Final Option Selection Report

Uncertainty Mechanism Submission

King's Lynn Compressor Station

January 2023

[redacted]

nationalgrid

Executive Summary

Project Snapshot

National Grid Gas Transmission (NGGT) is committed to reducing the impact of its activities on the environment. Critical to this is ensuring that our compressor fleet meets emissions limits as set out in the Medium Combustion Plant Directive (MCPD), while meeting our 1-in-20 peak demand obligation and maintain the accessibility of energy security and necessary resilience for Security of Supply.

King's Lynn Compressor Station utilises one Siemens (formerly Rolls-Royce) Avon gas compressor, along with two Siemens SGT-400s. The Avon unit is not compliant with MCPD legislation and therefore requires intervention. This project aligns with our RIIO-T2 stakeholder priorities "I want you to care for the environment and communities" and "I want to take gas on and off the transmission system where and when I want".

King's Lynn plays a critical role in ensuring gas can enter and exit the National Transmission System (NTS) through the Bacton terminal, including the Europe interconnector connections. To facilitate high exports to Europe via the Bacton Terminal, compression at King's Lynn is the only option while the site also plays an important role in moving gas away from the South-East when supplies exceed demand. Fluctuations in global supply patterns only serve to showcase the importance of King's Lynn. The 2022 Russia-Ukraine conflict resulted in record high volumes of gas being exported through Bacton terminal to mainland Europe; an essential action for the EU to replenish and maintain their storage levels. As the UK becomes more import dependent, it is critical that the entry and exit capability and resilience is at the required level to ensure UK and South-East Security of Supply.

NGGT have undertaken a full optioneering process, costing the most applicable options to achieve MCPD emissions legislation by 2030. Given the identified limitations with using Future Energy Scenarios (FES) 2021 to identify the right investment case, we have developed an options assessment process to determine our Final Preferred Option. This process compares shortlisted options against a number of key investment criteria and evaluation models to arrive at a Final Preferred Option which provides emissions compliant compression capability that the network needs via the most cost-effective means for consumers.

Taking into consideration compressor investment planned at other sites per CE-AMP and following evaluation of a range of options this report recommends the investment of a new compressor unit, and re-wheeling of the existing Siemens SGT-400s to increase their utilisation. Decommissioning of the non-compliant Avon compressor unit will be re-assessed after operational acceptance of the new unit. This will achieve emissions compliance while ensuring robust and capable compression at King's Lynn, providing resilient long-term operation and sufficient availability to accommodate high Bacton import and export scenarios. The indicative value of this investment is [redacted][1] (±30%).

Introduction

1. The purpose of this Final Option Selection Report (FOSR) is to seek Ofgem's approval of NGGT's proposed Final Preferred Option for King's Lynn Compressor Station to comply with the MCPD emissions legislation deadline while ensuring that the network is resilient and able to meet a wide range of future demand patterns, ensuring UK Security of Supply. This report will provide a detailed view of the project, its associated timings and setting out the different options considered.

2. As part of NGGT's RIIO-T2 submission in December 2019, we proposed to install two new, gas-driven compressor units and to decommission the two existing Avon units ahead of 2030 due to the site's criticality on the network. Due to the uncertainty in FES and the early stages of the options selection, it was requested that this project be included within an Uncertainty Mechanism, enabling further option development to be undertaken. The need for future investment was recognised by Ofgem in their 2020 Final Determinations.

3. This FOSR is submitted as part of a Compressor Emissions Price Control Deliverable (PCD) as detailed within the Gas Transporter Licence Special Condition 3.11 Compressor Emissions Re-opener and Price Control Deliverable, Part C, and as per Price Control Deliverable Reporting Requirements and Methodology Document[1] and RIIO-2 Re-opener Guidance and Application Requirements Document[2]. Our Compressor Emissions Asset Management Plan (CE-AMP), in support of this FOSR, details our approach for how the whole of our compressor fleet will comply with emissions legislation, while meeting the required network resilience and customer needs.

Investment Driver

4. NGGT is committed to reducing the impact of its activities on the environment while operating with the required network resilience and capability to meet the needs of UK gas consumers. Critical to this is ensuring that our compressor fleet meets emissions limits as set out in MCPD. MCPD requires that our existing compressor fleet, between 1 MW and 50 MW net thermal input, must not exceed Nitrogen Oxide (NO_x) emission levels of 150 mg/m³ by 1 January 2030.

5. In addition to meeting emission legislation, NGGT must ensure the right level of network capability and resilience is maintained to fulfil our customer's needs and our operational requirements. This ensures we efficiently minimise network constraints, meet the peak demand obligation of a 1-in-20 scenario[3], provide Security of Supply to the UK and the necessary assets to maintain market stability. NGGT must ensure that the National Transmission System (NTS) is safe, reliable and available, and that it delivers value for our consumers and stakeholders, while minimising the impact on the environment.

6. King's Lynn has two Avon units, Unit A (disconnected) and Unit B (operational), which are non-compliant with MCPD. Unit B is over 50 years old, operating well beyond its original design life. Failure to meet emissions legislation means that, without

[1] Version 2, published by Ofgem on 17 March 2021
[2] Version 2, published by Ofgem on 3 February 2022
[3] National Grid (2021), Transmission Planning Code, Standard Special Condition A9: Pipe-Line System Security Standards

investment, Unit B would be limited to 500-hours running per year, restricting the operation of the site. Insufficient compression would cause network constraints, resulting in higher gas prices for consumers, and risking Security of Supply. High site reliability and availability is critical for reliable gas importation and exportation at Bacton between the UK and Europe throughout the year.

7. King's Lynn plays a critical role in ensuring gas can enter and exit the National Transmission System through the Bacton terminal, including the Europe interconnector connections. To facilitate high exports to Europe via the Bacton Terminal, compression at King's Lynn is the only option while the site also plays an important role in moving gas away from Bacton and Isle of Grain when supplies exceed demand. As the UK becomes more import dependent, it is critical that the entry and exit capability and resilience is at the required level to ensure UK and South-East Security of Supply. High forecasted gas exports via EU interconnectors and increased supplies from GB LNG terminals are strong indicators for sustained King's Lynn compression. For this reason, a long-term secure, flexible and reliable solution needs to be implemented at the site.

Optioneering

8. NGGT, with the support of Option Selection Consultant [redacted] considered a full suite of solutions to enable King's Lynn to comply with MCPD including:

    - Building new low-emission, high-efficiency compressor(s) (gas or electric-driven)
    - Retrofitting Unit B with emissions abatement technology (such as Control System Restricted Performance (CSRP), Selective Catalytic Reduction (SCR), or a Dry Low Emissions (DLE) combustion system)
    - Minimal investment to enable MCPD compliance (counterfactual), where Unit B operates under a 500 run hour derogation from 2030
    - Decommissioning Unit B (as well as Unit A)
    - Delaying our investment decision, to account for uncertainties in the energy landscape
    - Modification (compressor re-wheel) of the existing compliant units to reduce reliance on the non-compliant Avon

9. An options shortlist was derived where each of the main solutions (new build, abatement, derogation, decommissioning, etc.) is represented across eight options. These options and detail on unit status can be seen in **Table 1**. All shortlisted options incorporate compressor re-wheeling (replacement of the impeller bundle for the two emissions compliant SGT-400s) on Unit C and D. This will increase utilisation of the MCPD compliant units as they will be better matched to future requirements. Decommissioning of the disconnected non-MCPD compliant Unit A has also been included within the options.

Option Shortlist	Unit A	Unit B	Unit C	Unit D	Unit E	Unit F
1 – Counterfactual	Decom.*	500Hr EUD	Compressor Re-Wheel	Compressor Re-Wheel	/	/
2 - 1 x CSRP	Decom.*	CSRP Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
3 - 1 x SCR	Decom.*	1533 SCR Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
4 – 1 x DLE	Decom.*	1533 DLE Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
5 - 1 x New Unit	Decom.*	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	/
6 - 2 x New Unit	Decom.*	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	New Unit (Brownfield)
7 - 1 x New Unit + EUD	Decom.*	500Hr EUD	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	/
8 - 1 x Decom	Decom.*	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	/	/
*Unit A was disconnected in 2017 and partially decommissioned.						

Table 1 - Optioneering Shortlist

Option Evaluation Process

10. During the development of the King's Lynn Needs Case, it was determined that FES do not capture the impact of imbalances in global markets which are the primary driver for usage of King's Lynn. Therefore, FES 2021 could not be used to highlight the consequences of a loss of capability. The option evaluation process used within this report considered the outputs of the CBA process along with other investment drivers and assessments to provide a diverse evaluation of King's Lynn future requirements.

11. A decision tree was used to help guide investment decisions through a number of logical steps, including definition of the investment need and its timeline for implementation. This helped us to assess costed shortlisted options against key investment criteria, evaluation models such as Cost Benefit Analysis (CBA) and Best Available Technique (BAT) and consider solution technical maturity and total installed cost within our decision making.

12. This ensured that our Final Preferred Option achieves our core investment requirements and network needs, as well as providing value for money for consumers and avoids over-investment which can lead to asset stranding. This roadmap can be seen in **Figure 1**. These essential criteria were evaluated in an option assessment matrix to discount options until a Final Preferred Option remained.

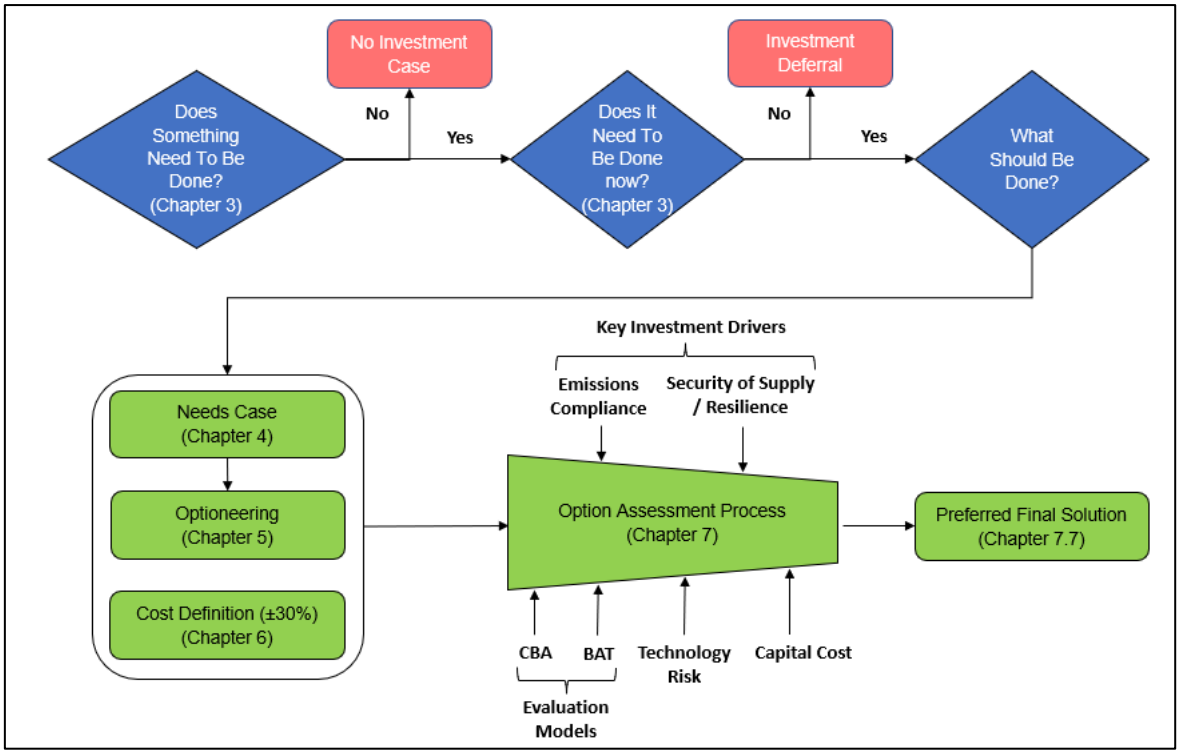


Figure 1 - Option Assessment Process

Assumptions

13. Capability boundary analysis[4] and assessment has been updated from our RIIO-T2 submission with FES 2021 data[5], producing option constraint costs. However, the uncertainty and limitations of FES gives a poor representation of scenarios for King's Lynn, forecasting low constraint costs. Investment based on this data gives a significant risk of underinvestment, leading to network constraints and Security of Supply issues.

14. FES's limitations include no consideration of market trends such as significant historic global supply pattern changes over recent years as Europe reduced its dependence on Russian gas supplies. Therefore, realistic and historical scenarios as seen throughout 2022 with sustained high Bacton export are not considered within FES. Assessing these realistic scenarios is important in determining the required compression at King's Lynn and the necessary resilience to enable sufficient levels of compression to remain available throughout the year enabling GB's market to be flexible to changing supply and demand patterns, see CE-AMP[6] for more information on our position on FES.

Final Preferred Option

15. To maintain parallel operation at King's Lynn, the third unit requires a high level of availability and reliability during periods of planned and unplanned outages. Multiple assessments have been completed to determine the Final Preferred Option, including considerations for emissions compliance, BAT assessment, cost benefit analysis,

[4] For more information on how capability boundaries are produced, refer to ANCAR 2022.
[5] This FOSR has used the FES 2021 data. FES 2022 was published on 18 July 2022, but elements of our analysis had already commenced and therefore we have progressed the FOSR using FES 2021. See Sect. 4.1 for more context.
[6] Compressor Emission Asset Management Plan v2.0

impact to Security of Supply, case study assessment, technology maturity and capital investment assessment.

16. The option assessment matrix used to determine our Final Preferred Option can be seen in **Table 2** below.

Option Assessment Matrix Kings Lynn	Emissions Compliance	BAT Assessment	CBA	Security of Supply / Case Studies	Technology Risk	Capital Investment
1 – Counterfactual						
2 - 1 x CSRP						
3 - 1 x SCR						
4 – 1 x DLE						
5 - 1 x New Unit						
6 - 2 x New Unit						
7 - 1 x New Unit + EUD						
8 - 1 x Decom						

Table 2 - Option Assessment Process

17. Following the evaluation process mentioned above, this report recommends the investment of one new compressor unit by 2030 at King's Lynn Compressor Station. Our Final Preferred Option also includes re-wheeling of Unit C and D compressors and the decommissioning of Unit A. The cost of decommissioning of Unit B has been included in the option assessment, but decommissioning will be assessed after operational acceptance of the new unit. This solution ensures high site availability and resilience to a multitude of uncertain customer and market requirements, and gas supply and demand scenarios.

Justification for our Final Preferred Option

18. Option 5 scored highest in terms of network versatility, future proofing against changes in energy legislation, maintainability and emissions. Modern compressors also offer efficient operation, long-term reliability, high availability and low emission compression which is essential to protecting the UK's Security of Supply. The new unit solutions feature the most up-to-date technology and support packages, which provides some protection from future changes in energy legislation ahead of the UK's commitment to achieve Net Zero by 2050.

19. Option 5 remains the preferred solution as it is the lowest cost solution that provides sufficient compression capability that the site requires with an acceptable level of risk. Further resilience is provided in options 6 and 7 through adding a fourth compressor train to the site but we do not feel that the additional investment required for these options can be justified.

20. Options requiring the 50-year-old Avon to remain operational for the enduring future to support UK Security of Supply poses a high risk to the operation of the NTS and the UK's Critical National Infrastructure. In addition to this, limiting Unit B to 500 run hours through derogation doesn't provide the required site resilience to parallel operation (as

highlighted in 2022 where the unit had significantly higher run hours than previous years). Installing Emission Abatement technology onto the existing Avon add additional risks to those already present.

21. New unit investment is justified through evaluation of several specific scenarios which highlight the importance of King's Lynn to the UK's gas imports and exports. Real World analysis highlighted the risks posed by sustained high exports, as seen in 2022, and how these flows could lead to exceeding the 500-hour limit on the Avon. For example, based on our analysis, if the third unit was subject to 500-hour derogation, there would be more than 162 hours where capability could not be met. This would equate to 9.4 mcm per day, and 63 mcm in total. This would cost between £13-23m based on the gas price at the time (i.e. BEIS long term average price = 60 p/th; early 2022 prices = 150 p/th). Longer term analysis shows the consequences of high utilisation of King's Lynn for an extended period and highlights the value of the greater resilience provided by new units.

22. Delaying this investment has not been evaluated due to the criticality of Unit B, and that a viable solution is in place by the 2030 MCPD compliance deadline. Given the fact that future investment at King's Lynn is driven by a number of key investment criteria (as stated above), such investment criteria cannot easily be represented in economic modelling and therefore any Real Options Analysis performed on deferring new unit investment would not provide any meaningful insight.

Conclusion and Next Steps

23. Ofgem are invited to assess and approve the proposed Final Preferred Option for King's Lynn Compressor Station in line with Special Condition 3.11, Part C, 3.11.9. Following Ofgem's decision on the Final Preferred Option, NGGT will use the received Baseline allowances to develop our preferred option further and submit a Re-opener application in line with Special Condition 3.11, part D and appendix 2 for Ofgem's consideration in April 2025. We welcome the engagement with Ofgem throughout the option selection process and intend to keep engaging with the regulator at all relevant project development stages, so they remain informed throughout and ensure we successfully deliver our proposed solution at King's Lynn Compressor Station.

Table of Contents

1. Introduction

Background

24. NGGT is committed to reducing the impact of its activities on the environment. Critical to this is ensuring that our compressor fleet meets emissions limits as set out in the MCPD. MCPD requires that our existing compressor fleet, between 1 MW and 50 MW net thermal input, must not exceed 150 mg/m³ Nitrogen Oxide (NO_x) by 1 January 2030. Units can also be restricted 500 run hours per year, on a rolling five-year average with a maximum of 750 run hours permitted in a single year. This removes the use of the compressors from standard operation, where they can only be run to prevent commercial constraints (Essential Use) or exit constraints (Emergency Use) on the network.

25. The purpose of this FOSR is to seek Ofgem's approval of NGGT's proposed Final Preferred Option for King's Lynn Compressor Station to comply with MCPD emissions legislation, while ensuring that the network is resilient and able to meet a wide range of likely future supply and demand patterns, ensuring UK Security of Supply. Existing Avon Unit B is not compliant with MCPD and therefore a solution needs to be operational before the compliance deadline of 1 January 2030.

26. By assessing the options available to make Unit B emissions compliant we have considered the long-term capability and resilience requirements for the site. These include the impact on GB Security of Supply considering high forecasted gas exports via EU interconnectors and increased supplies from GB LNG terminals which are all strong indicators for sustained King's Lynn compression and underline the value for GB to maintain the transit capability. As part of our option selection process, we have taken into consideration the results of CBA and BAT assessments as well as underlying technology risks. We have considered appropriate case studies such as Bacton supply and demand scenarios to support our Final Preferred Option.

Ofgem FOSR Pre-Engagement

27. Robust and regular engagement is essential to bring internal and external stakeholders along on the investment journey. We have prioritised monthly touchpoints with Ofgem to update them on our investment progress, outline the next steps and seek their feedback on any gaps or technical challenges we have discovered. The following is a series of Ofgem engagements which have influenced the Options Selection process for King's Lynn:

- 9 December 2022: King's Lynn Final Preferred Option update and Security of supply overlay
- 18 October 2022: King's Lynn key investment considerations and treatment
- 20 September 2022: King's Lynn key messages, option shortlist, Bacton pressure service overview and preliminary CBA results
- 26 July 2022: King's Lynn Needs Case & Option Selection
- 7 June 2022: General compressor NO_x emissions
- 3 May 2022: CBA/BAT interface presentation
- 1 April 2022: Reliability, Availability and Maintainability (RAM) model
- 22 March 2022: Avon DLE/CSRP initial results

Site Overview

28. There are a total of three operational units at King's Lynn that can run in multiple configurations to move gas East or West. Unit B is a Siemens (formerly Rolls-Royce) Avon compressor, and Unit C and D are Siemens SGT-400s. Unit C and D are the lead units on site, compliant with MCPD legislation. Unit C and D were commissioned in 2003, Unit B was commissioned in 1973. Current operation is reliant on the oldest unit on site (Unit B) due to the operational envelopes of Unit C and D.

Unit	Engine	Fuel Type	Power Base (MW)	Installation Date	Minimum Operational Flow (mscm/d)	Nominal Capacity (mscm/d)
A (disconnected)	Avon	Gas	12.34	1971	13	56
B	Avon	Gas	12.34	1971	9	56
C	SGT400	Gas	12.9	2000	15	42
D	SGT400	Gas	12.9	2003	16	42

Table 3 – Existing Assets Summary

29. Unit A was removed from service in 2017 in alignment with our 2019 Business Plan proposal to replace these units with new unit investment. Decommissioning of Unit A is included as part of the Final Preferred Option for King's Lynn.

Document Structure

30. This FOSR follows the structure of Ofgem's Engineering Justification Paper Guidance for RIIO-GD2 and RIIO-GT2 (published 20 September 2019[7]). The FOSR is supported by the CE-AMP, which also contains reports regarding CSRP, Avon DLE retrofit and the RAM Model for the NTS fleet. This report has been prepared under National Grid Gas plc Gas Transporter Licence (as effective from 1 April 2022) following Ofgem's Price Control Deliverable Reporting Requirements and Methodology Document: Appendix 5: Supplementary Re-opener Reporting Requirements - Final Option Selection Report[8] and the RIIO-2 Re-opener Guidance and Application Requirements Document[9].

31. The current status of the project describes the work we have completed on site to date and a summary of the request for Ofgem of NGGT's Final Preferred Option, which is summarised in **Section 2**.

32. **Section 3** states the problem which is present at King's Lynn regarding future emissions compliance and provides context regarding interactions with industry, related NGGT projects and identifies the criteria for a successful delivery.

33. **Section 4** confirms the Needs Case for future investment at King's Lynn, which has been approved by Ofgem as part of the RIIO-T2 Final Determinations in December 2020. The section discusses the used supply and demand scenarios and defines the Bacton high import and high export scenarios, which are further discussed in **Section 7**. In this section we provide the detail on current compressor operation, utilisation and

[7] RIIO-2 final data templates and associated instructions and guidance | Ofgem
[8] Version 2, published by Ofgem on 17 March 2021
[9] Version 2, published by Ofgem on 3 February 2022

availability, which was used to support our option selection assessment. This section provides a summary of the scope of the Final Preferred Option.

34. The option selection process identifies credible solutions to the problem and scope described in **Section 4**. **Section 5** details NGGT's option selection process alongside detailed description of all short-listed options. The section provides how we have evaluated options including the option scoring results in the preliminary BAT assessment.

35. **Section 6** describes the cost methodology used to produce cost estimates to ±30% accuracy and details the base data which was used to arrive at the current option costing. This section provides a detailed cost breakdown per shortlisted option as well as cost phasing for the Final Preferred Option. This section together with **Sections 4 and 5** provide the inputs into the option evaluation and final recommendation of the Final Preferred Option.

36. **Section 7** builds on the scenarios defined in **Section 4** and describes the option assessment process (including a decision tree using information provided in **Section 3, 4, 5 and 6**), which defines the selection of the Final Preferred Option. The section summarised the key investment drivers including emissions compliance, BAT, network capability, CBA, Security of Supply, resilience, technology risks and total installed costs (capex). Security of Supply and resilience considerations include the analysis of Bacton high import and export scenarios, which includes a Real World analysis of the 2022 gas flows and 'The Beast from the East' as well as a long-term analysis utilising the [redacted] gas demand forecast[10]. Each investment driver is described in detail, then summarised in our final option justification and recommendation of our Final Preferred Option. The result of our recommendation is summarised in an option evaluation matrix.

37. **Section 8** summarises detail of our Final Preferred Option including the estimated delivery programme, risks and opportunities identified and reiterates how the project has been funded to date.

38. **Section 9** concludes our reason for the Final Preferred Option selected and identifies the next steps to option delivery.

39. The FOSR appendices contain detailed engineering back-up material and documentation including the models for site availability and the CBA for all considered FES, engineering and asset health reports (including execution programmes and risk registers), emissions abatement technology testing studies for SCR and the preliminary BAT assessment report. In addition to these technical documents, we also provide the assurance letter and a mapping of Ofgem requirements. For ease of reference, a data book of all tables used in this report is also provided within **Appendix K**.

[10] [redacted] Q4 2022 Long Term European Outlook

1.1. Summary Table

Name of Project	King's Lynn MCPD		
Scheme Reference	PAC1051190		
Primary Investment Driver	Compliance with MCPD legislation		
Project Initiation Year	2019		
Project Close Out Year	2029		
Total Installed Cost Estimate (£)	[redacted] (does not include spend to date)		
Cost Estimate Accuracy (%)	±30%		
Project Spend to date (£)	[redacted] (until end of December 2022)		
Price Base	2018/19 prices		
Current Project Stage Gate	4.2 - Option Selection		
Reporting Table Ref	RRP Table 6.2 (Projects) and Table 6.1 (CAPEX_Summary)		
Outputs included in RIIO-T1	No		
Outputs included in RIIO-T2	<u>Compressor Emissions PCD:</u> PCD to ensure NGGT delivers a Final Options Selection Report, long lead items and Re-opener submission[11]. Final Option Selection Report: January 2023[12] Re-opener application window: April 2025 Baseline allowances: [redacted] (excl. RPEs)		
Spend Apportionment	**RIIO-T1**	**RIIO-T2**[13]	**RIIO-T3**[14]
	[redacted]	[redacted]	[redacted]

Table 4 - FOSR Summary Table

[11] Detailed in Special Condition 3.11 Compressor emissions Re-opener and Price Control Deliverable
[12] FOSR submission date as directed by Ofgem on 5 September 2022
[13] Spend profile does not include previous spend, only forecast spend associated with the Final Preferred Option.
[14] As per project spend profile – Option 5; See **Section 6.3**

2. Project Status and Request Summary

Overview

40. As part of NGGT's RIIO-T2 submission in December 2019, we proposed to install two new, gas-driven compressor units and to decommission the two existing Avon units ahead of 2030 due to the site's criticality on the network. Due to the uncertainty in FES and the early stages of the options selection, it was requested that this project be included within an Uncertainty Mechanism, enabling further option development to be undertaken. This additional option development takes the format of a two-step process whereby this FOSR is submitted in January 2023, followed by a cost submission in April 2025 once the project has gone through a full FEED phase for the preferred option and tender process.

41. This FOSR has been created through our Option Selection (Stage 4.2 of the Network Development Plan (NDP); overview in CE-AMP[15]) process to assess credible options aimed at achieving MCPD legislative compliance while meeting customer and stakeholder needs.

Project Status

42. Since 2019, NGGT have selected an Option Selection Consultant, [redacted] to support in further evaluating the available options to achieve MCPD compliance by 2030. All options proposed as part of the RIIO-T2 submission have been further evaluated, along with new Emission Abatement technology and decommissioning options.

43. A preliminary BAT assessment undertaken by [redacted] was also completed, feeding into the decision-making process. BAT analysis is an assessment of the available techniques best placed to prevent or minimise emissions and impacts on the environment. Options that were considered in the preliminary BAT assessment are aligned to those described in **Section 5** and include abatement options identified since the previous assessments included in our 2019 RIIO-T2 business plans. The preliminary BAT Assessment report can be found in **Appendix G**.

44. The required initial and ongoing Asset Health expenditure applicable for each of the shortlisted options described in **Section 5** has been investigated, see **Appendix D** for the Asset Health Report.

45. A qualitative risk assessment has been undertaken for all options with a focus on risks that may differentiate between options for concept selection purposes. As part of the risk assessment process, significant areas of risk requiring onward management and opportunities to be further investigated as part of value engineering were also identified. Risks relating to specific options can be found within **Appendix F**.

46. Network operating scenarios have been assessed as part of this FOSR. These include scenarios based on the high exports to Europe during 2022, where high site utilisation was required. FES 2021 has also been assessed, however due to its limitations (as

[15] CE-AMP Appendix F - Process

observed with high export to Europe in 2022), it doesn't appropriately mitigate risks associated with under investment. Details of this can be found in **Section 7.**

Request Summary

47. To achieve MCPD legislative compliance and the required resilience levels at King's Lynn Compressor Station, NGGT's Final Preferred Option is to install one new compressor at King's Lynn by 2030, re-wheeling of the MCPD compliant Units C and D, and decommissioning of the non-MCPD compliant Avons, Unit A & B. This has an associated cost of [redacted], to be funded through the Re-opener following submission in April 2025. Funding to decommission Unit B will not be included within the Re-opener funding request, with actual decommissioning being re-assessed after operational acceptance of the new unit. The total project cost includes the already received Baseline funding of [redacted] (excl. Real Price Effects (RPEs)). The Baseline funding will be subject to true up following our Re-opener submission in April 2025.

48. Our Final Preferred Option supports the fleet's operational and availability requirements. Assessments have shown that the third unit on site will be operated in excess of 500-hours a year to prevent network constraints and negatively impacting GB's gas market. Restricting the third unit (Unit B) to 500-hours poses a significant risk to the site meeting its operational requirements. As stated in **Section 7**, retrofit solutions are not viable solutions for the site. The increase in availability and long-term reliability that a new unit provides, along with the re-wheeling of Unit C and D, will increase the site's versatility and ability to respond to multiple operational scenarios.

49. The Final Preferred Option provides the right level of network capability and delivers a reduction in greenhouse gas emissions and fuel usage. This option has been selected from a wide range of potential options that have been evaluated against a range of potential future operating scenarios to identify a solution with an appropriate risk exposure to maximise benefit to consumers. See **Section 7**.

50. Ofgem are invited to assess and approve our proposed Final Preferred Option for King's Lynn in line with Special Condition 3.11, Part C, 3.11.9. NGGT's view is that the PCD should be viewed as fully delivered once we have submitted our Re-opener application at which point the PCD will be revised to reflect the outputs and allowances related to the delivery of our preferred option. NGGT is reporting on our PCD progress and spend as part of the annual Regulatory Reporting Pack (RRP).

51. Following Ofgem's decision on the Final Preferred Option, NGGT will use the received Baseline allowances to develop our preferred option further and submit a Re-opener application in line with Special Condition 3.11, part D and appendix 2 for Ofgem's consideration in April 2025. We welcome engagement with Ofgem throughout the Option Selection process and intend to keep engaging with them at relevant project development stages, so they remain informed throughout and ensure we successfully deliver our proposed solution at King's Lynn Compressor Station.

3. Problem/Opportunity Statement

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

52. NGGT is legally obligated to have its compressor fleet compliant with MCPD legislation[16] by 1 January 2030. Two of the compressors at King's Lynn Compressor Station, Units A and B, fall within the MCPD category and can breach the NO_x limits imposed. Unit A was disconnected in 2017, in line with the 2019 Business Plan request to minimise early asset write off costs as it was proposed to be replaced with a new unit. Retrofit options involving the utilisation of Unit A have been excluded from this project due to the high capex required to restore it to a fully functioning unit. Unit B requires intervention to ensure it remains legally compliant.

53. There are a total of three operational units at King's Lynn that can run in multiple configurations. Unit B is a Siemens (formerly Rolls-Royce) Avon compressor, and Unit C and D are Siemens SGT-400s. See **Figure 2** for a site overview. Unit C and D are the lead units on site, and are compliant with MCPD legislation.

54. Current compressor configuration has seen higher operational hours on Unit B than Unit C and D throughout 2022. This was due to high Bacton export, with Unit B taking primary duty as Unit C and D compressor wheels aren't appropriately mapped to the current flow conditions. Unit B required significant support to keep it operational during this period. Re-wheeling Units C and D will align the operational envelopes to current flows, enabling them to take primary duty.

[redacted]

[16] https://www.gov.uk/guidance/medium-combustion-plant-mcp-comply-with-emission-limit-values

Figure 2 – King's Lynn Compressor Station overview

55. Utilisation of the compressors at King's Lynn is directly linked to the import and export at Bacton. King's Lynn compression is used to supply gas to Bacton during high exportation to Europe through the interconnectors, and to pull gas away from Bacton during high importation from Europe.

56. King's Lynn's two SGT-400s operate in parallel to meet high flow requirements. To maintain the required level of site resilience, an unrestricted unit with a high level of availability is required as backup. This is required to uphold UK Security of Supply.

57. The location of King's Lynn and Bacton is illustrated in **Figure 3**.

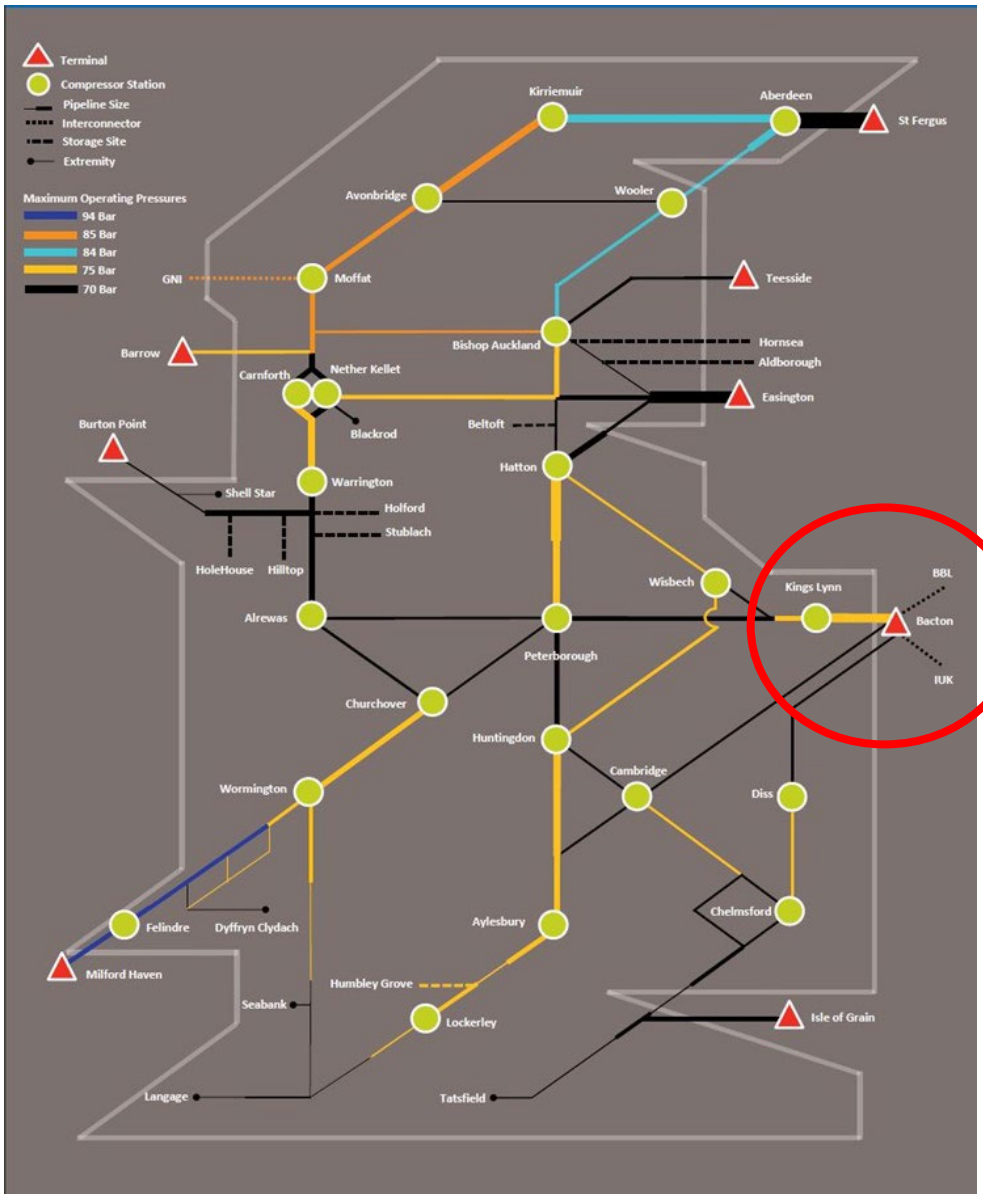


Figure 3 - Location of King's Lynn Compressor Station and Bacton Terminal

58. "Doing nothing" for this project is defined as the 'Counterfactual' within this FOSR. This is where Unit B is derogated with only asset health works being completed on it, and

Units C and D are re-wheeled. Derogation of Unit B would limit it to 500 run hours per year over a five-year rolling average, with a maximum of 750 in any given year, with no reduction in emissions from the unit during its operation.

59. Limiting the available run hours of Unit B will impact the ability to maintain network capability, preventing us from meeting our customers' requirements. In 2022, all three units at King's Lynn were operated in excess of 1,000 hours, with planned maintenance being deferred to enable continual operation to support the high flows.

60. Deferring investment in the UK's National Transmission System due to uncertainty in the future energy scenarios will significantly increase the risk to the whole of the UK. An investment decision has to be made now, so that the solution can be in place before the 2030 deadline, minimising risks of restrictions on the compressor fleet, leading to Security of Supply and 1-in-20 peak demand obligation risks.

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

61. The Final Preferred Option of a new unit by 2030 is further reinforced with any forecasts of high import or export at Bacton.

62. Any increase in the net gas demand at Bacton will increase the requirement for a new unit at King's Lynn. A new unit will increase the site's reliability, availability and capability, therefore increasing its versatility to respond to more operational requirements. Below is a list of changes that could increase the net gas demand at Bacton:

- Changes in the interconnectors' operating models or services that increase supplies to Europe.
- Requests from interconnectors to increase export flows (through a PARCA submission).
- Reduction of Europe's gas supply from Russia, requiring more from other sources, e.g. GB.
- UK, Europe and Norway move to a predominantly blue[17] hydrogen-based market. This could increase export through the interconnectors.
- The European Union plans to make Europe independent from Russian fossil fuels by 2030. This could result in a sustained increase in interconnector export demand as seen in 2022.
- Changes in world markets could increase the amount of LNG coming to the UK, increasing the export to Europe.
- Reduction in UKCS supply into the Bacton terminal, increase the volume of gas required from the NTS.
- Increase of industrial / power station demand near Bacton.

63. Increase in net gas supply at Bacton will support the requirement for a new unit at King's Lynn. A new unit will increase the site's reliability, availability and capability, therefore increasing its versatility to respond to more operational requirements and support the

[17] Blue hydrogen is produced from natural gas, and other non-renewable energy sources

UK's Security of Supply. Below is a list of changes that could increase net gas supply at Bacton:

- Closure of storage sites on the NTS, resulting in additional gas being supplied to the network, increasing supplies from Europe.
- Changes in the interconnectors' operating models or services that increase import to the UK.
- Requests from interconnectors to increase import flows (through a PARCA submission).
- Changes in world markets resulting in a reduction of LNG coming to the UK, requiring increase supplies from the interconnectors to meet the shortfall.
- Increase of UKCS supply at Bacton.
- Reduction of industrial / power station demand near Bacton.

64. Any changes in legislation could impact the preferred option for a new unit. Below is a list of changes that could impact the Final Preferred Option:

- Unilateral change in the UK environmental legislation to rescind or alter the conditions of MCPD. Lowering the required NO_x levels and/or including CO limits may favour new more efficient units over existing units that just meet the current legislative levels.
- Introduction of legislation that defines the required energy efficiency of our compressors may favour new units.
- Changes in Gas Safety (Management) Regulations requirements allowing entry of different quality gas from suppliers and the blending of Hydrogen. This has the potential to alter the gas supply mix due to lower processing requirements.

65. Any other changes that could impact the preferred option for a new unit, are listed below:

- Increasing energy costs would favour new units that are more efficient than the existing ones.
- Increasing material costs is less favourable to new units due to the larger material quantities required when compared with retrofit options.
- Unforeseen maintenance and/or failure of the existing Avon resulting in increased asset health costs would favour new units.
- Reduction in the availability of spares for the existing Avon could result in increased down time, favouring new units.
- Reduction in OEM support for the existing Avon would favour new units.
- Energy forecasts with low gas import / export at Bacton is less favourable for new units.
- Energy forecasts with high gas import / export at Bacton is more favourable for new units.

What are we going to do with this project?

66. In order to achieve MCPD compliance and meet the required levels of resilience at King's Lynn Compressor Station, NGGT's Final Preferred Option is to invest in a new

compressor unit to replace the non-MCPD compliant Avon, and to re-wheel the existing Siemens SGT-400s. Once the new unit has been commissioned and operationally accepted, Unit B will be considered for decommissioning. Unit A shall be decommissioned when appropriate, with the aim to align fleet wide projects for efficiency. More detail on our Final Preferred Option can be found within **Section 8.1.**

What makes this project difficult?

67. Uncertainties around the UK's energy landscape and the wide range of averaged demand led energy scenarios detailed within FES has led to a non-representative CBA. If FES, and the CBAs produced from it are the main drivers for investment, there is a very high risk to consumers of underinvestment, leading to network constraints.

68. Construction of new units on our network takes approximately six years from confirmation of preferred option to operational acceptance. To ensure that the Final Preferred Option is operationally accepted by the 2030 deadline, construction cannot be delayed. A level 2 programme for the preferred option is included in **Section 8.1**.

69. The objective of the project is to provide enduring emissions compliant compression capability that meetings the needs of the network now and into the future. Energy supply and demand forecasts are inherently difficult to predict, with large variations from traditional network operational patterns seen in recent years. For this reason, we have had to consider a number of discrete operational case studies in addition to the Future Energy Scenarios produced by National Grid ESO.

70. The current national and international geopolitical situation is creating significant uncertainty in prices and availability of materials and labour which makes estimating project delivery costs more challenging. This will need to be a consideration when finalising the delivery strategy after confirmation/approval of the preferred option.

71. Risks and opportunities associated with the preferred option can be found in **Section 8.2** and details of risks and opportunities of all shortlisted options can be found in **Appendix F**.

What are the key milestone dates for project delivery?

72. The project is currently forecast to have the new unit commissioned in 2028, allowing time for it to become operationally accepted prior to the 2030 deadline. Re-wheeling of the SGT-400s and decommissioning of Unit A will commence when appropriate. Milestone dates have been informed by scheduling of this project against other planned investment work as summarised in **Figure 4**.

ND500 – Network Development Stage Gates & Key Milestones			
ND500 Phase	**Key Activities**	**Sanction**	**Indicative**
4.0 Needs Case **4.1 Establish Scope and Options**	• Identification of Needs Case • Define strategic approach and outputs required to deliver • F1 Sanction – Optioneering • F2 Sanction - Feasibility	**T0**	N/A
		T1	April 2019
		F1	April 2019
		T2	April 2021
		F2	April 2021
4.2 Option Selection	• BAT Assessment and Compressor Machinery Train selection • Final Option Selection Report Submission • Agreement to Proceed to Conceptual Design • F3 Sanction - Conceptual Design and Long Lead Items	**T3**	January 2024
		F3	January 2024
4.3 Concept Design & Development	• UM Cost Reopener Submission • Scope Freeze • F4 Sanction – Detailed Design & Build	**T4**	Sept 2025
		F4	Sept 2025
4.4 Project Execution	• DDS Challenge, Review and Sign off • Maintenance Requirements Identified	**T5**	March 2026
		T6	January 2029
4.5 Acceptance/Closure	• Post Commissioning Handover to GT • Operational Acceptance • Project Closure	**F5**	December 2029

Figure 4 - Key Project Milestones

73. The stage gates within our NDP process ensure minimum requirements are met for each phase of investment development.

74. Decommissioning of Unit B will be reassessed after operational acceptance of the new unit.

How will we understand if the project has been successful?

75. Overall project success will be confirmed by operational acceptance of the preferred option, meeting customer demands throughout the construction period, compliance with MCPD requirements as well as the project completed safely and to time, quality and cost.

76. For this Option Selection stage, the project will be deemed a success if the PCD set out in Special Condition 3.11 will be deemed as fully delivered. The PCD entails the FOSR being submitted to Ofgem in January 2023, and the Re-opener submission in April 2025 following Ofgem's review of the preferred option.

3.1. Related Projects

77. There are key interactions with other significant investments, both at King's Lynn, Bacton and across the National Transmission System (NTS):

- **Bacton Enhanced Filtration Project:** As part of the Bacton Investment Strategy, the Bacton Enhanced Filtration Project aims to enhance gas filtration at Bacton to mitigate against material ingress. Recent instances of solid debris have caused outages during high export flows from the NTS to Europe via the interconnectors. The project is currently in stage 4.2 of the Network Development Process (ND500), and has no impact on this project.
- **Other MCPD Projects:** The option evaluation and recommendations made in this report are predicated on the investment in the Final Preferred Options at other MCPD impacted sites being undertaken prior to 2030 as indicated in CE-AMP. Should any of the Final Preferred Options change, then option evaluation would need to be revisited.
- **Control System replacement:** Units C, D and the station control system replacement is due to take place in 2027/28. Depending on the outcome of this project and the FEED report, unit B's control system may also be included in this project for efficient delivery.
- **King's Lynn AGI subsidence project:** In December 2021 NGGT reported to Ofgem that the outcomes of the various assessments carried out for the King's Lynn AGI subsidence project invalidated the subsidence driver. The perceived extent of subsidence and associated integrity risks had been reduced to manageable levels without the need for major re-build intervention. As a result, NGGT curtailed any further subsidence related project spend. There are other issues that unfolded from the assessments that were considered to be 'secondary requirements' and not part of the subsidence Uncertainty Mechanism project, largely around outstanding asset health interventions needed such as valve seal rates, cathodic protection, potential coating failures, corrosion and refurbishment of actuators. Following the principle of Uncertainty Mechanisms, which is spending money efficiently, NGGT decided these AGI asset health issues would be addressed in suitably identified intervention submissions. As a result, the asset health issues at King's Lynn AGI have been included as part of the Plant and Equipment Asset Health UM which will be submitted separately - currently planned for January 2024.
- **King's Lynn Site Upgrade Project:** This project will remove the functionality of valve(s), pressure(s), etc. associated with the Above Ground Installation (AGI), that are being telemetered via the existing compressor telemetry system. A new telemetry kiosk, field equipment, cabling etc. will be installed close to the AGI area within the compressor fence line to house a new telemetry system dedicated just for the AGI and to align with current applicable NGGT and industry specifications.
- **Other MCPD Projects:** Project efficiency shall be sought with other MCPD projects. This will be determined at project delivery stages.
- **Plant 1 Decommissioning**: There are various decommissioning works planned to be delivered during the RIIO-T2 period. These consist of three

Plant 1 concrete plinths, a GRP topped pit (containing redundant pipework from the Plant 1 control building), a disused gas analyser and a lube oil transfer tank (which is associated with Unit A). These works have been developed with conceptual design and option selection completed. These works are due to be tendered during Q1 2023 with the works planned to take place during the 2023/4 financial year.

- **CH4RGE:** CH4RGE seeks to develop new technologies, which will allow process gas emissions from gas transmission rotating machinery operations to be captured and returned to the network, increasing efficiency, reducing heat delivery costs and associated carbon emissions. These technology solutions, identified as Best Available Technique (BAT), are potentially suitable for installations either as a new build or can be retrofitted to existing equipment.
- **RIIO-T2 Funded Asset Health Scope**: For the purpose of this submission, we have assumed that any asset health scope at King's Lynn that has already been funded in RIIO-T2 will be complete prior to the MCPD project site mobilisation. Opportunities for synergies and delivery efficiency will be reviewed during the MCPD FEED

78. To increase the options available to comply with MCPD legislation, NGGT are trialling emissions abatement technologies to determine their viability and legal acceptance. Trials are ongoing, and yet to be operationally accepted. These technologies are:

- Control System Restricted Performance (CSRP). This involves permanently derating or reducing the power output of an Avon through modification of the control system relative to the Exhaust Cone Temperature. A CSRP proof-of-concept trial was conducted at Huntingdon and Chelmsford Compressor Stations in winter 2021, successfully confirming a correlation between Exhaust Cone Temperature and NO_x emissions. More information can be found within a dedicated CSRP report included as an appendix in CE-AMP.
- Dry Low Emissions (DLE). An Avon DLE retrofit modifies the combustion system within the Avon engine so that air and fuel are premixed before combustion. This reduces the peak combustion temperature, which in turn reduces the amount of NO_x produced. NGGT have funded development of a DLE retrofit 1533 Avon in partnership with [redacted] beginning with combustor can trials in early 2022. A full engine test bed performance trial to determine NO_x reduction, and operational trial on an NTS unit to determine unit availability has been planned. As the performance trials are ongoing, an interim summary report is provided as an appendix to CE-AMP**.**
- Selective Catalytic Reduction (SCR). Exhaust gas NO_x levels are reduced through the use of ammonia injection and a catalyst. A report on the feasibility of the use of SCR technology across the NGGT compressor fleet was produced by [redacted] in 2017, which was updated and revised by consultant [redacted] in June 2022, see **Appendix I**.

79. This project has no impact on planned investments at other compressor stations on the network. However, the delivery strategy across the MCPD projects shall be aligned to increase efficiencies.

80. To support our Option Selection process, we have developed a detailed RAM Model which has evaluated unit availability across the entire NGGT fleet. This study was developed in collaboration with [redacted] An overview of the RAM Model and how it has been applied and used in the CBA can be found in CE-AMP. More detail on this can be found in our Annual Network Capability Assessment Report (ANCAR) 2022[18].

81. An updated version of our Compressor Emission Compliance Strategy (CECS), that was released to support our 2019 RIIO-T2 Business Plan, has been produced. CE-AMP (Compressor Emissions Asset Management Plan) supports this and our other MCPD FOSR submissions. CE-AMP outlines our approach to how our compressor fleet will comply with the emissions legislation, including units to be decommissioned, derogated, retrofitted with emissions abatement technology, and replaced with new units.

3.2. Project Boundaries

82. The scope of this project is delivery of emissions compliant compression which meets forecast network capability requirements. For King's Lynn, these are costs associated with construction of a new compressor unit, re-wheeling of the two SGT-400s, and decommissioning of the Avon. Funding for other costs, such as ongoing asset health costs and operational running costs for the existing units and site, will not be included in the planned Re-opener submission in April 2025.

83. Decommissioning costs for Unit B are included within this option selection report. However, funding will not be included within the 2025 cost Re-opener. Decommissioning of Unit B will be reassessed once the new unit has been operationally accepted and requested as part of the RIIO-T3 decommissioning business plan if required.

84. As detailed within **Section 3.1**, asset health investment which is already funded as part of our RIIO-T2 business plan is not included within this report.

[18] https://www.nationalgas.com/insight-and-innovation/network-capability

4. Project Definition

4.1. Expected Flows and Site Operation

85. The details in the following section are drawn from the Needs Case which is based on the analysis undertaken in support of our 2019 RIIO-T2 business plan submission to Ofgem. The information within the needs case has been updated and refined to support this FOSR. Ofgem accepted the Needs Case to retain compression capacity at King's Lynn as part of their RIIO-T2 Final Determinations in December 2020. As such, the Needs Case was established in our RIIO-T2 Business Plan and has not been issued in a separate Needs Case document. The associated Annex A24.18 King's Lynn Compressor Engineering Justification Paper dated December 2019 also informs the Needs Case and was issued as part of the NGGT Business Plan Submission.

Supply and Demand Scenario Discussion and Selection

86. To fully assess the project, a network assessment to define the capability boundaries was completed. The output from this was used in a risk and constraint assessment to define the associated constraint costs. For more information on how capability boundaries are produced, refer to ANCAR 2022[19].

87. This FOSR has used FES 2021 data. The FES 2022 (published on 18 July 2022) framework is consistent with 2021, however there are concerns with how heat has been decarbonised in the Falling Short (previously SP) scenario and the potential source of hydrogen in the System Transformation scenarios, reinforcing our decision to use FES 2021 data for consistency during this planning cycle. Full details of the review and differences are detailed in **CE-AMP Section 3**.

88. For FES 2020, the published scenario framework was updated (see **Figure 5** below), with Net Zero targets included. This framework was continued for both FES 2021 and FES 2022.

[19] https://www.nationalgrid.com/gas-transmission/insight-and-innovation/network-capability

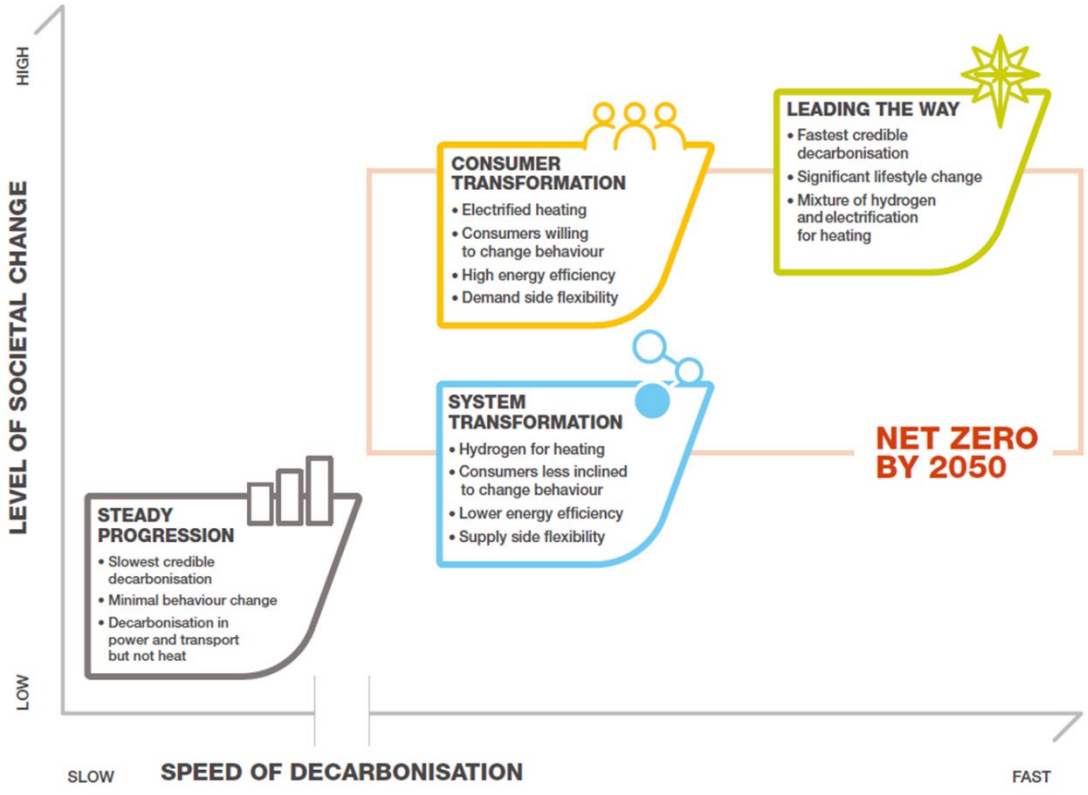


Figure 5 - FES 2021 Framework

89. The four FES scenarios do not consider shorter term market trends and only forecasts supply to meet UK demand whereas other market factors, such as the current curtailment of Russian supplies to Europe would take supply through interconnector export demand. Therefore, none of the FES scenarios provide an appropriate case for the expected range of operation at King's Lynn, specifically high export and import scenarios through the Bacton terminal. Please see **Section 7.3** for more context on how FES has been used in our investment decision making.

90. As a result of this, we have defined high export and high import scenarios to reflect the appropriate range of demands that could be placed on the NTS and its assets. These scenarios highlight the significant need for King's Lynn compression outside of forecasted FES flows. For the export scenario we have used the last 12 months actual data to indicate how King's Lynn has enabled the levels of exports seen and what the impact would have been if compression at King's Lynn had not been fully available. For the high import scenario, we have assessed the flows during 'the Beast from the East' in late February/early March of 2018. This shows a loss of capability if parallel operation of King's Lynn was not available, resulting in the likely restriction of entry flows at these terminals which would likely have impacted supply security.

91. The gas landscape has changed considerably in the last 20 years. With the continued decline of UK Continental Shelf (UKCS) supplies and the need to decarbonise, NGGT expects gas supply and demand patterns to continue to change and become more volatile going forwards. This includes a greater dependence on imports, **Figure 6** shows

the increase in imports in the Steady Progression (SP) scenario[20]. There are two major import routes into the UK supported by compression at King's Lynn, these being LNG from Isle of Grain and the two interconnectors to continental Europe at Bacton. To ensure these import routes are not restricted under the appropriate range of supply/demand conditions reliable and unrestricted compression at King's Lynn will be critical.

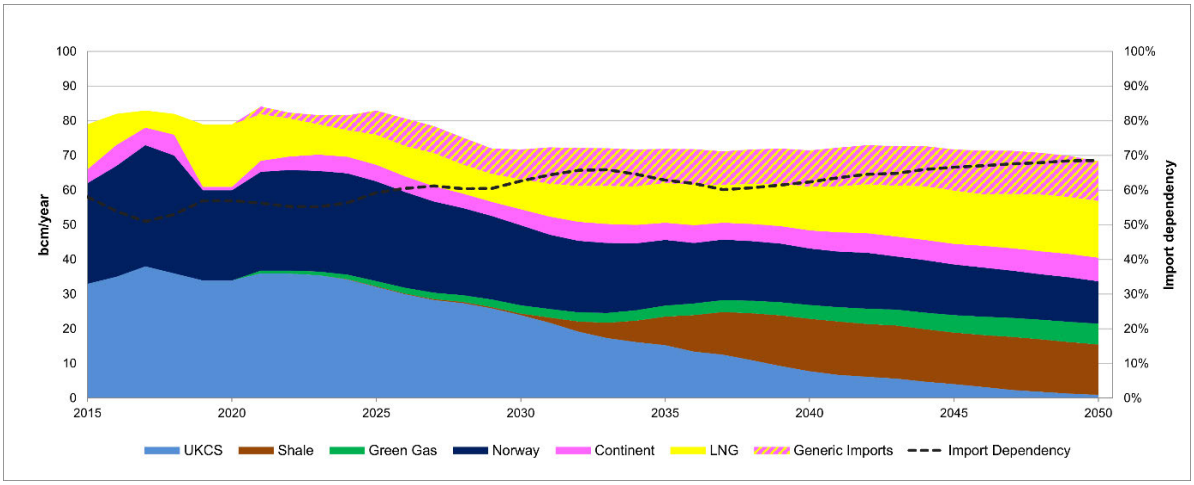


Figure 6 - Steady Progression: FES 2021 Annual gas supply and Import dependency

92. There are many factors which create uncertainty on the extent and speed of change. Global events can happen at any time and have the potential to impact the global gas market and therefore, the source of gas for the UK can change drastically both short and long term. The Russian curtailment of gas to Europe has caused record levels of gas exports from the UK to Europe since February 2022 and great reliance on the functioning and reliability of the NTS assets.

Current Operation

93. King's Lynn Compressor Station comprises three operational compressor units, Avon Unit B and Siemens SGT-400 Units C and D. The site is critical in supporting NTS gas entering and exiting through the Bacton terminal and utilisation is likely to remain high over a wide range of network conditions.

94. Bacton and Isle of Grain terminals are both significant entry points to the NTS in the South-East. Compression at King's Lynn is required to move gas away from the South-East when supplies exceed demand in the region.

95. To facilitate high exports to Europe, compression at King's Lynn is the only option. This means the site needs to be fully available all year round to support both exit and entry flows, requiring maintenance scheduling to be aligned to interconnector outages. The inability to complete maintenance when required will increase the likelihood of unplanned outages, leading to network constraints.

96. [redacted]

[20] https://www.nationalgas.com/insight-and-innovation/gas-ten-year-statement-gtys

[redacted][21]

Key Flows and Boundaries

97. The key flows which drive the usage of King's Lynn are imports at Bacton and Isle of Grain and exports of gas at Bacton. These flows are subject to the global market conditions that can be difficult to forecast and have the potential to significantly alter the need for and usage of King's Lynn at short notice.

Bacton exports

98. Exports at Bacton have traditionally followed a seasonal pattern linked to the traditional relative market price levels and movements, they also have the ability to respond to the daily differences between the UK and European markets. There are occasions when more significant energy and price imbalances drive flows outside these patterns. This has been particularly evident in 2022 with very high exports to Europe driven by reduced imports of Russian gas in Europe and associated increases in price.

99. The exports in recent years are shown in **Figure 7**.

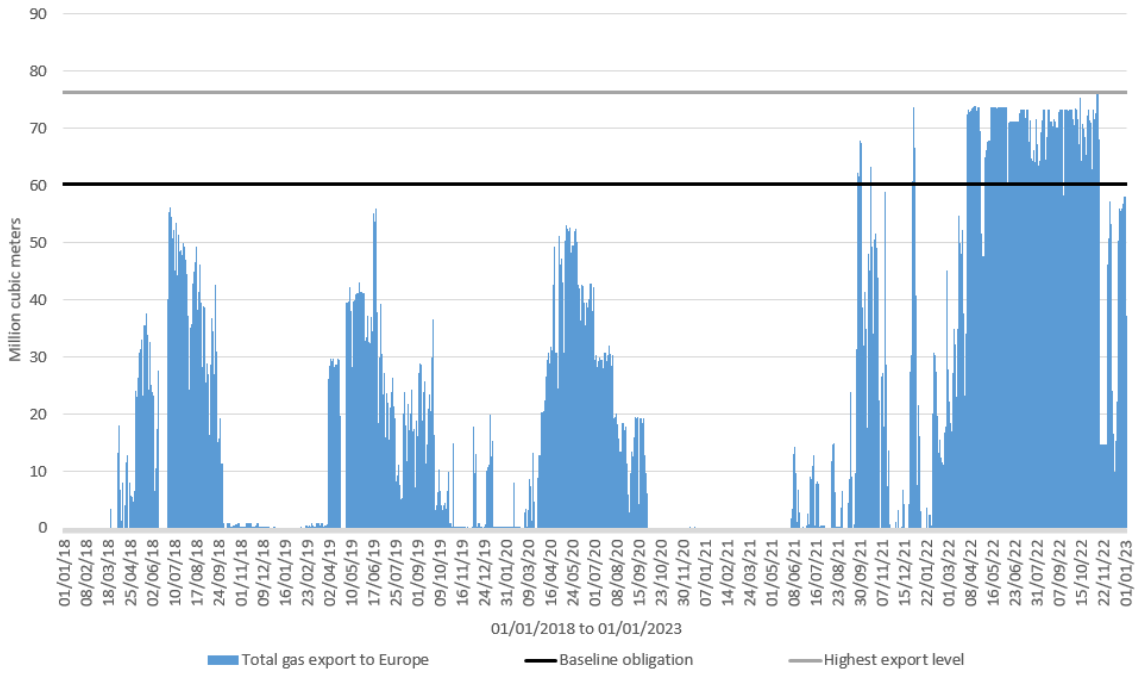


Figure 7 - Total Bacton exports from 01/01/2018 to 01/01/2023

[21] [redacted]

100. As a result, King's Lynn Compressor Station has seen significantly higher run hours in the eight-month period between April 2022 and December 2022 than any other period from the last five years. The total run hours for the eight-month period were 7,081 hours across all of the units on site, with parallel running required at times. Exports to Europe are expected to remain high in the short to medium term. To understand the long-term outlook for exports to Europe we have used [redacted] long term GB market projections[22] which show a prolonged need for increased flows out to 2050. The impact of this is assessed in **Section 7.4**.

Bacton Imports

101. Imports via BBL and INT interconnectors at Bacton are commercially driven to flow towards the most favourable market price. Historically, this has meant imports to GB during winter to meet demand and exports during summer to re-fill European storage. The levels of imports to GB via interconnectors also depends on the LNG market. Historically, when LNG deliveries to GB have been lower due to higher prices/demand in Asia, imports via Bacton interconnectors have been higher as GB prices have been higher than EU.

102. In winter 2017/18, there was very low LNG supply to GB as shown in **Figure 8** below. This was due to high demand for LNG in Asia.

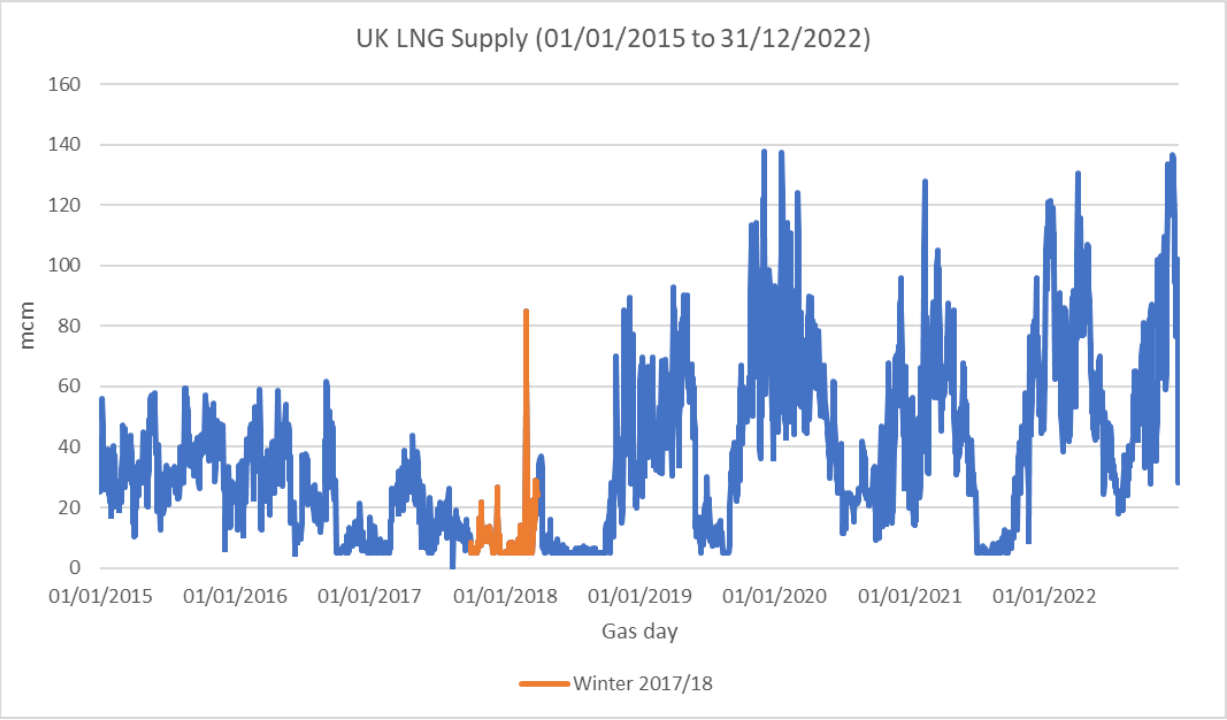


Figure 8 - LNG supply to the NTS (1 Jan 2015 to 31 Dec 2022)

103. As a result of low LNG supply into GB, the price differential with EU was in favour of GB and hence imports from continental Europe were much higher than typical as shown in **Figure 9** below.

[22] [redacted] Q4 2022 Long Term European Outlook

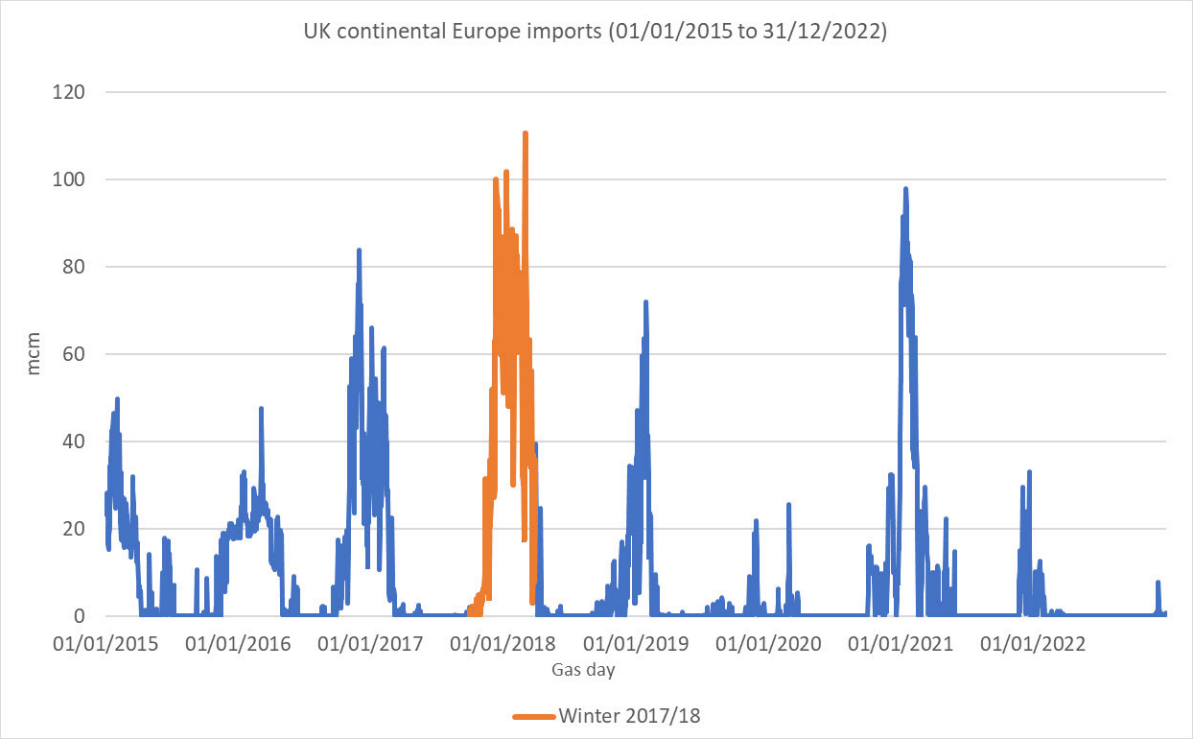
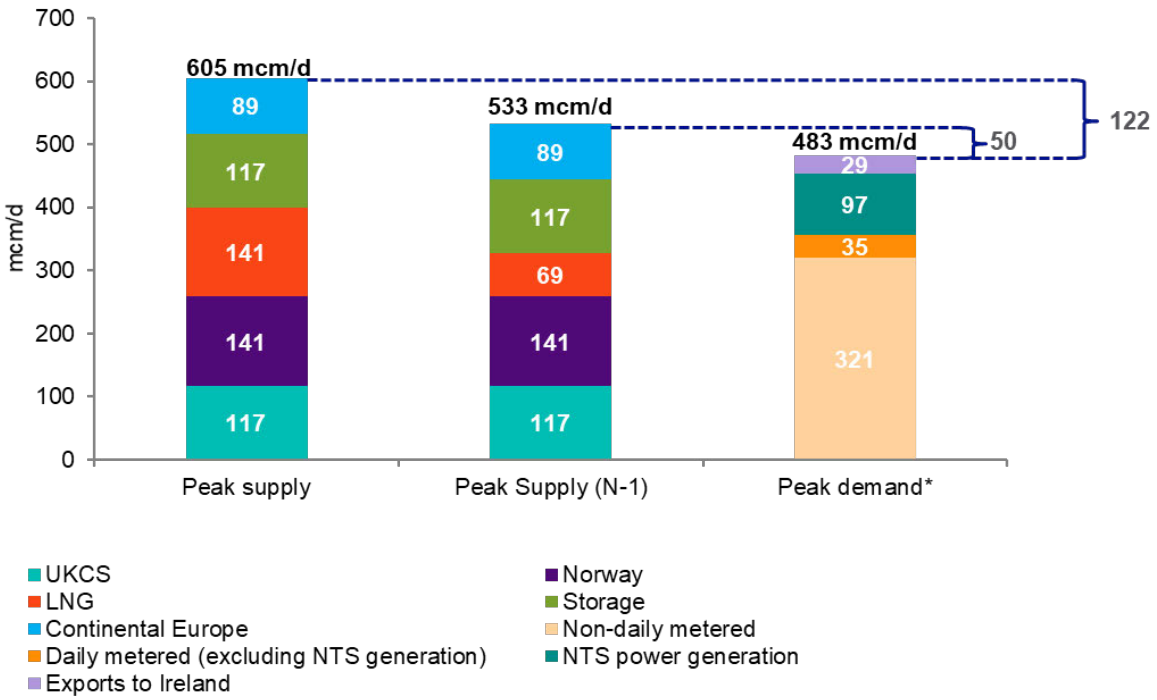


Figure 9 - Continental Europe import supply to the NTS (1 Jan 2015 to 31 Dec 2022)

104. Both the high imports seen in 2017/18 and high exports in 2022 are examples of how global events happening unexpectedly, in a short period of time, can impact the supply and demand sources to the UK. The UK was well positioned to manage these changes because of the access to the high supply margin (see **Figure 10**). To retain this supply margin, it is pertinent to retain the current levels of Network Capability and resilience on the NTS so that maximum import capability is retained. This will allow the network to react and adapt to sudden changes to minimise the impact of these events and continue transporting gas to UK homes and businesses.



**Peak day total demand contains shrinkage and therefore will not tally*

Figure 10 - Peak day, N-1 largest supply and demand totals and margins

Compressor Utilisation

105. The annual (financial year) running hours of the three operational units are shown in **Figure 11**. Changes in the level of run hours are due to changing supply and demand levels at Bacton.

Kings Lynn Historical Running Hours (hours)							
Unit	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	Apr-Dec 22
B	12	747	21	1	178	126	2891
C	22	10	72	40	778	109	2794
D	139	1131	26	30	628	199	1396
Total	173	1887	118	71	1584	434	7081

Figure 11 - Run Hours as reported in the Regulatory Reporting Pack

106. Running hours in 2017/18 and 2020/21 were associated with higher continental import supplies, leading to a need for compression to move gas away from Bacton. Isle of Grain supplies were also low during this period, if supply from Isle of Grain was higher, the need for King's Lynn would have been greater.

107. The run hours of Unit B are noticeably high due to the flow limitations on Unit C and D. Re-wheeling Unit C and D would improve the performance of these units, enabling their operation at higher flows, subsequently decreasing the reliance on Unit B as shown in **Figure 11** above.

108. The high levels of exports demonstrate the current resilience of the NTS network to adapt quickly and effectively to changing supply and demand patterns. However, King's Lynn is the only compressor that can directly enable higher exit flows at Bacton.

4.2. Capability and Availability

Network Capability

109. The details of the capability analysis process are given in our annual publication Gas Ten Year Statement (GTYS) 2021[23], and in our annual ANCAR[24] statement. **Figure 12** and **Figure 13** below show the entry and exit capability lines for Bacton and the maximum entry and exit capability of the interconnectors.

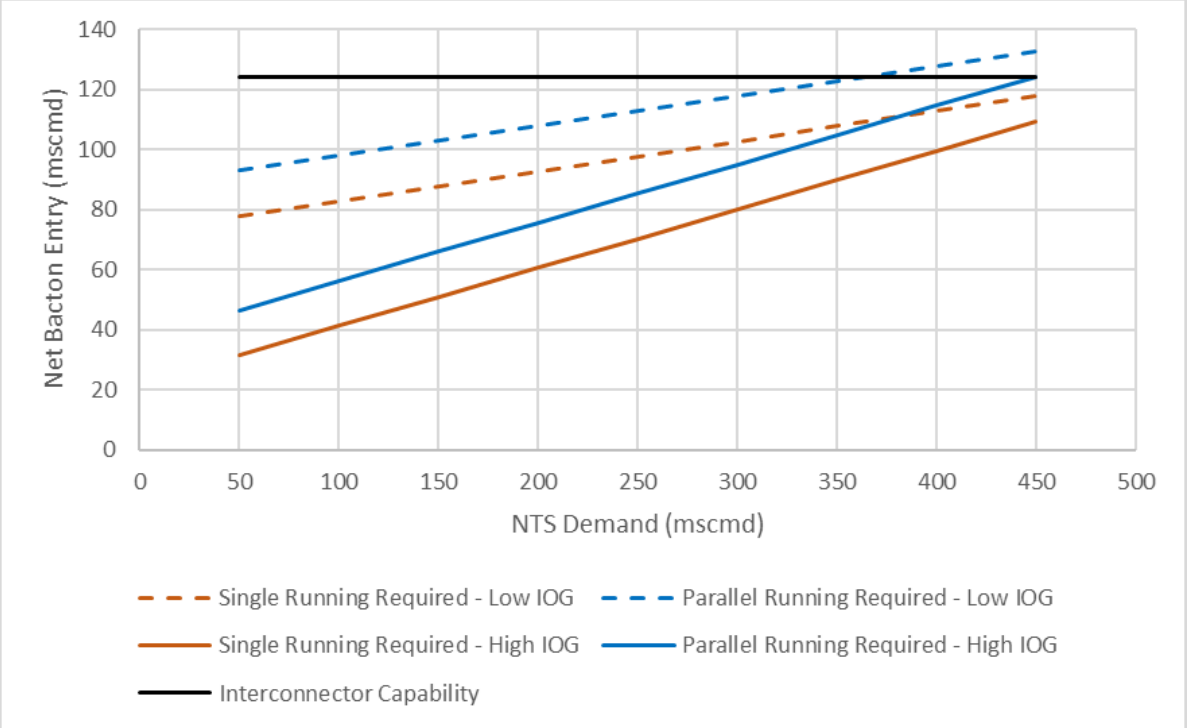


Figure 12 - Bacton Entry Capability Lines

110. **Figure 12** shows the capability lines of parallel and single operation with both high and low Isle of Grain flows. The lines show the entry capability of the Bacton terminal is reduced if two units at King's Lynn are not available to operate in parallel. Only parallel operation at King's Lynn, when NTS demand is greater than 375 mcm and there are low Isle of Grain flows, would be able to accommodate full interconnector supply capability. This shows King's Lynn is critical to the NTS facilitating high interconnector imports.

111. Entry capability of Bacton is reduced when Isle of Grain supply is higher. This is because the quantity of gas able to flow to Southern areas of demand is lower due to supplies from Isle of Grain meeting those demands. Therefore, supplies from Bacton during periods of high Isle of Grain supply, are primarily transported away from the South-East to other areas via King's Lynn Compressor Station. This means the level of Entry capability at Bacton is dependent on King's Lynn during periods of high Isle of Grain supplies.

[23] https://www.nationalgrid.com/gas-transmission/insight-and-innovation/gas-ten-year-statement-gtys
[24] https://www.nationalgrid.com/gas-transmission/insight-and-innovation/network-capability

112. This illustrates the significant potential disruption to customer entry flows when parallel operation isn't available. This could be due to either planned or unplanned outages, or limits on running hours if a derogation had been applied.

113. UK import dependency is increasing and these supplies could be from continental Europe or LNG. The destination for LNG imports is commercially driven with the international LNG market gravitating supply towards the most favourable gas market prices, which can move and change quickly. This has typically meant low UK LNG imports when the Asian markets have their highest demand which creates the need for high levels of imports from continental Europe via Bacton. Therefore, a high level of capability and resilience is required for unexpected supply mix changes.

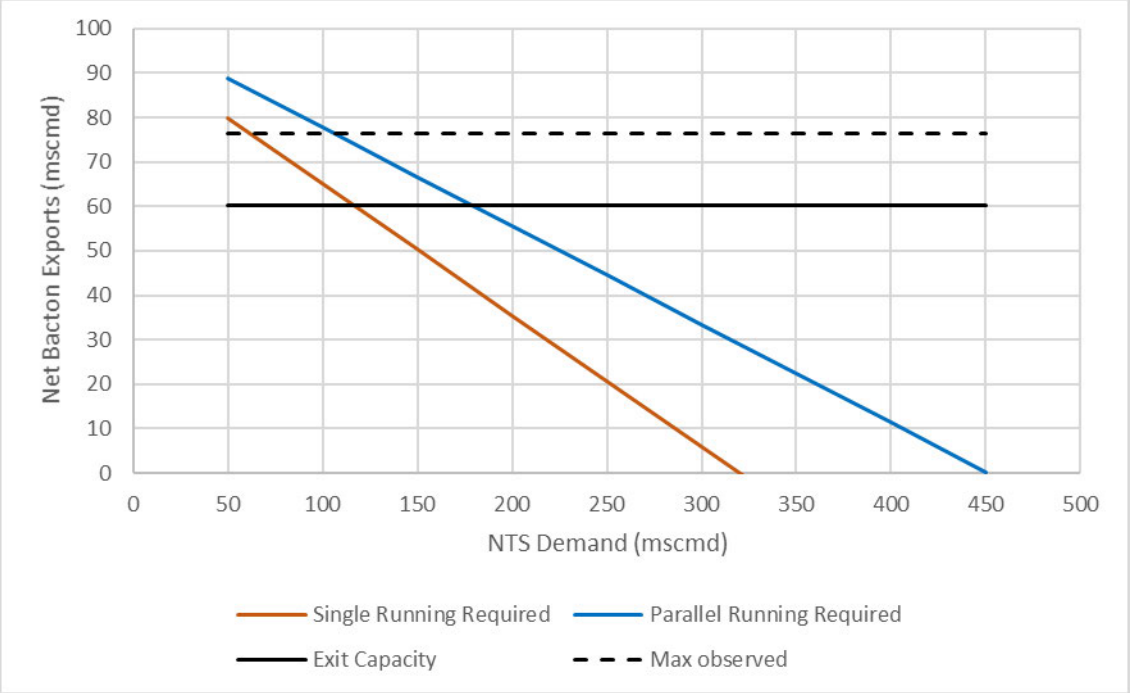


Figure 13 – Bacton exit capability.

114. **Figure 13** shows Bacton export exit capability with single and parallel operation at King's Lynn. Full Bacton export capability is not achieved for most NTS demands and is reduced further when only a single unit is available at King's Lynn. Having King's Lynn fully available is critical to the UK in supporting periods of high exports of gas to Europe.

115. There is little certainty as to when LNG imports into GB will occur during the year, however with UKCS supplies declining, the trend currently is for increasing LNG imports. Currently, Russian imports to European countries have been curtailed. This has led to high levels of exports via Bacton to the continent through the interconnectors which would not have been facilitated if it wasn't for the availability and high run hours of King's Lynn. Therefore, it is important to maintain resilience at King's Lynn throughout the whole year to ensure imports and exports can be facilitated at any time.

Compressor Availability

116. The compressor availability,

Unit Availability	Train Type	Availability used in CBA	Aligns with RAM Scenario
Avon 500 Hours with enhancement	Avon	79.50%	A3
Avon CSRP	Avon	79.50%	A3
Avon SCR	Avon	79.50%	A3
Avon DLE	Avon	74.50%	A3
SGT	SGT-400	80.00%	S2
New Unit	TBC	90.00%	N/A

117. **Table** 5**,** used in our assessment has been based on the RAM Model developed in collaboration with [redacted] An overview of the RAM Model and how it has been applied and used in the CBA can be found in CE-AMP.

Unit Availability	Train Type	Availability used in CBA	Aligns with RAM Scenario
Avon 500 Hours with enhancement	Avon	79.50%	A3
Avon CSRP	Avon	79.50%	A3
Avon SCR	Avon	79.50%	A3
Avon DLE	Avon	74.50%	A3
SGT	SGT-400	80.00%	S2
New Unit	TBC	90.00%	N/A

Table 5 - Compressor Availability

118. Availability for King's Lynn MCPD is based on the likely scenarios from the RAM Study that represents the interim investments that would be made for the proposed option.

119. [redacted]

120. The CSRP option uses the same scenario and investments as scenario A3, as this is limiting peak temperature and NO_x emissions on the same unit so expect no operational reduction.

121. Avon DLE assumes a 5% reduction on the same A3 scenario reducing availability to 74.5%. It would undertake the same investments, but the technology is unproven in operation and is likely to see commissioning and design issues in the short to medium term. [redacted]

122. For each option the site availability is defined based on the compressors required to meet the required capability and the availability of the compressors on site for that option. This availability is then adjusted to account for any 500-hour restrictions which may apply, these are calculated for each scenario every five years. These are detailed further in **Appendix B**.

123. Unit C and D availability are assumed to be 80% based on the S2 scenario which accounts for the new control system and safety/protection/ESD sub-units being replaced under a separate project as part of our RIIO-T2 cyber and asset health investment.

124. New Unit availability is based on the average availabilities for the two Felindre Gas driven Units B and C, which represent the highest availability of a modern gas driven compressor train on the network. This was rounded up to zero decimal places. Their availability is consistent with the RAM Model p10 value for the scenario with the highest availability, S4, representing a re-lifed and supported DLE unit.

4.3. Project Scope Summary

125. Our Final Preferred Option is for one new unit (including SGT-400 compressor re-wheels and Avon unit decommissioning) at King's Lynn to achieve emissions compliance while ensuring robust and capable compression, ensuring resilient long-term operation. **Table 6** provides a summary of the project scope.

Final Preferred Option	One New Gas Driven or Electric VSD Driven Compressor Unit[25]				
Location	Brownfield				
Unit Investment Details	Unit A[26]	Unit B	Unit C	Unit D	Unit E
Investment Action	Decom	Decom	Compressor Re-Wheel	Compressor Re-Wheel	New Build
Year of Commission	1973	1973	2003	2003	2028
Size	12.3 MW	12.3 MW	13.4 MW	13.4 MW	~15 MW[27]
Type of unit	GT	GT	GT	GT	GT/VSD
Scope Boundaries	The scope of this project is for costs associated with the implementation of MCPD emissions compliance. At King's Lynn, these are costs associated with building one new unit (incl. Unit C & D re-wheels and Unit A & B decommissioning). Decommissioning of Units A & B has been included in costs within option evaluations in this document but a decision regarding when to decommission these units will be made separately. The new unit is recommended to be located on the existing site.				
Station Design Discharge Pressure	75 barg (West) 70 barg (East)				
Station Suction Trip Pressure	38 barg				
Availability Required	The optimum level of availability is determined by the cost benefit analysis.				
Supply & Demand Scenario	FES are not appropriate to model the risk of restrictions to the King's Lynn compressors. To quantify the risks associated with loss of King's Lynn we have included analysis to show the impact of sustained high parallel running.				

Table 6 – King's Lynn Project Scope Summary

[25] During engineering evaluation, a GT compressor installation at King's Lynn was found to be of comparable cost to a VSD compressor at ±30% cost certainty. A decision on the specific technology will be made during the FEED phase following confirmation of the Final Preferred Option.
[26] Unit A is already disconnected from the network and is partially decommissioned.
[27] New unit will be appropriately sized to meet capability requirements. To be determined during compressor equipment tender event.

5. Option Selection

5.1. Options Considered

Introduction

126. As part of NGGT's RIIO-T2 Business Plan submission in December 2019, we proposed to install two new, gas-driven compressor units and to decommission the existing Avon units ahead of 2030, following operational acceptance of the new units. However, due to the uncertainty in this decision and the early stages of the options selection, it was requested that this project be included within our Uncertainty Mechanisms, enabling further option development to be undertaken.

127. The options described within the King's Lynn Engineering Justification Paper (EJP) that supported the RIIO-T2 business plan have been investigated in more detail as part of this Option Selection process including previously discounted options and new Emission Abatement solutions. As outlined within **Section 3,** NGGT have considered the full suite of solutions to achieve the required emissions compliant compression capability that the network is likely to require in the future.

128. This section focuses on the engineering options and commercial rules and tools available to solve the problem described in **Section 3.1** and uses the project scope in **Section 4** to generate plausible engineering solutions. This section will describe the option selection process used to identify the Final Preferred Option for this investment, starting from option identification, through option development to option selection. **Figure 14** below serves to identify the various stages involved in a typical option selection process.

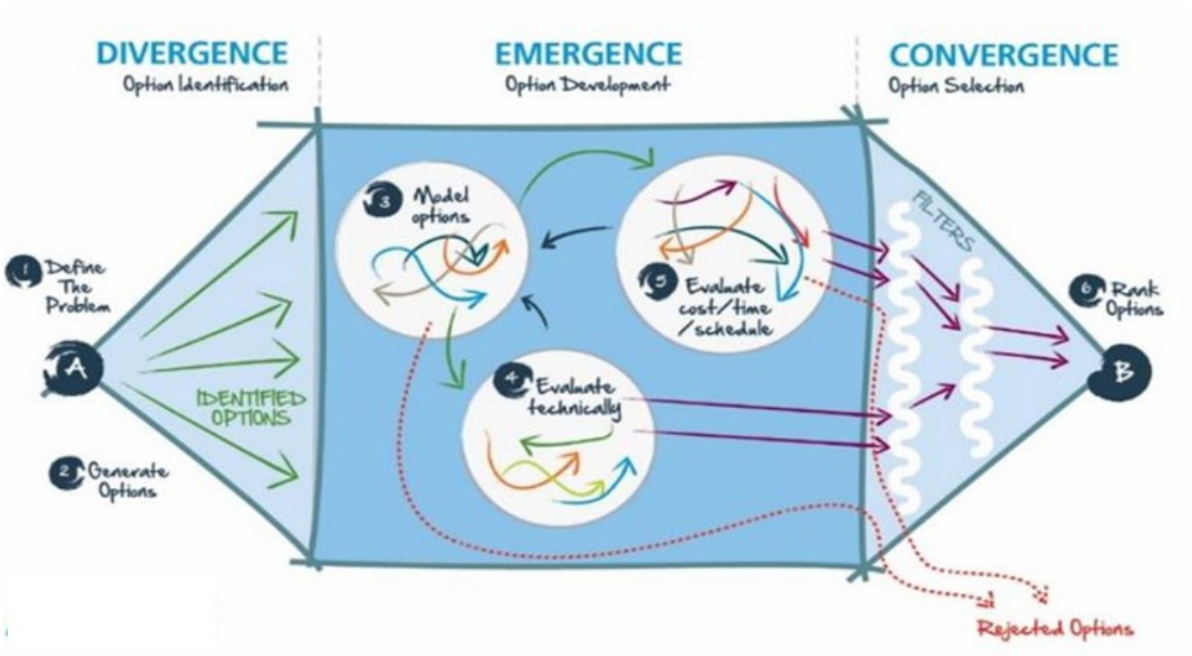


Figure 14 - Generic Options Selection Process

Options Interaction with CBA and BAT

129. The options considered for MCPD compliance are evaluated in a CBA and via preliminary BAT assessment. Our CBA tool is used to conduct whole life cost benefit analysis using a consistent methodology across all our investments. The CBA aims to identify the option with the lowest cost to consumers which is represented by the option with the highest NPV.

130. NGGT is legally bound under the Industrial Emissions Directive (IED) to comply with the requirements of BAT in respect of its compressor installations on the NTS. The BAT assessment methodology, which was developed by NGGT in discussion with the EA and SEPA, is a stepwise process underpinned by an environmental cost-benefit analysis methodology, which draws together environmental and operational priorities to support decision making. The Preliminary[28] BAT assessment, led by [redacted] ([redacted]), was undertaken separately from the CBA using a different methodology. However, it does incorporate common assumptions on cost (incl. constraint costs) and future gas supply predictions. For more information on the BAT process and result, see **Appendix G**.

131. The CBA and BAT are used in conjunction with key investment criteria, technology risks and consideration for capital investment cost to help determine our preferred final option. An option assessment process is used to bring all of these considerations together, please refer to **Section 7** for more detail.

Initial Option Selection and Justification

132. In January 2022, we selected an Option Selection Consultant, [redacted] to support us in identifying and evaluating the feasibility of potential investment solutions. In consultation with [redacted] we have considered the full suite of solutions to enable King's Lynn to comply with MCPD including:

- Investing in a "do minimum" option to improve the site (counterfactual), where Unit B is derogated to run only 500-hours per year from 2030 and Unit C&D compressors are re-wheeled
- delaying our investment decision, to account for uncertainties in the energy landscape
- retrofit or modification of our existing compressors with emissions abatement technology to ensure compliance with the MCPD
- building new low-emission, more efficient gas-driven compressors or VSD units

133. NGGT assessed the full range of options above via an engineering study led by [redacted] and supported by other specialist contractors. **Table 7** references all solutions which have been assessed and provides narrative on the solutions which have been discounted from further investigation. Further detail on how each investment solution has been considered during option selection is provided in the following pages. Please see **Appendix C** for more information on the option evaluation methodology used.

[28] Final BAT will be part of the permit variation submission. For New Units, the BAT is also part of the tender process for new units under T/SP/ENV/21 and the Strategic Sourcing Process

Potential Investment Solutions	Assessed	Option & Compressor Unit Reference Or Option Discounting Justification
Derogation 500-hours Derogation	Yes	Option 1 "Counterfactual" (Unit B) Option 7 (Unit B)
Emissions Abatement Control System Restricted Performance	Yes	Option 2 (Unit B)
Emissions Abatement Selective Catalytic Reduction (SCR)	Yes	Option 3 (Unit B)
Emissions Abatement Dry Low Emissions (DLE) technology retrofitted to Avon	Yes	Option 4 (Unit B)
Decommissioning Disconnect & Decommission Avon once alternative solutions are commissioned	Yes	All Options (Unit A) Option 5, 6, 8 (Unit B)
Reducing Site to Two Units Only Decommission Existing Avon	Yes	Option 8 (Unit B)
New Build New Gas Turbine Compressors, decommission Avon's once new units are operational.	Yes	Option 5 (Unit E) Option 6 (Unit E & F) Option 7 (Unit E)
Compressor Modification Compressor Re-Wheel (Impeller Bundle Replacement)	Yes	Re-wheeling of the SGT-400s (Unit C & D) is included across all options.
Commercial Actions Commercial contracts to manage constraints and to ensure compliance with 1-in-20 obligations	Yes	Contracts not required to ensure 1-in-20 compliance. Value of constraint calculated for all options.
New Build – Dual VSD Two new 15 MW Electric Drive Compressors, decommission Avons once new units are operational.	Yes	Two new VSD units were considered as part of Option Selection process. As costs were comparable to two new GT units, Option 6 was progressed within CBA and preferred technology will be defined as part of tendering event.
Investment Deferral Option Deferral	No	Deferral of this investment has not been evaluated during optioneering given the requirement for action ahead of the MCPD deadline to avoid placing the asset under EUD. See below for further context.
Emissions Abatement Mixing Combinations of abatement technology (SCR + CSRP, etc.)	No	Not required as there is only one non-MCPD compliant unit in service at King's Lynn.

Table 7 - Full List of Investment Solutions

134. In order to evaluate the impact for no further capital investment at King's Lynn, NGGT have included the "counterfactual" or "do minimum" investment option in our CBA **[Option 1; Table 8]**. While this option includes compressor re-wheel modifications for Units C & D, the majority of the investment is related to asset health to ensure reliable unit operability beyond 2030. Should no investment be made to achieve MCPD compliance by 1 January 2030, Unit B will fall into EUD where it will be limited to 500-hours run time per year.

135. We have considered several Emission Abatement innovation technologies, which can be used in isolation or in combination with new build units, to reduce NO_x emissions **[Options 2-4; Table 8]**. CSRP, retrofit DLE and SCR Emission Abatement technologies have been investigated through dedicated external studies and performance trials. For more information on these abatement solutions and their respective reports please see **Section. 3.1**. Additionally, the specific test reports and studies can be found within the CE-AMP document.

136. It should be noted that, as DLE retrofit has not yet been technically proven on the NTS, there are risks surrounding its selection and implementation. It is discussed in **Section 3.1** that NGGT are currently running controlled performance trials on DLE technology with a view to permanently installing a unit on the NTS for more established operational running. [redacted] Please see **Appendix F** for further context surrounding risk identification for this and other technologies.

137. Similarly, CSRP is an innovative control system modification which has not been implemented on the NTS previously. Solution implementation is dependent on gaining environmental permit approval from the Environment Agency (EA). Permit applications are being sought for different sites with lower running hours and so will be an indicator of EA acceptance of the solution concept however permit approval is not a guarantee for these sites.

138. Existing unit disconnection or decommissioning is considered across several options **[Options 1-8; Table 8**]. To enable reasonable option comparison within this FOSR, decommissioning costs have been included however, the requirement for Unit B decommissioning post new unit installation will be reassessed following evaluation of network capability following the MCPD legislative deadline. Unit A was disconnected from the NTS in 2017 and we recommend full decommissioning of the asset down to plinth level. This is consistent with NGGT approach at St. Fergus and the strategy is detailed within the RIIO-T2 decommissioning business plan.

139. Options 1-7 concern solutions to achieve our stated goals using at least three units on-site to provide compression. Option 8 reduces the number of site compressors to two through the decommissioning of Unit B. Physical compressor backup is required to ensure compression can be maintained to cover the full operating envelope during planned or unplanned outage of a compressor unit. Such an eventuality would result in a failure to achieve our licence obligations and the requirements of our customers. As such, this option is a solution we would not consider implementing however it is provided to bookend the option selection analysis.

140. A number of new build options were also considered as part of NGGT's full suite of measures to reduce emissions **[Options 5-7]**. Several brownfield site locations were considered for these new build options. The selected location for new units is a currently unused area to the North-East of the site as shown in **Figure 15**. This location has been used as the basis for all new unit options (including single/dual VSD units). For

additional information on the selection of site locations for new build units and relevant engineering layout drawings, please see the Engineering Report; **Appendix C**.

Figure 15 – Selected Location for New Compressors

141. The SGT-400s (Unit C and D) were originally designed for higher head and lower flow duty compared with current and forecast operation. Re-wheeling the Unit C and D compressors results in reduced reliance on Unit B and reduced parallel compressor operation. Details of the compressor capability impact of re-wheeling Units C and D is discussed in Appendix C. Re-wheeling of Unit C and D has been included in all MCPD investment options. Failure to invest in re-wheeling would result in increased fuel consumption and higher emissions due to increased parallel compressor operation; increased start frequency of Unit C and D resulting in reduced run hours between overhauls and reduced site compressor availability due to increased reliance on parallel compressor operation. Therefore SGT-400 re-wheels are included across all investment options.

142. All options have included consideration of rules and tools which may be available as an alternative to proposed capital investment. In this context, amendments to rules relate to code changes. With these being relevant to all sites, no code rule changes have been identified for King's Lynn which would also be appropriate to all other sites. Regarding available tools, in all options there are no commercial contracts required to ensure compliance with the 1-in-20 licence obligation. Network Entry constraints would be managed using existing tools.

143. Our counterfactual was based on the option which required the least intervention but still represented a course of action we would consider pursuing. In this case it was to

continue to maintain Unit B and place it on 500-hour derogation and re-wheel Unit C and D compressors.

144. Replacement of Avon Unit B with new electric driven compression has been considered. As the cost for a new VSD unit was initially found to be comparable to a new GT unit, it was decided to progress with a new GT unit as the new unit basis under Options 5 and 7 within the CBA and a decision on the specific new unit technology will be made during the tender event following confirmation of the preferred final option. The same applies for dual VSD consideration as part of Option 6.

145. Deferral of this investment has not been evaluated during optioneering. Given Unit B is the only non-compliant unit at King's Lynn and is critical to daily operation, action must be taken ahead of the MCPD deadline to avoid placing the asset under EUD. Future investment at King's Lynn is driven by a number of key investment criteria such as protecting UK Security of Supply and meeting our Entry/Exit licence obligations. Such investment criteria cannot easily be represented in economic modelling and therefore any Real Options Analysis performed on deferring new unit investment would not provide any meaningful insight.

146. Partial or complete investment deferral could be beneficial where short term solutions can be implemented to maintain minimum required capability until further certainty of long-term capability requirements is known. However, delaying investment may result in higher overall spend and/or unacceptable levels of capability in the short-term. The relatively long investment programme durations, particularly for new unit installation also need to be factored into any deferral considerations.

147. At King's Lynn any delay in investment would result in a reduction in compression capability/resilience from the 2030 MCPD legislative deadline and therefore no deferral options have been evaluated.

148. To understand existing unit condition (availability) and how specific asset health interventions impact unit availability, we developed a site-specific availability model for King's Lynn. In addition to this, we commissioned [redacted] to develop a RAM Model, which has evaluated unit availability across the entire NGGT fleet. These unit availability statistics are a key CBA input which ultimately influences network capability, constraint cost and informs the NPV for each option.

Final Option Selection & Short-Listing

149. Following on from the analysis performed on the full list of investment solutions, a shortened options list was derived where each of the main solutions (derogation, abatement, new build, etc.) is represented across eight key options. These key options and detail on which units they have been applied across can be seen in **Table 8** below. Additional sensitivities assessed as part of the CBA are described in **Section 7.3**.

Option Shortlist	Unit A	Unit B	Unit C	Unit D	Unit E	Unit F
1 – Counterfactual	Decom.	500Hr EUD	Compressor Re-Wheel	Compressor Re-Wheel	/	/
2 - 1 x CSRP	Decom.	CSRP Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
3 - 1 x SCR	Decom.	1533 SCR Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
4 – 1 x DLE	Decom.	1533 DLE Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
5 - 1 x New Unit	Decom.	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	/
6 - 2 x New Unit	Decom.	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	New Unit (Brownfield)
7 - 1 x New Unit + EUD	Decom.	500Hr EUD	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	/
8 - 1 x Decom	Decom.	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	/	/

Table 8 - Option Shortlist

Option Descriptions

150. Option 1 is the counterfactual which considers no future emissions related capital investment at King's Lynn. By 1 January 2030, Unit B will be derogated to 500-hours per year operation based on a five-year rolling average. This option contains asset health investment on Unit B to ensure unit reliability from 2030.

151. Option 2 considers control system modifications or restriction (CSRP) of Unit B.

152. Option 3 considers SCR system modification to Unit B.

153. Option 4 considers modifying Unit B with DLE technology.

154. Option 5 involves a new emissions compliant compressor unit situated on a brownfield location. Unit B is proposed to be decommissioned once the new unit is operational.

155. Option 6 involves two new compressor units on a brownfield location. Unit B would be targeted for decommissioning once the new units are operational.

156. Option 7 considers Option 5 but maintains Unit B on 500-hours derogation.

157. Option 8 considers decommissioning Unit B and reduces the site to two operational units.

158. All options above include full decommissioning of Unit A to plinth level which was disconnected in 2017.

Option Assessment Criteria

159. Detailed descriptions of each considered option can be found in **Section 5.2**. Within this section, each option is discussed according to the following criteria:

- Option Description
- Cost Breakdown
- Commercial Actions
- Option BAT Assessment Scoring
- Option Risks

160. Option description provides context on the main features of the option.

161. Each option is provided with a cost breakdown table where total installed cost, asset health cost, operating cost, decommissioning and constraint costs are defined. Additional detail on the cost basis for each option can be found in **Section 6.2.**

162. The presence of any commercial contracts available to manage constraints and ensure compliance with 1-in-20 is detailed within "commercial actions".

163. A breakdown of the option preliminary BAT[29] assessment scores is also provided to give the reader additional context on the technical and environmental benefits and limitations for each option. The BAT assessment consists of a series of importance weighted technical and environmental criteria, against which each option is scored, see Figure 16. BAT assessment scores and weighting were qualitatively determined by representative business stakeholders. Scores are not intended to be used to determine the Final Preferred Option but to support the decision-making process in parallel with cost benefit analysis and other option selection criteria. For detailed information on the BAT assessment, please see **Appendix G**.

Technical Criteria:	65%
Versatility	15%
Future Proofing	15%
Ownership	13%
Constructability	7%
Environmental Amenity	10%
Hazard	5%
Environmental Criteria:	35%
Emissions (NOx = 20%; CO2 = 10%; CO = 5%)	35%

Figure 16 - BAT Assessment Technical & Environmental Comparison Criteria

164. The technical and environmental criteria are defined as follows:

- **Versatility** refers to the extent and usability of the MCPD emissions compliant compressor envelope. This criterion is a combination of unit capability and availability to meet the pre-defined Process Duty Specification (PDS) points.

[29] National Grid is legally bound under the Industrial Emissions Directive (IED) to comply with the requirements of BAT in respect of its gas turbine compressor installations. Beyond this, National Grid made a policy decision in 2013 that BAT would be the primary selection mechanism for all new and substantially modified compressor machinery trains. The BAT assessment methodology has been developed by National Grid in consultation with the Environment Agency (EA) and Scottish Environmental Protection Agency (SEPA).

- **Future Proofing**[30] is defined as the headroom above current emission limits and performance against anticipated energy efficiency levels which may be contained in a future BAT Reference (BREF)[31] Document.
- **Ownership** refers to maintenance complexity and the availability of spares for the compressor unit(s).
- **Constructability** refers to the ease of construction and potential for disruption to existing site operations. Also considers number of outage periods required.
- **Environmental Amenity** refers to the potential for visual impact and noise concerns resulting from the selected option.
- **Hazard** refers to perceived risk to the environment.
- **Emissions** criteria refers to predicted NO_x, CO_2 & CO emissions for each technology solution.

165. A breakdown for option technical (65%) and environmental (35%) scores across all options can be found in Figure 16 as well as a consolidated score breakdown in **Table 27**.

166. A semi-quantitative risk assessment methodology has been used to provide an indication of the relative level of risk associated with each option. Each identified risk is quantified in terms of probability of occurrence and severity of impact in order to determine an overall risk classification. Risks were classified as; Negligible, Minor, Significant, Major or Critical. Within **Section 5.2** only the highest risks are referenced within the discussion. The King's Lynn risk report and project risk register can be found in **Appendix F**. Discussion on risks associated only with the Final Preferred Option can be found in **Section 8.3**. It should be noted that the cost estimate has not been adjusted based on the output of the risk assessment process.

167. Level 2 delivery programmes have been used to determine deliverability within outage constraints and estimate capital spend profile for each option. All investments are planned to meet the legislative deadline of 1 January 2030. These programmes were also used to estimate capital spend profile for each option. The cost Re-opener planned for April 2025 will be supported by a more detailed delivery programme for the selected option based on an appropriate delivery strategy. The Level 2 programme for the Final Preferred Option can be found in **Section 8.2** while the project programme report can be found in **Appendix E**.

168. For information on the CBA & sensitivities used, please see **Section 7.3.**

169. Regarding considerations for solution design life within option selection, unit design life varies depending on the asset element in question. **Figure 17** below outlines the design life requirements for each new compressor asset on the NTS. For example, Protection and Control Systems have a design life of 15 years and therefore replacement will be required and has been considered during the CBA period. All other new assets installed as part of the MCPD project will have a design life greater than the

[30] Future Proofing does not contain consideration for future unit hydrogen compatibility due to the lack of defined requirements associated with future hydrogen compression on the NTS and targets for blend composition.
[31] The UK environmental agencies have indicated that any forthcoming BAT Reference (BREF) document will contain energy efficiency targets

CBA period and replacement cost has therefore not been included. Routine maintenance and estimated ad-hoc repairs have also been included in cost estimates included in the CBA.

Asset	Life (years)
Compressors	40
Gas Generators	20
Power Turbines	25
Pipework and Valves	30
Protection and Control Systems	15
Enclosures and Buildings	60

Figure 17 - T/PM/Comp/20 Asset Design Life[32]

Option Summary Tables

170. Summary tables of the main options considered, including costs and BAT scores, can be found within **Section 5.3**.

[32] Section 11; T/PM/COMP/20 - Management Procedure for Compressor Installations for the National Transmission System

5.2. Main Option Breakdown

Option 1 – Counterfactual (1 x 500-hours Derogation)

Option Description

171. This option maintains Avon Unit B until 31 December 2029 and places it on 500-hours EUD (Emergency Use Derogation) from 1 January 2030.

172. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

173. Unit A was disconnected from site in 2017. This option also includes full decommission of the asset down to plinth level.

Cost Breakdown

174. The cost breakdown of the option is given in **Table 9.**

175. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found in **Appendix E** for more details on option timeline (same programme as CSRP).

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
1 – Counterfactual	2019	2027	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 9 - Option 1: Cost Breakdown

Cost Basis

176. Initial asset health costs consider investments which are required as part of MCPD capex investment to ensure units are of sufficient reliability to operate effectively from 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D**.

177. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

178. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

179. A high-level view of how the option was scored from a technical, environmental and emissions perspective is summarised in **Table 10**. A summary of the BAT assessment scores across all options can be found in **Section 5.3** to enable comparison across options. See **Section 5.1** for the definition of each criterion.

180. The lead configuration for all options would be one fully compliant DLE Unit (new unit or SGT-400) either operating singularly or in parallel with another fully compliant DLE unit (new unit or SGT-400). As such there is negligible difference in performance between options in the lead configuration and therefore BAT assessment has been conducted based on the back-up configuration. It should be noted that overall performance of the site must take into consideration the availability of compressors and number of run hours that the site would operate in back up configuration. This is considered in the CBA and business case assessment discussed in section 7. For further detail please see the BAT Report (**Appendix G**).

181. In this option the lead configuration would involve operation of one or both SGT-400s with back-up provided by the Avon on a 500-hour per year derogation to be utilised when parallel operation is required and one of the SGT-400s is unavailable. The scores below represent backup parallel operation (i.e. 1 off SGT-400 and 1 off Avon).

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
1 – Counterfactual (1 x SGT400 rewheel; 1 x 500hrs)	3%	0%	10%	4%	10%	4%	20%	51%
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 10 - Option 1: BAT Assessment Breakdown

182. **Versatility:** This solution was scored 3% out of 15% as it is critically constrained by the 500-hours limitation.

183. **Future Proofing**: This solution was scored 0% out of 15% as it achieves current emissions limits but with no headroom for future increase in legislation (emissions or energy efficiency).

184. **Ownership**: This solution was scored 10% out of 13% as the Avon has acceptable service agreements in place for maintenance and there is a medium availability of spares but solution is not as robust as new unit service agreement and availability of spare components.

185. **Constructability**: This solution was scored 4% out of 7% as it involves the following two outage periods:

- Outage A: Unit B compressor overhaul and refurbishment
- Outage B: Unit B control system upgrade

186. **Environmental Amenity**: This solution was scored 10% out of 10% as the solution does not involve increased footprint or exhaust stack height.

187. **Hazard**: This solution was scored 4% out of 5%. Oil containment is to NGGT standards, however solution cannot effectively design out all significant environmental risks.

188. **Emissions**: This solution was scored 20% out of 35% (9/20 NO_x; 10/10 CO_2; 1/5 CO) for emissions performance due to the fact that NO_x emissions are not curtailed through system modification, but a limitation placed on run hours. The Avon unit in this solution still has the potential to exceed NO_x emissions limits.

Risks

189. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks are identified below.

190. **Major**: The existing Avon unit is over 30 years old. This brings increased asset health maintenance exposure and higher probability of unavailability due to technical issues (CM-1)

191. **Major**: Country specific and worldwide geopolitical issues affecting the supply & cost of equipment, materials and workforce. (CPO-11)

Option 2 – One Derated (CSRP) Avon

Option Description

192. This option considers restricting high power running of Avon Unit B through control system modifications to limit its performance and thereby restrict NO_x emissions to within acceptable limits.

193. This option would necessitate a control system software modification to limit Exhaust Cone Temperature which has been proven, via a CSRP performance trial, to correlate with NO_x emissions. This control system software update is controlled by our management of change process (T/PM/G/35) which ensures that the governor controller setpoints cannot easily be returned to their original settings or otherwise amended without undergoing a rigorous review and approval process.

194. The CSRP solution has not yet been fully implemented on the NTS before and is currently undergoing environmental permit approval with the EA.

195. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

196. Unit A was disconnected from site in 2017. This option also includes full decommission of the asset down to plinth level.

Cost Breakdown

197. The cost breakdown for the option is given in **Table 11**.

198. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found in **Appendix E** for more details on option timeline.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
2 - 1 x CSRP	2019	2027	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 11 - Option 2: Cost Breakdown

Cost Basis

199. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments likely to be required to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D.**

200. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

201. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

202. A high-level view of how the option was scored from a technical, environmental and emissions perspective is summarised in **Table 10**. A summary of the preliminary BAT assessment scores across all options can be found in **Section 5.3** to enable comparison across options. See **Section 5.1** for the definition of each criterion.

203. The lead configuration for all options would be one fully compliant DLE Unit (new unit or SGT-400) either operating singularly or in parallel with another fully compliant DLE unit (new unit or SGT-400). As such there is negligible difference in performance between options in the lead configuration and therefore BAT assessment has been conducted based on the back-up configuration. It should be noted that overall performance of the site must take into consideration the availability of compressors and number of run hours that the site would operate in back up configuration. This is considered in the CBA and business case assessment discussed in section 7. For further detail please see the BAT Report (**Appendix G**).

204. In this option the lead configuration would involve operation of one or both SGT-400s with back-up provided by the Avon upgraded with CSRP to be utilised when parallel operation is required and one of the SGT-400s is unavailable. The scores below represent backup parallel operation (i.e. 1 off SGT-400 and 1 off Avon with CSRP).

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
2 - 1 x CSRP (1 x SGT400 rewheel; 1 x CSRP)	9%	0%	10%	4%	10%	4%	20%	57%
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 12 - Option 2: BAT Assessment Breakdown

205. **Versatility:** This solution was scored 9% out of 15% as it contains sufficient power to meet all the PDS points but is not as versatile as a new compressor unit.

206. **Future Proofing**: This solution was scored 0% out of 15% as it achieves current emissions limits but with no headroom without further significant performance restriction implications for future increases in legislation (emissions or energy efficiency).

207. **Ownership**: This solution was scored 10% out of 13% as the Avon has acceptable service agreements in place for maintenance and there is a medium availability of spares but solution is not as robust as new unit service agreement and availability of spare components.

208. **Constructability**: This solution was scored 4% out of 7%. Two outage periods have been determined for:

- Outage A: Unit B compressor overhaul & refurbishment
- Outage B: Unit B control system upgrade & CSRP updates

CSRP software modification is targeted to take place during control system installation to minimise the impact on site operation.

209. **Environmental Amenity**: This solution was scored 10% out of 10% as the solution does not involve increased footprint or exhaust stack height.

210. **Hazard**: This solution was scored 4% out of 5%. Oil containment is to NGGT standards and asset health investment will upgrade system to use dry gas seals. However, solution cannot effectively design out all significant environmental risks.

211. **Emissions**: This solution was scored 20% out of 35% (9/20 NO_x; 10/10 CO_2; 1/5 CO) for emissions compliance due to the fact that although NOx emissions concentrations are limited to within legislative limits through restricted compressor operation, absolute mass emissions are not reduced in this option.

Risks

212. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks are identified below.

213. **Critical:** Coordination and alignment between internal stakeholders. Potential for delay in gaining alignment on a preferred option (CPO-8)

214. **Major:** The existing Avon unit is over 30 years old. This brings increased asset health maintenance exposure and higher probability of unavailability due to technical issues (CM-1)

215. **Major**: Country specific and worldwide geopolitical issues affecting the supply & cost of equipment, materials and workforce. (CPO-11)

216. **Major/Critical (Escalated from Significant following risk workshop)**: Potential that CSRP is not approved by Environment Agency (EA) resulting in rejection of permit request. NGGT are engaging with the EA to mitigate against this risk. Formal approval or denial will only be provided after a permit variation request has been submitted and full assessment has taken place, after the Final Option Selection.

Option 3 – One SCR Retrofit Avon

Option Description

218. This option considers adding a Selective Catalytic Reduction (SCR) system to Unit B to reduce NO_x emissions to within MCPD limits. SCR technology enables conversion of NO_x to Nitrogen (N_2) and water (H_2O) by reacting NO_x with Ammonia (NH_3).

219. The SCR system consists of a number of critical components such as a self-supporting exhaust stack and silencer, ammonia storage and pumping system, ammonia vaporisation system, ammonia tanker unloading system, control system modifications and a Continuous Emissions Monitoring System (CEMS) to verify that NO_x emissions have been sufficiently limited to within MCPD limits.

220. While SCR is a proven technology, no compressors on the NTS currently use SCR to ensure NOx compliance.

221. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

222. Unit A was disconnected from site in 2017. This option also includes full decommission of the asset down to plinth level.

Cost Breakdown

223. The cost breakdown of the option is given in **Table 13.**

224. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found in **Appendix E** for more details on option timeline.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
3 - 1 x SCR	2019	2027	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 13 - Option 3: Cost Breakdown

Cost Basis

225. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D.**

226. Operating cost also includes the cost of replacing the catalyst and the supply of ammonia for this solution.

227. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

228. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

229. A high-level view of how the option was scored from a technical, environmental and emissions perspective is summarised in **Table 14**. A summary of the BAT assessment scores across all options can be found in **Section 5.3** to enable comparison across options. See **Section 5.1** for the definition of each criterion.

230. The lead configuration for all options would be one fully compliant DLE Unit (new unit or SGT-400) either operating singularly or in parallel with another fully compliant DLE unit (new unit or SGT-400). As such there is negligible difference in performance between options in the lead configuration and therefore BAT assessment has been conducted based on the back-up configuration. It should be noted that overall performance of the site must take into consideration the availability of compressors and number of run hours that the site would operate in back up configuration. This is considered in the CBA and business case assessment discussed in section 7. For further detail please see the BAT Report (**Appendix G**).

231. In this option the lead configuration would involve operation of one or both SGT-400s with back-up provided by the Avon upgraded with SCR technology to be utilised when parallel operation is required and one of the SGT-400s is unavailable. The scores below represent backup parallel operation (i.e. 1 off SGT-400 and 1 off Avon with SCR).

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NO_x, CO_2, CO)	Total Score
3 - 1 x SCR (1 x SGT400 rewheel; 1 x SCR)	9%	9%	5%	3%	4%	2%	25%	57%
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 14 - Option 3: BAT Assessment Breakdown

232. **Versatility:** This solution was scored 9% out of 15% as it contains sufficient power to meet all the PDS points but is not as versatile as a new compressor unit. It has been assumed that the increase in exhaust back pressure due to the catalyst will have negligible impact on maximum power.

233. **Future Proofing**: This solution was scored 9% out of 15% as it achieves current emissions limits. Avon SCR includes catalyst for NO_x and CO reduction therefore good emissions headroom. Avon energy efficiency may not meet required targets in a future MCP BREF. Decreased headroom when compared to new unit solutions.

234. **Ownership**: This solution was scored 5% out of 13% as the Avon SCR retrofit is a new application on the NTS which introduces a number of new assets which require operations management and new maintenance procedures. There is expected to be a medium availability of spares.

235. **Constructability**: This solution was scored 3% out of 7% due to the construction complexity associated with the additional SCR exhaust stack steelwork which drives an additional construction outage compared to alternative options. There is significant risk in being able to complete this construction work within one outage. Two outage periods have therefore been determined:

- Outage A: Unit B compressor overhaul & refurbishment
- Outage B: Unit B control system upgrade & SCR retrofit

236. **Environmental Amenity**: This solution was scored 4% out of 10%. While horizontal exhaust stack will limit height impact, additional noise is likely to be introduced as well as the potential for visual impact (size, colour). Possible planning permission required due to new equipment exceeding permitted height limits of 15m. This has the potential to cause programme delay.

237. **Hazard**: This solution was scored 2% out of 5% due to the added complexity brought by ammonia use as a reagent in SCR process. This introduces a new hazardous substance which requires management. Ammonia tanker deliveries require additional containment systems.

238. **Emissions**: This solution was scored 25% out of 35% (13/20 NO_x; 10/10 CO_2; 2/5 CO) for emissions compliance. SCR option produces comparable NO_x with DLE retrofit albeit with the new GT option offering lower emissions and represents significant improvement in NO_x performance compared to an unabated Avon.

Risks

239. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks are identified below.

240. **Critical:** Coordination and alignment between internal stakeholders. Potential for delay in gaining alignment on a preferred option (CPO-8)

241. **Major:** The existing Avon unit is over 30 years old. This brings increased asset health maintenance exposure and higher probability of unavailability due to technical issues (CM-1)

242. **Major**: Country specific and worldwide geopolitical issues affecting the supply & cost of equipment, materials and workforce. (CPO-11)

Option 4 – One Avon DLE Retrofit (1533)

Option Description

243. This option involves retrofitting Avon Unit B with DLE technology.

244. Unit B modification with DLE technology is based on the existing 1533 Avon powertrain.

245. The DLE retrofit solution has not yet been fully proven on the NTS and is currently undergoing performance testing planned to be completed within 2023.

246. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

247. Unit A was disconnected from site in 2017. This option also includes full decommission of the asset down to plinth level.

Cost Breakdown

248. The cost breakdown of the option is given in **Table 15.**

249. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found in **Appendix E** for more details on option timeline.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
4 – 1 x DLE	2019	2027	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 15 - Option 4: Cost Breakdown

Cost Basis

250. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D**.

251. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

252. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

253. A high-level view of how the option was scored from a technical, environmental and emissions perspective is summarised in **Table 16**. A summary of the BAT assessment scores across all options can be found in **Section 5.3** to enable comparison across options. See **Section 5.1** for the definition of each criterion.

254. The lead configuration for all options would be one fully compliant DLE Unit (new unit or SGT-400) either operating singularly or in parallel with another fully compliant DLE unit (new unit or SGT-400). As such there is negligible difference in performance between options in the lead configuration and therefore BAT assessment has been conducted based on the back-up configuration. It should be noted that overall performance of the site must take into consideration the availability of compressors and number of run hours that the site would operate in back up configuration. This is considered in the CBA and business case assessment discussed in section 7. For further detail please see the BAT Report (**Appendix G**).

255. In this option the lead configuration would involve operation of one or both SGT-400s with back-up provided by the Avon upgraded with DLE technology to be utilised when parallel operation is required and one of the SGT-400s is unavailable. The scores below represent backup parallel operation (i.e. 1 off SGT-400 and 1 off Avon with DLE).

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
4 – 1 x DLE (1 x SGT400 rewheel; 1 x DLE)	9%	6%	8%	4%	10%	4%	25%	66%
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 16 - Option 4: BAT Assessment Breakdown

256. **Versatility:** This solution was scored 9% out of 15% as it contains sufficient power to meet all the PDS points but is not as versatile as a new compressor unit**.**

257. **Future Proofing**: This solution was scored 6% out of 15% as it achieves current emissions limits, but the existing Avon limits the solution with no headroom for future increase in legislation (emissions or energy efficiency).

258. **Ownership**: This solution was scored 8% out of 13% as the Avon DLE retrofit is a new application on the NTS, still currently being technically validated and there are potential limitations on the availability of spares but solution is not as robust as new unit service agreement and availability of spare components.

259. **Constructability**: This solution was scored 4% out of 7% as DLE modifications are expected to be completed in one summer outage however constructability is more complex when compared to other options due to requirement to retrofit the Avon. Two outage periods have been determined for:

- Outage A: Unit B compressor overhaul & refurbishment
- Outage B: Unit B control system upgrade & DLE retrofit

260. **Environmental Amenity**: This solution was scored 10% out of 10% as the solution was determined unlikely to introduce a new amenity risk.

261. **Hazard**: This solution was scored 4% out of 5%. Oil containment is to National Grid standards and asset health investment will upgrade system to use dry gas seals. However, solution cannot effectively design out all significant environmental risks.

262. **Emissions**: This solution was scored 25% out of 35% (13/20 NO_x; 10/10 CO_2; 2/5 CO) for emissions compliance. Through DLE abatement, NO_x emissions will be reduced to within existing MCPD limits. However, NO_x reduction is not as effective as with the new unit option.

Risks

263. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks are identified below.

264. **Critical:** Coordination and alignment between internal stakeholders. Potential for delay in gaining alignment on a preferred option (CPO-8)

265. **Major:** The existing Avon unit is over 30 years old. This brings increased asset health maintenance exposure and higher probability of unavailability due to technical issues (CM-1)

266. **Major**: Country specific and worldwide geopolitical issues affecting the supply & cost of equipment, materials and workforce. (CPO-11)

267. **Major**: While DLE technology is well established within the UK & European gas networks, the retrofit of DLE technology to Avon gas turbines is not yet technically proven or commercially available. NGGT are working with [redacted] to develop an Avon DLE retrofit solution. A full engine performance trial on the NTS is currently planned for completion in 2023. For this reason, there are significant risks associated with selecting such an unproven technology for use on a critical compressor station like King's Lynn. For the purpose of this assessment, it is assumed that this option can be proven technically viable with acceptable level of operational risk. (CM-14)

Option 5 – One New Unit (Brownfield)

Option Description

268. This option involves the installation of a new compressor unit which will be commissioned by 2028. The required compressor driver type (electric or gas) and power rating will be confirmed during FEED. Cost estimates and capability assessment are based on a gas driven unit of 15 MW capacity. This unit would become the lead unit on site.

269. New unit is proposed to be installed on a brownfield site location.

270. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

271. This option also includes decommissioning of Units A & B down to plinth level once the new compressor has been commissioned. The requirement for Unit B decommissioning will be reassessed following operational acceptance of the new unit.

Cost Breakdown

272. The cost breakdown of the option is given in **Table 17**.

273. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found **Appendix E** for more details on option timeline.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
5 - 1 x New Unit	2019	2029	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 17 - Option 5: Cost Breakdown

Cost Basis

274. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D**.

275. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

276. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

277. A high-level view of how the option was scored from a technical, environmental and emissions perspective is summarised in **Table 18**. A summary of the BAT assessment

scores across all options can be found in **Section 5.3** to enable comparison across options. See **Section 5.1** for the definition of each criterion.

278. The lead configuration for all options would be one fully compliant DLE Unit (new unit or SGT-400) either operating singularly or in parallel with another fully compliant DLE unit (new unit or SGT-400). As such there is negligible difference in performance between options in the lead configuration and therefore BAT assessment has been conducted based on the back-up configuration. It should be noted that overall performance of the site must take into consideration the availability of compressors and number of run hours that the site would operate in back up configuration. This is considered in the CBA and business case assessment discussed in section 7. For further detail please see the BAT Report (**Appendix G**).

279. In this option the lead configuration would involve operation of a new unit with back-up provided by the second SGT-400 to be utilised when parallel operation is required and the first SGT-400 is unavailable. The scores below represent backup parallel operation (i.e. 1 off new unit and 1 off SGT-400).

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
5 - 1 x New Unit (1 x New Unit; 1 x SGT400 rewheel)	15%	15%	13%	3%	4%	4%	35%	89%
Score Sub-Total	**15%**	**15%**	**13%**	**7%**	**10%**	**5%**	**35%**	**100%**

Table 18 - Option 5: BAT Assessment Breakdown

280. **Versatility:** This solution was scored 15% out of 15% as the solution meets all the required PDS points in both bulk and back-up duty as the new unit and Unit C & D re-wheels would be sized and mapped appropriately to suit site conditions.

281. **Future Proofing**: This solution was scored 15% out of 15% as the new unit & two SGT-400 provides maximum headroom for NO_x and CO emissions in the event the new unit is unavailable. Unit C & D are more energy efficient than the existing Avon unit so maximum energy efficiency headroom is also achieved.

282. **Ownership**: This solution was scored 13% out of 13% as the SGTs have existing service agreements and there is long-term availability of spares. New compressor should have excellent new maintenance/service arrangements in place.

283. **Constructability**: This solution was scored 3% out of 7% as there is moderate complexity associated with the installation of a new unit on a brownfield location. One outage period has been determined for:

- Outage A: Site shutdown for hook-up of new compressor[33]

[33] Appendix E (Project Programmes & Report) references two shutdowns being required for this option – cable trench extensions and compressor hook-up. However, the cable trench extensions can be managed without the need for a full site shutdown (depressurisation etc.).

A decision on decommissioning will be taken once new unit is operational and a capability assessment confirms there is no further reliance on Unit B's continued operation.

284. **Environmental Amenity**: This solution was scored 4% out of 10% due to the visual impact (increased stack height) of the new unit having the potential to raise challenges during permit & planning applications. This has the potential to cause programme delay.

285. **Hazard**: This solution was scored 4% out of 5% as it is expected that the new compressor unit will comply with new and anticipated future standards for oil containment.

286. **Emissions**: This solution was scored 35% out of 35% (20/20 NO_x; 10/10 CO_2; 5/5 CO) for emissions compliance. Through the use of the low-emission new units, NO_x emissions will be reduced to well within existing MCPD limits. New units represent the most environmentally friendly solution in the NGGT suite of emissions reduction options.

Risks

287. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks and opportunities are identified below.

288. **Critical:** Unknown/undefined scope elements associated with HV grid connection for VSD compressor. Potential for cost and schedule escalation to enable HV grid connection which are reliant on third part executing the works in a timely manner. Not applicable to GT compressors. (CM-10)

289. **Critical:** Coordination and alignment between external stakeholders. Potential for delay in gaining alignment on a preferred option. (CPO-7)

290. **Critical:** Network outage periods are not yet confirmed. Allowed outage may be shorter than anticipated or at less optimum time for construction of new build units. (CPO-9)

291. **Critical**: Country specific and worldwide geopolitical issues affecting equipment supply and workforce (greater impact for new build unit). (CPO-11)

292. **New Risk:** No investment on the Unit B control system has been allowed for. There is a risk that additional investment is required to maintain safe and secure Unit B operation until the new unit is operational. There is a risk that there will be challenges associated with interface of Unit B with the new station control system being installed as part of the RIIO-T2 Cyber investment.

293. **Opportunity**: A conservative basis has been taken regarding space/footprint requirement for new build compressors. Opportunity to optimise and reduce with resulting impact on fence extension requirements, foundations etc. (CM-12)

294. **Opportunity**: Opportunity to coordinate decommissioning works with other projects. (CPO-6)

Option 6 – Two New Units (Brownfield)

Option Description

295. Option involves the installation of two new compressor units, located on the existing site, which will be commissioned by 2028.

296. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

297. This option also contains decommissioning costs for Unit A & B once the new units are commissioned. The requirement for decommissioning will be reassessed following operational acceptance of the new units.

298. This option has been costed to assess the benefit for increased resilience at high flows. It was not originally considered within the BAT assessment as the benefit of two new units over one new unit is additional site resilience which is best assessed via other option selection tools, i.e. CBA.

Cost Breakdown

299. The cost breakdown of the option is given in **Table 19**.

300. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found in **Appendix E** for more details on option timeline.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
6 - 2 x New Unit	2019	2029	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 19 - Option 6: Cost Breakdown

Cost Basis

301. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D**.

302. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

303. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

304. A BAT assessment was not performed on this option. The benefit of two new units over one new unit is additional site resilience which is best assessed via other option

selection tools, i.e. CBA. Please refer to **Section 7** where this option is discussed in the context of the CBA.

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
6 - 2 x New Unit	4 Unit options not included in BAT Assessment							
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 20 - Option 6: BAT Assessment Breakdown

Risks

305. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks and opportunities are identified below.

306. **Critical:** Coordination and alignment between external stakeholders. Potential for delay in gaining alignment on a preferred option (CPO-7)

307. **Critical:** Unknown/undefined scope elements associated with HV grid connection for VSD compressor. Potential for cost and schedule escalation to enable HV grid connection which are reliant on third part executing the works in a timely manner. Not applicable to GT compressors. (CM-10)

308. **Critical:** Network outage periods are not yet confirmed. Allowed outage may be shorter than anticipated or at less optimum time for construction of new build units (CPO-9)

309. **Critical**: Country specific and worldwide geopolitical issues affecting equipment supply and workforce (greater impact for new build unit). (CPO-11)

310. **Major:** Extension of the existing site boundary is necessary for brownfield new builds. This will have an impact on permitting/consents as well as environmental and commercial negotiations. Potential for schedule delay. (CPO-10)

311. **Opportunity**: A conservative basis has been taken regarding space/footprint requirement for new build compressors. Opportunity to optimise and reduce with resulting impact on fence extension requirements, foundations etc. (CM-12)

312. **Opportunity**: Opportunity to coordinate decommissioning works with other projects. (CPO-6)

Option 7 – One New Unit (Brownfield) + One 500-hour Avon

Option Description

313. This option involves the installation of a new compressor unit, approximate size 15MW, which will be commissioned by 2028.

314. New unit is proposed to be installed on a brownfield site location.

315. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

316. This option also includes maintaining Avon Unit B on 500-hours EUD from 1 January 2030 and decommissioning Unit A down to plinth level.

317. This option has been costed to assess the benefit for increased resilience at high flows (four-unit site). It was not originally considered within the BAT assessment as the benefit of four site units over three site units is additional site resilience which is best assessed via other option selection tools, i.e. CBA.

Cost Breakdown

318. The cost breakdown of the option is given in **Table 21.**

319. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. Project finish date represents the year commissioning activities are planned to take place. Level 2 delivery programmes can be found in **Appendix E** for more details on option timeline.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
7 - 1 x New Unit + EUD	2019	2029	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 21 - Option 7: Cost Breakdown

Cost Basis

320. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D**.

321. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

322. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

323. A BAT assessment was not performed on this option. It was not originally considered within the BAT assessment as the benefit of four site units over three site units is additional site resilience which is best assessed via other option selection tools, i.e. CBA. Please refer to **Section 7** where this option is discussed in the context of the CBA.

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
7 - 1 x New Unit + 500 Hrs	4 Unit options not included in BAT Assessment							
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 22 - Option 7: BAT Assessment Breakdown

Risks

324. Please see **Appendix F** for more detail on the risks defined for this option. The highest rated risks and opportunities are identified below.

325. **Critical:** Unknown/undefined scope elements associated with HV grid connection for VSD compressor. Potential for cost and schedule escalation to enable HV grid connection which are reliant on third part executing the works in a timely manner. (CM-10)

326. **Critical:** Coordination and alignment between external stakeholders. Potential for delay in gaining alignment on a preferred option. (CPO-7)

327. **Critical:** Network outage periods are not yet confirmed. Allowed outage may be shorter than anticipated or at less optimum time for construction of new build units. (CPO-9)

328. **Major:** The existing Avon unit is over 30 years old. This brings increased asset health maintenance exposure and higher probability of unavailability due to technical issues. (CM-1)

329. **Major:** This option requires routing of new cables via existing trenches. Available space in the existing trenches for new cabling is currently unknown without further survey work. Potential for increase in capex spend should existing trenches need to be expanded or new trenches required to be implemented. (S-2)

330. **Opportunity**: A conservative basis has been taken regarding space/footprint requirement for new build compressors. Opportunity to optimise and reduce with resulting impact on fence extension requirements, foundations etc. (CM-12)

331. **Opportunity**: Opportunity to coordinate decommissioning works with other projects. (CPO-6)

Option 8 - Decommission Avons

Option Description

332. This option considers decommissioning of Avon Units A & B leaving the SGT-400 Units C and D as the only remaining compressors on site providing limited compressor resilience. Option description references one decommissioning as the decommissioning of Unit A is included across all options.

333. Option includes compressor re-wheel modifications for Unit C & D to improve compression mapping.

334. This option has been included to bookend the option selection process and assess the impact of constraints when the site is reduced to a two-unit site. It is not considered to be a viable option due to the lack of back-up for parallel compressor operation (i.e. it does not achieve n-1). Therefore, it was not originally considered within the BAT assessment and has not been scored.

Cost Breakdown

335. The cost breakdown of the option is given in **Table 23**.

336. The project start date is the NGGT 2019 RIIO-T2 business plan submission to develop the final preferred investment option. The finish date for this option is dependent on prioritisation against other decommissioning works and as such cannot be defined at time of writing.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
8 - 1 x Decom	2019	VARIES	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	±30%

Table 23 - Option 10: Cost Breakdown

Cost Basis

337. Initial asset health costs consider investments which are required as part of the MCPD capex investment to ensure units are of sufficient reliability to operate effectively to 1 January 2030. Ongoing asset health costs concern investments necessary to ensure future running from 2030 to 2050. More detail can be found in the **Appendix D**.

338. Please see **Section 6** for commentary on how the cost estimate for this option was developed.

Commercial Actions

339. There are no commercial contracts required to ensure compliance with the 1-in-20 design standard for this option. Network Entry constraints would be managed using existing tools.

BAT Assessment Summary

340. A high-level view of how the option was scored from a technical, environmental and emissions perspective is summarised in **Table 24** to enable comparison across options. A summary of the BAT assessment scores across all options can be found in **Section 5.3** to enable comparison across options. See **Section 5.1** for the definition of each criterion.

341. A BAT assessment was not performed on this option. Please refer to **Appendix G** for more information on the BAT assessment process.

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
8 - 1 x Decom	Not included in BAT Assessment as there is no backup when 2 units are require to be operated in parallel							
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 24 - Option 8: BAT Assessment Breakdown

Risks

342. This option considers decommissioning of the existing Avon Unit A & B as the entirety of the MCPD work scope. No specific decommissioning related risks have been identified in advance of detailed asset surveys which are normally performed as part of the associated FEED study. However, there is one associated opportunity which has been identified with this option:

343. **Opportunity**: Opportunity to coordinate decommissioning works with other projects. (CPO-6)

5.3. Option Table Summary

344. Option summary tables are provided for the following aspects to allow for comparison across the main options considered:

- Option Shortlist
- Option Cost Breakdown
- Option Consolidated BAT Scores

345. Options are provided with a description and a numerical label to aid in referencing options throughout this report.

Option Shortlist

Option Shortlist	Unit A	Unit B	Unit C	Unit D	Unit E	Unit F
1 – Counterfactual	Decom.	500Hr EUD	Compressor Re-Wheel	Compressor Re-Wheel	/	/
2 - 1 x CSRP	Decom.	CSRP Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
3 - 1 x SCR	Decom.	1533 SCR Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
4 – 1 x DLE	Decom.	1533 DLE Retrofit	Compressor Re-Wheel	Compressor Re-Wheel	/	/
5 - 1 x New Unit	Decom.	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	/
6 - 2 x New Unit	Decom.	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	New Unit (Brownfield)
7 - 1 x New Unit + EUD	Decom.	500Hr EUD	Compressor Re-Wheel	Compressor Re-Wheel	New Unit (Brownfield)	/
8 - 1 x Decom	Decom.	Decom.	Compressor Re-Wheel	Compressor Re-Wheel	/	/

Table 25 - Option Shortlist

Option Cost Breakdown

346. **Table 26** below outlines the cost breakdown and start/end dates for each option.

347. Detail on how project start & finish dates are determined can be found within **Section 5.1.**

348. Detail on the estimating methodology and option capex cost accuracy can be found within **Section 6.2**.

349. Regarding considerations for unit design life within option selection, please see **Section 5.1** for more information.

Option Cost Comparison Table (18/19 Prices)	Project Start Date	Project Finish Date	Total Installed Cost (£m)	Initial Asset Health Cost (£m)	Ongoing Asset Health Cost (£m)	Operating Cost (£m/pa)	Decom. Cost (£m)	Capex Cost Accuracy
1 – Counterfactual	2019	2027	[redacted]					±30%
2 - 1 x CSRP	2019	2027						±30%
3 - 1 x SCR	2019	2027						±30%
4 – 1 x DLE	2019	2027						±30%
5 - 1 x New Unit	2019	2029						±30%
6 - 2 x New Unit	2019	2029						±30%
7 - 1 x New Unit + EUD	2019	2029						±30%
8 - 1 x Decom	2019	VARIES						±30%

Table 26 - Option Cost Breakdown

Option Consolidated BAT Scores

350. **Table 27** contains a summary of how the BAT assessment technical & environmental scores compare across all options. Technical scores (65%) and environmental scores (35%) are combined to provide for an overall 100% evaluation score. For detailed information on the BAT assessment, please see **Appendix G**.

351. BAT assessment scores & weighting were qualitatively determined by representative business stakeholders. Scores are not intended to be used to determine the Final Preferred Option but to support the decision-making process in parallel with cost benefit analysis.

Investment Option BAT Assessment Scoring Back-Up Configurations	Versatility	Future Proofing	Ownership	Constructability	Environmental Amenity	Hazard	Emissions (NOx, CO2, CO)	Total Score
1 – Counterfactual (1 x SGT400 rewheel; 1 x 500hrs)	3%	0%	10%	4%	10%	4%	20%	51%
2 - 1 x CSRP (1 x SGT400 rewheel; 1 x CSRP)	9%	0%	10%	4%	10%	4%	20%	57%
3 - 1 x SCR (1 x SGT400 rewheel; 1 x SCR)	9%	9%	5%	3%	4%	2%	25%	57%
4 – 1 x DLE (1 x SGT400 rewheel; 1 x DLE)	9%	6%	8%	4%	10%	4%	25%	66%
5 - 1 x New Unit (1 x New Unit; 1 x SGT400 rewheel)	15%	15%	13%	3%	4%	4%	35%	89%
6 - 2 x New Unit	4 Unit options not included in BAT Assessment							
7 - 1 x New Unit + 500 Hrs	4 Unit options not included in BAT Assessment							
8 - 1 x Decom	Not included in BAT Assessment as there is no backup when 2 units are require to be operated in parallel							
Score Sub-Total	15%	15%	13%	7%	10%	5%	35%	100%

Table 27 - BAT Assessment Consolidated Scores

352. In-depth discussion on how each option is ranked is provided within **Section 5.2.**

6. Cost Definition

6.1. Cost Estimate Methodology

353. As the project has developed since our 2019 RIIO-T2 business plan submission, the accuracy of the scope of works and the estimate itself has improved. The current level of cost confidence (±30%) is consistent with other projects at a similar stage and reflects the inherent uncertainties due to further engineering work required to finalise the scope of works; detailed design; and the completion of tendering processes for engineering, procurement and construction.

354. The level of cost certainty in our estimates is aligned with an AACE Class 4[34] estimate which the classification system defines as appropriate for project screening, feasibility, concept evaluation and preliminary budget approval. The Infrastructure Projects Association (IPA) published cost estimate guidance[35] classifies a ±30% cost estimate as suitable for "Outline Business Case".

355. The cost estimates, which are consistent between options, are appropriate to inform the option selection process including CBA and BAT assessment. As detailed in the PCD guidance, the cost Re-opener submission (planned for 2025) will be based on a finalised scope of works, Detailed Design and Build Main Works Contractor (MWC) tendered prices and order values for long lead items.

Estimate Scope

356. We have developed estimates of total installed cost for all 8 shortlisted options. We have then determined approximate spend profiles for all options (per **Section 6.3**) so that discounting could be applied in the CBA and BAT assessment tools. All the estimates have been developed based on an assumed standard EPC delivery strategy consisting of the following main contracts: pre-FEED; FEED; EPC, and compressor machinery train equipment.

357. The total installed cost estimates are based on the following main cost elements:

- Installation of new build Compressor Machinery Train equipment including CAB
- Tie-in of new equipment to existing station piping; control and protection systems, electrical, drainage and utilities connections, process vent
- Asset Health scope for existing Avon to be retained considering planned interventions already funded via our RIIO-T2 business plans (see Asset Health Report**, Appendix D**)
- Retrofit emissions abatement modifications to existing Avon driven compressor train (SCR, DLE, CSRP)
- Engine upgrades for applicable retrofit options
- Re-wheel of existing Units C and D (Siemens SGT-400s)
- Decommissioning of redundant compressor units

[34] AACE International Recommended Practice No. 18R-97 – Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for The Process Industries
[35] IPA_Cost_Estimating_Guidance.pdf (publishing.service.gov.uk)

358. Whole life cost estimates also include estimated ongoing asset health spend for new and retrofit GTs until 2050. These costs include asset refurbishment and replacements based on our asset management policies, procedures and specifications and they are consistent with asset health plans approved as part of our 2019 RIIO-T2 business plans.

359. Other recurring costs in our whole life cost estimates include OPEX, fuel consumption, reagent use and catalyst replacement for SCR option and network constraint cost.

Base Data

Compressor Machinery Train Equipment

360. Equipment costs for the new build option were provided by [redacted] based on cost models and norms by equipment type. King's Lynn Compressor Station, as with many of our sites, is located in an area of low background noise meaning compressor noise must be mitigated through the use of low noise compressor acoustic enclosures. Costs for these enclosures are included in the compressor machinery train equipment cost estimates and are based on costs for similar equipment purchased for other sites.

Tie-in of New Equipment

361. New compressor machinery train equipment will be installed on a brownfield location in the redundant Plant 1 area to the north (Plant East) of the existing plot based on a layout developed by [redacted] as described in the Engineering Report in **Appendix C**. Tie-in of new assets into existing site infrastructure has been priced based on Material Take Offs (MTOs) produced by [redacted] with the following allowances applied:

- **Technical Allowance –** Covers design development (e.g., Equipment specifications, changes in size and valve specifications etc)
- **Growth –** Covers increase in size/complexity of the project as engineering definition develops (e.g. Plot layout definition increase due to additional small bore piping, valves, non-tagged minor equipment etc)
- **Cut and Waste –** bulk material off-cuts, overages and waste
- **MTO Allowance –** margin to cater for items not included MTOs (e.g., Small bore piping and valves, bolts and gaskets, minor electrical and instrumentation material etc)

362. Procurement costs are based on assumed material cost data provided by [redacted] and fabrication and installation costs are based on assumed labour rates provided by [redacted] Given the prevailing national and international geopolitical conditions, labour and material rates present a risk to the project, particularly for new build options involving larger scope. This risk is noted in the risk register in **Appendix F**.

Asset Health Interventions

363. The scope of asset health interventions required on the existing Avon compressor trains and associated equipment is defined in the Asset Health Report in **Appendix D**. Our RIIO-T2 asset health plans were based on retaining the existing Avon at King's Lynn until 2030 when it would be replaced with a new unit as part of our preferred option for MCPD compliance.

364. Asset health costs are based on unit costs agreed as part of our RIIO-T2 business plans where available as shown in the table below. These costs are total installed cost and therefore no additional cost factors or Unallocated Provision (UAP) has been applied.

Cost Element	Unit Cost ID	Total Installed Cost Estimate *(18/19 price base)*	Comment
Control			
Unit control system	N/A[36]	[redacted]	From RIIO-T2 Control System Cyber and Asset Health business plan submission
Fire and Gas Detection	N/A[37]	[redacted]	
Anti-Surge System	N/A[38]	[redacted]	
Electrical			
Distribution Boards	[redacted]	[redacted]	
Auxiliary Equipment	[redacted]	[redacted]	
LV Switchboards	[redacted]	[redacted]	
Rotating Equipment			
Gas Generator - overhaul	[redacted]	[redacted]	
Power turbine	[redacted]	[redacted]	
Compressor Impeller Refurb	[redacted]	[redacted]	
Compressor - dry gas seal	[redacted]	[redacted]	
Compressor Acoustic Building			
Building - CAB (Major)	[redacted]	[redacted]	
Building - CAB (Minor)	[redacted]	[redacted]	
CAB Ventilation (Major)	[redacted]	[redacted]	
CAB ventilation (Minor)	[redacted]	[redacted]	
Air intake (Major)	[redacted]	[redacted]	
Air intake (Minor)	[redacted]	[redacted]	
Exhausts (Major/Replace)	[redacted]	[redacted]	
Exhausts (Minor)	[redacted]	[redacted]	
Piping & Valves			
Unit Isolation Valves	[redacted]	[redacted]	
Non-Return Valves	[redacted]	[redacted]	
Other Ancillary Systems			
Fuel Gas Skid	[redacted]	[redacted]	
Oil System (GG, PT, Comp)	[redacted]	[redacted]	
Fire Suppression	[redacted]	[redacted]	

Table 28 - Asset Health Costs

[36] Cost based on RIIO-T2 Plan Annex 15.07 – Cyber Resilience Plan
[37] Approved RIIO-T2 funded scope excluded
[38] Intervention frequency of 20 years for 500-hour EUD

365. A re-wheel of Units C & D (Siemens SGT-400) compressors has been included in all options to ensure efficient load sharing. The cost for this re-wheel is based on vendor quotation for similar work at another of our compressor stations.

366. For each of the retrofit options (CSRP, DLE, SCR), we have also included a cost for the replacement of the existing wet seals to new, more efficient dry gas seals. This cost is a lump sum including in-directs and UAP.

Decommissioning

367. We have included the cost for decommissioning the existing Avon Unit A in all options and the decommissioning of existing Avon Unit B where it will be replaced with new unit(s). These costs are based on confirmed allowances for decommissioning of similar units at other sites. However, the investment decision on decommissioning scope and investment timing will be made seperately.

Emissions Abatement Technology

Selective Catalytic Reduction

368. The SCR system consists of a replacement exhaust stack incorporating NO_x and CO catalysts. Emissions must be monitored via a continuous emissions monitoring system connected to the control system. Aqueous ammonia is used as the reagent and is supplied by tanker to a storage and loading area which is connected to the injection points in the exhaust stacks via permanent piping connections. Equipment supply and installation costs were provided by [redacted] per the report included in **Appendix H**. The structural, civil and tie-in costs were then estimated by [redacted]

369. Catalyst replacement cost and reagent costs are included in the OPEX estimate and are based on prices provided by [redacted] and forecast compressor run hours to 2050.

Control System Restricted Performance

370. The CSRP option involves restricting emissions through control system modifications and there are no physical asset modifications required. Therefore, option costs are assumed similar to the 500-hour EUD option and include asset health scope only. There may be some incremental costs associated with the application of the CSRP restrictions, these are assumed to be negligible in the context of the ±30% estimates.

Dry Low Emissions

371. The Avon DLE retrofit modification involves replacement of the combustion system in the gas generator with DLE combustors, a modified engine casing and modifications to the fuel supply system and associated controller. Cost estimates for this scope are based on negotiated prices with [redacted] which are based on our Avon 1533-75G gas generators per the scope summarised in **CE-AMP**.

Remaining Project Cost

372. All remaining project costs were estimated by [redacted] using their approved Cost Estimate Methodology **(Appendix C).** These costs include the following:

- Engineering design including FEED, Detailed Design, surveys and third party consultancy
- Client and contractor project management during design and construction

- Other client costs (overhead)
- Freight
- Certification and documentation
- Commissioning and operational spares
- Insurance
- Vendor representatives
- Third Party inspection
- First Fills
- Royalties

Unallocated Provision

373. Unallocated provisions are included in the estimate to account for unidentified growth and/or uncertainties in rates, etc. A [redacted] UAP factor has been applied to the base cost for all options excluding asset health and decommissioning spend. If all the assumptions on which the base estimate was made turn out to have been valid, then the base cost estimate should represent the expected cost or [redacted]

374. There are many potential sources of over-run for a project of this type, such as schedule delays, labour disputes, supplier problems, etc. There will be many such risks on the project risk register, many of which will not occur. However, as they all have a finite chance of happening, some will occur and have a cost impact, others might require mitigation to be put in place, at a cost, to ensure that either they do not occur or they can be dealt with.

375. Moreover, not all assumptions made in the study design premise will turn out to be valid. Some will have been first guesses but there is no allowance in the base estimate for wrong assumptions. There may also be considerable uncertainty in the estimate because of work yet to be performed or finalised; e.g., flow assurance, weather or contracting strategy. Any one of these could have a significant impact on the cost estimate.

376. Because there will be problems and changes, even though we do not yet know what they will be, a provision needs to be added to the base estimate to obtain the [redacted] estimate. This provision is not a management reserve or budget contingency (such a contingency, typically included by operating companies, would be added on top of the [redacted] estimate); instead, it is an unallocated provision for project risks, weak data and inadequate scope definition.

377. UAP does not cover force majeure, major changes, political upheaval, major location change, capacity changes >10%, major / national strikes, major legislation change, major cost inflation change, major industrial disputes, bankruptcy major contractor, major exchange rate fluctuations and natural disasters.

6.2. Option Cost Estimate Details

378. Capex estimates for each option are provided per the breakdown requested in the 2019 Engineering Justification Paper (EJP) guidance document. Asset health costs are included separately as they are based on RIIO-T2 unit costs. All costs are provided in 2018/19 price base year and should be considered accurate to ±30%. An unallocated provision of [redacted] is included as detailed within **Section 6.1**. A detailed cost breakdown can be seen in **Table 29** below.

Cost Element	Description	1 - Counterfactual 1 off 500-hour Avon	2 - 1 Derated CSRP Avon	3 - 1 SCR	4 - 1 Retrofit DLE 1533	5 - 1 New GT + Decommission both Avons	6 - 2 New GT + Decommission Both Avons	7 - 1 New GT + 1 500-hour Avon	8 – Decommission Avon
Engineering Design	studies/FEED/Detailed design as appropriate.	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Project Management	project management, not direct or indirect company costs.	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Materials	Bulk materials, breakdown preferred	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Main Works Contractor	Project construction contractor costs.	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Specialist Services	additional services used to support the project i.e., surveys, data procurement etc	-	-	-	-	-	-	-	-
Vendor Package costs	Compressor Machinery Train Equipment procurement	-	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Direct Company Costs	Refer to Regulatory Instructions and Guidance for definition.	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Indirect Company Cost	Refer to Regulatory Instructions and Guidance for definition	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Contingency	Contingency included in base cost estimate	-	-	-	-	-	-	-	-
Total Installed Cost	**Cost excluding asset health cost and UAP**	-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Unallocated Provision (UAP)		-	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	-
Asset Health	Total installed costs for asset health scope required prior to 2030	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Overall Total		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 29 - Option Cost Breakdown (Detailed)

6.3. Project Spend Profile

379. Capex profiles for each option have been produced and used in the CBA and BAT assessment.

380. The spend profile for the Final Preferred Option is shown in **Table 30** below.

Period	Spend
FY22	[redacted]
FY23	
FY24	
FY25	
FY26	
RIIO-T2	
FY27	
FY28	
FY29	
FY30	
FY31	
RIIO-T3	
Total	

Table 30 - Preferred Option (Option 5) Spend Profile

7. Option Evaluation and Final Recommendation

7.1. Option Assessment Process

381. This section shows the reasoning behind the Final Preferred Option selection, including detailed evaluation of costed shortlisted options (defined in **Section 5 and 6**) against our Needs Case (**Section 4**). A decision tree was used to help guide investment decisions through logical steps, defining why this investment is necessary and the required time frame for implementation. Our options were then assessed against our key investment criteria and evaluation models. This process is defined in **Figure 18**.

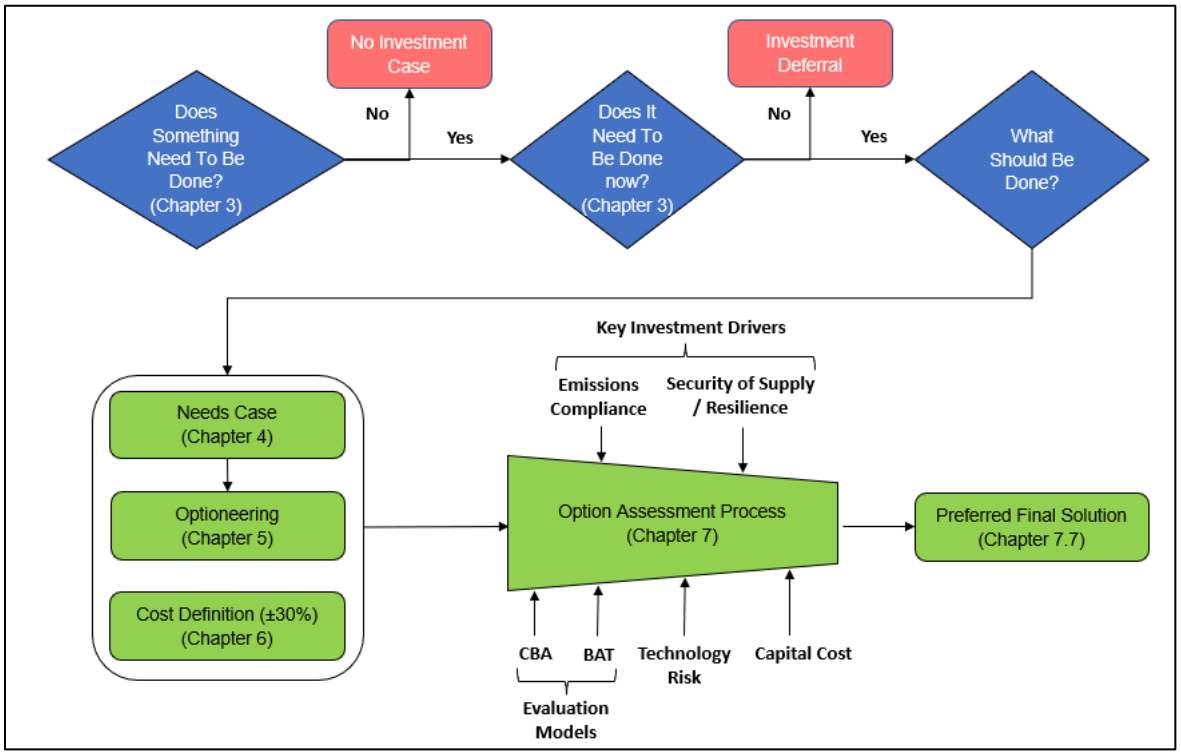


Figure 18 - Option Assessment Process

382. The first stage of the option assessment process was to define the Needs Case, which showed the that further action is required. **Section 3 and 4** outlines the need to retain the compression capability currently provided by Unit B beyond 2030 when it will no longer be compliant with MCPD legislation. Failure to invest in an MCPD compliant solution will place King's Lynn Unit B under 500-hour derogation.

383. Once the requirement of future investment was determined, the timeline of the investment was assessed. If near-term investment was not deemed necessary, an evaluation of investment deferral through Real Options Analysis or similar could be performed. There are benefits and drawbacks associated with deferring investment, where deferral increases the confidence in the needs case and gives awareness of future legislation changes. However, it also increases the risk of constraints due to the viable solutions not being implemented in time. Investment is required now at King's Lynn to ensure there is sufficient time to achieve emissions compliance by the MCPD deadline without reducing the network's resilience, see **Section 5** for further detail.

384. Key investment drivers were used to assess options against principles which are important to the future running of the site, which aren't necessarily included in existing economic analysis e.g. CBA which relies on FES 2021. The following key investment drivers are applicable to King's Lynn and are covered in more detail in the sections below:

- Emissions Compliance is a key investment driver for future investment at King's Lynn given the need to meet MCPD emissions legislation by 2030
- King's Lynn plays an important role in ensuring overall Security of Supply to the UK as defined in **Section 4**

385. Traditional evaluation models such as CBA and BAT have been used, incorporating whole life cost, fuel and emissions costs, technical, environmental and emissions reduction appraisal, to best inform option selection and decision making. Technology maturity was also an important tool used to aid decision making considering the critical nature of King's Lynn operation.

386. Consideration was also given for the capital investment cost of the options, ensuring that the final option provides value for money for consumers and prevents over investment with the potential for asset stranding as a result of changing future legislation or network capability requirements.

387. Key investment drivers, evaluation models (such as CBA and BAT), technology risk and capital investment analysis are combined in an option assessment matrix below **Table 31**. The option assessment criteria noted above were used to help filter out non-viable options, giving the most appropriate investment solution. Further discussion on each of these criteria is provided in the sections below.

Option Assessment Matrix Kings Lynn	Emissions Compliance	BAT Assessment	CBA	Security of Supply / Case Study	Technology Risk	Capital Investment
1 – Counterfactual	Achieves MCPD Compliance through **Derogation** **Note**: No NOx emissions abatement.	Lead Configuration: BAT Back-Up Score: 51% Versatility: 9/15%	**Modelling based on FES does not capture key use cases of the site and risks resulting from loss of capability**	**Ruled Out** Unrestricted backup necessary in event of parallel running		
2 - 1 x CSRP	Achieves MCPD Compliance through **Abatement** **Note**: No NOx emissions abatement.	Lead Configuration: BAT Back-Up Score: 57% Versatility: 9/15%		Provides Unrestricted Running	**Ruled Out** Avon exceeds original design life which risks critical site operation. Additional risk of CSRP permit rejection from EA	
3 - 1 x SCR	Achieves MCPD Compliance through **Abatement**	Lead Configuration: BAT Back-Up Score: 57% Versatility: 9/15%		Provides Unrestricted Running	**Ruled Out** Avon exceeds original design life which risks critical site operation. Requires new HSE procedures to handle ammonia on site and introduces new failure mode onto NTS.	
4 – 1 x DLE	Achieves MCPD Compliance through **Abatement**	Lead Configuration: BAT Back-Up Score: 66% Versatility: 9/15%		Provides Unrestricted Running	**Ruled Out** Avon exceeds original design life which risks critical site operation. Additional risk that solution not yet commercially proven.	
5 - 1 x New Unit	Achieves MCPD Compliance through **New Unit Build**	Lead Configuration: BAT Back-Up Score: 89% Versatility: 15/15%		Provides Unrestricted Running	New Compressor Technology proven on NTS	[redacted]
6 - 2 x New Unit	Achieves MCPD Compliance through **New Unit Build**	Not Assessed (4 Unit Site)		Provides Unrestricted Running	New Compressor Technology proven on NTS	
7 - 1 x New Unit + EUD	Achieves MCPD Compliance through **New Unit Build / Derogation**	Not Assessed (4 Unit Site)		Provides Unrestricted Running **Note**: Avon exceeds original design life but any risks are balanced out by new unit	New Compressor Technology proven on NTS	
8 - 1 x Decom	Achieves MCPD Compliance through **Decommission**	Not Assessed (2 Unit Site)		**Ruled Out** back-up required for parallel running		

Table 31 - Option Evaluation Matrix

7.2. Emissions Compliance and BAT Assessment

Emissions Compliance

388. All options achieve MCPD compliance through derogation, Emission Abatement, new-build or decommissioning. MCPD compliance was accessed through the optioneering process defined within **Section 5,** and as such, only options which were MCPD compliant were taken forward for costing and further consideration.

389. It should be noted that while all options achieve MCPD compliance, not all options can be considered equal in their ability to reduce NO_x levels. Unit derogation and CSRP do not reduce NO_x levels to the same level as DLE, SCR or new build options, achieving emissions compliance through reduced operation or limited power output.

390. In this regard, from a purely emissions reduction perspective, options featuring DLE, SCR or new build would be preferred over unit derogation or CSRP retrofit.

Preliminary BAT Assessment

391. The preliminary BAT assessment outlined within **Appendix G** determined that "when the lead unit is available, there is sufficient capability available to meet all the duty requirements using a single unit or with two units in parallel. It was considered that there will be no significant difference between all options in a lead configuration". For this reason, Options 1-5 were considered BAT compliant in the lead unit configuration.

392. Option BAT scores are identified within the option assessment matrix to recognise the differing levels of BAT capability between the options (back-up configurations only). As detailed within the BAT report, unit derogation and CSRP scored lowest due to reduced versatility, poor future proofing and lack of NO_x abatement. DLE and SCR were the next best performing options which feature improved emissions reduction but are limited by remnant Avon infrastructure. New units provide the most significant technical and environmental advantage over Avon based options.

393. It should be noted that options considering King's Lynn as a four-unit site (Option 6 and 7) have not been BAT assessed as these options alter the site resilience, which is better assessed via CBA. However, as these options also feature two MCPD compliant units as lead units, they can also be considered BAT compliant in line with the context above. Option 8 (decommission Avon) has not been BAT assessed and wouldn't be considered BAT as it doesn't provide the required network capability. Please see **Section 7.3** for further detail on this assessment.

394. In summary, the preliminary BAT assessment has not been used to filter out any of the shortlisted solutions.

7.3. Cost Benefit Analysis (incl. key assumptions and sensitivities)

395. The Cost Benefit Analysis in this section is based on data from FES 2021. As stated in Section 4.1, FES is primarily focussed on GB supply and demand market fundamentals. It does not appropriately reflect the impact of imbalances in related global markets (which affect LNG and EU interconnector flows) which are the primary driver for the usage of King's Lynn. As such, the constraints calculated in the CBA based on FES 2021 do not show the appropriate consequences of the loss of capability at King's Lynn.

396. Nevertheless, in this section we outline the results, assumptions and sensitivities used in our cost benefit analysis despite the limitations of FES 2021 for consistency with our other compressor emissions FOSR submissions. However, due to the limitations outlined above, see **Section 4** for more detailed context, the CBA has not been used as a distinguishing factor in discounting options from further consideration.

Constraints

397. The constraints modelled are based on the average FES 2021 flows. As discussed above, these do not highlight the appropriate range of potential risks which could occur if capability at King's Lynn was restricted.

398. To avoid the underlying constraints distorting the differences between the options, **Figure 19** shows the annual constraints relative to the lowest constraint option, Option 6 (Two New units). Option 6 has also been removed to show how the other options perform relative to each other. It is worth noting Options 1, 2 and 3 all have the same constraints as they have the same capability and reliability.

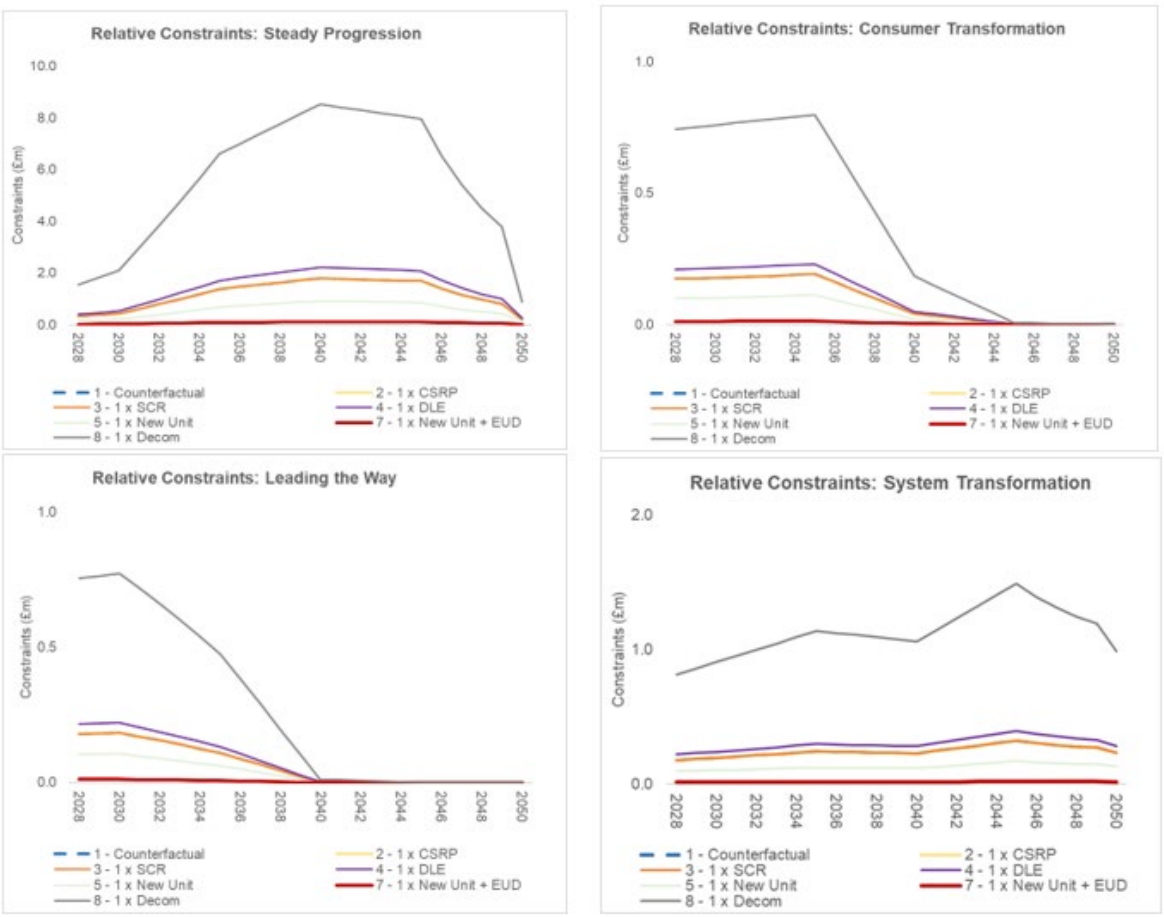


Figure 19 - Relative Annual Constraints

399. The relative performance relationship among all the options is similar in most scenarios with constraints based on the capability of each option along with the level of availability. Option 8 (decommission) gives the highest constraint cost, especially in SP. Option 4 (DLE) comes as the second highest cost due to the lower availability it has compared to a derogated, CSRP or SCR Avon unit. The constraint costs are similar in Option 1, 2 and 3, while in Option 5 and 7, costs are closing to zero among all FES scenarios.

Operational and Investment costs

400. The breakdown of the costs included in the CBA on System Transformation (ST) scenario are detailed in **Figure 20** and **Figure 21** below. Being split into the investment costs and compressor running costs it allows a comparison over the relative costs in each of the options.

401. As would be expected, Option 6 (two new units), has the highest investment costs, followed by Option 7 (1 new unit and 500-hours Avon derogation) and Option 5 (1 new unit and decommission existing Avon). The options which retain the Avon and mitigate the emissions by 500-hours derogation (Option 1), retrofitting DLE (Option 4) or installing CSRP (Option 2) have lower investment costs. The ongoing asset health of Option 7 (1 new unit and 500-hours Avon derogation) and Option 6 (two new units) are higher than other options. These costs are covered in more detail in **Section 6.2.**

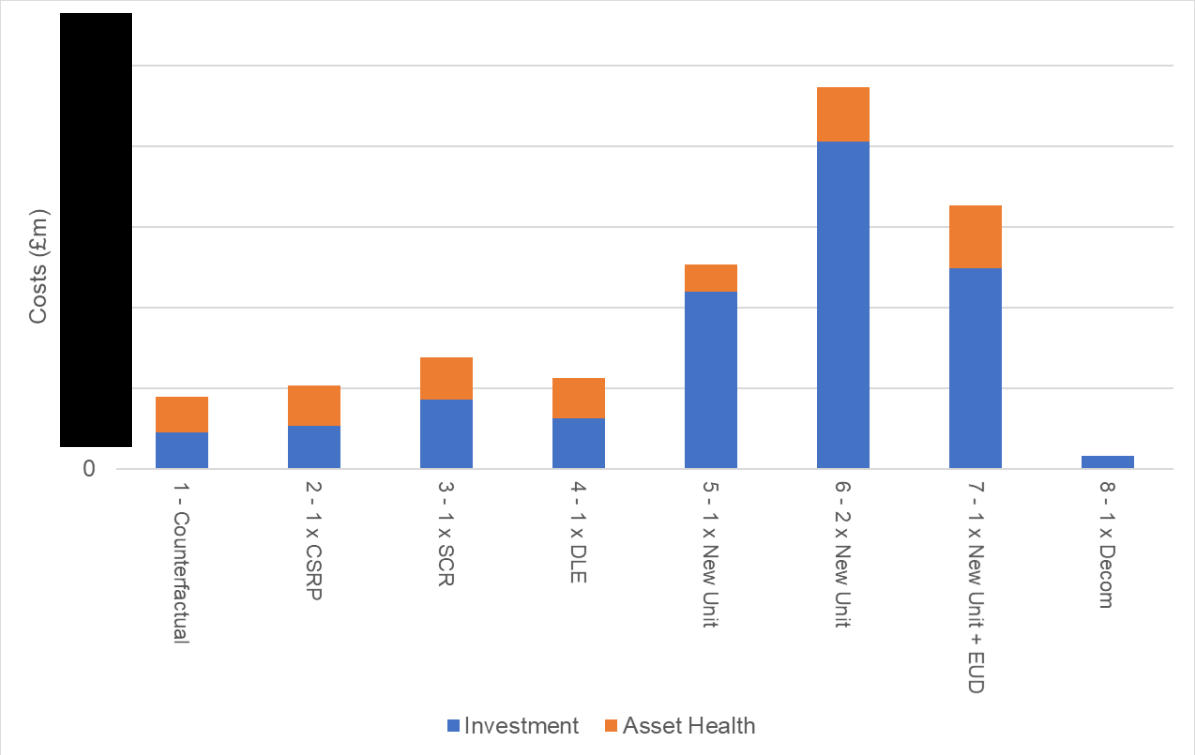


Figure 22 - Asset Costs included in the CBA

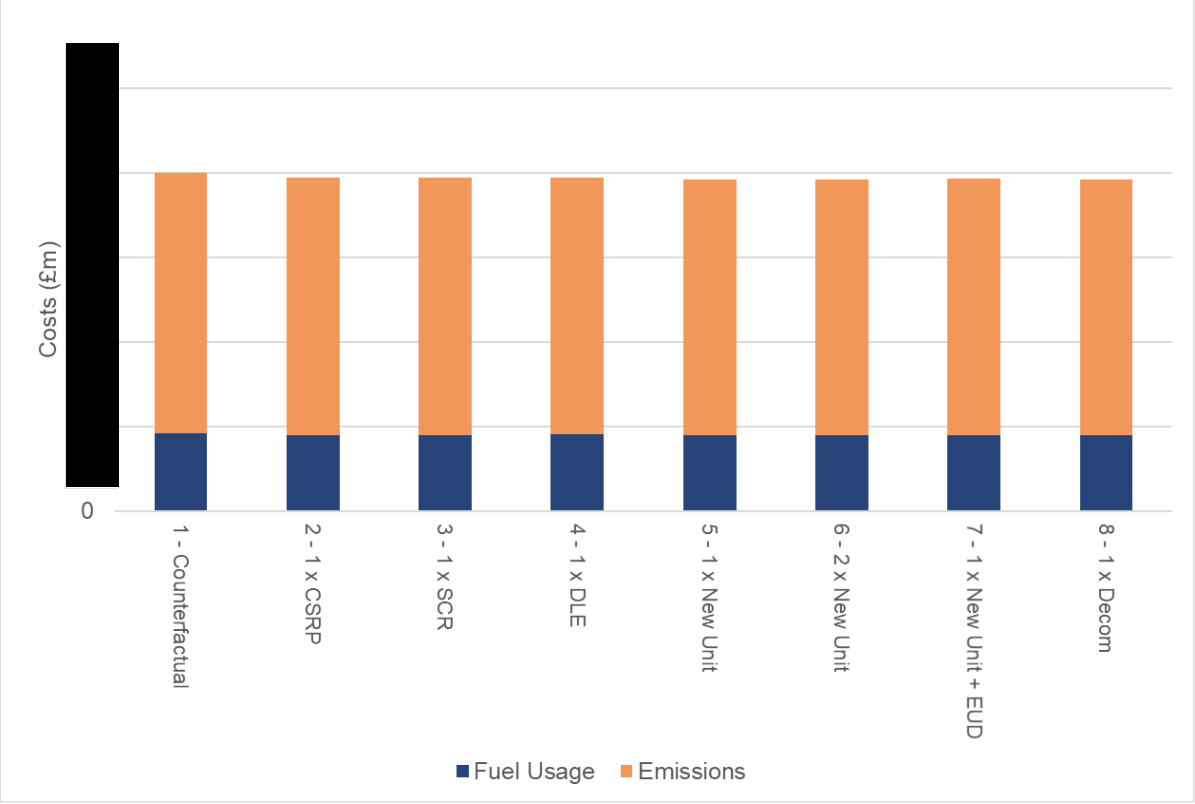


Figure 23 - Operational Costs included in the CBA

402. Given the low running hours in the model, based on the FES 2021 scenarios, there are no significant differences between the fuel usage and emissions in the options

assessed, **Figure 23**. Option 5, along with Option 6, have the lowest fuel and emissions costs, with all running taken by clean/compliant units.

Key CBA Assumptions

403. The key assumptions behind the King's Lynn needs case, based on FES 2021 are detailed in **Table 32** below.

Category	Assumption	Base Assumption	Rationale
CBA parameters	WACC	2.81%	Defined in RIIO-T2
	Social Time Preference Rate	3.5% (Years 0 – 30) / 3.0 % (30+)	Defined in Green Book
	Regulated Asset Life	45 years	Defined in RIIO-T2
	Assessment Period	25 years	Based on lifetime of asset
	Depreciation	SOTYD	Defined in RIIO-T2
	Capitalisation	75.00%	Defined in RIIO-T2
Constraints and Fuel	Gas Price	Annual price 50 – 64 p/th	BEIS reference scenario
	Compressor Fuel Costs	Gas Price	
	Constraint management pricing	[redacted]	As defined by Commercial Constraint Price Methodology
	Constraint management method	50% buybacks/50% locational actions	Reflective of tools available to manage constraints
Emissions	CO2 cost	Annual price 241 – 378 £/tonne	BEIS Valuation of greenhouse gas emissions: for policy appraisal and evaluation : Central Case
	NOx price	£6,199 £/tonne	DEFRA damage costs

Table 32 - Key Assumptions and Sensitivities

CBA Outputs

404. Sensitivities for all four FES 2021 scenarios have been assessed. The relative and absolute NPVs of these can be seen in Table 33 and Table 34 respectively.

405. The highest NPV option in SP scenario was Option 1 (500-hours derogation). Based on FES 2021, the required running hours on King's Lynn's third unit is less than 500-hours. This also results in low constraints across all scenarios due to the limited requirement for parallel operation in these scenarios. As discussed earlier in the section, this does not highlight some of the key real-world scenarios in which King's Lynn would be required, therefore does not capture the full risks of a loss of capability at the site.

Option	Steady Progression	Consumer Transformation	Leading the Way	System Transformation
1 - Counterfactual	£0 m	£0 m	£0 m	£0 m
2 - 1 x CSRP	-£2 m	-£3 m	-£3 m	-£3 m
3 - 1 x SCR	-£10 m	-£11 m	-£11 m	-£11 m
4 - 1 x DLE	-£8 m	-£5 m	-£5 m	-£6 m
5 - 1 x New Unit	-£31 m	-£40 m	-£40 m	-£38 m
6 - 2 x New Unit	-£72 m	-£89 m	-£89 m	-£86 m
7 - 1 x New Unit + EUD	-£37 m	-£52 m	-£53 m	-£50 m
8 - 1 x Decom	-£47 m	£8 m	£10 m	£0 m

Table 33 - CBA Results vs. FES 2021 - Relative NPV

Option	Steady Progression	Consumer Transformation	Leading the Way	System Transformation
1 - Counterfactual				
2 - 1 x CSRP				
3 - 1 x SCR				
4 - 1 x DLE				
5 - 1 x New Unit				
6 - 2 x New Unit				
7 - 1 x New Unit + EUD				
8 - 1 x Decom				

Table 34 - CBA Results vs. FES 2021 - Absolute NPV

406. The highest NPV in Consumer Transformation (CT), Leading the Way (LW) and ST is Option 8 (decommission Avon). However, decommissioning of the Avon without replacement will significantly reduce the resilience of the site. No backup would be provided to parallel operation, impacting the site's ability to meet network requirements during planned or unplanned outages and what is considered ta more appropriate range of supply and demand. Option 8 will be discussed further in **Section 7.4**.

CBA Summary

407. Across the four FES 2021 scenarios, the CBA doesn't identify any option as a clear leader, with small differences between many of the options which provide back-up to the existing MCPD compliant Units C and D. Given these scenarios do not cover many of the key use cases with more appropriate supply/demand scenarios for King's Lynn, further analysis is required to understand how the options perform under these use cases, which is detailed in **Section 7.4**.

7.4. Security of Supply and Case Studies

Bacton Supply and Demand Sensitivities

408. The Cost Benefit Analysis in **Section 7.3** is based on the FES 2021 scenarios. These scenarios are developed based on a forecast UK gas demand and what level of supply is required to meet that demand. FES does not account for any local or global market dynamics. As a result of this, we cannot appropriately quantify the impact of prolonged periods of imports or exports at Bacton by basing our assessments on FES alone.

409. Prolonged periods of either imports or exports which require parallel running of the compressors at King's Lynn would risk breaching any 500-hour limit on the Avon unit. As defined in **Section 4**, there are no alternative compressor stations which can deliver this capability once the limit is reached; we would need to curtail flows, resulting in constraints as well as disrupting the market.

Real World Assessment – 2022 Flows and 'Beast from the East'

2022 flows

410. Due to disruptions to European supplies, there was significant increase in demand for exports from Bacton to both The Netherlands and Belgium observed in 2022, which hasn't been forecasted appropriately through FES modelling. To understand how this could impact our future operation of King's Lynn we have modelled this under the assumptions used for our long-term assessments. This applies the availabilities based on the RAM Model, with the associated improvements based on the asset health interventions, as detailed in **Section 4.2**. It also incorporates our updated network capability, which includes the impact of re-wheeling the SGT-400s (Units C and D) to better match the expected duty.

411. **Figure 24** below calculates the running of the compression with the above assumptions applied.

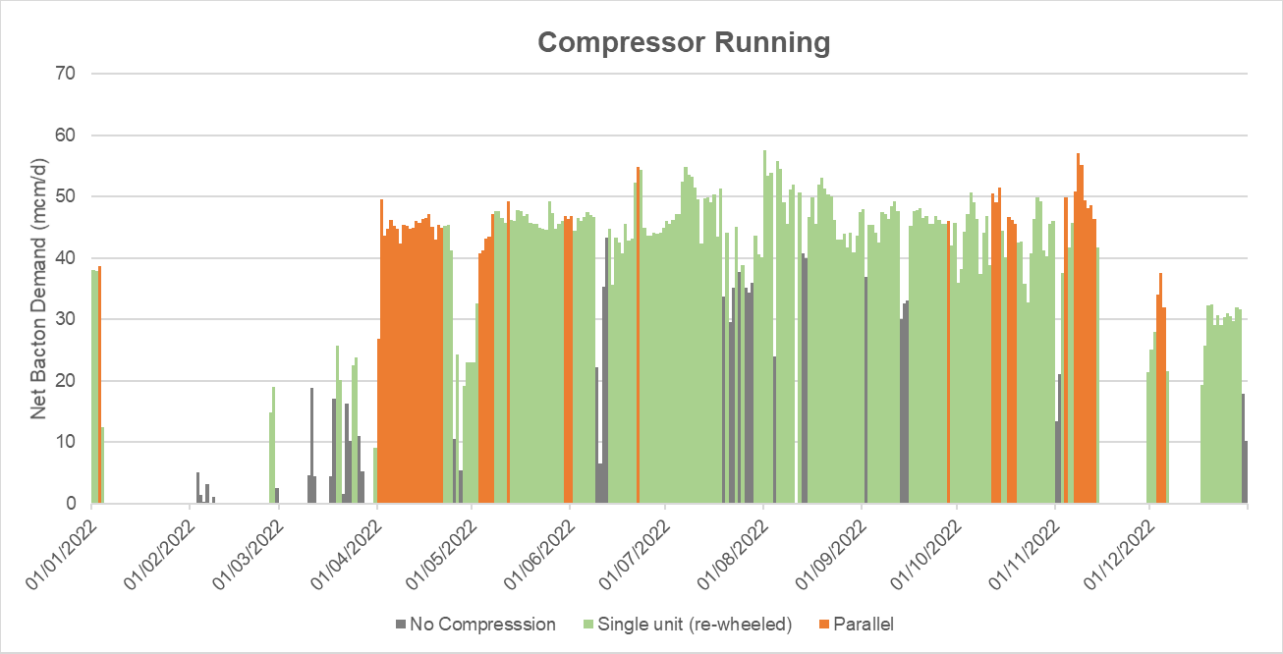


Figure 24 - Compressor Running in High Export Case

412. In this assessment the requirements for compression at King's Lynn result in single unit running for 4,560 hours (190 days) and parallel running for 2400 hours (50 days). Based on existing availability data of King's Lynn SGT-400 units, this would result in assignment of 662 hours to the third unit.

413. If the third unit was subject to a 500-hour derogation, there would be more than 162 hours where capability could not be met. Based on the average loss of capability the constraint volume would be 9.4 mcm per day, and 63 mcm in total. The cost of these constraints would vary depending on the price. At the BEIS long term average price of about 60p/th this would cost around £13m. However, at the prices experienced in early 2022 of around 150p/th the cost would be around £32m, with the potential to be much higher given the price volatility seen during 2022. It should also be noted that an inability to supply the appropriate capability to interconnector export flows will have a wider market impact across EU that would be significant.

'Beast from the East'

414. Alongside the constraint impact, restriction of Bacton could result in issues with Security of Supply. While King's Lynn is not directly linked to any domestic demand obligations, restricting imports at times of high demand could result in supply shortages.

415. During the winter of 2018, the UK experienced a significant cold snap, often referred to as 'The Beast from the East'. During this period imports at Bacton were very high, with LNG imports not sufficient to meet demand. On 2 March 2018, the LNG imports required parallel operation of King's Lynn, any restriction during this period would likely have resulted in supply shortages given the weather issues had widespread effects across the network which could have resulted in a gas supply emergency.

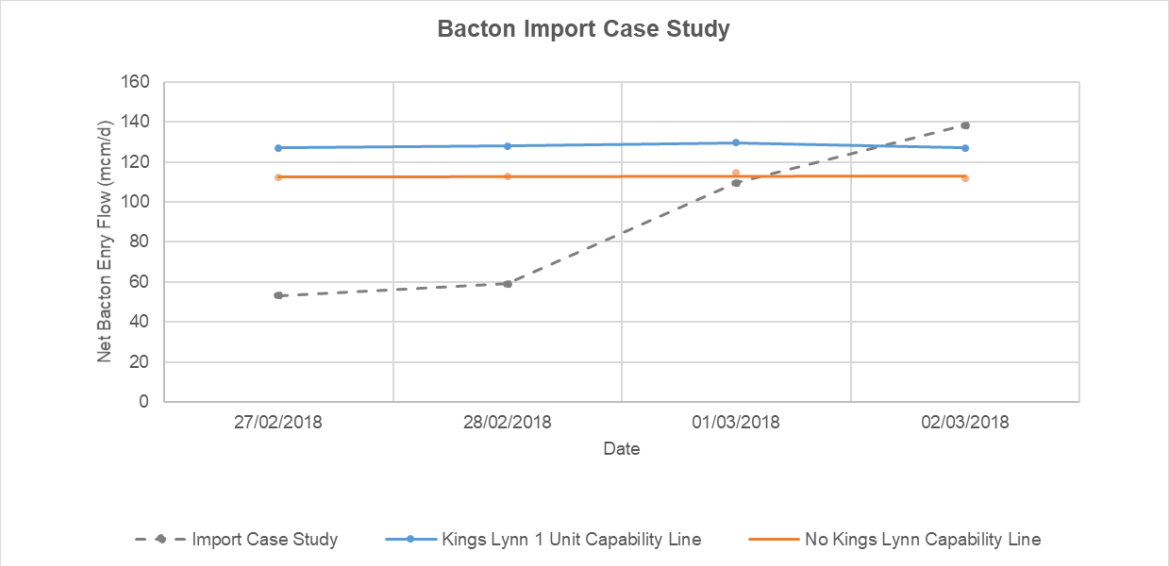


Figure 25 - Bacton Entry Capability during 'Beast from the East'

416. These potential short-term issues and impacts highlight the potential risks of the loss of capability at King's Lynn. With little alternative compression to provide this capability any losses on the site would directly impact the capability of the network. This could result in constraint costs, market price impacts or Security of Supply concerns potentially leading to a gas supply emergency. To avoid these, it is critical to ensure we maintain a reliable unrestricted third unit at King's Lynn to maintain this capability. Our preferred option, Option 5 (1 New Unit), would ensure the site has the appropriate assets.

417. As stated in **Section 7.3**, Option 8 (decommissioning Avon) would result in a two-unit site, with no redundancy and resilience for parallel operation.

Long Term Assessment – Sustained High Bacton exports

418. An alternative long-term view to FES 2021 is provided by [redacted] long term GB market projections[39], see **Figure 26**. These highlight high exports to Europe, via the GB network, to persist well into the future.

Figure 26 – [redacted] GB Demand Forecast

419. To evaluate the potential impact of these flow patterns we have created a scenario to best represent this level of sustained exports. This was achieved by increasing exports in our SP scenario to match the levels in the long term [redacted] forecast.

420. Given the uncertainty on prices we have also tested two price scenarios, one based on the average BEIS price of around 60p/th. The other is based on the current prices (Feb-23) of around 150p/th, as prices have been at or above this level for much of the last year.

421. The NPVs in Table 35 show that with additional flows there is significantly increased value in the additional resilience a new unit would provide. In a case where these flows persist, the most beneficial NPV would be where there are four units on site, maximising the resilience and minimising constraints. A four-unit solution could also, with further work, enable greater flexibility to take outages without impacting capability.

[39] [redacted] Q4 2022 Long Term European Outlook

Option	High Exports – BEIS central price		High Exports – current price (150p/th)	
	Absolute	Relative	Absolute	Relative
1 - Counterfactual	[redacted]	£0 m	[redacted]	£0 m
2 - 1 x CSRP		£0 m		£1 m
3 - 1 x SCR		-£8 m		-£7 m
4 - 1 x DLE		-£16 m		-£35 m
5 - 1 New Unit		-£7 m		£35 m
6 - 2 New Units		-£26 m		£58 m
7 - 1 New Unit + 1 x EUD		£6 m		£85 m
8 – 1 x Decommission Avon		-£208 m		-£516 m

Table 35 - High Exports NPVs

422. These sensitivities also greatly increase the NPV of Option 5 (1 New Unit). Option 5 balances increases in the resilience and reliability new unit options provide, against the costs associated with a four-unit solution, Option 6 and 7. Option 5 allows for a four-unit solution to be considered should the demands of the network or the risks in this location increase.

Summary

423. Both the short and long-term assessments above highlight the consequences of a loss of capability at King's Lynn. This could result in significant constraint costs, disrupt gas markets, and risk Security of Supply, as no other compressor station can provide this capability it is essential to have a high level of resilience and reliability at King's Lynn.

424. Option 8 (Decommission Avon) would provide no resilience at King's Lynn for any planned or unplanned outages. Given the potential consequences, this is not sufficient to protect consumers from constraint costs or maintain Security of Supply. For these reasons, this option should not be implemented.

425. Option 1 (500-hours derogation Unit B (Counterfactual)) only provides limited resilience for failures to Unit C and D. As highlighted in the Real-World analysis, a period of sustained high exports could drive a greater than 500-hour requirement resulting in a loss of resilience at the site. With the long-term case study highlighting the potential for these flow patterns to continue, the 500-hour limit could risk significant constraint costs and market disruption for an extended period. For these reasons, this option should not be implemented.

426. The remaining options all provide at least one unrestricted unit to provide resilience to the primary units at King's Lynn. The longer-term assessment does show benefits to the enhanced availability provided by new units, with the potential further benefits of a four-unit site (Option 6 and 7).

7.5. Technology Risk

427. **Section 5** described a number of innovative abatement solutions which were considered as part of the optioneering process. These solutions reflect technologies which are at various levels of technical maturity and implementation on the National Transmission System. For example, SCR is a proven technology in the European gas network, however no compressors on the NTS currently use SCR to ensure NO_x compliance.

428. For this reason, the technological readiness level of these technologies is an important consideration for implementation at a compressor site of critical importance such as King's Lynn. The technological risk inherent in each of the abatement solutions below is described in **Section 5.2** and is also contained within the Project Risk Register (**Appendix F**).

429. Important consideration is given to the age and current condition of the Avon. As described in **Section 3**, King's Lynn B is over 50 years old, currently operating well beyond its original design life. While we have considered an appropriate level of initial and ongoing asset health investment to achieve the unit availability targets set out in the RAM Model (see **Section 4.2** and **CE-AMP**), continued reliance on 50-year-old assets remains a risk to site availability and resiliency. Enduring reliance on the unit poses a high risk to the operation of the NTS and the UK's Critical National Infrastructure.

430. The asset health scope of the Avon has been assumed based on the recommendations of the RAM Study; visual, non-intrusive site inspection, and feedback from site Operations team. Confirmation of the asset health scope for retrofit options would require condition assessment and detailed remnant life surveys to be conducted during FEED and there is a major risk[40] that additional scope will be identified during survey. Further risks associated with the age of the Avon include the risk that reliability will be worse than expected due to age related issues[41] and that long term support will become problematic[42].

431. Therefore, following due consideration for the criticality of King's Lynn Compressor Station and the role it plays in ensuring UK Security of Supply, each of these abatement solutions has been filtered out of consideration due to the concerns raised above, and the high level of risk these present (Options 2, 3 and 4). This can be seen in the option assessment matrix represented in **Table 31**. Additional justification for ruling out these abatement solutions is described further below:

Dry Low Emissions (DLE) Avon Retrofit

432. The DLE retrofit solution has not yet been fully proven in commercial operation and is currently undergoing performance testing. As such, there are risks surrounding its selection and implementation, see **CE-AMP** for further detail.

[40] Risk Register ref. CM-1
[41] Risk Register ref. CM-6
[42] Risk Register ref. CM-7

433. This technology risk is represented in the Project Risk Register under CM-14 as a Major risk (High Probability/Medium Impact). This risk has the potential to impact unit availability and given the future requirement for parallel running (as established within **Section 4**), site availability could be impacted in the event of planned or unplanned downtime involving the lead units on site.

434. It is discussed in **Section 3.1** and **5.1** that we are currently running controlled performance trials on DLE technology with a view to permanently installing it on units on the NTS for more established operational running. Following the accumulation of 10,000 operational hours on a single unit, and a full review and inspection the technology could be recommended for wider roll out across the NTS.

435. As part of the St Fergus MCPD Final Option Selection Report, a DLE performance trial was recommended as part of the Final Preferred Option. This approach considered the risks inherent in using the unproven technology. These included the impact on site capability during the trial (should major issues be encountered) and the deliverability of an alternative long-term and MCPD compliant solution should the performance trial not prove successful. Ultimately, given the number of alternative high-availability compressor units present at St. Fergus (2 x VSD and up to 3 x Avon) analysis showed there was sufficient resilience present to meet contractual requirements and a DLE trial could be accommodated.

436. As part of the Peterborough and Huntingdon MCPD Final Option Selection Report, DLE retrofit is recommended to be applied to Huntingdon Unit C as part of the Final Preferred Option. The approach at Huntingdon differs from St Fergus, due to the location of the site on the network and its interaction with Peterborough. The risk of DLE retrofit failure at Huntingdon is decreased due to the ability of nearby Peterborough Compressor Station to support compression. DLE retrofit would be applied on Huntingdon Unit C during the 2027 summer outage following implementation of the necessary asset health works in preceding outages/years. Should concerns be raised regarding the viability of the DLE solution, either through the St Fergus trial or otherwise, derogation or CSRP remain viable alternatives for consideration at Huntingdon.

437. Given the risks associated with implementation of an unproven technology at a high criticality site with minimal resilience, and the associated age profile of Unit B, DLE retrofit (Option 4) has been removed from future consideration at King's Lynn as identified in **Table 31**.

Control System Restricted Performance (CSRP)

438. CSRP is an innovative control system modification which has not been implemented on the NTS previously. Solution implementation is dependent on gaining environmental permit approval from the Environment Agency (EA). Permit applications are being sought for the sites that were used for performance tests, to determine if the EA would accept it as an MCPD solution. Individual permits would have to be submitted for each unit where CSRP is the selected solution, with the relevant environment agency reviewing each application specifically.

439. This technology risk is represented in the project risk register under HSSE-11 as a significant risk. This risk has the potential to impact the execution schedule through experiencing delay due to challenges in obtaining an environmental permit from the EA.

440. In certain circumstances, CSRP would reduce the top end power of the compressor. The exact reduction in performance is specific to the particular compressor in question, taking into account multiple variables specific to its location and operation on the NTS. Installation of CSRP on compressors requiring top end utilisation could significantly impact operation, leading to constraints.

441. There is an increased risk that, due to the potential for high forecast future run hours at King's Lynn, the EA could deem CSRP an inadequate solution for emissions reduction compared to DLE, SCR or new unit(s). If deemed "available", CSRP is an ideal candidate for lower run hour sites which wouldn't be impacted from performance restrictions.

442. Given the risks outlined above and the case made against continued use of compressor units which have exceeded their design life, Unit B, CSRP is removed from future consideration (option 2).

Selective Catalytic Reduction (SCR)

443. The SCR solution uses Ammonia (NH_3) and a catalyst to convert NO_x into Nitrogen (N_2) and water (H_2O), in turn reducing the total NO_x emissions.

444. SCR represents a new technology on the NTS, as no compressors currently use SCR to reduce NO_x emissions. A catalyst solution has been implemented at Aylesbury, but this is a passive solution which reduces CO, and does not use a reagent (ammonia) to reduce NO_x. SCR requires a continuous emissions monitoring system to monitor NO_x and control ammonia injection rate and engine speed accordingly. Implementation of a new technology on a critical site poses a significant risk to site availability and resilience.

445. As described in Section 5, the SCR solution involves extensive construction near operational assets which, given the complexity of the works involved, risks exceeding the outage period and further impacting site compression operations.

446. SCR involves the use of ammonia as a reagent which would introduce a new hazardous substance onto the NTS which would require new procedures to be developed. For this reason, this option scores worse than alternatives in terms of "hazard" on the BAT assessment.

447. Given the concerns outlined above and the case made against continued use of compressor units which have exceeded their design life, SCR is removed from future consideration (option 3).

New Unit

448. New units will have some technology risk associated with their installation and operation, however this is mitigated through strict qualification requirements which must be met prior to compressor equipment being approved for use on the network. We will

also look to commission new units in 2028 to allow a winter proving period prior to the legislative deadline when non-compliant units must be removed from service.

7.6. Capital Investment

450. As stated in **Section 7.1**, our key investment drivers are to comply with MCPD emissions legislation, while ensuring that the network is resilient and able to meet a wide range of likely future supply and demand patterns, thereby ensuring UK Security of Supply.

451. By filtering options based on criteria which assess the relative merit and viability across a wide range of key considerations, we have reduced the available options down to three solutions, which involve variations of new build compressors as displayed below in **Table 36.**

Option Assessment Matrix Kings Lynn	Emissions Compliance	BAT Assessment	CBA	Security of Supply / Case Study	Technology Risk	Capital Investment
5 - 1 x New Unit	Achieves MCPD Compliance through **New Unit Build**	Lead Configuration: BAT Back-Up Score: 89% Versatility: 15/15%		Provides Unrestricted Running	New Compressor Technology proven on NTS	[redacted]
6 - 2 x New Unit	Achieves MCPD Compliance through **New Unit Build**	Not Assessed (4 Unit Site)		Provides Unrestricted Running	New Compressor Technology proven on NTS	
7 - 1 x New Unit + EUD	Achieves MCPD Compliance through **New Unit Build / Derogation**	Not Assessed (4 Unit Site)		Provides Unrestricted Running **Note**: Avon exceeds original design life but any risks are balanced out by new unit	New Compressor Technology proven on NTS	

Table 36 - Final Option Assessment Capital Investment Filter

452. Of the remaining options which comply with emissions, are BAT compliant, ensure Security of Supply and are technically available, Option 5 (1 New Unit) represents the best value for consumers.

453. The additional capital investment for Option 6 and 7 cannot be justified at this stage. However, in the future there may be potential benefit to the additional resilience provided by these options, which will assessed and monitored as part of wider Security of Supply and network resilience review.

7.7. Final Option Justification

Our Investment Recommendation

455. The Final Preferred Option is to install one new compressor at King's Lynn by 2030, re-wheeling of the MCPD compliant Units C and D, and decommissioning of the non-MCPD compliant Avons, Unit A and B. For cost evaluation purposes, a gas-driven 15 MW sized unit was used, however following approval of the Final Preferred Option, new unit, either gas or electrically driven, will be appropriately sized to meet capability requirements. This option provides long-term emissions compliant compression resilience, providing the correct level of resilience and availability for the site.

Justification for the Final Preferred Option

456. Option 1 (500-hours derogation Unit B (Counterfactual)) isn't a viable option as detailed in **Section 7.3.** Analysis has shown that derogating the unit to 500-hours will incur significant levels of network constraints, and gives insufficient resilience to the site in meeting operational requirements and UK Security of Supply. This would impact both the UK and Europe's gas markets.

457. Option 1, 2, 3, 4 and 7 (options retaining Unit B) aren't viable options as detailed in **Section 7.5.** Unit B is currently over 50 years old, with an original design life. Enduring reliance on such an old compressor at a critical site poses an unacceptable risk to the operation of the NTS and the UK's Critical National Infrastructure

458. Further to the risks discussed above option 2, 3 and 4 (Emission Abatement solutions) result in additional risks as detailed in **Section 7.5.** DLE is currently undergoing performance trials, CSRP's acceptance by the environmental agencies is being assessed, and SCR poses significant operational risks which can't be accepted on a critical site. Therefore, these are not currently available solutions for the site to meet MCPD and operational requirements by the 2030 deadline.

459. Option 5, 6 and 7 (new unit solutions) are viable options as detailed in **Section 7.3.** New unit solutions scored highest in terms of network versatility, future proofing against changes in energy legislation, maintainability and emissions in the BAT assessments (note Option 6/7 were not assessed as part of the BAT assessment). Modern compressors also offer efficient operation, long-term reliability, high availability and low emission compression. The new unit solutions feature the most up-to-date technology and support packages, which protects the investment from future changes in energy legislation ahead of the UK's aspiration to achieve Net Zero by 2050.

460. Option 8 (Decommission Avon) isn't a viable option as detailed in **Section 7.4.** A two-unit site solution would provide no resilience for any planned or unplanned outages, resulting in reduced capability. As King's Lynn is critical in enabling high Bacton export and import flows, this is not a viable solution to protect consumers from constraint costs or maintain UK Security of Supply.

461. Option 5 (1 new unit) is the preferred solution for the site despite its high initial investment cost. This option provides significant technical and environmental gain over Avon-based solutions and is the highest performing option from an emissions reduction perspective.

462. King's Lynn is critical in enabling high import and export flows through Bacton terminal. These flows contribute significantly to UK Security of Supply, providing access to the European gas markets, responding to changes in supply and demand. Any disruptions which limit the capability of Bacton could pose a significant risk to Security of Supply and increase the chances of serious disruptions to the UK gas market. Option 5 provides appropriate levels of resilience at King's Lynn to minimise these risks, at a reduced cost compared to the four-unit solutions.

463. Deferring or delaying new unit investment isn't feasible due to the limited time available to implement this solution ahead of the MCPD deadline. Should an alternative abatement approach be taken, there are inherent high risks associated with the Avon being derogated to 500-hours beyond 2029 (Option 1).

464. Various planned investments are expected to interface with this Final Preferred Option, these are detailed within Section 4.2. Detail on the risks associated with the preferred option and other shortlisted options is included in **Appendix F**.

465. Specific project risks relating to the Final Preferred Option are covered within **Section 8.3**.

8. Additional Final Option Detail

8.1. Option Programme

466. Project delivery programmes for all shortlisted investment options have been developed to confirm the feasibility of delivery prior to the 1 January 2030 MCPD legislative deadline and to identify notable schedule related risks. These programmes have not been used to derive any elements of the capex estimates, but they have been used to determine basic spend profiles.

467. The delivery programme for the preferred option including the key assumptions and constraints is described below. Delivery programmes for the other shortlisted option are provided in **Appendix E**.

468. The project delivery programme is based on a standard EPC delivery approach including the following main contracts:

- Pre-FEED
- FEED
- Compressor machinery train equipment supply
- Engineering, Procurement, Construction and Commissioning

469. Pre-FEED stage will be initiated immediately following confirmation/approval of the Final Preferred Option via the Re-opener planned for completion February 2023. During this pre-FEED stage the delivery strategy will be confirmed and tender documentation for the FEED stage produced.

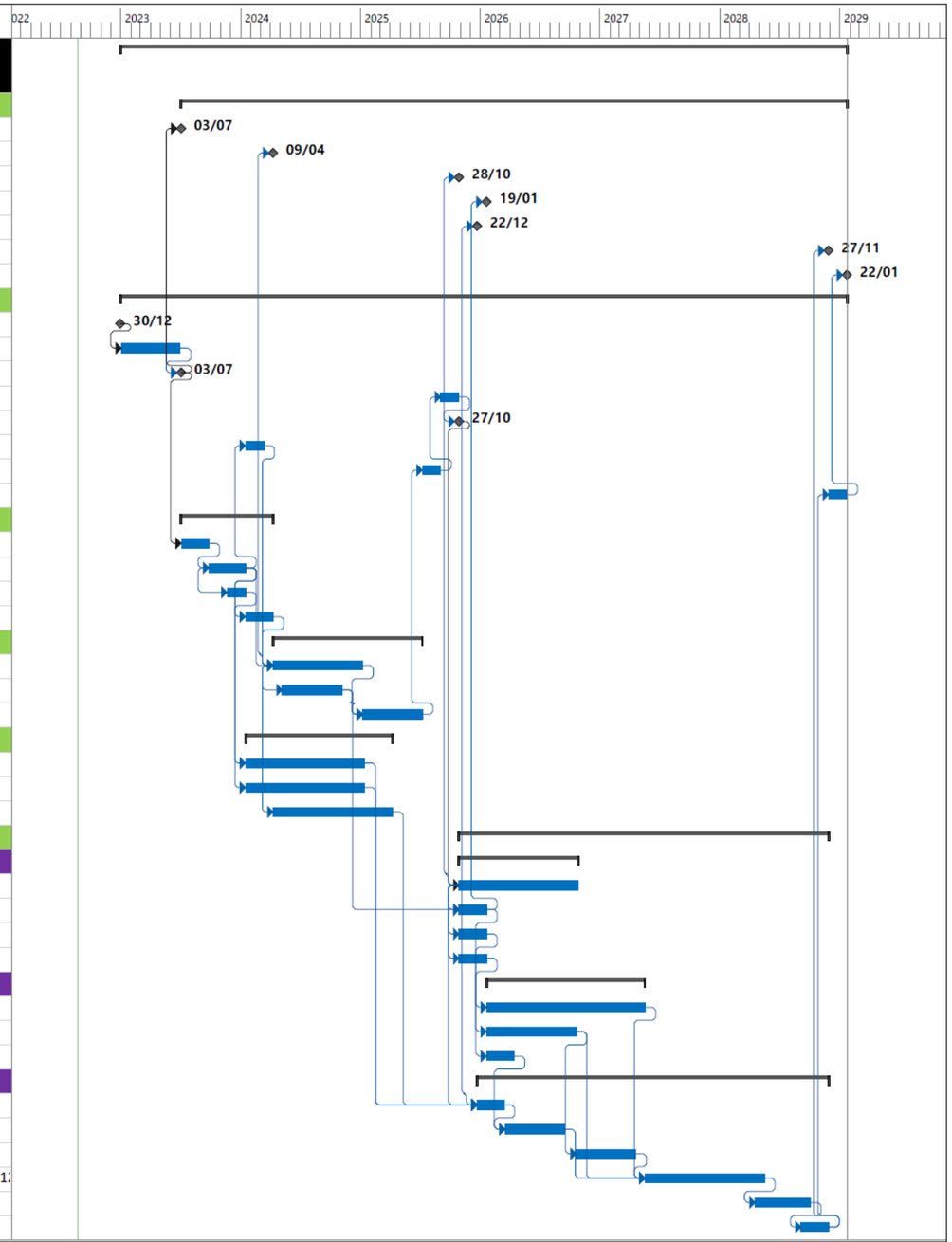
470. During the subsequent FEED phase the selected investment option will be defined to an appropriate level of detail to support the Re-opener to confirm remaining project costs and to allow the EPC phase to be contracted on a lump sum or target price basis.

471. The EPC phase will include development of tender package for the compressor machinery train equipment which will be purchased by NGGT and free issued to the EPC contractor. Site works will commence once detailed design has been sufficiently progressed and three years has been allowed for all site works up to operational acceptance. The selected location for the new unit will allow a significant amount of site works to be conducted in a separate CDM area segregated from the operational site thus reducing the impact on operations. A summer station outage will be required to allow tie-in and commissioning of the new unit.

472. Due to the criticality of King's Lynn Compressor Station, attaining appropriate outages has been identified as a schedule risk. For this reason, an extended window for construction works has been allowed for. Potential optimisation will be reviewed in the FEED stage once the scope has been refined and delivery approach confirmed. A single outage is forecast for new unit tie-in/commissioning which is a reduction compared to options which contain significant asset health investment.

473. After operational acceptance a winter running period has been allowed to operationally prove the new unit prior to the 2030 legislative deadline when any non-compliant units will be removed from service. **Figure 27** shows the preferred option's execution programme plan.

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Option B1 GT Driven Compression Machinery Equipment Located on Redundant Plant Area 1 Plinths**	**316.4 wks**	**Fri 30/12/22**	**Mon 22/01/29**	
2	**Milestones**	**290 wks**	**Mon 03/07/23**	**Mon 22/01/29**	
3	NG Option Selection Complete	0 wks	Mon 03/07/23	Mon 03/07/23	13
4	Commence FEED	0 wks	Tue 09/04/24	Tue 09/04/24	25SS
5	Commence Execute	0 wks	Tue 28/10/25	Tue 28/10/25	34SS
6	Place Oder for Compression Train	0 wks	Mon 19/01/26	Mon 19/01/26	35
7	Site Mobilisation	0 wks	Mon 22/12/25	Mon 22/12/25	43SS
8	Commissioning Complete	0 wks	Mon 27/11/28	Mon 27/11/28	48
9	Project Complete	0 wks	Mon 22/01/29	Mon 22/01/29	18
10	**Ofgem Approvals & National Grid Governance**	**316.4 wks**	**Fri 30/12/22**	**Mon 22/01/29**	
11	Select Study Complete	0 wks	Fri 30/12/22	Fri 30/12/22	
12	Ofgem Re-opener Window #1 Kings Lynn	26 wks	Mon 02/01/23	Fri 30/06/23	11
13	Option Approved	0 wks	Mon 03/07/23	Mon 03/07/23	12FS+1 day
14	Ofgem Re-opener Window #2 Kings Lynn	8 wks	Tue 02/09/25	Mon 27/10/25	17
15	Funding Approved	0 wks	Mon 27/10/25	Mon 27/10/25	14
16	National Grid F3 Sanction (FEED)	8 wks	Tue 16/01/24	Mon 11/03/24	21
17	National Grid F4 Sanction (EPC)	8 wks	Tue 08/07/25	Mon 01/09/25	27
18	National Grid T6 Sanction (Project Completion)	8 wks	Tue 28/11/28	Mon 22/01/29	48
19	**Pre-FEED**	**40 wks**	**Tue 04/07/23**	**Mon 08/04/24**	
20	Pre-FEED Study ITT & Award	12 wks	Tue 04/07/23	Mon 25/09/23	13
21	Pre-FEED Study	16 wks	Tue 26/09/23	Mon 15/01/24	20
22	FEED ITT Package	8 wks	Tue 21/11/23	Mon 15/01/24	21SS+8 wks
23	FEED ITT & Award	12 wks	Tue 16/01/24	Mon 08/04/24	22
24	**Define**	**65 wks**	**Tue 09/04/24**	**Mon 07/07/25**	
25	FEED Study	39 wks	Tue 09/04/24	Mon 06/01/25	23,21,16
26	Vendor Engagement	26 wks	Tue 07/05/24	Mon 04/11/24	25SS+4 wks
27	Execute ITT & Award	26 wks	Tue 07/01/25	Mon 07/07/25	25,26
28	**Consents**	**64 wks**	**Tue 16/01/24**	**Mon 07/04/25**	
29	Environmental Assessment	52 wks	Tue 16/01/24	Mon 13/01/25	21
30	Planing Consents and Approvals	52 wks	Tue 16/01/24	Mon 13/01/25	21
31	Construction Camp Lease Agreement	52 wks	Tue 09/04/24	Mon 07/04/25	25SS
32	**Execute**	**161 wks**	**Tue 28/10/25**	**Mon 27/11/28**	
33	**Engineering**	**52 wks**	**Tue 28/10/25**	**Mon 26/10/26**	
34	Detailed Engineering	52 wks	Tue 28/10/25	Mon 26/10/26	15
35	Compressor Purchase Order Placement	12 wks	Tue 28/10/25	Mon 19/01/26	34SS,26
36	Piping / Instruments / Electical / Structural Bulks Orders Placement	12 wks	Tue 28/10/25	Mon 19/01/26	34SS
37	Civils Bulks Orders Placement	12 wks	Tue 28/10/25	Mon 19/01/26	34SS
38	**Procurement**	**69 wks**	**Tue 20/01/26**	**Mon 17/05/27**	
39	Compression Train and Associated Equipment	69 wks	Tue 20/01/26	Mon 17/05/27	35
40	Piping / Instruments / Electical /Structural Bulks	39 wks	Tue 20/01/26	Mon 19/10/26	36
41	Civils Bulks	12 wks	Tue 20/01/26	Mon 13/04/26	37
42	**Construction**	**153.2 wks**	**Mon 22/12/25**	**Mon 27/11/28**	
43	Site Set-Up & Mobilisation	12 wks	Mon 22/12/25	Fri 13/03/26	29,30,31,34SS
44	Civil Work for New Compressor (Demolition & Construction)	26 wks	Tue 17/03/26	Mon 14/09/26	43,41FS-4 wks
45	Pre-Fabrication of Piping Spools / Structures	26 wks	Tue 20/10/26	Mon 19/04/27	40
46	Install New Compressor	52 wks	Tue 18/05/27	Mon 15/05/28	44,39,45,40FS-1
47	Site Shutdown for Hook-up of New Compressor	24 wks	Tue 18/04/28	Mon 02/10/28	46FS-4 wks
48	Pre-comm and Commissioning of New Compressor	12 wks	Tue 05/09/28	Mon 27/11/28	47FS-4 wks



Project: J25231 NG MCPD King
Date: Wed 24/08/22

Task | Split | Milestone | Summary | Progress

Figure 27 - Project Delivery Programme Final Preferred Option (Option 5)

8.2. Option Risks and Opportunities

474. Key risks and opportunities for all shortlisted options have been reviewed using a semi-quantitative approach. This risk methodology is described fully in the Risk Report & Register contained within **Appendix F**. This section of the FOSR concerns risks & opportunities specific to the Final Preferred Option.

475. For the preferred option much of the value erosion is associated with the risk of capex increase and schedule delay which will therefore be a focus area for onward risk management.

476. The highest rated risks & opportunities associated with the preferred option are identified below. Significant, Minor and Negligible risks are summarised within **Appendix F**.

Key Option Risks & Mitigation

477. There is a critical risk associated with UK specific and worldwide geopolitical issues which has the potential to impact equipment supply and labour rates and availability leading to capex increase and schedule delay. This risk will be a key focus area during development of the delivery strategy and lessons learnt from other similar projects will be applied appropriately.

478. Progression to the next phase of the project relies on agreement between National Grid and Ofgem on the preferred option. There is a critical risk that alignment will not be gained at the end of the 6-month Re-opener window allowed for in the project delivery programme causing schedule delays. To mitigate this risk we have held regular engagement meetings with Ofgem through the option selection phase. The output of these engagement sessions has informed this option selection process described in this submission.

479. The new unit installation requires a plot extension to ensure compliance with the required 39 m separation distance between the new unit and the perimeter fence. This will require permitting and consents which may result in schedule delay. Engagement with local authority and relevant stakeholders will be begin as soon as practicable to mitigate this risk. Plot optimisation will also be conducted in FEED to minimise required additional plot area.

Option Opportunities Identified

480. A conservative approach has been taken to determine the footprint required for new unit options. There is an opportunity to optimise the layout during FEED to reduce the plot extension required.

481. A new fuel gas package has been assumed for new build options. There is an opportunity to modify the existing fuel gas system so that the new unit can be tied in thus removing the requirement for a new system.

8.3. Efficient Cost

482. CBA and BAT assessments are based on ±30% capex estimates developed according to the methodology described in **Section 6.1**. These cost estimates were based on engineering inputs, including material quantities and equipment lists provided by [redacted] the engineering consultant used for the option selection phase. Asset Health costs were based on relevant funding allowances agreed for RIIO-T2.

483. Following confirmation of the Final Preferred Option we will develop the delivery strategy, engineering design and cost estimates through pre-FEED and FEED stages ahead of the cost Re-opener. As part of the development of the preferred option, value engineering and delivery efficiencies will be reviewed including consideration of opportunities identified during the option selection process discussed in the previous section.

484. Cost efficiencies will be incorporated into the updated cost estimates which will form the basis of the funding allowance request to be submitted in our cost Re-opener submission.

485. As noted in the programme for the preferred option described in **Section 8.2**, we plan to defer placement of the purchase order for the compressor machinery train equipment until after the cost Re-opener. This decision is based on lessons learnt from the Hatton LCPD project and improves the capex spend profile by moving the significant cost associated with this equipment later in the delivery programme.

486. An investment decision regarding decommissioning of Avon Unit B at King's Lynn will be taken after operational acceptance and a winter proving period for the new unit to be installed as part of the MCPD scope. This decommissioning investment will be reviewed alongside other similar scope on the wider NTS and will form part of a separate NTS wide decommissioning specific funding request in RIIO-T3. This will allow decommissioning scope to be assessed against the network capability requirements at the time and allow scope to be prioritised and bundled to ensure efficient spend.

8.4. Outputs and Allowances in RIIO-T2

487. In RIIO-T1 NGGT did not have any outputs related to King's Lynn Compressor Station emissions compliance. As detailed in the summary table, **Table 4**, we have spent [redacted] in RIIO-T1, which was to initiate the feasibility study and options selection process as well as the development of our RIIO-T2 business plan submission for MCPD compliance for King's Lynn Compressor Station. For further detail on RIIO-T1 outputs related to emissions compliance, please see **CE-AMP**.

488. In RIIO-T2 NGGT has a Compressor Emissions PCD detailed in Special Condition 3.11 Compressor emissions Re-opener and Price Control Deliverable, Appendix 2. The PCD is to ensure NGGT delivers a Final Options Selection Report, long lead items and a Re-opener submission for King's Lynn Compressor Station. Through pre-application engagement we agreed with Ofgem the most appropriate timing for submission of the Final Option Selection Report is January 2023 to ensure option selection is based upon results from all options under consideration and the Re-opener application window is in April 2025. The received Baseline allowances are [redacted] (excl. RPEs).

489. The PCD follows the GT Project Assessment Process (GTPAP), which is a two-step process whereby we submit the FOSR as part of the first step, and a cost submission once the project has gone through a full FEED for the preferred option and tender process, as a second step. The outcome of the second step (Re-opener submission in April 2025) will be to amend the licence to incorporate the PCD outputs associated with delivery of the Final Preferred Option set by Ofgem's Final Determinations in December 2020.

490. NGGT's Baseline allowance covers development costs and deposits on long-lead items, subject to a true-up during the associated Re-opener (cost submission). Up to December 2022 we have spent [redacted] of our Baseline allowance. We are reporting on spend and progress against our Baseline allowance and PCD as part of our annual RRP.

491. Following Ofgem's review and approval of our Proposed Final Preferred Option for King's Lynn Compressor Station MCPD compliance, we will continue working to develop our preferred option further in readiness for our Re-opener submission in April 2025 at which date we will propose a revised PCD to be included in the Gas Transporter Licence to reflect the delivery of our preferred option as detailed in **Section 8**.

9. Conclusions and Next Steps

492. This FOSR has detailed the Needs Case for parallel compressor operation at King's Lynn to maintain the UK's Security of Supply, meet our customers' needs and minimise network constraints. Investment is required to ensure the site is MCPD complaint by the 2030 deadline, while having sufficient availability and reliability to accommodate a wide range of forecasted flows.

493. To maintain parallel operation at the site, during periods of planned and unplanned outages, the third unit requires a high level of availability and reliability. Multiple assessments have been completed to determine the Final Preferred Option, including considerations for emissions compliance, BAT assessment, cost benefit analysis, impact to Security of Supply, case study assessment, technology maturity and capital investment assessment as detailed in **Section 7**.

494. To achieve MCPD legislative compliance and the required resilience levels at King's Lynn Compressor Station, NGGT's Final Preferred Option is to install one new compressor at King's Lynn by 2030, re-wheeling of the MCPD compliant Units C and D, and decommissioning of the non-MCPD compliant Avons, Unit A & B. This has an associated cost of [redacted], to be funded through the Re-opener following submission in April 2025. Funding to decommission Unit B will not be included within the Re-opener funding request, with actual decommissioning being re-assessed after operational acceptance of the new unit. The total project cost includes the already received Baseline funding of [redacted] (excl. Real Price Effects (RPEs)).

495. Following Ofgem's decision on the Final Preferred Option, NGGT will use the remaining baseline allowances confirmed in 2020 to develop our preferred option up to the cost Re-opener currently forecast for April 2025. We intend to initiate a pre-FEED stage immediately following preferred option confirmation where the delivery strategy will be confirmed, and tender documentation produced for the FEED stage. During the subsequent FEED phase, the selected investment option will be refined to support the cost Re-opener and confirmation of remaining project cost. The EPC phase will include development of tender package for the compressor machinery train equipment. Site works will commence once detailed design has been sufficiently progressed which allows for a maximum of three years for all site works up to operational acceptance. After operational acceptance in 2028, a winter running period is provided for the new unit prior to the 2030 legislative deadline when Unit B will be restricted to a maximum of 500-hours operation per year.

10.Appendices

- Appendix A – CBA
- Appendix B – Site Availability Model
- Appendix C – Engineering Report and Appendices
- Appendix D – Asset Health Requirements
- Appendix E – Project Programmes and Report
- Appendix F – Project Risk Register and Report
- Appendix G – Preliminary BAT Report Summary
- Appendix H – [redacted] SCR Technical Feasibility Study
- Appendix I – Assurance Letter
- Appendix J – Mapping of Ofgem Requirements
- Appendix K – FOSR Databook

Glossary	
1-in-20	The 1-in-20 peak day demand is the level of demand that, in a long series of winters, with connected load held at the levels appropriate to the winter in question, would be exceeded in one out of 20 winters, with each winter counted only once.
AGI	**Above Ground Installation:** Above ground gas assets (including, but not limited to; pipework, valves, pigtraps, meters and regulators) located within a fence line for the safe operation and maintenance of the National Transmission System
ASEP	**Aggregated System Entry Point:** A system entry point where there is more than one, or adjacent connected delivery facility; the term is of the used to refer to gas supply terminals.
Avon	Rolls Royce (Siemens) gas turbine engine which forms part of the compressor machinery train and is subject to MCPD.
Barg	Bar gauge is the pressure gauge reading.
BAT Reference Documents (BRef)	A series of reference documents covering, as far as is practicable, the industrial activities listed in Annex 1 of the EU's IPPC Directive. They provide descriptions of a range of industrial processes and their respective operating conditions and emission rates. EU Member States are required to take these documents into account when determining best available techniques generally or in specific cases under the Directive.
BAT	**Best Available Technique:** The most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent (and where that is not practicable), to reduce emissions and the impact on the environment as a whole.
Brownfield	Construction within the existing site perimeter fence.
Buyback	National Grid may request to buyback Firm capacity rights to manage a constraint on the NTS after any Interruptible/Off-peak capacity has been scaled back.
Capability	The physical limit of the NTS to flow a volume of gas under a given set of conditions; this may be higher or lower than the capacity rights at a given exit or entry point.
Carbon Dioxide (CO_2)	A naturally occurring chemical compound composed of two oxygen atoms and a single carbon atom. If there is not enough oxygen to produce CO_2 during combustion, carbon monoxide (CO) is formed.
Carbon Monoxide (CO)	A colourless, odourless and tasteless gas produced from the partial oxidation of carbon-containing compounds. It forms when there is not enough oxygen to produce carbon dioxide (CO_2), such as when operating an internal combustion engine in an enclosed space.

Glossary	
CE-AMP	Compressor Emission Asset Management Plan
Compressor Unit	Equipment used to compress gas to high pressure for transport through the NTS. Each compressor station consists of one or more compressor units as well supporting equipment such as meters, filters, valves and pipework. Compressor units can be driven by gas turbines or electric drives.
CSRP	**Control System Restricted Performance:** Technology that restricts the performance of a gas-driven compressor to limit NO_x emissions.
CBA	**Cost Benefit Analysis:** A mathematical decision support tool to quantify the relative benefits of each site option.
Counterfactual	The counterfactual option represents current network with minimum interventions to comply with emissions legislation.
DLE	**Dry Low Emissions:** An Avon DLE retrofit modifies the combustion system within the Avon engine so that air and fuel are premixed before combustion. This reduces the peak combustion temperature, which in turn reduces the amount of NO_x produced
DN	**Gas Distribution Network:** An administrative unit responsible for the operation and maintenance of the local transmission system and <7barg distribution networks within a defined geographical boundary.
EUD	**Emergency Use Derogation:** Compressor unit derogated under the MCPD limited to run 500-hours per year on a rolling 5-year average, with a maximum limit of 750-hours in any one year. This removes the use of the compressor from standard operation, where they can only be run to prevent commercial constraints (Essential Use) or exit constraints (Emergency Use) on the network
Emission Limit Values (ELV)	Limits set for industrial installations by the LCP directive and IPPC under the umbrella of the IED and MCPD.
Emission Abatement	Includes technology that reduces the emissions from a gas-driven compressor.
Entry Capacity	Holdings give NTS users the right to bring gas onto the NTS on any day of the gas year. Capacity rights can be procured in the long term or through shorter term processes, up to the gas day itself. Each NTS Entry point has an allocated Baseline which represents a level of Capacity that National Grid is obligated to make available for delivery against on every day of the year.
EA	**Environment Agency:** A non-departmental public body, sponsored by DEFRA, with responsibilities relating to the protection and enhancement of the environment in England.

Glossary	
Exit Capacity	Holdings give NTS users the right to take gas off the NTS on any day of the gas year. Capacity rights can be procured in the long term or through shorter term processes, up to the gas day itself. Each NTS Exit point has an allocated Baseline which represents a level of Capacity that National Grid is obligated to make available for offtake on every day of the year.
FOSR	Final Option Selection Report
FEED	**Front End Engineering Design:** The FEED is basic engineering which comes before the detailed design stage. The FEED design process focusses on the technical requirements as well as an approximate budget investment cost for the project.
FES	**Future Energy Scenarios:** An annual industry-wide consultation process encompassing questionnaires, workshops, meetings and seminars to seek feedback on latest scenarios and shape future scenario work. The Future Energy Scenarios document is produced annually by National Grid ESO and contains their latest scenarios.
Greenfield	Construction on land that is outside of the existing perimeter site boundary, where there is no need to demolish or rebuild any existing structures.
GVA	**Gross Value Added:** The measure of the value of goods and services produced in an area, industry or sector of an economy.
IED	**Industrial Emissions Directive:** An EU directive that came into force in January 2011.
Intrusive Outage	Significant outage works impacting the whole station and where the station cannot be returned to service until the scheduled works are completed.
LCPD	**Large Combustion Plant Directive:** An EU directive to reduce emissions from combustion plants with a thermal output of 50 MW or more. Combustion plant must meet the emission limit values (ELVs) given in the LCP directive for NO_x, CO, SO_2, and particles.
LNG	**Liquefied Natural Gas:** Natural gas that has been cooled to a liquid state (around -162^{o}C) and either stored and/or transported in this liquid form.
MCPD	**Medium Combustion Plant Directive:** A directive to reduce emissions from combustion plants with a net thermal input between 1-50 MW.
MTO	Material Take Offs
MWC	Main Works Contractor
NTS	**National Transmission System:** The high-pressure system consisting of terminals, compressor stations, pipeline systems and offtakes. Designed to operate at pressures up to 85 barg. NTS pipelines transport gas from terminals to NTS offtakes.

Glossary	
NPV	**Net Present Value:** NPV is the discounted sum of future cash flows, whether positive or negative, minus any initial investment.
NDP	**Network Development Process:** The process by which National Grid identifies and implements physical investment on the NTS.
NGGT	National Grid Gas Transmission
Nitrogen Oxide (NO_x)	Oxides of nitrogen which are a by-product of combustion of substances in the air, such as gas turbine compressors.
Ofgem	**Office of Gas and Electricity Markets:** The regulatory agency responsible for regulating Great Britain's gas and electricity markets.
Operating Envelope	All NTS compressors have been designed to operate within a certain range of parameters, namely maximum and minimum gas flow rates and maximum and minimum engine speeds. The limits of these ranges define the performance of a compressor and are referred to as the operating envelope.
Operationally Proven	A unit is operationally proven when it can be shown to be operating reliably and post commissioning / early life issues have been resolved.
PARCA	Planning and Advanced Reservation of Capacity Agreement
Plant	In the context of the Limited Lifetime Derogation, plant refers to an individual compressor unit.
Proximity Outage	Significant works on a site for which safety precautions must be put in place which make the station unavailable, but the station is capable of being returned to service in a few hours if required as the works taking place are not intrusive to the operation of the station.
RB211	A Rolls Royce (Siemens) gas turbine engine which forms part of the compressor machinery unit and is subject to LCPD.
Re-opener	Re-openers are a type of RIIO Uncertainty Mechanism. Depending on their design, they allow Ofgem to adjust a licensee's allowances (in some cases up and in some cases down), outputs and delivery dates in response to changing circumstances during the price control period.
Replacement	Installing a new unit to replace the capability provided; this may not be a like-for-like replacement.
RIIO	**Revenue = Incentives + Innovation + Outputs:** RIIO-T2 is the second transmission price control review to reflect the framework; it sets out what the transmission network companies are expected to deliver and details of the regulatory framework that supports both effective and efficient delivery for energy consumers.
RPE	Real Price Effects
RRP	**Regulatory Reporting Pack:** Annual submission to Ofgem on 31 July as per RIIO-T2 reporting requirements Standard Special Condition A40: Regulatory Instructions and Guidance

Glossary	
SEPA	**Scottish Environment Protection Agency:** Scotland's environmental regulator and flood warning authority.
Selective Catalytic Reduction (SCR)	A means of converting nitrogen oxides (NO_x) with the aid of a catalyst into diatomic nitrogen, N_2, and water, H_2O. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is adsorbed onto a catalyst. Carbon dioxide (CO_2) is a reaction product when urea is used as the reductant.
UAP	Unallocated Provision
Uncertainty Mechanism	Uncertainty Mechanisms exist to allow price control arrangements to respond to change. They protect both end consumers and licencees from unforecastable risk or changes in circumstances.
Unit Outage	Significant outage works impacting one or more compressor units on a compressor station, the unit cannot be returned to service until the scheduled unit works are completed, however, the station can still operate with other available units.
United Kingdom Continental Shelf (UKCS)	The region of waters surrounding the United Kingdom, in which the country claims mineral rights.