£656.6 m
2b	Existing plant 2: 1 new unit + 1x derogated Avon				-£1346.7 m
2c	Existing plant 2: 3 new units				-£670.8 m
3a	Redeveloped Plant 2: 2 new units and 1x derogated Avon				-£605.8 m
3b	Redeveloped Plant 2: 3 new units				-£613.7 m
3c	Redeveloped Plant 2: 3 new units (1 large)				-£623.4 m
4	New Greenfield Plant: 2 new units				-£866.9 m

We used the 2018 Future Energy Scenarios (FES) in our analysis, with the Steady Progression scenario as our central case for the CBA with sensitivities being run against the other three scenarios. Maximum flows at the NSMP sub terminal do vary depending on the FES Scenarios. Despite this, the CBA outcomes were not sensitive to changes in FES scenario.

The most cost effective and lowest risk option is to redevelop the Plant 2 area of the St Fergus Terminal with new compression. There are three potential compressor options, identified in

[1] Note that these calculated NPVs assume a capitalisation rate of 73.5% as set out in CECS (Annex A16.05). This capitalisation rate has now been updated, and therefore there may be a minor mismatch between quoted NPVs between this document and the associated CBA (Annex A16.11). Please note that this does not affect the final proposed option. The impact of the updated capitalisation rate is reflected in the CBA document.

green in the table above, that will continue to be assessed through the Front End Engineering and Design (FEED) study. For the RIIO-2 data tables we have currently selected as our proposed option redeveloping Plant 2 with 3 new ~15MW gas turbine compressors. The cost of our proposed option in RIIO-2 and RIIO-3 is [redacted][2] for asset health, Plant 2 redevelopment and decommissioning of plant 1 thereafter. Summary Table

Name of Project	St Fergus Plant 2 Redevelopment		
Scheme Reference	TBC		
Primary Investment Driver	Emissions and Asset Health		
Project Initiation Year	2021		
Project Close Out Year	2029		
Total Installed Cost Estimate (£)	FEED [redacted] New build, Asset Health (and Decommissioning RIIO-4) UM [redacted][3]		
Cost Estimate Accuracy (%)	P50		
Project Spend to date (£)	£0.0		
Current Project Stage Gate	4.1		
Reporting Table Ref	3.01 and 3.02 (Project Listing)		
Outputs included in RIIO-T1 Business Plan	No		
Spend apportionment	**RIIO-T1** £0m	**RIIO-T2** [redacted] FEED, [redacted] UM)	**RIIO-T3** [redacted] ([redacted] UM)

[2] Note that the CBA reflects project costs of XXXXX rather than XXXXX This is because the CBA includes additional cyber costs not covered by this paper, these are covered elsewhere in the business plan.

[3] This is the XXXXX total stated above minus XXXXX FEED costs and XXXXX no-regrets asset health.

1. Project Status and Request Summary

1.1. Capability is required at the St Fergus terminal to meet stakeholder needs to take gas on and off the system as and when they want. To ensure this capability can continue to be delivered and ensure continual safe and reliable operation of the critical terminal, National Grid is requesting funding to redevelop the Plant 2 area of the St Fergus Terminal. This is the most cost effective and lowest risk option.

1.2. The asset health investment associated with aspects other than Plant 1 or 2 are common to all cost-effective options considered. These investments are described as the no regrets asset health work for which funding is requested in the Asset Health Justification Papers (Cabs: A14.08, Compressors: A14.10, Plant & Equipment: A14.12, Valves: A14.14, Pipelines: A14.16, Civils: A14.18 and Electrical: A14.20).

1.3. More information on compressor investments associated with emissions legislation. can be found in the Compressor Emissions Compliance Strategy (CECS – Annex A16.05).

1.4. This preferred option has the following costs elements:

- Redevelopment of Plant 2, including 3 new compressor units.
- Resolving Plant 2 subsidence.
- Asset health for Plant 1. Some spend will be required to enable operation of the plant and compressor up to 2030.
- Decommissioning of Plant 1 once Plant 2 is commissioned (anticipated to be after 2030).

1.5. The cost of our proposed option is £244.1m for asset health, redevelopment of Plant 2 with 3 new compressors[4] and decommissioning of plant 1 thereafter. This is split into the following funding categories:

- [redacted] requested as no regret's asset health. Not requested as part of this funding request, included within the Asset Health Investment Plan.
- [redacted] baseline funding for Front End Engineering and Design (FEED) work at the beginning of RIIO-2.
- Funding for the remaining scope of plant 2 redevelopment and plant 1 asset health is not requested as ex-ante funding and will be subject to an Uncertainty Mechanism (UM) in year 3 of the RIIO-2 price control. We estimate this spend will be [redacted] over RIIO-2 and RIIO-3. More information on our proposed UM can be found in Annex A3.02.

1.6. The costs included in the JR and CBA included an initial set of assumptions surrounding the phasing of costs. Following the outcome and recommendation of the Cost Benefit Analysis, we looked at the deliverability of those phasing assumptions and chose to make some adjustments which, whilst changing the spend slightly per year, kept spend the same as included in the JR's and CBA's. We have included the costs with updated phasing in our TOTEX submission, and have not gone back to update the phasing in CBA's. The phasing would need to be updated across all options and therefore the impact on the outcome and recommendations provided

[4] Note: We have included the 3 new unit option as our preferred option in our RIIO-2 data tables as this is the central Capex option of the 3 lead options.

would be immaterial. Given the stage of the works at this site, it would not change the outcome of the options we propose to take to FEED. This difference is shown in Table 1.

Table 1: Preferred Option total costs £million, CBA and BPDT

Financial Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	TOTAL
CBA											
BPDT											

1.7. The evolution of St Fergus' total installed compression over time is described in Figure 1 and Table 2. The requirement for continuous operation of compression at the terminal dictates a phased replacement of compression assets. This creates periods of time where new compression exists alongside the compression it will replace. Only once the new units are operationally accepted, can older compression be removed. Our preferred option is mapped against total site compression in Figure 1. This demonstrates the overlap in site capability during construction but shows that the end state is a reduced compression capability on site.

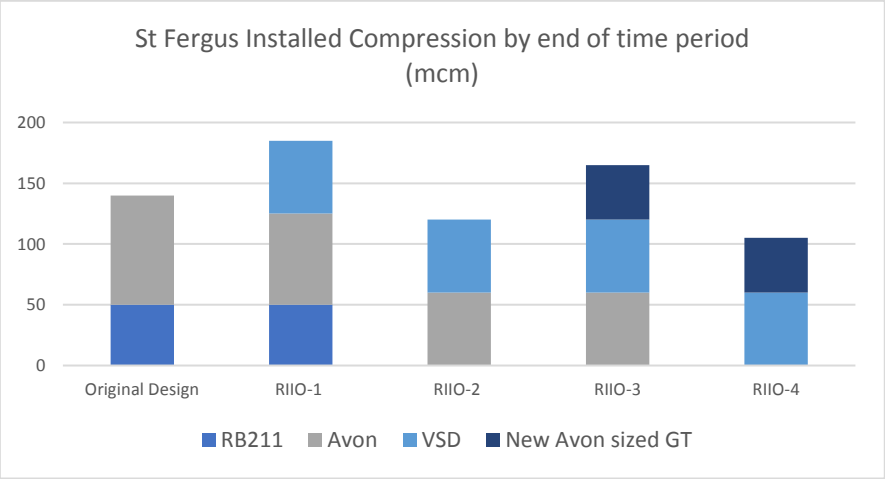

Figure 1: Total installed compression with time

Table 2: Compression changes with time

Original Design	6 Avons and 2x RB211s across plant 1 and plant 2
RIIO-1	1991 Avon 2C mothballed, 2015 Plant 3 and 2 VSDs commissioned
RIIO-2	Plant 2 redeveloped (1 Avon 2 RB211s removed)
RIIO-3	3 new Avon sized GT units commissioned (as per option 3b)
RIIO-4	Plant 1 and 4 Avons removed

2. Problem/Opportunity Statement

St Fergus Overview

2.1. The National Grid St Fergus gas terminal handles between 25% and 50% of the UK's gas supplies. The site has been in continuous operation for over 40 years and is now moving beyond the design life of the original critical assets. It is one of the most strategically important sites on the National Transmission Network (NTS) and one of the most critical in the wider UK energy system.

2.2. Similarly to our Bacton site, St Fergus is operational 24/7/365 and there has not been a complete maintenance outage of the site for its entire operating history. Although the sub-terminals which supply the site have regular maintenance outages, these are not coincident and usually occur for a few days at a time. Therefore, the terminal complex operates continuously.

2.3. The terminal receives gas from three sub-terminals (currently owned by Ancala, Shell and North Sea Midstream Partners/Gassco). Uniquely on the NTS, National Grid provide compression services for gas received from the NSMP terminal under the terms of the Network Entry Agreement (NEA). This is an historical legacy dating from when British Gas was privatised.[5]

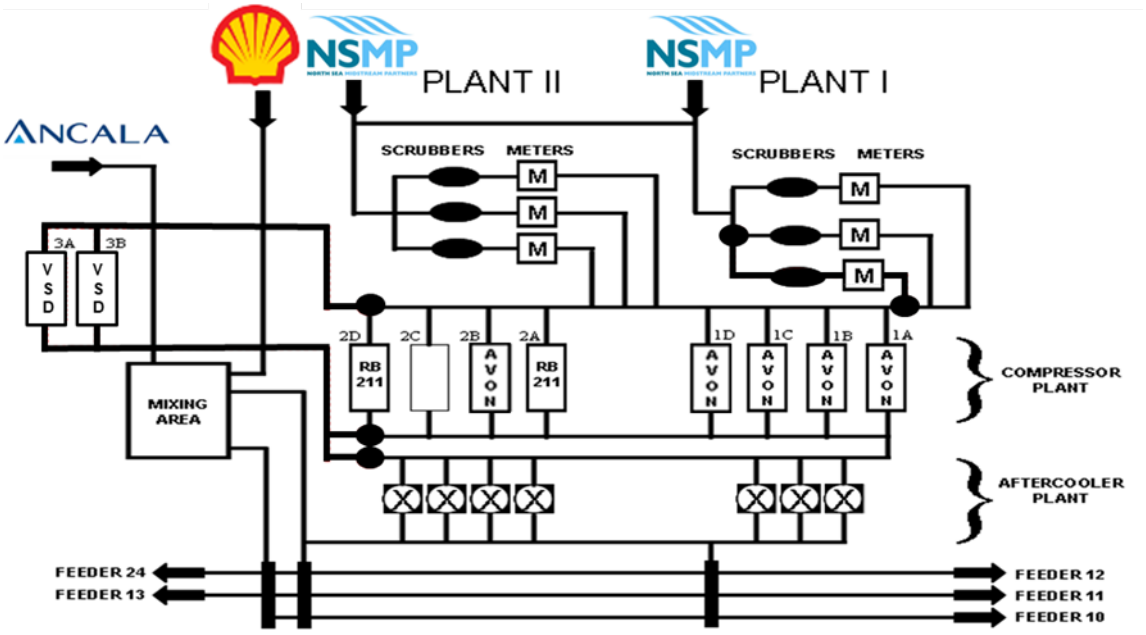

Figure 2: Terminal layout

2.4. There is an enduring need for the site until at least 2050 according to Future Energy Scenarios (FES), and the compression is used by our customers 24/7/365.

2.5. There is continued investment in the northern North Sea sector, with extensive new discoveries of natural gas coming on stream, particularly west of Shetland. There have been some substantial acquisitions of existing gas fields by new operators showing a long-term investment plan for the area. National Grid's St Fergus Terminal is critical in facilitating our customers current and future plans.

[5] More details are given in the commercial options section, paragraph 5.87

2.6. The terminal was commissioned in 1978 and is situated in an aggressively corrosive coastal environment. The present site requires extensive asset health investment to maintain safe, reliable and efficient operation. A significant volume of the assets are now life expired or operating beyond their original design life. Investment is now required to avoid the increasing rate of asset deterioration impacting on the safety and service levels of the St Fergus terminal.

2.7. The compressors at St Fergus have the combined highest running hours of the NTS compressor fleet (23% of 2018 total) and St Fergus is the highest polluting compressor emissions on the NTS (23% NO_x 13% CO and 10% CO_2 in 2018).

2.8. The compressors support the flows from the NSMP sub terminal. They do not provide compression for the general operation of the NTS. They are required to raise the pressure of the gas supplied via the NSMP sub-terminal to a pressure suitable for the gas to flow into the NTS. In contrast with all other compressors on the NTS, which are typically embedded in the network, St Fergus does not have an extended upstream pipe network so it must be able to respond to changes in the NSMP flow requirements on an almost immediate basis. As a result any necessary compression resilience must be fully located on site rather than relying on alternative sites for back up.

2.9. Inability to flow gas through the terminal for any reason has major implications for the offshore producers and the associated upstream processing plants. The continuous nature of the upstream gas processing plants means that interruptions to flow will have major implications for these processes which will generally result in flaring of gas until the processes can be shutdown or stabilised at low rate. More extended outages will result in shutdown of the offshore platforms impacting both gas and oil production once the linepack limits for the sea line have been reached. In the event that National Grid is unable to meet the end of day flow nominations, buy-back charges may be incurred.

2.10. The gas network in Scotland was designed to be fed solely by St Fergus flows, with very little ability to be supplied from the south. The effect of stopping flow into the network at St Fergus at any time of the year would impact gas supplies to Scottish consumers and businesses. The economic and societal impact would be significantly greater than the constraint management costs can quantify.

2.11. A wider effect on the NTS and UKPLC if St Fergus supplies were stopped., is that reliable and cost efficient North Sea gas would be reduced. The UK network would become heavily reliant upon imports. This has significant implications to security of supply, localised demand and supply shortfalls and would increase the price of gas.

2.12. The site is one of two top tier COMAH (Control of Major Accident Hazards) sites on the network, as it contains an inventory of [redacted] cubic metres of natural gas, hazardous material, which represents a major accident hazard which must be managed. Failure to do so represents a major process safety risk.

2.13. Table 3, along with whether the compressor unit is compliant with relevant emissions legislation.

Table 3: St Fergus compressor inventory and details

Plant	Unit	Engine	Fuel Type	Power Base (MW)	Emissions Non-compliance	Minimum Operational Flow (mscm/d)	Nominal Capacity (mscm/d)	Maximum discharge pressure (barg)
1	1A	RR/Avon	Gas	12.34	MCP	4	15	68.5
	1B	RR/Avon	Gas	12.34	MCP	4	15	
	1C	RR/Avon	Gas	12.34	MCP	1	15[6]	
	1D	RR/Avon	Gas	13.97	MCP	4	15	
2	2A	RR/RB211	Gas	21.2	LCP	11	30	
	2B	RR/Avon	Gas	13.97	MCP	4	15	
	2C	Empty	-	-	n/a	-	-	
	2D	RR/RB211	Gas	21.2	LCP	10	30	
3	3A	VSD	Electric	24	n/a	7	30	
	3B	VSD	Electric	24	n/a	7	30	

2.14. Since the commissioning in of the 2x Electric Variable Speed Drive compressor (3A and 3B) in 2015, these units have taken over the bulk compression load, supported by the existing Gas Turbine (GT) compressors.

2.15. Ofgem are considering our recent submission on compliance with the Large Combustion Plant Directive (LCP) at St Fergus and have issued a consultation on their minded-to view. This minded-to position does not support the need to construct any new compressor units at St Fergus at this time.

2.16. If the reopener outcome is the current minded to position, plant 2 will be placed on extended outage. The cost to maintain plant 2 for a single operational unit (Avon), is not considered value to the consumer, and the loss of compression capability is acceptable while the four remaining Avon units (plant 1) are unrestricted.

2.17. Our assumption following the minded to position is that we can continue to operate the Avon units on our current environmental permit basis until 2030. In anticipation of the minded-to outcome, National Grid has taken a step back to consider the site from a whole system perspective against current and future site requirements. This included evaluating asset health and all emissions compliance investments together, to deliver the best enduring solution for our customers, at the best whole cost to consumer. SEPA's expectation is that the investment being required at some point in the future (to meet the requirements of MCPD), we will meet the IED Chapter 2 (the old IPPC requirement) requirements as part of those works.

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

2.18. Our investment proposals at St Fergus will:

- Ensure that adequate levels of capability are maintained at St Fergus to meet stakeholder requirements to take gas on and off the system as and when they want.
- Comply with emissions legislation such as Large Combustion Plant (LCP – 31st December 2023 compliance) and Medium Combustion Plant (MCP – 1st January

[6] Avon 2C is limited via temperature control to 10mcm

2030 compliance). More information on this can be found within CECS, in Annex 23.05

- Rectify asset health issues in the most efficient way.

2.19. There is no practical option to “do nothing”. The condition of the assets and expected deterioration is likely to result in increasing plant failures and unavailability. This would result in constraint costs and upstream impacts to oil and gas production. Combined with the restrictions that will be imposed by upcoming emissions legislation affecting compression capability, supply restriction or supply loss at St Fergus is too severe to allow a “do nothing” option.

2.20. If this investment is not funded, we will still need to comply with MCP and LCP legislation. Therefore, the following would need to occur:

- Decommissioning of the RB211s on plant 2 in 2023.
- Derogating to 500hrs the Avons on plant 1 by 2030.
- Extended outage of Plant 2 (2x RB211, 1x Avon); it is likely that plant 2 would be permanently disconnected.

2.21. This Option is treated as the “**counterfactual”** in our analysis.

2.22. The total combined compression capacity of the current site is 180mcm, accounting for unit 1C 10mcm limit, allowing different combinations of units to provide the range of up to 75mcm with sufficient redundancy. If the counterfactual investment, described in paragraph 2.20 above, were enforced, combined capacity would be reduced to 60mcm unrestricted (2 VSDs) and 60mcm limited to 500hr per year (4 Avons). This would not provide sufficient cover of the full range of flows and not provide sufficient resilience to unit planned or unplanned outages.

2.23. The only unrestricted use units on site would be the 2x electric drives which are dependent on external electricity supplies and for which there are no fleet spares. Both of these factors could result in extended outages of the electric drives which would result in the 4x Avons on Plant 1 quickly approaching their 500hr limit as they attempt to fully cover the VSD duty. The VSDs can only provide compression when flows are above 22.4mcm/d, therefore 100% of flows below this level can only be covered by the Avons. Restricted hour units would not be sufficient, causing constrains and network supply disruptions. This is detailed in Section 6 of this report.

2.24. In this counterfactual flows through St Fergus would be regularly constrained. We estimate the constraints to be greater than £120m pa from 2030, due to the Avon’s restricted hours and consequentially being unable to cover the range of flows

2.25. There would be an additional asset health investment requirement of £84m on Plant 1 to facilitate the counterfactual. This is in addition to the £64.6m requested for no regrets asset health elsewhere on the terminal.

Under what circumstances would the need or option change for this project?

2.26. A fundamental change in the need to provide compression would change the need for this project. The need for compression at St Fergus is driven by a contractual arrangement and is also dependent on North Sea gas flows into the sub terminal. Consultation with stakeholders confirms there is no appetite to amend the contractual

arrangement and that there is an enduring need and business gas for North Sea gas flows.

2.27. Legislation changes to weaken or enhance the environmental requirements such as bringing forward compliance dates or different guidance on the 500hr derogation application. However, we anticipate that any changes if made would enhance rather than weaken requirements, and it would affect our older compression fleet before the new units we would propose to install through these proposals.

2.28. The proposed option could change as a result of the FEED study, whereby costs and available technology become more certain. This risk is mitigated by inclusion of an Uncertainty Mechanism, which will reflect the optimum option and costing following FEED. Costs for post-FEED activities have not been included in the baseline and will be included following the proposed reopener. Please see Annex A3.02 for further information.

What are we going to do with this project?

2.29. Our current proposal is to redevelop Plant 2 with 3 new Gas Turbine (GT), Dry Low Emission (DLE) compressors. This will give the site a combined unrestricted compression capacity of 105mcm. This provides the resilience of 75mcm if one of the largest units (VSD) became unavailable. The 3 new units provide back up to an electric drive unit as well as covering the primary duty of below 22.5mcm flows and above 60mcm flows.

2.30. The decommissioning of the existing compressor units on Plant 2 (2 RB211s and 1 Avon) is undertaken as part of the redevelopment work. Our expectation is to then decommission Plant 1 and the 4 Avons post 2030.

What makes this project difficult?

2.31. The 24/7/365 nature of the compression requirement at St Fergus requires the compression to be fully maintained through the construction period. Our customers and stakeholders have indicated that no significant compression outages will be available. This is due to the effective shut down of winder upstream wider North Sea Oil and gas production that would be created under a full NSMP outage.

2.32. Pipework which connects Plant 3 and the VSDs to metering and aftercoolers of plant runs through Plant 2. This pipework will need to be kept operational throughout the redevelopment and construction on plant 2.

2.33. Integrating existing plant 1 Avons, existing VSDs and new compressor units presents complex control system requirements.

2.34. The location of St Fergus presents a challenging local climate. The remoteness of the location impacts the efficiency of delivery and contractor availability.

2.35. During the construction of the new compressors, the maintenance and availability of the retained VSD compressor and Plant 1 Avons will be more critical. Greater reliance will be placed on the remaining units whilst others are offline for maintenance.

2.36. Funding uncertainty may lead to a reduced appetite from contractors and OEMs to tender for the work. National Grid has experienced this during the LCP reopener process with Hatton and St Fergus.

What are the key milestone dates for project delivery?

2.37. Key milestone dates for the project are:

- Commence FEED feasibility April 2021
- Uncertainty Mechanism reopener submission – November 2022
- Uncertainty Mechanism reopener decision – March 2023
- Commissioning of Plant 2 redevelopment and new compressors build – financial year 2028
- Project close out – financial year 2029

How will we understand if the project has been successful?

2.38. Once a fully compliant and working compression facility has been operationally accepted, it will be able to meet the current and future compression requirements and do so in a more environmentally sustainable way.

2.39. Delivery of FEED and subsequent construction project will be measured through Price Control Deliverable (PCDs). More information on these can be found in Annex A3.01.

2.40. We achieve carbon neutral construction for the St Fergus Construction by following an external framework to reduce our capital carbon from construction as much as possible, then offset the remaining emissions.

2.41. Maintaining Security of UK energy supply, facilitating enabling supply at St Fergus maintains the environmental and economic efficiency of using North Sea supplies, compared to other import sources. This impacts UK consumer's energy bills. It will also reduce the need to rely upon gas imports from less politically stable sources.

Related Projects

2.42. Ofgem are currently considering our recent submission on compliance with the Large Combustion Plant Directive (LCPD) at St Fergus and have issued a consultation on their minded-to view. This minded-to position does not support the need to construct any new compressor units at St Fergus at this time.

2.43. Our July proposals assumed an investment outcome for this LCP project and an aligned asset health investment plan ([redacted] across RIIO-2 and RIIO-3) and further emissions work ([redacted] across RIIO-2 and RIIO-3) were developed.

2.44. Subsidence has also been discovered on the site, which had not been fully assessed in time for the July submission, and required more investigation. This is now reflected in this version of our business plan.

2.45. The size, criticality and age of the St Fergus terminal means that we have reviewed all other RIIO-2 and RIIO-3 proposed investments at the site to enable us to determine the optimum future strategy for the site.

2.46. Specifically, the RIIO-2 and RIIO-3 investments related to, but independent of our proposal for Plant 2 redevelopment are:

- Enhanced Physical Security Systems (Annex A15.08)
- Asset Health Investment Plan (multiple Annexes)
- Cyber Resilience Plan (Annex A15.07)

2.47. We undertook a number of other emissions compliance projects in RIIO-1 and learnings will feed into our RIIO-2 compressor emissions compliance projects. More information on this can be found in CECS annex A16.05.

Project Boundaries

2.48. Several aspects of the site's investments are deemed out of scope of the uncertainty mechanism. This is any investment which is:

- Common to all options.
- Where critical investment is required in RIIO-2, but prior to the UM outcome decision.

2.49. These investment themes are accounted for separately in the relevant Justification Papers. Figure 3 below indicates theses out of scope aspects in a simplified site block diagram.

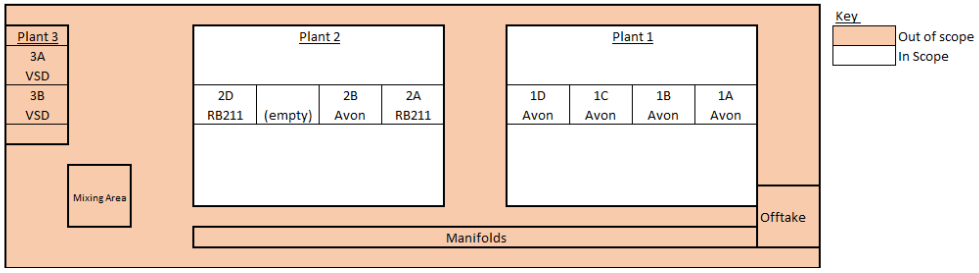

Figure 3: St Fergus terminal UM project scope indication

2.50. Out of scope (contained within No Regrets Asset Health plan or Enhanced Physical Security Systems) and common to all investment options considered in CBA:

- Asset Health on Plant 3 and VSD compressors (x2)
- Mixing area
- Manifolds
- Offtake
- All other aspect of the terminal not directly linked to Plant 1 or Plant 2
- Enhanced Physical Security Systems

2.51. In scope of the FEED considerations and UM:

- Asset Health for Plant 1
- Asset Health for Plant 1 Avons (x4)
- Asset Health for Plant 2 – starting position is that it is on extended outage
- Asset Health for Plant 2 Avon (x1)
- When to decommission Plant 2 RB211s (x2)
- New compression on existing Plant 2 or Greenfield

2.52. None of the asset health investments forecast for Plant 1 or the 4 Avons are planned until later in RIIO-2. We propose using the uncertainty mechanism (UM Decision by the start RIIO-2 Year 3) to request funding for this work, which would also include any urgent, but unanticipated asset health work on Plant 1 prior to the UM. This will enable the asset health investment decision to be made on the basis of clear knowledge on the future need for the Plant 1 compression area. If the UM decision is delayed, then asset health interventions on Plant 1 and Plant 1 Avons may need to begin to ensure compliance due to the constrained access of only having plant 1 and the VSDs operational.

3. Project Definition

Supply and Demand Scenario Discussion and Selection

3.1. We have used the Steady Progression scenario from the 2018 FES as the base scenario for this proposal and this is consistent with our other business plan proposals. The other FES scenarios are considered as sensitivities. Figure 4 shows the Peak supply for the UK Gas terminals within Steady progression with St Fergus imports shown at the bottom.

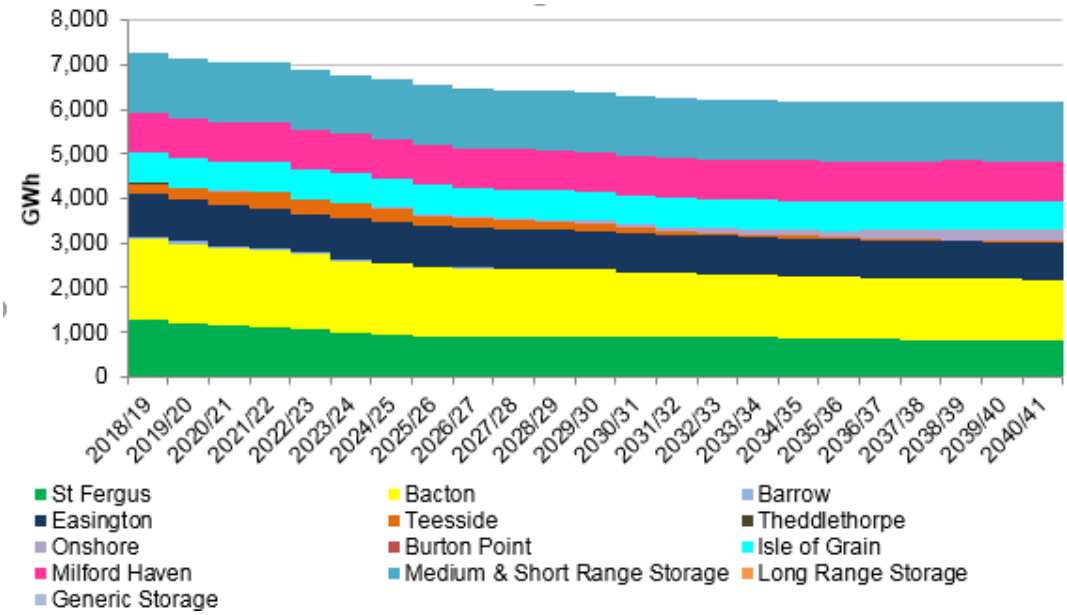

Figure 4: Peak Supply by Terminal, Steady Progression

Current Operation

3.2. Gas flows from the NSMP sub-terminal and enters St. Fergus terminal at a pressure of approximately 40 barg. The gas then flows through scrubbers and meter streams before passing through the compression plants where the gas pressure is raised. Depending on network conditions this is typically to between 60 barg and 65 barg, although often up to the maximum allowable system pressure for this part of the network of 70 barg. The gas is then cooled in the aftercoolers to remove the heat of compression before joining gas from the Apache and Shell sub-terminals. The gas is supplied into the NTS down the five pipelines towards Aberdeen and further south.

3.3. Individual Avon units can support a nominal flow of 15 mscm/d, whilst the individual RB211s and VSDs can support flows of up to 30 mscm/d.

3.4. Plants 1 and 2 offer flexibility; they can operate independently but are generally operated together. The supporting assets – scrubbers and after-coolers – are nominally assigned to the individual plants but can also be cross connected. Plant 3 provides baseload compression and is designed to operate in conjunction with Plant 1 and/or Plant 2 as these provide the necessary scrubbing, metering and after cooling.

3.5. For over 40 years of operation (circa mid-1970s to 2012) two RB211 driven compressor units provided primary compression capacity at the St Fergus site, run in

conjunction with the five Avon compressor units, the 6th Avon unit 2C was moth balled in 1991. This provided successful operation for many years. A significant change occurred when the Plant 3 electrically powered VSD units were introduced, and since this point the VSDs and Avons have provided the main compressor capacity, with the RB211 units being used as backup to the VSDs.

3.6. The VSDs provide bulk compression capability, effectively mimicking the capability of the RB211s. To effectively map the entire operating envelope of the site, the smaller Avon gas units continue to be required for when flows are:

- below the minimum turndown capacity of a single VSD
- mid-range i.e. greater than a single VSD but less than two VSDs at minimum turndown capacity
- very high i.e. greater than two VSDs in parallel.

3.7. This is summarised in Table 4 along with compression requirement to provide resilience to the loss of one of the VSD compressors.

Table 4: Flow range and corresponding compression

NSMP Flow Range (mcm/d)	Primary Compression	If 1x VSD is unavailable
0 - 15	1 Avon	1 Avon
15 – 22.5	2 Avons	2 Avon
22.5 - 30	1 VSD	1 VSD
30 - 45	1 VSD + 1 Avon	1 VSD + 1 Avon
45 - 60	2 VSD	1 VSD + 2 Avons
60 +	2 VSD + 1 Avon	1 VSD + 3 Avons

3.8. The Avons (or any future compressor units) provide primary compression duty at the lower flows below 22.5mcm, supporting middle flows 30-45mcm and at the top end for flows above 60mcm.

3.9. In addition, there is a requirement for gas turbine driven compressors to provide back up in the event of loss of the incoming electrical power supply or unavailability of the VSDs because of maintenance (the site operates 24 hours a day, 365 days a year).

3.10. The primary means of achieving the required flexibility is by selecting a combination of compressors of appropriate capacity with further flexibility achieved by exploiting the range of individual compressors. A load share controller ensures that the compression duty is shared evenly between the online compressors. Further flexibility in operation can be achieved by recycling gas via the plant recycle line but this is both noisy and inefficient and is thus minimised.

3.11. From an operational perspective, flows through St Fergus have always shown a high degree of variability. As shown by the red bars in Figure 5 in the mid-2000s, typical daily flows through NSMP's sub terminal were more than 50mscm/d. However, from 2009 flows were significantly lower and with the decline in UKCS gas, flows of 10-20mscm/d were more common.

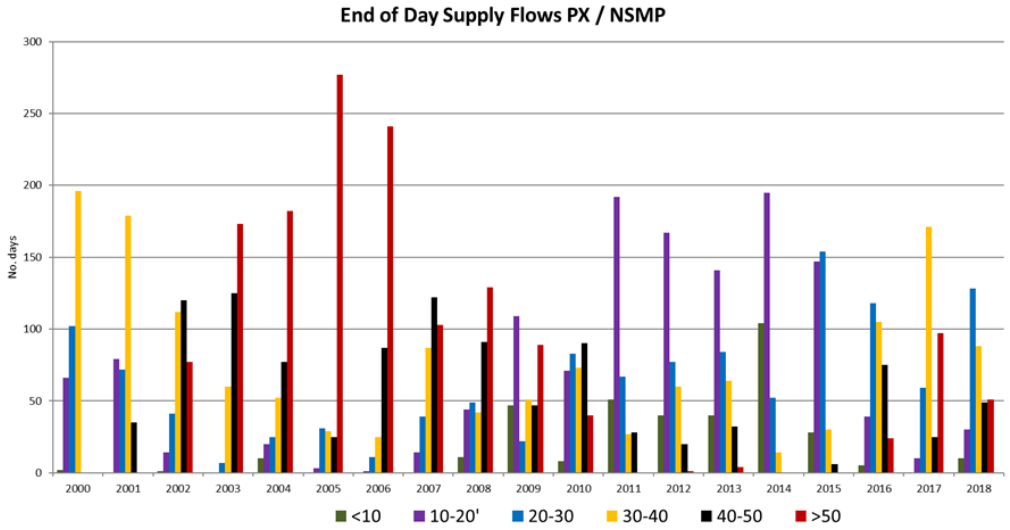

Figure 5: NSMP Flows by year

3.12. In 2016 with a change of ownership at the sub-terminal, there was a marked change in flows. Typical flows at the sub-terminal increased up to the region of 30-40mscm/d and then in October 2016 there was another significant increase up to 50-60mscm/d. On two days in January 2017 flows exceeded 60mscm/d. NSMP has indicated that flows are likely to be around the 50mscm/d level for the foreseeable future and potentially higher.

Future Requirements

3.13. The obligated entry level at the St Fergus Aggregated System Entry Point (ASEP) is 154.22 mcm/d. This is the total entry for all three sub-terminals, Apache, Shell and NSMP and it is not broken down to sub-terminal level. The compression requirement at St Fergus relates to the NSMP flows only.

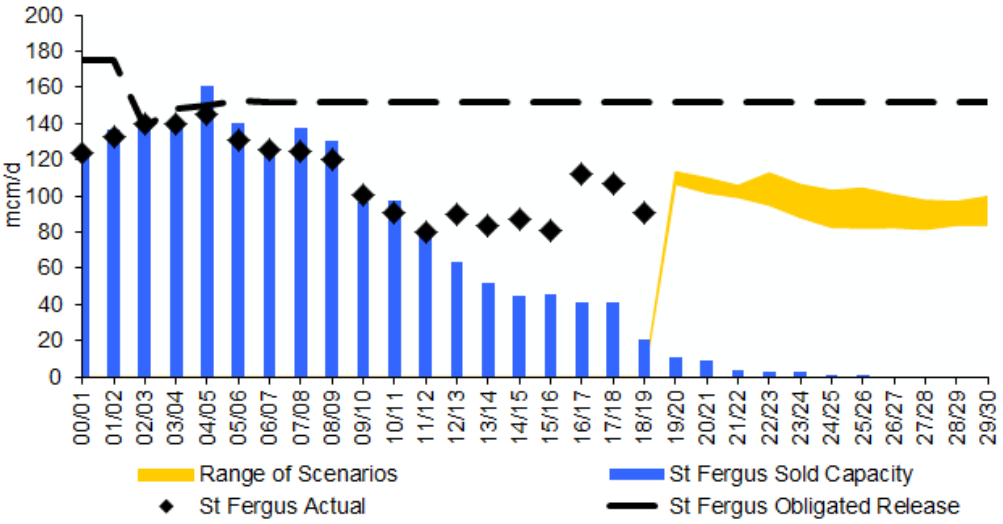

Figure 6: St Fergus capacity and flow - GTYS 2018

3.14. The chart above shows the level of long-term capacity sold at St Fergus since 2000. The long-term sold levels are well below the entry baseline for the ASEP with shippers deciding to wait to obtain capacity on the day for free as opposed to paying the entry charges. Therefore, sold levels cannot be taken as a guide to the likely physical flows through the ASEP into the future.

Requirements under FES

3.15. Looking to the future, the analysis carried out as part of FES 2018 indicates there is a capability requirement at St Fergus out to 2040 and beyond. The forecast flow range for NSMP is large, between 10 mcm/d and 68 mcm/d across the four different scenarios. Overall, the predicted flows show a slight decline over the next 10 years, with existing gas field decline being largely offset from 2024/25 by new fields connecting in at the West of Shetland. The change in ownership at NSMP, and the strategy for their upstream assets is likely to push actual supplies towards the top of the range in the chart below.

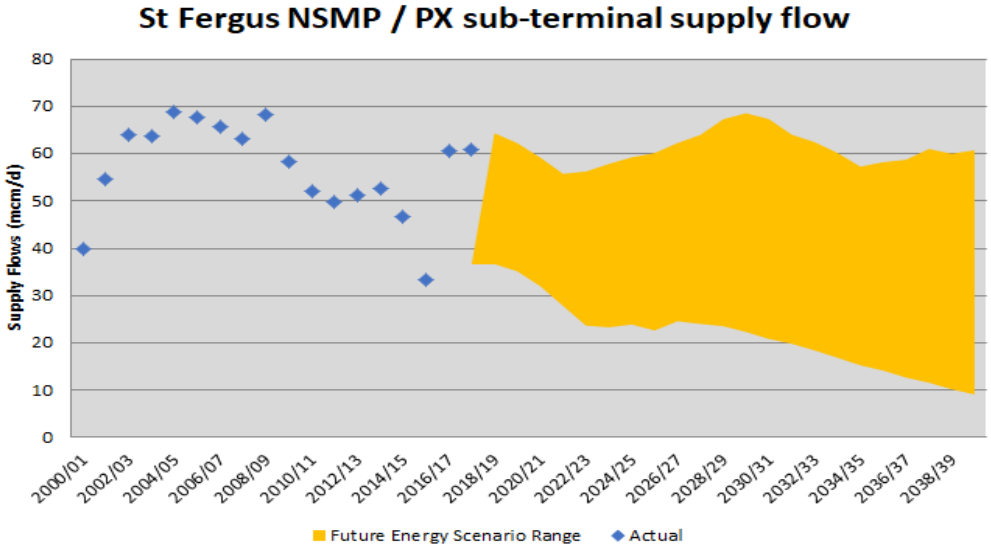

Figure 7: St Fergus NSMP sub-terminal flow – GTYS 2018

3.16. Figure 8 shows the capability assessment of NSMP flow into St Fergus under the steady progression scenario (the full range of flows in all 4 FES 2018 scenarios in this assessment are show in the appendices). This chart also shows the importance of compression flexibility across VSD's and Avon sized units, in order to meet the flow ranges.

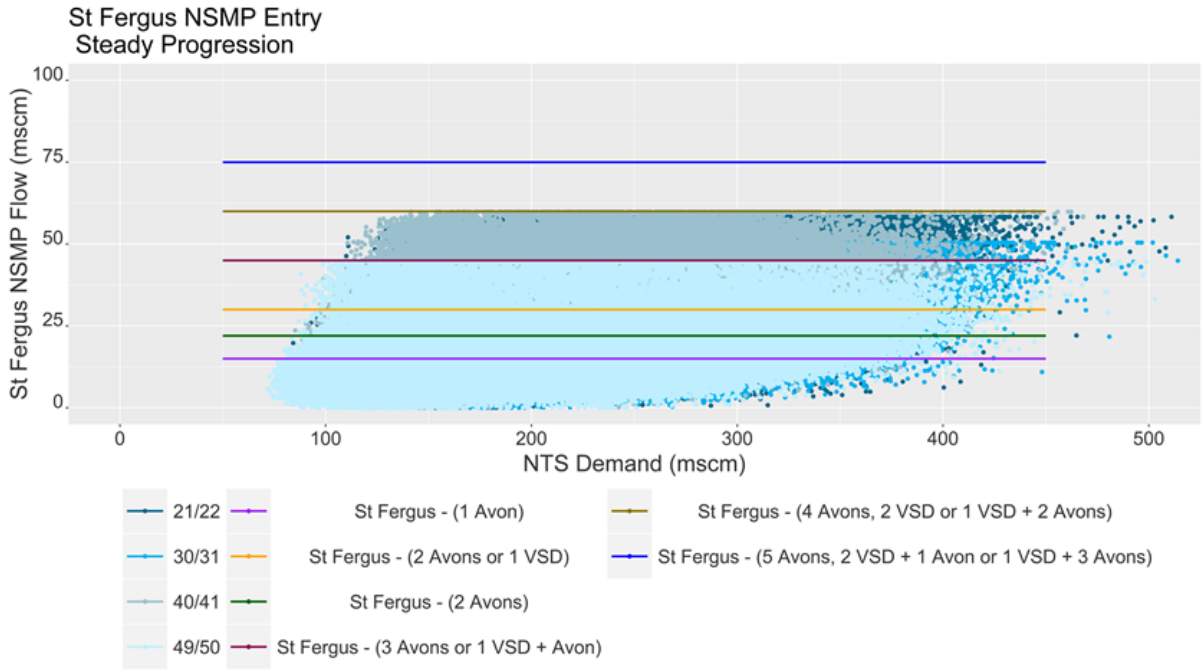

Figure 8: NSMP Entry Capability (FES 2018 Steady progression only) an compressor combinations

The Network Entry Agreement

3.17. NSMP acquired the former Total Oil and Marine (TOM) sub-terminal in August 2015. It is operated on their behalf by PX Limited. PX Limited signed an accession Network Entry Agreement (NEA) contract on the 15th March 2016. Contractually, the NEA specifies the pressure of the gas supplied (between 41 and 44 barg).

Standby requirements

3.18. The compression at St Fergus is used to provide a sub-terminal specific pressure service, not bulk transmission, hence there is no viable option to turn down demand, known as Operating Margins (OM). There is also no ability for any other compressor site to provide back up. The Transmission Planning Code (TPC) sets out what should be assessed when considering compressor standby. Any investment decision therefore considers the required transmission capability, forecast compressor run hours, economic and efficient system operation, maintenance and fuel security (electricity and/or gas).

Future Requirements Summary

3.19. The assessment of the site's future requirements is a key factor in the St Fergus options assessment and analysis in the next section. This is informed by the maximum level and also the potential range of compression required going forward. The key values for the maximum flow rates are:

- 68 mcm/d – The highest peak flow from NSMP (2018 FES, Consumer Evolution);
- 68mcm/d highest flow seen recently (February 2018)
- 74mcm maximum flow rate since the 2015 in change of ownership (November 2016)

- 75 mcm/d – The peak capability of the upstream NSMP Ltd pipelines;

3.20. And the minimum flow required is:

- 2mcm/d – The minimum flow requested by NSMP
- 5mcm/d - Minimum average day flows to date from NSMP

Project Scope Summary

3.21. Engineering scope of the project:

St Fergus Plant 2 Redevelopment	
Location	St Fergus Terminal
Number of units[7]	Three medium sized new units on Plant 2; Maintaining 4 Avon units on Plant 1 until Plant 2 is fully operational.
Size of units	New units: Medium – circa 12-15MW, subject to BAT
Type of unit	Gas Turbine (GT)
Other Scope	Address subsidence on Plant 2 Auxiliary equipment on Plant 1 and Plant 2
Scope boundaries	The scope of this project is the asset health and MCPD compliance investments on Plant 1 and 2 at St Fergus.
Station design discharge pressure	Up to 70 barg
Design capacity (maximum flow)	75mscm/d[8]
Availability required	100% terminal compression availability; 100% auxiliary equipment availability on Plant 2

Stakeholder Engagement

3.22. As part of our RIIO-2 stakeholder engagement programme we held a workshop in summer 2018 at a venue close to the St Fergus terminal. We have also held 1:1 sessions with offshore companies and our safety and environmental regulators. A proportion of this engagement was about our St Fergus terminal and our stakeholder's requirements of it. We have not yet engaged in detail on the particular proposals in this project.

3.23. In the summer 2018 workshop we gave a series of overview presentations which were followed up with facilitated discussions and voting to capture stakeholder's views. In particular, we asked about the consequences of interruption to gas supplies coming in through St Fergus. Key things we were told which have also been substantiated in 1:1 meetings are:

- Unplanned interruptions to service would quickly lead to flaring of gas, dependent on the length of physical infrastructure between us and the offshore terminal. For Px this is almost instantaneous.
- There is a strong interaction between gas and oil production in the North Sea, whereby if we caused gas production to be shut down it would also cause oil production to be shut down.
- The market is very commercial; if the cost of entry to the UK is too high, or our service is unreliable, gas supplies may be diverted away from the UK to other European markets.

[7] Note : actual combination of new and/or derogated units will be determined during FEED study.
[8] The maximum design flow be assessed under FEED, whether the maximum of 75mcm/d is considered value above the FES peak flow of 68mcm/d

- Whilst there was almost no tolerance to unplanned outages, stakeholders thought that periodic planned outages could only be facilitated for up to 6 hours each day.

3.24. We have also been engaging with the St Fergus stakeholders on their long-term requirements for the terminal. This has resulted in the following findings:

- Ancala are experiencing high flows from Norway, which is rich/ high calorific gas. Norwegian gas is likely to come into St Fergus more in the future and they are keen to arrange a blending service.

- Gassco reported that their shippers had supported significant investment in North Sea assets feeding into St Fergus to maintain their current capability rather than pursuing a cheaper reduced capability option. They have gas fields that feed into St Fergus which have a 30 year life.

- Gassco informed us that the St Fergus terminal was seen as being really important, even though the cost differential can make it more attractive to land gas at Easington.

3.25. On the compression requirements for St Fergus we have been engaging with Px. They have said that:

- Flexibility in compression provision from 75mcm/day down to 2mcm/day is important to them.

- Reliability of compression is very important; we meet with them regularly to discuss compressor reliability.

3.26. In response to the LCP minded to position, the Scottish Environmental Protection Agency (SEPA) acknowledged that investment in RB211 replacement compressors could be deferred, with the site relying on the unrestricted Avons in the interim. However they were clear that whilst they support the no investment position for LCP, this was predicated on the terminal requiring emissions investment under MCPD. SEPA were clear that this should form part of National Grid's Compressor Emissions Compliance Strategy (Annex A16.05).

4. Options Considered

4.1. Both commercial and physical investments have been considered to determine the preferred solution. The 24/7 nature of St Fergus compression, and the variation in flow rate that is seen, requires a reliable, resilient and flexible compression capability. Commercial options were considered but were discounted, having many of the same challenges as obtaining outages at St Fergus discussed in Section 3. The options considered, both commercial and physical, are discussed in detail in within this section.

Physical Options

4.2. Our assumption for the RIIO-1 LCP reopener is no investment at this time. This is likely to result in an extended outage of the existing Plant 2 in RIIO-1 since, to use the plant and remaining Avon, significant asset health investment would be required. This will mitigate risks associated with asset integrity issue and avoid inefficient investment while the long-term future of the plant and compression is under review. Whilst this decision will increase operational risk on site due to reduced capacity, the four unrestricted Avon's are expected to be able to deliver operational requirements in the interim.

4.3. As a result, the options considered have a starting point of plant 2 being on an extended outage. In any options where the existing plant 2 is required, the asset health work reflects returning the plant to service and the asset health scope required to maintain it.

4.4. A range of options have been considered as part of our assessment, from complete site rebuild to do nothing. However, some were ruled out early on in the process; see discounted options section for further details.

4.5. All asset health, emissions compliance, control system and cyber security costs were included within the options for CBA assessment.

4.6. The compression at St Fergus is split into 3 Plant areas, as shown in the site layout in Figure 9. Plant 1 and Plant 2 can operate in isolation whereas Plant 3 requires the use of either Plant 1 or Plant 2's scrubber, metering and aftercoolers in order to operate.

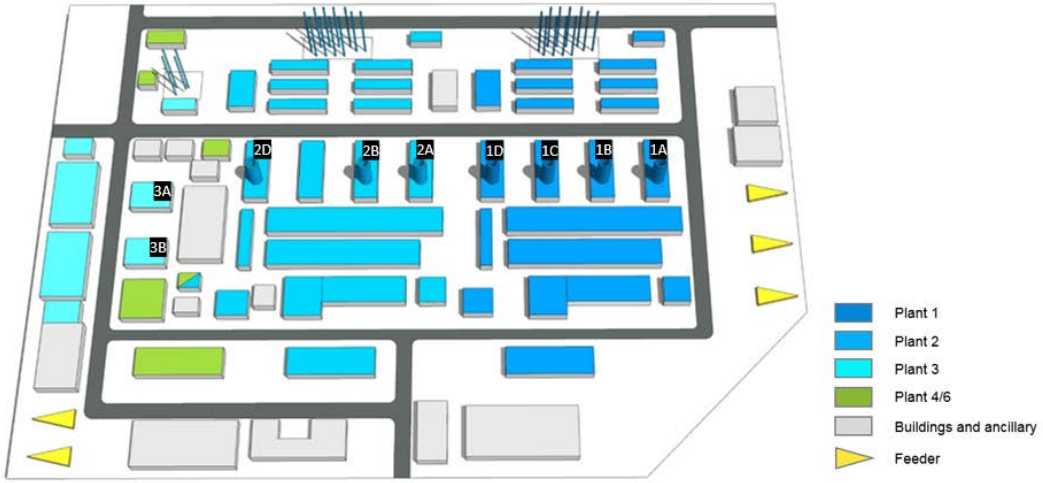

Figure 9: Site Layout by Plant No. and compressors

4.7. The options shown in the table below were costed and analysed and are detailed individually in this section.

4.8. All options considered require long-term use of the plant 3 VSD compressors, mixing area, incoming pipelines from suppliers, mixing manifolds and general site facilities. Investment in these areas of plant is common to all Cost Benefit Analysis (CBA) options. The option titles describe the variable aspects of the options.

Table 5: Considered Options

Option Number	Option Title
0	Derogate 4 Avons (plant 1 only). Decommission plant 2.
1	Derogate 5 Avons (plant 1 and 2)
2a	Existing plant 2: 2 new units and 1x derogated Avon Plant 1: Decommission after 2030
2b	Existing plant 2: 1 new unit + 1x derogated Avon Plant 1: Decommission after 2030
2c	Existing plant 2: 3 new units Plant 1: Decommission after 2030
3a	Redeveloped Plant 2: 2 new units and 1x derogated Avon Plant 1: Decommission after 2030
3b	Redeveloped Plant 2: 3 new units Plant 1: Decommission after 2030
3c	Redeveloped Plant 2: 3 new units (1 large) Plant 1: Decommission after 2030
4	New Greenfield Plant: 2 new units Decommission plant 1 and 2 after 2030

4.9. Option group 2 retains the existing plant 2 equipment. They require the return to service of plant 2 in addition to significant asset health interventions to repair or replace equipment.

4.10. Option group 3 redevelops plant 2 by removing current assets and rebuilding t with new assets. This redevelopment will be within the existing Plant 2 footprint and will provide the ancillary services, such as metering, scrubbing and aftercooling, to plant 3.

4.11. Options which decommission plant 1 after 2030, model the decommissioning in calendar year 2030 for simplicity. The optimum time to do so may be different, but 2030 is used for an estimate as this is the beginning of MCP legislation. This would be continually assessed according to need.

4.12. Each option is described in detail in the remainder of this section. A colour ranking system has been applied to key assessment criteria to visually demonstrate the options effectiveness and cost. The Cost Benefit Analysis results are shown in section 6, including the Net Present Value.

Table 6: Red Amber Green assessment criteria

RAG Status Definition	
Insufficient compression to meet customers Insufficient resilience High relative Asset Health spend High relative capital cost Challenging delivery due to site constraints	Sufficient compression for customer needs Sufficient resilience Low relative Asset Health spend Low relative capital cost Offline delivery

Table 7: Option RAG assessment summary

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
0 Derogate 4 Avons (plant 1 only).						
1 Derogate 5 Avons (plant 1 and 2)						
2A Existing plant 2: 2 new units and 1x derogated Avon						
2B Existing plant 2: 1 new unit + 1x derogated Avon						
2C Existing plant 2: 3 new units						
3A Redeveloped Plant 2: 2 new units and 1x derogated Avon						
3B Redeveloped Plant 2: 3 new units						
3C Redeveloped Plant 2: 3 new units (1 large)						
4 New Greenfield Plant: 2 new units						

Option 0 (counterfactual) Derogate 4 Avons (plant 1 only)

Description

4.14. This option is the minimum investment option in RIIO-2 and RIIO-3 to maintain the existing compressors across the operational areas of site. For existing Avon compressors to be compliant with emission legislation, they would need to be restricted to 500hr emergency use derogations.

4.15. Plant 1 is kept with the 4x Avons (1A, 1B, 1C and 1D) placed on 500hr derogation. The Avons would be subject to Asset Health interventions ahead of the 1st January 2030 compliance date to make sure the units are maintained to a suitable level for running past 2030.

4.16. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.17. The simplified block diagram below shows investment types within this option for 2030:

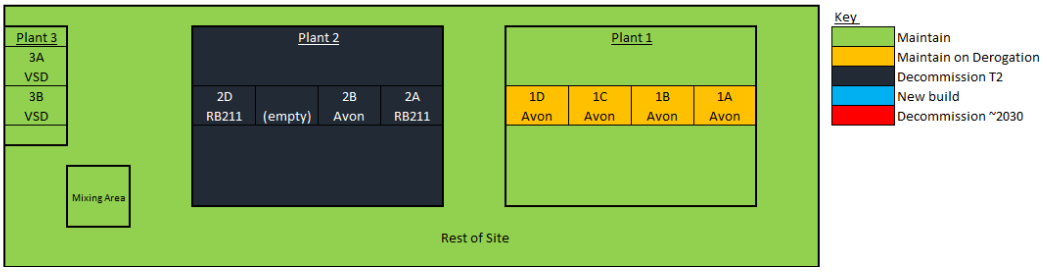

Figure 10: Option 0 investments indication diagram

Table 8: Option 0 cost estimates £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 ▪ 500hr Interventions for Avons 1A, 1B, 1C, 1D ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site	47.5	93.1
Major Construction	▪ None	0	0
Decommissioning	▪ Plant 2	7.5	0

Option Pros and Cons

4.18. This option reduces back-up to the primary VSD's, as the Avon's are restricted to 500 hours. Therefore, we will not be able to meet compression requirements at lower or higher flows, as all Avon hours will be used in the first part of the year. Significant constraint costs would be incurred.

4.19. Additionally, in the event of a VSD being unavailable, the resilience on site is limited by the amount of remaining Avon hours, with significant constraints once 500hours is used. Two Avons are required to compensate for one VSD, therefore in this instance Avon hours would be depleted at an even higher rate.

4.20. Continued high use of Plant 1 would have high ongoing asset health cost, due to the age of the plant and equipment. Achieving the partial outages required to maintain

Plant 1 and the 4 Avons for long term use, whilst the Avon's remain operational will be challenging, given the 24/7/365 nature of the compression and variable incoming flows. Asset health works would be difficult to schedule, adding time and cost.

Table 9: Option 0 RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
0 - Derogate 4 Avons (plant 1 only).						

Option 1 - Derogate 5 Avons (plant 1 and 2)

4.21. This option maintains the maximum existing compression and requires the existing Plant 2 to be fully operational. Plant 2 will therefore require asset health work to return the plant to service and the asset health scope required to maintain it on an enduring basis. For existing Avon compressors to be compliant with emission legislation, they would need to be restricted to 500hr emergency use derogations from 2030.

4.22. Plant 1 is maintained with asset health interventions to allow 500hr derogation for Avons 1A, 1B, 1C and 1D. Plant 2 is returned to service and maintained to keep unit 2B operational. The 5x Avons would be subject to Asset Health interventions within T2/T3 ahead of 1st January 2030 derogations to make sure the units are maintained to a suitable level for running past 2030.

4.23. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.24. The simplified block diagram below shows investment types within this option for 2030:

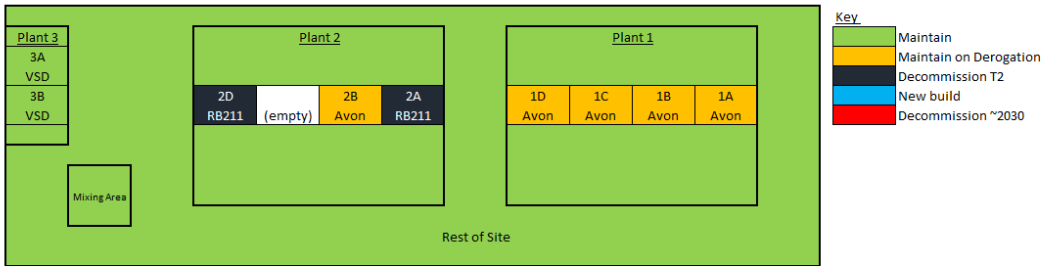

Figure 11: Option 1 investments indication diagram

Table 10: Option 1 cost estimates £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 ▪ 500hr Interventions for Avons 1A, 1B, 1C, 1D, 2B ▪ Return Plant 2 to service and maintain ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain Mixing area ▪ Maintain rest of site	[redacted]	
Major Construction	▪ None		
Decommissioning	▪ RB211 x2		

Option Pros and Cons

4.25. This option reduces back-up to the primary VSD's, as the Avon's are restricted to 500 hours. Therefore, we will not be able to meet compression requirements at lower or higher flows, as all Avon hours will be used in the first part of the year. Significant constraint costs would be incurred, despite the extra Avon being available compared to option 0.

4.26. Additionally, in the event of a VSD being unavailable, the resilience on site is limited by the amount of remaining Avon hours, with significant constraints once 500hours is used. Two Avons are required to compensate for one VSD, therefore in this instance

Avon hours would be depleted at an even higher rate than with just their low flow and supporting high flow duty.

4.27. Continued high use of Plants 1 and 2 would have high ongoing asset health cost, due to the age of the plant and equipment. The cost of restoring and maintaining plant 2 for a single operational unit (Avon), is not considered value to the consumer. Achieving the partial outages required to maintain Plant 1 and the 4 Avons for long term use, whilst the remaining Avon's remain operational will be challenging, given the 24/7/365 nature of the compression and variable incoming flows. Asset health works would be difficult to schedule, adding time and cost.

Table 11: Option 1 RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
1 Derogate 5 Avons (plant 1 and 2)						

Option 2A - Existing plant 2: 2 new units and 1x derogated Avon

4.28. In this option Plant 2 is returned to service, with the addition of 2 new Gas Turbine compressor units (2E and 2F) and Avon unit 2B placed on derogation. Plant 2 will therefore require asset health work to return the plant to service and the asset health scope required to maintain it on an enduring basis. Plant 1 and the 4x Avons are utilised during the Plant 2 return to service asset health works and compressor builds and would be decommissioned appropriately following works.

4.29. Reduced asset health works are required for Plant 1 and the 4x Avons as they are not operational beyond 2030. Avon 2B would be subject to Asset Health interventions within T2/T3 ahead of 1st January 2030 derogation to make sure the unit is maintained to a suitable level for running past 2030.

4.30. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.31. The simplified block diagram below shows investment types within this option for 2030:

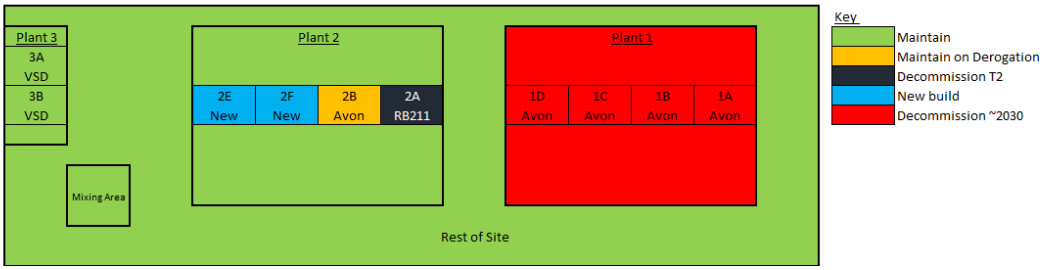

Figure 12: Option 2A investments indication diagram

Table 12: Option 2A cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ 500hr derogation intervention Avon 2B ▪ Return Plant 2 to service and maintain ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site	[redacted]	
Major Construction	▪ 2 new compressors on existing plant 2		
Decommissioning	▪ 1x RB211 (2nd accounted for in new build on its berth) ▪ Plant 1 2030		

Option Pros and Cons

4.32. This option retains unrestricted back-up to a primary VSD through two new GT units. One Avon is retained restricted to 500 hours. This is a decrease compared to current resilience and would limit site flow to 60mcmd + 1 restricted Avon if a VSD is unavailable. In a high flow scenario, the Avon 500 hours would be used up at a high rate. Significant constraint costs would be expected.

4.33. The cost to return Plant 2 to service, and maintain would have a high asset health cost, due to the age of the plant and equipment. Maintaining the existing plant 2 does not provide an opportunity to rationalise plant 2 and build BAT equipment.

4.34. Deliverability would be less challenging than options 0 and 1, relying on Plant 1 for compression whilst the works on plant 2 are undertaken. However, asset health investment will require old and new assets and associated systems to interface with each other creating delivery complexity and risk.

Table 13: Option 2A RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
2A Existing plant 2: 2 new units and 1x derogated Avon						

Option 2B - Existing plant 2: 1 new unit + 1x derogated Avon

4.35. In this option Plant 2 is returned to service, with the addition of 1 new Gas Turbine compressor unit (2E) and Avon unit 2B placed on derogation. Plant 2 will therefore require asset health work to return the plant to service and the asset health scope required to maintain it on an enduring basis. Plant 1 and the 4x Avons are utilised during the Plant 2 return to service asset health works and compressor build and would be decommissioned following works.

4.36. A reduced asset health scope for Plant 1 and the 4x Avons can be applied as they are not operational beyond 2030.

4.37. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.38. The simplified block diagram below shows investment types within this option for 2030:

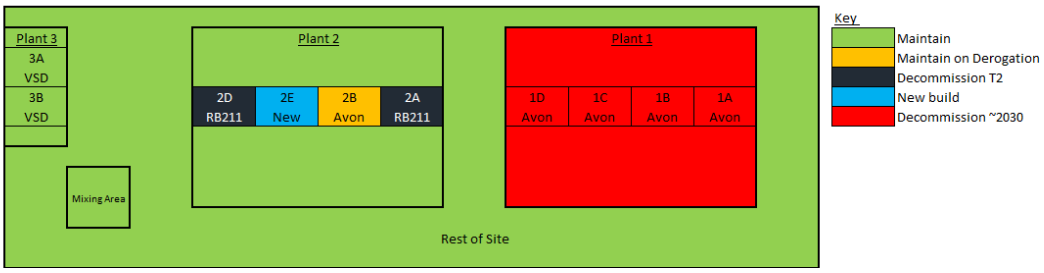

Figure 13: Option 2B investments indication diagram

Table 14: Option 2B cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ 500hr derogation intervention Avon 2B ▪ Return Plant 2 to service and maintain ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing areas ▪ Maintain rest of site	[redacted]	
Major Construction	▪ 1 new compressors on existing plant 2		
Decommissioning	▪ 2x RB211 ▪ Plant 1 2030		

Option Pros and Cons

4.39. This option retains restricted back-up to a primary VSD through one new GT unit and 1 Avon. The Avon is retained but restricted to 500 hour derogation. This is a significant decrease compared to current resilience and would limit site flow to 45mcmd + 1 restricted Avon if a VSD is unavailable. The Avon's 500 hours would be used up at a high rate in medium to high flow scenarios. Significant constraint costs would be expected.

4.40. Flows of between 15 and 22.5 mcmd, where the new GT requires support, but flows are still too low for the VSD to take the duty, would also require the Avon to be operational. Therefore it is likely that the 500 hours would be used up quickly, leading to high constraint costs.

4.41. The cost to return Plant 2 to service, and maintain would have high ongoing asset health cost, due to the age of the plant and equipment. Maintaining the existing plant 2 does not provide an opportunity to rationalise plant 2 and build BAT equipment.

4.42. Deliverability would be less challenging than options 0 and 1, relying on Plant 1 for compressions whilst the works on plant 2 are undertaken. However, asset health investment will require old and new assets and associated systems to interface with each other creating delivery complexity and risk.

Table 15: Option 2B RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
2B Existing plant 2: 1 new unit + 1x derogated Avon						

Option 2C - Existing plant 2: 3 new units

4.43. In this option Plant 2 is returned to service, with the addition of 3 new Gas Turbine compressor units (2E, 2F and 2G). Plant 2 will therefore require asset health work to return the plant to service and the asset health scope required to maintain it on an enduring basis. Plant 1 and the 4x Avons are utilised during the Plant 2 return to service, asset health works and compressor builds and would be decommissioned appropriately following works.

4.44. A reduced asset health scope for Plant 1 and the 4x Avons can be applied as they are not operational beyond 2030.

4.45. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.46. The simplified block diagram below shows investment types within this option for 2030:

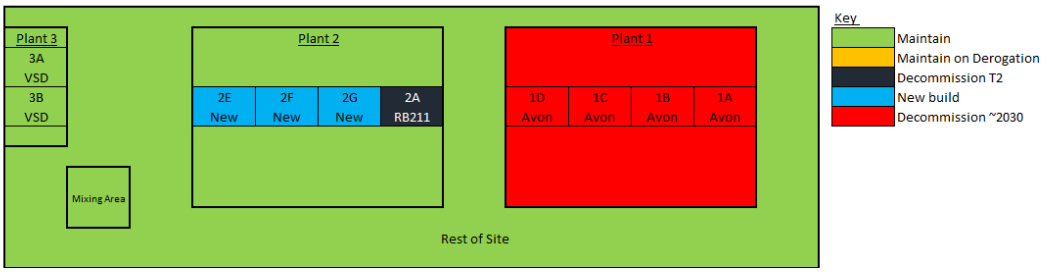

Figure 14: Option 2C investments indication diagram

Table 16: Option 2C cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ Return Plant 2 to service and maintain ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site	[redacted]	
Major Construction	▪ 3 new compressors on existing plant 2		
Decommissioning	▪ 1x RB211 ▪ Plant 1 2030		

Option Pros and Cons

4.47. This option retains unrestricted back-up to a primary VSD through three new GT units. This is a decrease compared to current resilience, however would still offer the resilience required to limit constraint costs due to the three GT units being unrestricted.

4.48. The cost to return Plant 2 to service, and maintain would have high ongoing asset health cost, due to the age of the plant and equipment. Maintaining the existing plant 2 does not provide an opportunity to rationalise plant 2 and build BAT equipment.

4.49. Deliverability would be less challenging than options 0 and 1, relying on Plant 1 for compressions whilst the works on plant 2 are undertaken. However, asset health investment will require old and new assets and associated systems to interface with each other creating delivery complexity and risk.

Table 17: Option 2C RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
2C Existing plant 2: 3 new units						

Option 3A - Redeveloped Plant 2: 2 new units and 1x derogated Avon

4.50. In this option, Plant 2 is redeveloped with the addition of 2 new Gas Turbine compressor units (2E and 2F) and Avon unit 2B placed on derogation. Plant 1 and the 4x Avons are utilised during the Plant 2 re-development and compressor builds and would be decommissioned appropriately following works.

4.51. A reduced asset health scope for Plant 1 and the 4x Avons can be applied as they are not operational beyond 2030.

4.52. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.53. The simplified block diagram below shows investment types within this option for 2030:

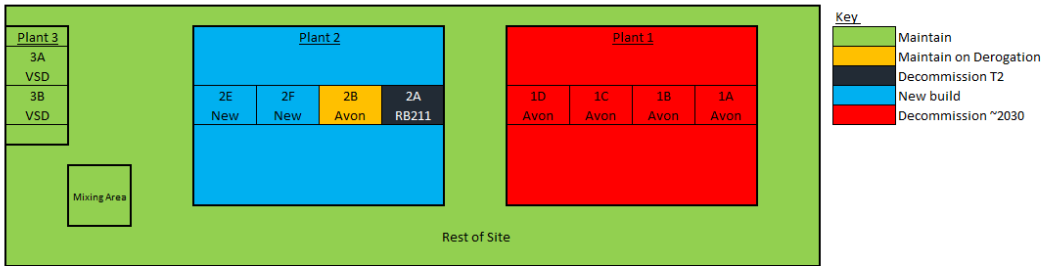

Figure 15: Option 3A investments indication diagram

Table 18: Option 3A cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ 500hr derogation intervention Avon 2B ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site	[redacted]	
Major Construction	▪ Redeveloped Plant 2 with 2 compressors		
Decommissioning	▪ Plant 1 2030 ▪ RB211s (included in redevelopment)		

Option Pros and Cons

4.54. This option retains unrestricted back-up to a primary VSD through two new GT units. One Avon is retained, restricted to 500 hours. This is a decrease compared to current resilience and would limit site flow to 60mcmd + 1 restricted Avon if a VSD is unavailable. However, constraint costs are limited due to the two GT units being unrestricted.

4.55. Redeveloping plant 2 would result in a purposefully designed plant to support plant 3 compression and would result in low asset health costs. Constructing new equipment and new plant in one go will be a more efficient way of delivering work, potentially enabling modular construction and fewer interfaces with old plant. It enables

rationalisation of the plant compared to the exiting design along with utilisation of Best Available Technologies (BAT).

4.56. Developing the plant around a retained Unit 2B will provide construction complexities compared to a total brownfield development.

Table 19: Option 3A RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
3A Redeveloped Plant 2: 2 new units and 1x derogated Avon						

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Option 3B - Redeveloped Plant 2: 3 new units

4.57. In this option, Plant 2 is redeveloped with the addition of 3 new Gas Turbine compressor units (2E, 2F and 2G). Plant 1 and the 4x Avons are utilised during the Plant 2 re-development and compressor builds and would be decommissioned appropriately following works.

4.58. A reduced asset health scope for Plant 1 and the 4x Avons can be applied as they are not operational beyond 2030.

4.59. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.60. The simplified block diagram below shows investment types within this option for 2030:

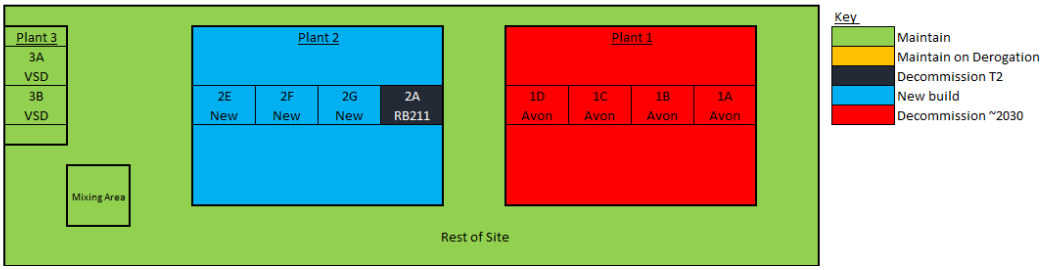


Figure 16: Option 3B investments indication diagram

Table 20: Option 3B cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site		
Major Construction	▪ Redeveloped Plant 2 with 3 compressors		
Decommissioning	▪ Plant 1 2030 ▪ RB211s (included in redevelopment)		

Option Pros and Cons

4.61. This option retains unrestricted back-up to a primary VSD through three new GT units. This is a decrease compared to current resilience, however would still offer the resilience required to limit constraint costs due to the three GT units being unrestricted.

4.62. Redeveloping plant 2 would result in a purposefully designed plant to support plant 3 compression and would result in low asset health costs. Constructing new equipment and new plant in one go will be a more efficient way of delivering work, potentially enabling modular construction and fewer interfaces with old plant. It enables rationalisation of the plant compared to the exiting design along with utilisation of Best Available Technologies (BAT).

Table 21: Option 3B RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
3B Redeveloped Plant 2: 3 new units						

Option 3C - Redeveloped Plant 2: 3 new units (1 large)

4.63. In this option, Plant 2 is redeveloped with the addition of 3 new Gas Turbine compressor units (2E, 2F and 2G), 2 medium and 1 large. Plant 1 and the 4x Avons are utilised during the Plant 2 re-development and compressor builds and would be decommissioned appropriately following works.

4.64. A reduced asset health scope for Plant 1 and the 4x Avons can be applied as they are not operational beyond 2030.

4.65. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.66. The simplified block diagram below shows investment types within this option for 2030:

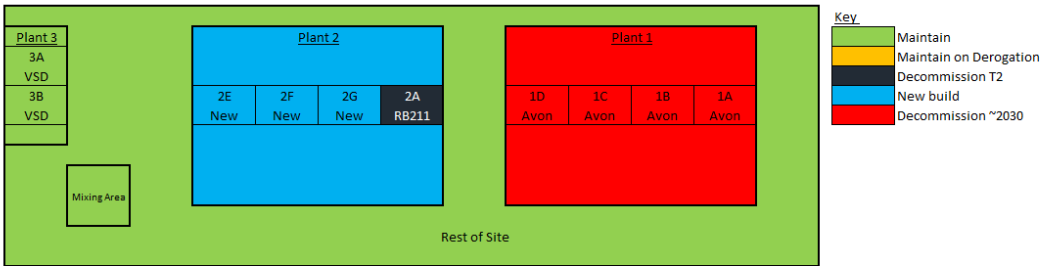


Figure 17: Option 3C investments indication diagram

Table 22: Option 3C cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ Plant 2 subsidence ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site		
Major Construction	▪ Redeveloped Plant 2 with 3 compressors (2 medium, 1 large)		
Decommissioning	▪ Plant 1 2030 ▪ RB211s (included in redevelopment)		

Option Pros and Cons

4.67. This option retains unrestricted back-up to 1 primary VSD (or both in below 60mcm flows) through three new GT units (2 Avon sized and 1 large). This is a decrease compared to current resilience, however would still offer the resilience required to limit constraint costs due to the three GT units being unrestricted.

4.68. Redeveloping plant 2 would result in a purposefully designed plant to support plant 3 compression and would result in low asset health costs. Constructing new equipment and new plant in one go will be a more efficient way of delivering work, potentially enabling modular construction and fewer interfaces with old plant. It enables rationalisation of the plant compared to the exiting design along with utilisation of Best available technologies (BAT).

Table 23: Option 3C RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
3C Redeveloped Plant 2: 3 new units (1 large)						

Option 4: New Greenfield Plant: 2 new units

4.69. In this option, a new greenfield plant would be built in the open area to the North of the existing plant 3, extending plant 3. This plant would include all of the required auxiliary functions for the existing plant 3 VSD compressors and also include 2 additional GT compressor units (3C and 3D). Once complete the new combined plant 3 would be self-sufficient and would not require use of plant 2 or plant 1 assets.

4.70. Plant 1 and the 4x Avons are utilised during the new greenfield build. This results in a reduced Asset health scope for Plant 1 and the 4x Avons as they are not operational beyond 2030.

4.71. Plant 2 could be decommissioned within RIIO-2, although it may be more efficient and give less risk to site operations to delay this until Plant 1 can also be decommissioned.

4.72. The core functionality of the shared aspects of site (mixing area, manifolds etc.) are maintained and Plant 3 and VSDs are maintained.

4.73. The simplified block diagram below shows investment types within this option for 2030:

Figure 18: Option 4 investments indication diagram

4.74. The investment diagram is an indicative block diagram, and does not convey the extent of land this option would free up. Areas well outside of the existing Plant 1 and Plant 2 footprints would become open due to the new plant 3 extension changing the routing of flows around the site.

Table 24: Option 4 cost estimate £million

Cost Element	Description	RIIO-2	RIIO-3
Asset Health	▪ Maintain Plant 1 until 2030 ▪ 2030 decommission interventions for Avons 1A, 1B, 1C, 1D ▪ Maintain Plant 3 & VSDs ▪ Maintain mixing area ▪ Maintain rest of site	[redacted]	
Major Construction	▪ New Greenfield Plant 3 extension with 2 compressors		
Decommissioning	▪ Plant 2 ▪ Plant 1 2030		

Option Pros and Cons

4.75. This option retains unrestricted back-up to a primary VSD through two new GT units. This is a decrease compared to current resilience and would limit site flow to 60mcmd if a VSD is unavailable

4.76. A greenfield build would result in a purposefully designed plant to support plant 3 compression and would result in low asset health costs. Constructing new equipment and new plant in one go will be a more efficient way of delivering work, potentially enabling modular construction and fewer interfaces with old plant. There would be a clear demarcation between the operational plant, and the construction site. The capital costs on constructing on greenfield is higher than the redevelopment described in option group 3 solutions, which is why option 4 is limited to a 2 new unit solution.

Table 25: Option 4 RAG Assessment

Option	Does this meet predicted FES flow requirements?	Does this option provide resilience to the loss of one VSD?	What is the relative Asset Health expenditure of this option?	What is the relative capital cost of this option?	What is the relative constraint cost of this option?	How deliverable is this option relative to others?
4 New Greenfield Plant: 2 new units)						

Discounted Options

4.77. There are two potential ways of making gas turbine units compliant with MCPD legislation without replacing the units with new units. These are Selective Catalytic Reduction (SCR) and Control System Restriction. A full discussion of the advantages and disadvantages of these is given in CECS.

4.78. St Fergus is currently the highest polluting site on our network due to the current use of the gas turbine compressors. Neither of the above options will reduce emissions as effectively as new units. More detailed discussion of the applicability of each technique is given below.

Emissions reductions

4.79. Selective Catalytic Reduction (SCR) emissions reduction technologies cannot be considered a viable option for St Fergus. This is because they would not be able to achieve the Best Available Technology (BAT) efficiency levels of new machines at 36.5%. This in combination with the 24/7 nature of the compression requirement does not lend itself to retro fit reduction measures as it is a substandard reduction, compared to new units, to already aged asset base.

4.80. National Grid was unsuccessful in getting any tenderers to supply SCR solutions at St Fergus as part of the May 2018 reopener. This was despite there only being one tenderer who could potentially supply the technology. They instead preferred to enter into a competitive tender process submitting a bid for new units. This was due to the age and condition of the compressor units, indicating that it is not currently a suitable or achievable solution for this site.

Control System Restriction

4.81. Reducing the power of non-compliant compressors by applying operating restrictions via the control systems could bring the emissions to within the MCPD limits. Given the combination of age of the Avon units, the requirement for the full operating range and long term need for a continuous and flexible compression at St Fergus, this option has been discounted.

4.82. Enduring compliance could also be challenging and the 24/7/365 nature of the compression at St Fergus results in long running hours for units. Longer running hours with Nitrous Oxide (NOx) levels just below legislative limits would produce greater total NOx emissions than compressors with above legislative limits, limited to a maximum 500hrs. This option, for the duty of St Fergus compression, would be unlikely to achieve BAT. A preliminary BAT assessment at Wormington for this technology found it was not BAT and St Fergus compressors run for significantly more hours than Wormington.

New Greenfield Terminal

4.83. A completely new green field terminal was discounted. It would have had high capital costs, resulted in some disruption to all sub terminal supplies on commissioning and could not have utilise the 2015 commissioned Plant 3, 2x electric drive compressors on the existing site. The approach was considered to have significantly higher costs for consumers with few additional benefits. Greenfield compression plant is considered in option 4.

New Brownfield terminal

4.84. Similarly to the new greenfield terminal, a full site redevelopment on brownfield was not considered to give value for customers. Redeveloping Plant 1 and Plant 2 would

have provided in excess of the compression requirements, and would therefore not be in consumer interests. There would either have been significant disruption to existing functionally if Plant 1 and 2 were redeveloped together or an extended build period to redevelop the Plants separately. Partial brownfield redevelopment is considered in options 3A, 3B and 3C.

Additional Electric Drive Compression

4.85. St Fergus BAT units are 2x electric drive compressors. The existing GT Avon units and/or any further new compressor units are needed to provide support to the electric drives, as well as provide the primary compression should the power supply be temporarily lost. Therefore site redundancy is required to allow operation in the event of electrical supply loss, given the critical nature and 24/7 compression requirement at the site. CECS describes this is more detail, but the arguments against having solely electric driven units at a site are exaggerated at St Fergus due to the 24/7 compression running.

Maintain existing VSDs and minimum plant only

4.86. In this option, Plant 1 and the plant 1 Avons would have been utilised up until 2030 then would be decommissioned. Plant 2 would be returned to service to provide the auxiliary support to the Plant 3 compressor (scrubber, metering and aftercoolers), along with derogation of Avon 2B.

4.87. This option is known to be unsuitable as it would not cover the required compression range, but is described here to demonstrate an option maintaining only the minimum number of compliant compressors. Compression would be provided only by VSDs and a restricted hours Avon 2B to theoretically cover the flow range required.

4.88. The option provides such a reduced compression capability compared even to the counterfactual option that is was discounted. There would be little possibility of maintenance outages on the VSDs and the 500hours on 2B would be used up very quickly.

New Technologies

4.89. Compressor manufacturers are continuing to develop their commercial offerings. As part of this work we have not considered any technology that is not yet commercially available. However, we work closely with manufacturers and will take into account the latest available technology in our FEED studies and BAT assessments. This may include future proofing by installing hydrogen compatible compressors (hydrogen blended in the fuel gas system could reduce emissions further) or new options for emissions compliance. Given the criticality of compression at St Fergus our preference will be to use proven technology.

Do Nothing

4.90. In this option, we would continue to run the VSDs on Plant 3 and no regret asset health work would continue. Plant 1 and Plant 1 Avons would continue to run until investment was required, at which point they would be disconnected. This would also impact on the VSDs availability as they are reliant upon Plant 1's metering, scrubber and aftercoolers.

4.91. The terminal needs to continue operating reliably and safely, providing 24/7 compression. Much of the hardware is of the original installation and there are sign of significant deterioration. Without appropriate interventions and replacements, we

would expect an acceleration of failure rates and demonstrated in the Bathtub curve of asset failure model in Figure 19.

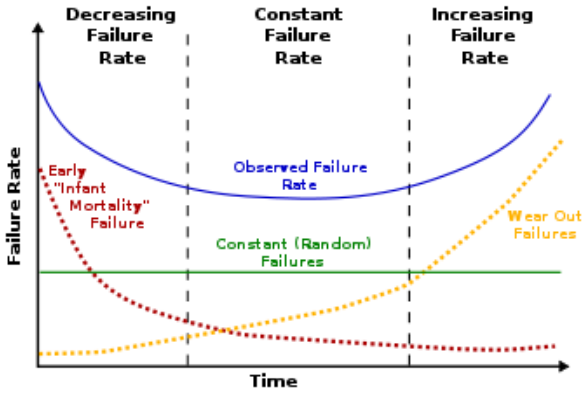


Figure 19: Bathtub curve of asset failure

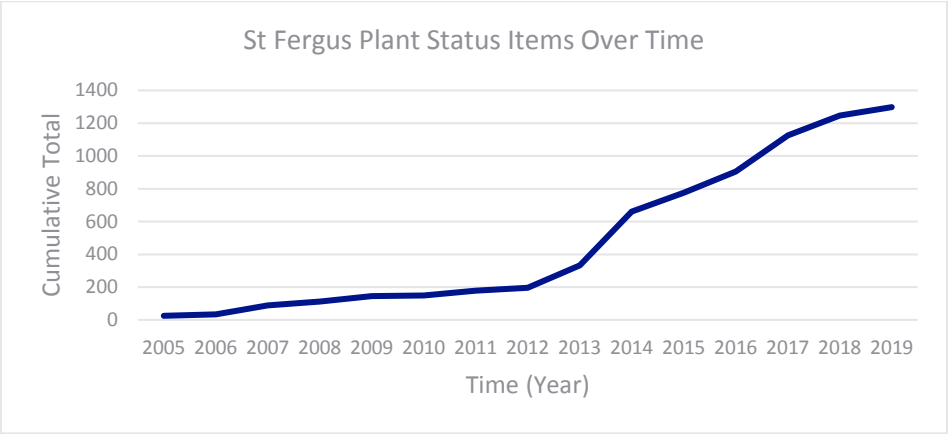


Figure 20: Cumulative Plant Status Items Raised at St Fergus Terminal and Multi Junction

4.92. Figure 20 shows the cumulative amount of plant status items (PSI) since 2005. These are defects/site issues raised for correction by site operational teams, which cannot be dealt with locally and form part of our investment plan. There has been a much higher rate of failures since 2013, and whilst this may be in part down to reporting improvements, the sustained level of high PSIs would indicate many assets are approaching “increased failure rate” condition in line with Figure 19. This leaves the site susceptible to increasing amounts of failures, and therefore becoming more likely to lead to operational impacts.

4.93. St Fergus Terminal is classified as an upper tier COMAH site and as such represents a major hazard which National Grid must manage. Failure to do this represents a major process safety risk, and we cannot continue to operate assets if they pose an unacceptable risk to the safety of site staff or the public. In this instance, we would have no option but to isolate and make the asset safe, constraining customers and significantly affecting the UK gas supply network. St Fergus is subject to increased scrutiny from the Health and Safety Executive (HSE). There are regular intervention visits by the HSE to the terminal independently and along with SEPA under the remit of Competent Authority under COMAH.

4.94. In the event of constraining gas supplies through St Fergus Terminal as a whole or even just the NSMP sub terminal, a significant cost penalty would be incurred. These

costs are constraint only and does not take into account wider economic and social impacts of constraining significant gas at St Fergus Terminal.

4.95. In a scenario where flow is significantly constrained or stopped at St Fergus, there would be a large effect on Scottish gas supplies. Directly connected consumers would experience disruption via the onsite SGN offtake. NTS offtakes and subsequent consumers and businesses would also be affected by unstable supply.

4.96. The Scottish network is designed to be supplied from St Fergus, and not from gas coming from the south. Should the terminal be closed, the network could not provide gas to Scotland as there is no South to North compression capability. The effect of stopping flow into the network at St Fergus at any time of the year would impact gas supplies to Scottish consumers and businesses. The economic and societal impact would be significantly greater than the constraint management costs above.

Commercial Options

4.97. Consideration was initially given to the renegotiation of the Network Entry Agreement (NEA) with a view to remove the compression requirement from being a National Grid provided service. National Grid cannot unilaterally change the NEA and so approached NSMP for early engagement. It was determined that the other party had no appetite for contract negotiations and under their current model, could not make an economic case to do so. This option was therefore discounted.

4.98. Capacity buy-back mechanisms can also be considered as a commercial option to reduce absolute compression through the site. Typically used as a way to manage a physical constraint risk on the NTS, entry capacity is only sold at the ASEP level rather than the sub-terminal level. Capacity buy-backs can therefore only economically address a constraint at an ASEP level. This means at St Fergus, there is no effective means of targeting capacity buy-backs at the specific shippers who are unable to flow gas through the affected sub-terminal, as opposed to the broader portfolio of shippers in possession of entry capacity at the ASEP. Only the shippers at NSMP would be impacted by the lack of compression, not those flowing through the other two sub terminals.

4.99. There is a precedent for splitting an ASEP. Following European legislation, designed to harmonise transparent and non-discriminatory access to transmission capacity at interconnection points across the European Union, it was necessary to split the Bacton ASEP. This necessitated different arrangements and processes for the European Interconnectors (BBL and IUK) than for the other Bacton sub-terminals bringing in gas from the UKCS. The process was longwinded and complex, driven by the need for legislative change. It was not broadly supported by industry, as a split of the ASEP reduces the optionality for shippers looking to trade their flows between different sub-terminals. Based on this experience, a split of the St Fergus ASEP was discounted.

4.100. As capacity buy back mechanisms are not appropriate we have also considered the use of alternative flow based contractual arrangements. These would be designed to reduce peak flows at the sub terminal and therefore minimise investment in compression capability. Feedback from the sub terminal indicates that entering into a turn down contract when compression is needed is contradictory to the agreement we have to provide pressures to accommodate flow onto the network from the sub-terminal. In addition, the price of such a contract would be very high given the consequential impact of calling off flows at any time, impacting multiple shippers. Also feedback through stakeholder engagement clearly indicated that fundamentally

stakeholders want to flow gas onto the network – they do not want National Grid to restrict flow even with financial compensations.

4.101. Another commercial option considered changes to the Uniform Network Code (UNC). Under UNC Section Y, National Grid is entitled to levy a compression charge to shippers to recover compressor fuel costs where compression is needed to increase the pressure of gas delivered from the NSMP sub-terminal. One alternative code change considered was the option to modify the UNC (Section Y) whereby National Grid can levy a charge for the cost of investment in the compressor assets as well as the fuel usage for the compression to the customer who benefit from it's use. This option was discounted as although it would change the proportion of the investment cost picked up by relevant shippers – it would not alter the total cost of investment – and would be subject to a potentially lengthy code review process.

4.102. In summary, these options, whilst designed to either reduce absolute compression at the site or pay compensation where back up/resilience is inadequate, were discounted. Given the criticality of the St Fergus sub-terminal and the volume of flows through the site, commercial and regulatory options could not offer a better, more cost-effective alternative to physical site investment.

Options Summary

4.103. The impacts of options on the existing sites operating costs (OPEX) of the terminal were not quantified at this stage. Fuel costs and the cost of carbon for each option is quantified in the CBA and is listed in the operating cost column in Table 26.

Table 26: Option Summary table, costs in £million

Option title	*Project start date (Financial year)*	*Project commissioning date*	*Project design life*	*Decommissioning*	*Asset Health Cost (RIIO-2 and RIIO-3)*	*Major Construction Cost*	*Total installed cost (AH + Construction RIIO-2 and RIIO-3)*	*Cost estimate accuracy (%)*
Derogate 4 Avons (plant 1 only)	*2024*	*n/a*	*n/a*					*P50*
Derogate 5 Avons (plant 1 and 2)	*2024*	*n/a*	*n/a*					*P50*
Existing plant 2: 2 new units and 1x derogated Avon	*2022*	*2028*	*25 years*					*P50*
Existing plant 2: 1 new unit + 1x derogated Avon	*2022*	*2028*	*25 years*					*P50*
Existing plant 2: 3 new units	*2022*	*2028*	*25 years*					*P50*
Redeveloped Plant 2: 2 new units and 1x derogated Avon	*2022*	*2028*	*25 years*					*P50*
Redeveloped Plant 2: 3 new units	*2022*	*2028*	*25 years*					*P50*
Redeveloped Plant 2: 3 new units (1 large)	*2022*	*2028*	*25 years*					*P50*
New Greenfield Plant: 2 new units	*2022*	*2028*	*25 years*					*P50*

5. Business Case Outline and Discussion

5.1. This section shows the breakdown of operational costs for each option. These costs along with the others detailed in this section are included in the CBA to produce a NPV for each option.

Key Business Case Drivers Description

Constraint Costs

5.2. The annual constraints rise significantly from 2030 in options 0, 1, 2b, and 4, these can be seen on Figure 21 below.

Figure 21: Annual constraint costs

5.3. The increase in costs occur where the availability of the compressors falls below today's levels. In the counterfactual, this is caused by the 500-hour limit to the Avon units. With no unrestricted units on site to cover for the VSDs and low flows the Avons would be required for more than 500 hours each – which restricts compression availability. All options without at least two unrestricted units and a third unit (either new or limited to 500-hours) result in significantly higher constraints than today's levels.

Cost Breakdown

5.4. The estimates for option costs in RIIO-2 and RIIO-3 are described in the options section of this report. Ongoing costs following RIIO-3 have been estimated to give a 25 year view. It is expected that assets associated with new compression will require less interventions over 25 years than original terminal assets, therefore this has been reflected in the cost estimate.

5.5. Figure 22 shows the breakdown of the costs included in the CBA. This is split into the investment costs for compressors, asset health, decommissioning and compressor running costs. This allows a comparison over the relative costs in each of the options.

5.6. The fuel usage is high across all of the options but as it is similar for most options does not have a significant impact on the CBA. The only significant differences in fuel are for option 0 – Derogate 4 Avons (plant 1 only) and Option 1 – Derogate 5 Avons (Plant 1 and 2) in both options the 500-hour restriction on the Avons result in the

compressors not being available when required, this results in lower fuel costs as the compressors are not available to run. These fuel savings are more than outweighed by the resultant constraint costs. The cost of carbon emissions costs also reflect this pattern of new unrestricted unit running for more hours.

Figure 22: Cost breakdown

5.7. Figure 23 shows how each option effects the constraint and contracting costs. This allows comparisons to be made between derogate, 2 unit and 3 unit solutions.

Figure 23: Constraint and contracting costs included in CBA

CBA Assessment

5.8. Based on our central scenario all options have a positive NPV compared to the counterfactual. As can be seen in Table 27 and Figure 24.

Table 27: CBA Summary [9]

Short Name	Description	NPV £m	Relative NPV £m
0	0 - Derogate 4 Avons (plant 1 only)	-£2180.8 m	
1	1 - Derogate 5 Avons (plant 1 and 2)	-£1554.1 m	£625.8 m
2a	2a - Existing plant 2: 2 new units and 1x derogated Avon	-£656.6 m	£1524.5 m
2b	2b - Existing plant 2: 1 new unit + 1x derogated Avon	-£1346.7 m	£833.4 m
2c	2c - Existing plant 2: 3 new units	-£670.8 m	£1511.1 m
3a	3a - Redeveloped Plant 2: 2 new units and 1x derogated Avon	-£605.8 m	£1575.4 m
3b	3b - Redeveloped Plant 2: 3 new units	-£613.7 m	£1568.8 m
3c	3c - Redeveloped Plant 2: 3 new units (1 large)	-£623.4 m	£1559.7 m
4	4 - New Greenfield Plant: 2 new units	-£866.9 m	£1311.9 m

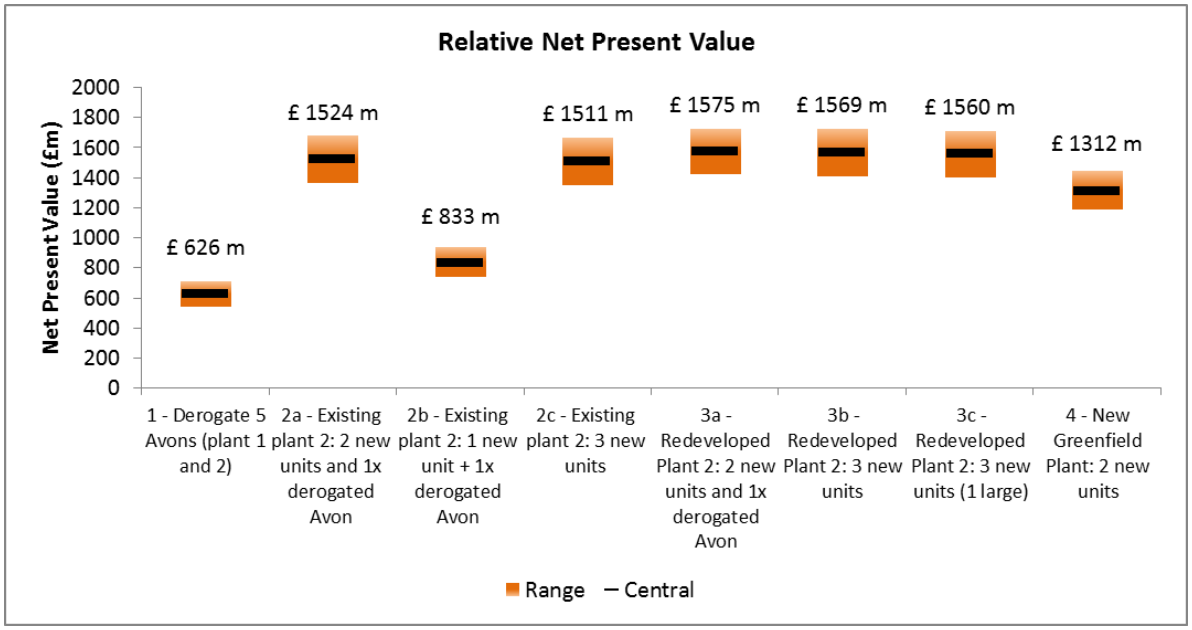


Figure 24: Relative NPV [10]

5.9. The option 3 variants are the lead options in the CBA. The savings in the ongoing asset health, when compared to option 2, outweighs the initial cost of the redevelopment.

5.10. The options with at least three GT units (2a/2c/3a/3b/3c) in addition to the VSDs clearly outperform those with two or fewer GTs. The three unit options achieve significantly higher availability at both high and low level flows. These flows are outside the range of the VSD units. This greater availability reduces the constraint risk.

[9] Note that these calculated NPVs assume a capitalisation rate of 73.5% as set out in CECS (Annex A16.05). This capitalisation rate has now been updated, and therefore there may be a minor mismatch between quoted NPVs between this document and the associated CBA (Annex A16.11). Please note that this does not affect the final proposed option. The impact of the updated capitalisation rate is reflected in the CBA document.
[10] See footnote 9

Sensitivities

5.11. To test the sensitivity of the St Fergus case to different supply and demand scenarios we have tested the case against all four FES scenarios. Since the proposals are based on FES 2018 there is no specific scenario focussed on achieving the net zero target. However, the expected gas usage outlined in the net zero sensitivity in FES 2019 fell between the gas usage of the Two Degrees and Community Renewables scenarios which are examined here.

5.12. Under all scenarios, the option 3 variants are the lead option. All four scenarios have flows continuing at the NSMP sub-terminal beyond 2050. During this period, all scenarios see flows decline from current levels, with the steepest falls seen in Community Renewables. Despite the declines in flows compression is still required, and in many cases more support is needed for lower flows which are outside the range of the VSDs.

Table 28: CBA Sensitivities

Short Name	Description	Central Case Steady Progression	High Sensitivity Two Degrees	Low Sensitivity Consumer Evolution	Additional Sensitivity Community Renewables
Option 0	0 - Derogate 4 Avons (plant 1 only)	£ 0.0m	£ 0.0m	£ 0.0m	£ 0.0m
Option 1	1 - Derogate 5 Avons (plant 1 and 2)	£625.8 m	£ 631.8m	£ 659.1m	£ 510.7m
Option 2a	2a - Existing plant 2: 2 new units and 1x derogated Avon	£1524.5 m	£ 1473.9m	£ 1488.4m	£ 1147.8m
Option 2b	2b - Existing plant 2: 1 new unit + 1x derogated Avon	£833.4 m	£ 893.2m	£ 952.9m	£ 780.0m
Option 2c	2c - Existing plant 2: 3 new units	£1511.1 m	£ 1460.8m	£ 1470.6m	£ 1130.0m
Option 3a	3a - Redeveloped Plant 2: 2 new units and 1x derogated Avon	£1575.4 m	£ 1527.6m	£ 1541.6m	£ 1202.8m
Option 3b	3b - Redeveloped Plant 2: 3 new units	£1568.8 m	£ 1517.5m	£ 1529.9m	£ 1188.3m
Option 3c	3c - Redeveloped Plant 2: 3 new units (1 large)	£1559.7 m	£ 1496.9m	£ 1503.0m	£ 1157.7m
Option 4	4 - New Greenfield Plant: 2 new units	£1311.9 m	£ 1313.1m	£ 1337.2m	£ 1065.7m

5.13. For all group 2 options, consideration to the enduring reliability and availability of the existing plant 2 assets has not been quantified or modelled as part of the CBA. This, in addition to the complexities of tying in new to old plant, and significant deliverability challenges increases and the ability to rationalise and utilised BAT equipment and designs strengthens the justification for group 3 options. Therefore, option group 3 will be taken forward into FEED.

Business Case Summary

5.14. The table below shows costs over the project life. The project NPV considers lifetime costs over a 25 year periods in comparison to the counterfactual option. The counterfactual presents a -£2180.8 m NPV.

Table 29: Summary of costs

Option no.	*Option title*	*Supply and Demand Scenario*	*Project commissioning date*	*Total installed cost (Inc. decom)in RIIO2 and RIIO3*	*Cost estimate accuracy (%)*	*Project operating lifespan*	*Relative Project NPV over 25 year CBA*[11]
0	Derogate 4 Avons (plant 1 only)	*Steady progression*	*Ongoing*	[redacted]	*P50*	*n/a*	£ 0.0m
1	Derogate 5 Avons (plant 1 and 2)	*Steady progression*	*Ongoing*		*P50*	*n/a*	£ 626.8m
2A	Existing plant 2: 2 new units and 1x derogated Avon	*Steady progression*	*2028*		*P50*	*25 years*	£ 1521.1m
2B	Existing plant 2: 1 new unit + 1x derogated Avon	*Steady progression*	*2028*		*P50*	*25 years*	£ 836.1m
2C	Existing plant 2: 3 new units	*Steady progression*	*2028*		*P50*	*25 years*	£ 1510.0m
3A	Redeveloped Plant 2: 2 new units and 1x derogated Avon	*Steady progression*	*2028*		*P50*	*25 years*	£ 1577.7m
3B	Redeveloped Plant 2: 3 new units	*Steady progression*	*2028*		*P50*	*25 years*	£ 1568.2m
3C	Redeveloped Plant 2: 3 new units	*Steady progression*	*2028*		*P50*	*25 years*	£ 1556.3m
4	New Greenfield Plant: 2 new units	*Steady progression*	*2028*		*P50*	*25 years*	£ 1312.8m

[11] See footnote 9

6. Preferred Option Scope and Project Plan

Preferred Option for this Request

6.1. The most cost effective and lowest risk option for St Fergus Terminal is to redevelop Plant 2 with new compression. Further work as part of the FEED study will establish whether this is with 2x new GT units with Unit 2B placed on derogation, 3 new Avon sized unit or 2 Avon sized and 1 large unit. This will be determined by the BAT assessment.

6.2. Option 3A retains Avon 2B on derogation, however this currently has unquantified deliverability complexities and cost inefficiencies compared to option 3B (where 3 new compressors are built simultaneously). This is likely to increase costs therefore the preferred option is 3B.

6.3. The cost of this preferred option is [redacted] in Asset Health, construction and decommissioning.

- [redacted] requested as no regrets asset health (included in baseline Asset Health plan)
- [redacted] Baseline for FEED
- [redacted] via UM for the remaining scope of Asset Health (plant 1 and plant 1 Avons until 2030), new construction (redeveloped Plant 2 and 3x compressors) and decommissioning (Plant 1 after 2030).

Efficient Cost

6.4. St Fergus has previously been considered as part of five separate themes; asset health, emissions LCP, emission MCP, enhanced physical security and cyber security. Each theme formed an NTS wide strategy.

6.5. However, OfGEM and SEPA feedback from the LCP reopener has led us to take a step back and consider the investment we are proposing at St Fergus for RIIO-2 and RIIO-3 in a more holistic way.

6.6. Asset health and Emissions unit cost efficiencies of 4% have been included, reflecting the work undertaken in RIIO-1 on our Richmond asset management improvement project.

6.7. The current uncertainty around project costs has led us to prose an Uncertainty Mechanism for this project.

6.8. The uncertainty around plant 1 asset health is regarding the longevity of the existing plant and units and hence the scope of asset health work.

6.9. Compressor cost forecasts are based on the most recent tender returns.

6.10. There are lessons learnt from RIIO-1 regarding the clear definition of operational and construction zoning.

7. Project Plan

7.1. An Indicative timeline is provided in Figure 25..

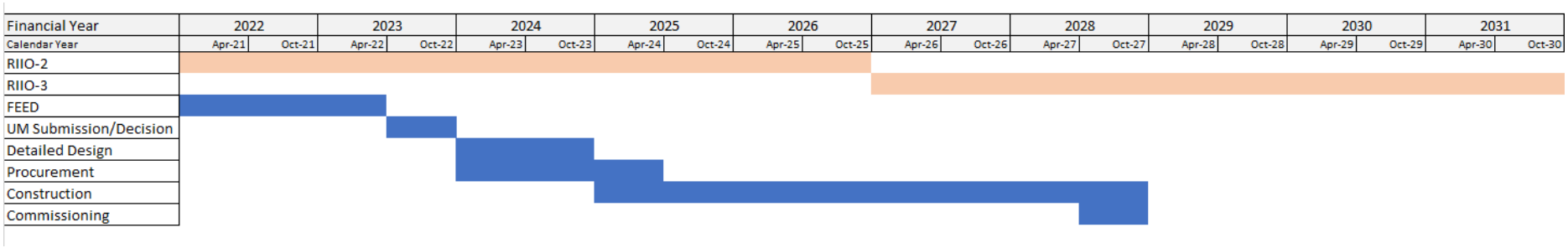


Figure 25: Indicative programme

8. Key Business Risks and Opportunities

What changes to the system operation or supply/demand scenario are required to alter the outcome of this justification paper?

- Changes in supply and demand patterns beyond the FES 2018;
- Changes in offshore operating models or new discoveries that increase or reduce UKCS and Norwegian gas supplies into St Fergus specifically;
- Changes in European markets;
- Changes in the global LNG markets;
- Clarity on the impact on the gas industry of the net-zero target for 2050.

Other circumstances that could affect this proposal

- How the government implements the findings of the Climate Change Act 2008 (2050 Target Amendment) from May 2019; specifically changes in legislation that impact compressor operation or construction work.
- Outcomes from preliminary BAT assessment and tender which may influence the choice of technology, with alternative units being provided by OEMs;
- A major unexpected failure of either VSD on site resulting in an extended outage and significant associated investment.
- A change to the re-opener decision from the minded to position will impact this proposal, depending on the level of change.
- Any changes to the contractual obligation for compression for the NSMP sub terminal.
- Access to skills in the St Fergus area when competing with the offshore industry. We've already taken this in to account based on our RIIO-1 experience, but if the situation changed significantly it could result in higher or lower costs.

Risks

- The continued need for 24/7/365 compression throughout any construction will result in some working around operational equipment, including operational compressors and pipework.
- Access to plant 1 compression and plant 1 in all options is dependent on delivering the required plant 1 maintenance within limited and partial outages.
- Delay in regulatory funding for the 2024 reopener, resulting in the requirement to fund asset health scope at risk in the interim.
- Unexpected asset health issues on Plant 1, resulting in some or all of Plant 1 becoming non-operational. This would significantly reduce the compression capability of the site until the issues can be remedied. Funding for significant remediation costs would be sought for in the Uncertainty Mechanism.

- Deliverability challenges are exaggerated at St Fergus due to climate, daylight hours and remoteness of the site.

9. Appendix A Acronyms

Acronym	Description
AH	Asset Health
ASEP	Aggregated System Entry Point
BAT	Best Available Technology
CBA	Cost Benefit Analysis
CECS	Compressor Emissions Compliance Strategy
COMAH	Control of Major Accident Hazards
DLE	Dry Low Emissions
FEED	Front End Engineering Design
FES	Future Energy Scenarios
GT	Gas Turbine
HSE	Health and Safety Executive
IED	Industrial Emission Directive
ISS	Integrated Security Systems
LCP	Large Combustion Plant
LNG	Liquefied Natural Gas
MCP	Medium Combustion Plant
NEA	Network Entry Agreement
NEA	Network Entry Agreement
NPV	Net Present Value
NSMP	North Sea Midstream Partners
NTS	National Transmission System
OEM	Original Equipment Manufacturer
OM	Operating Margins
PAC	Project Allocation Code
PSI	Plant Status Items
SCR	Selective Catalytic Reduction
SEPA	Scottish Environmental Protection Agency
SME	Subject Matter Expert
TOM	Total Oil and Marine
TPC	Transmission Planning Code
UKCS	United Kingdom Continental Shelf
UM	Uncertainty Mechanism
UNC	Uniform Network Code
VSD	Variable Speed Drive

10. Appendix B – St Fergus Stakeholder Engagement

In the summer 2018 workshop we gave a series of overview presentations which were followed up with facilitated discussions and voting to capture stakeholder's views. In particular we asked about the consequences of interruption to gas supplies coming in through St Fergus.

Relevant quotes are:

- "The customer has a choice between Europe or the UK, they may move to Europe more often. This will impact UK supply security" – [redacted] entry customer.
- "There would be potential platform shutdowns, and an inability to export"– [redacted] entry customer
- "There is a commercial impact on shippers due to the impact on the imbalance position if you can't input/offtake when and where you want." – unknown
- "Oil and gas production is associated so if the gas is turned off oil can't be brought on. They are reliant on each other, vice versa e.g. Shetland" – [redacted] customer (shipper).
- "The maximum disruption we could deal with is a couple of hours a day for a week. This is because of potential platform shutdowns and an inability to export. There will be flaring and shutdown" - [redacted] customer (shipper)
- On interruptions:
    - "It is acceptable to not flow to National Grid for at most six hours a day any more is not acceptable. if unplanned not acceptable" – [redacted] entry customer
    - "Unless stoppage was planned the most disruption we could manage would be six hours a day for two weeks. Seven-14 days per year acceptable" – [redacted] entry customer

The St Fergus terminal is, and will continue to be, a top tier COMAH site, with significant process safety risks to manage. Up to 50% of UK gas has come into St Fergus in recent years, meaning that interruptions to supplies at the wrong time could impact Scottish consumers if not UK consumers. Therefore the engagement we have done on safety is relevant. We have heard that all stakeholder segments see safety as a top priority that should not be taken for granted. Compliance with legislation is expected as a minimum. Consumers think about the impacts that occur in their homes of interruptions to their gas supply. Some relevant quotes are:

- "The network needs to be safe. A major accident has the potential for injury to be caused. You need to think about the Gas Safety (Management) Regulations 1996 (GSMR) and customer impact. Domestic customers should not face any supply security risk" –[redacted]
- "There should be an assessment of process safety. National Grid needs process safety indicators and to consider the health of the system" – [redacted] customer (shipper)
- "Safety is a priority that should be taken for granted." – [redacted] industry trade body

- "In terms of health and safety, there should be continual improvement for safety" – [redacted] regulator
- "You've separated safety and reliability but for GSMR there are elements of continuity of supply, (minimise risk of gas interruption) – if you improve reliability, you're probably improving safety as well" – [redacted] regulator.

Further broader stakeholder engagement relating to compressor emissions compliance can be found in Chapter 12 and 16 of the business plan and the Compressor Emissions Compliance Strategy in Annex A16.05.

11. Appendix C – FEED Scope

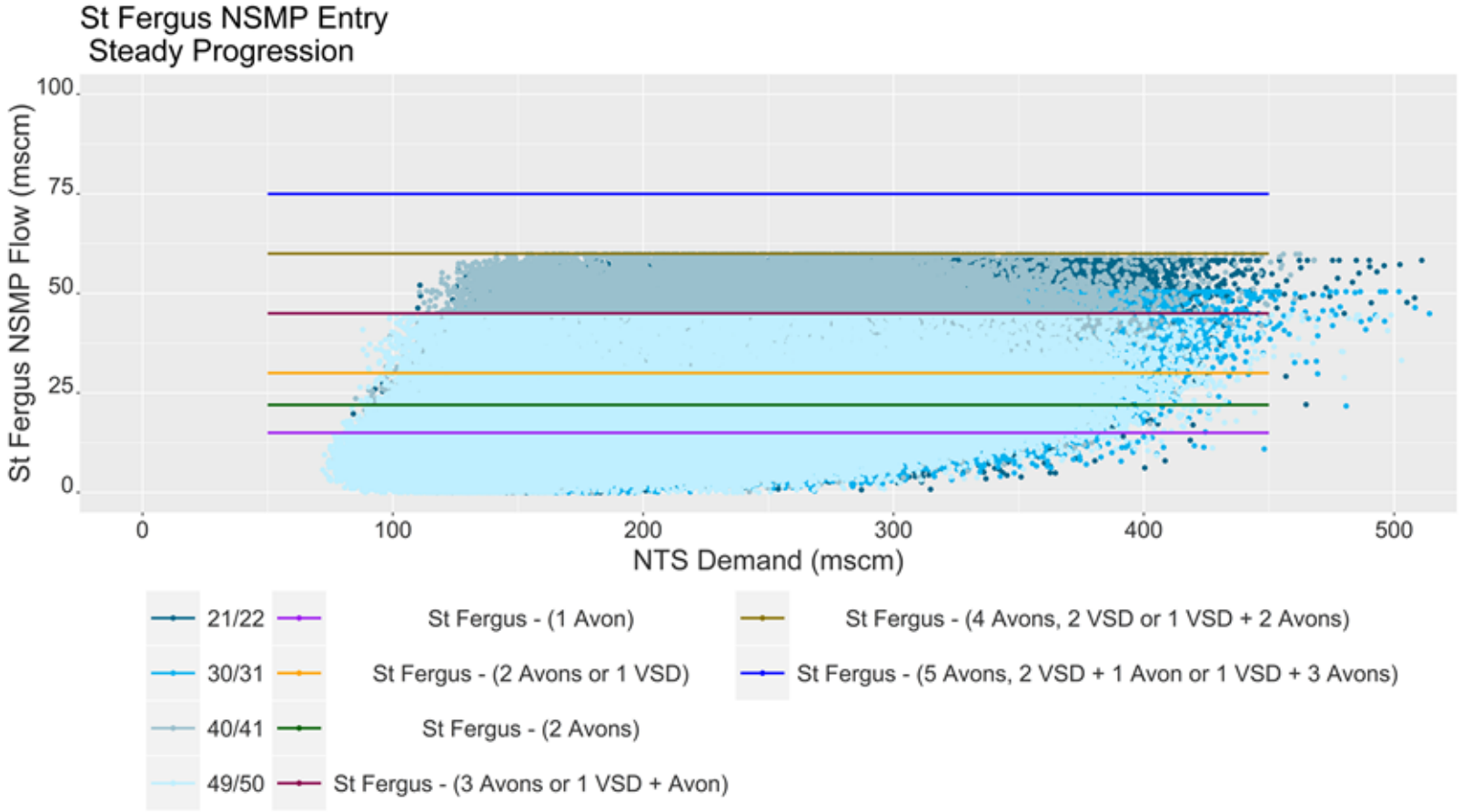
- Establish FEED Delivery strategy.
- Commence supplier engagement with potential FEED Consultants.
- Carry out FEED Consultant tender event.
- Prepare National Grid governance sanction information (for FEED Consultant award).
- Develop Project Scope.
- Establish Process Duty Specification requirements.
- Liaise with Shippers and carry out legal review of compression obligations.
- Liaise with local Planning Authority.
- Liaise with SEPA.
- Establish planning limits (including noise constraints).
- Develop Basis of Design.
- Establish National Grid applicable Policies, Procedures and Specifications.
- Establish Delivery, Procurement and Contracting Strategies.
- Establish Cost Certainty level required for FEED Cost Estimate.
- Define FEED Deliverables.
- Establish and carry out necessary site surveys.
- Carry out detailed asset health condition assessments.
- Collate site information.
- Establish 'Rely upon Information'.
- Establish tie-in and interface points.
- Determine any 'enabling works' requirements (will influence 'Delivery Strategy').
- Identify long lead items.
- Determine Site Establishment requirements.
- Carry out preliminary Process Safety assessments.
- Carry out preliminary Environmental assessments.
- Liaise with System Operator.
- Establish outage constraints.
- Commence supplier engagement with potential Compressor OEM suppliers.
- Commence supplier engagement with potential MWC's.
- Develop Divisions of Responsibility and Interface Management requirements.
- Identify Risks.
- Identify Opportunities.
- Establish Schedule (Programme).
- Carry out Cost Benefit Analysis of viable options.
- Establish Cost Estimates.
- Establish technical and economic viability of options.
- Produce FEED report with recommendations on option to progress.
- Confirm option recommendation with Ofgem and agree funding.
- Prepare National Grid governance sanction information (for progression and completion of FEED).
- Complete FEED Deliverables for the selected option.
- Develop Compressor OEM Machinery Train User Requirement Specifications. **SEE NOTE 1**
- Carry out Compressor OEM Machinery Train tender event. **SEE NOTE 1**
- Prepare National Grid governance sanction information (for Machinery Train award). **SEE NOTE 1**
- Develop MWC User Requirement Specifications. **SEE NOTE 2**

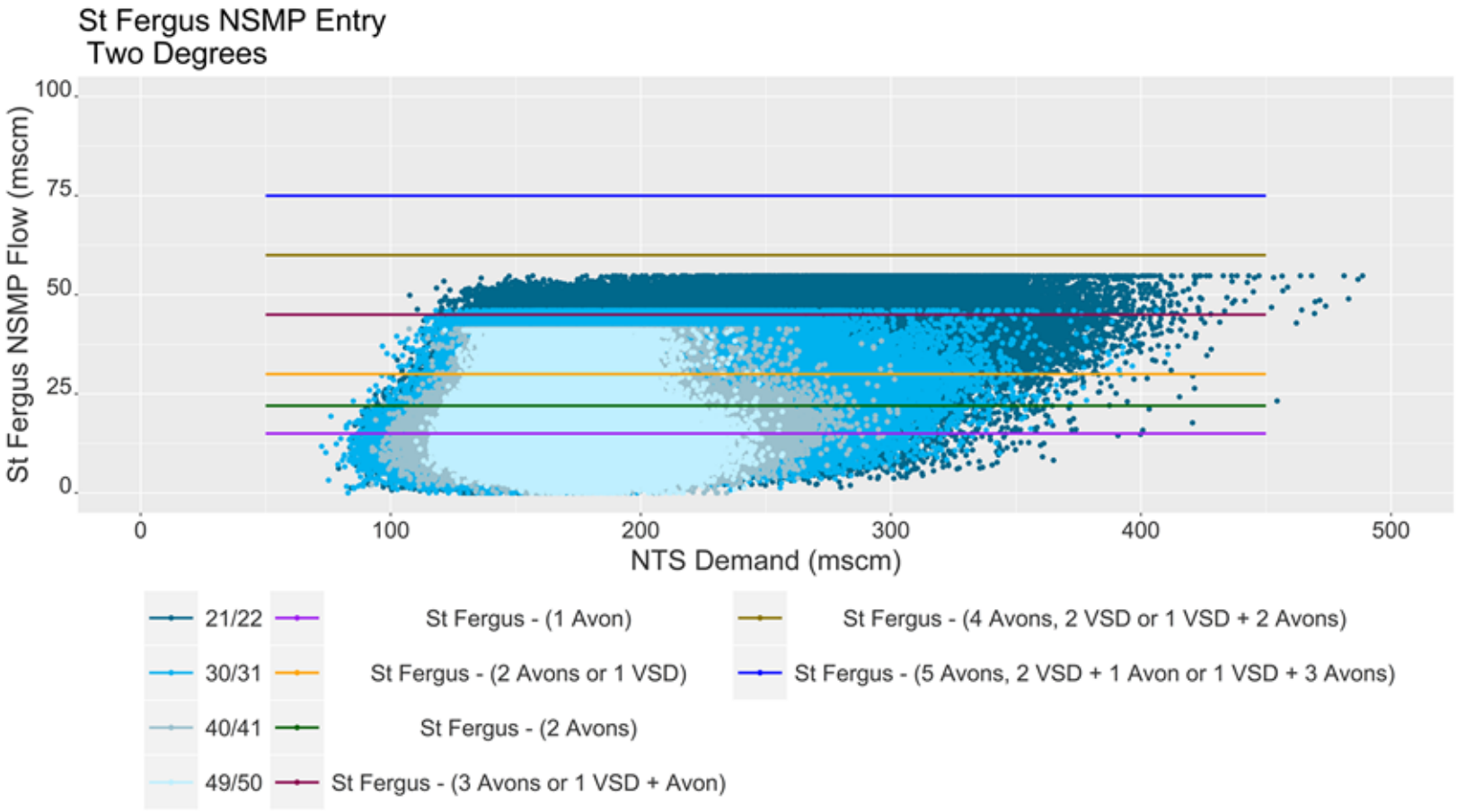
- Carry out MWC tender event. **SEE NOTE 2**
- Submit Environmental Permit application.
- Submit Planning application.
- Prepare National Grid governance sanction information (for post-FEED contract awards).
- End of FEED (including end of any tender evaluations).

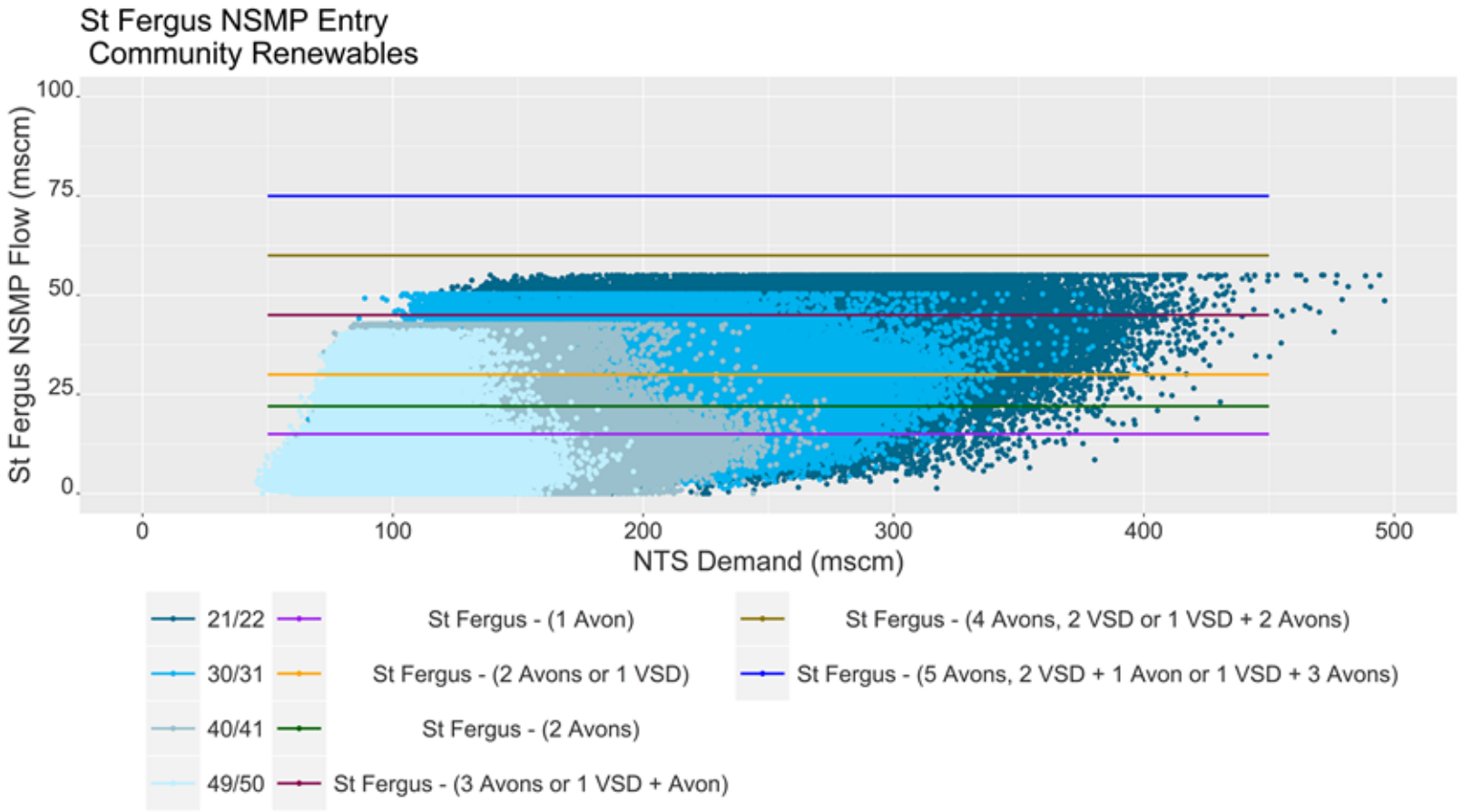
NOTES

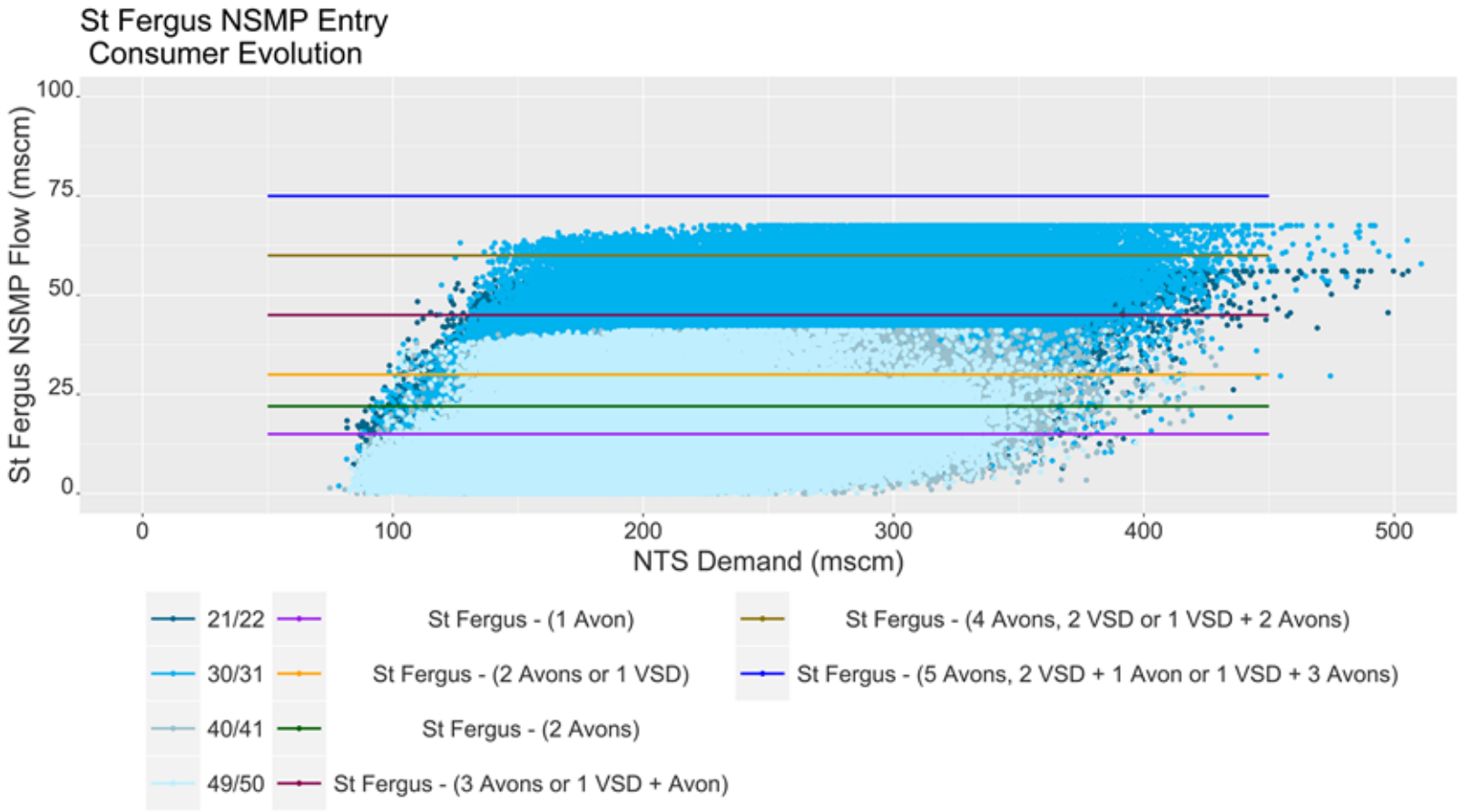
1. Delivery strategy may not require a Compressor OEM tender event by National Grid.
2. Requirement dependent upon selected Delivery Strategy.

12. Appendix D NSMP Entry Capability




St Fergus NSMP Entry
Two Degrees
St Fergus NSMP Flow (mscm)
100
75
50
25
0
0
100
200
300
400
500
NTS Demand (mscm)
21/22
30/31
40/41
49/50
St Fergus - (1 Avon)
St Fergus - (2 Avons or 1 VSD)
St Fergus - (2 Avons)
St Fergus - (3 Avons or 1 VSD + Avon)
St Fergus - (4 Avons, 2 VSD or 1 VSD + 2 Avons)
St Fergus - (5 Avons, 2 VSD + 1 Avon or 1 VSD + 3 Avons)


St Fergus NSMP Entry
Community Renewables
St Fergus NSMP Flow (mscm)
100
75
50
25
0
0
100
200
300
400
500
NTS Demand (mscm)
21/22
30/31
40/41
49/50
St Fergus - (1 Avon)
St Fergus - (2 Avons or 1 VSD)
St Fergus - (2 Avons)
St Fergus - (3 Avons or 1 VSD + Avon)
St Fergus - (4 Avons, 2 VSD or 1 VSD + 2 Avons)
St Fergus - (5 Avons, 2 VSD + 1 Avon or 1 VSD + 3 Avons)


St Fergus NSMP Entry
Consumer Evolution
St Fergus NSMP Flow (mscm)
100
75
50
25
0
0
100
200
300
400
500
NTS Demand (mscm)
21/22
30/31
40/41
49/50
St Fergus - (1 Avon)
St Fergus - (2 Avons or 1 VSD)
St Fergus - (2 Avons)
St Fergus - (3 Avons or 1 VSD + Avon)
St Fergus - (4 Avons, 2 VSD or 1 VSD + 2 Avons)
St Fergus - (5 Avons, 2 VSD + 1 Avon or 1 VSD + 3 Avons)