national gas transmission

King's Lynn Compressor Station Re-wheel Need Case

6 June 2024

Contents

1. Executive Summary

1. King's Lynn compressor station 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. More recent volatility in global supply patterns only serve to showcase the importance of King's Lynn.

2. King's Lynn compressor station has two emissions compliant Siemens (formerly Rolls-Royce) SGT-400s, units C and D, and two Avon units, units A and B, which fall within the Medium Combustion Plant Directive (MCPD) legislation and can breach the NOx limits imposed. Unit A was disconnected in 2017 after becoming life expired and beyond economical to continue investing in for current and future requirements.

3. The Final Preferred Option approved by Ofgem in November 2023 to comply with MCPD by 2030 is the counterfactual 'do nothing' option, with the existing non compliant Avon unit B to be retained under the 500-hour Emergency Use Derogation (EUD) allowed for in the Directive, with significant asset health investment to improve unit availability. The Final Preferred Option also includes the decommissioning of unit A. To ensure operational mapping alignment across all site compressors, Ofgem stated in its direction to consider the case for a re-wheel of the existing SGT-400s during this phase of the project review.

4. This report is to provide Ofgem with the Needs Case for the compressor re-wheels of units C and D to enable NGT to apply for funding to deliver the works as part of the King's Lynn MCPD re-opener which is due for submission to Ofgem in April 2025.

5. In summary the re-wheel will enable the two compliant units to operate in single unit running across the full range of station flows, which will improve site resilience as well as efficient operation across the full operating range. Following the re-wheel unit B will only be required to provide back-up to units C and D. This will be increasingly important from 2030 when the non-compliant Avon unit will only be available for an average of 500-hour per year[1]. There will be a continued need for the Avon unit to provide back-up to the two lead SGT400 units, especially at flows above 50 mscm/d when parallel operation is required. The site will be configured to allow any two from three of the units to operate in parallel.

6. The need case assessment demonstrates the following benefits from completing the re-wheels:

   I. Resilience:

      - The re-wheels will enable units C and D to cover the full operating range required by King's Lynn Compressor Station. Including low head running that can currently only be met with the use of unit B.

[1] Under the MCPD non-compliant units can be restricted to 500-hours over a five-year rolling average with a maximum of 750-hours per individual year under EUD, this can be classed as Essential or Emergency Use for our operating strategies. This removes the use of the compressors for standard operation, where they can only be run to prevent commercial constraints (Essential Use) or exit constraints (Emergency Use) on the network. This derogation currently has no end date.

- The re-wheeled units will each be able to support flows of up to 50 mscm/d, improving single unit compressor resilience at flows above the current 42 mscm/d limit by 9%, providing increased support for export and entry flows at Bacton.

- Unit B will only be required for back-up to the compliant units with run hours reduced by 44%[2]. Reducing the risk of the unit breaching the 500-hour derogation, which it would have exceeded in 2022 and 2023.

II. Emissions:

- [redacted]

- [redacted]

- [redacted]

7. The costs of delivery of the re-wheels is based on the Original Equipment Manufacturer (OEM), Siemens Energy, derived through preliminary engineering at this stage. [redacted] The delivery programme and further cost confidence will be provided as part of the re-opener submission to an accuracy of +/-15% following detailed design/engineering.

8. NGT is requesting approval of the need case, which will allow us to include the funding request as part of the MCPD re-opener submission in April 2025. Following Ofgem's approval of the need case, we are aiming to secure long lead items production slot for 2024 ready for the first unit re-wheel to be completed in summer 2025. This is the most effective delivery programme completing both re-wheels ahead of the planned asset heath works on unit B in 2027. Missing the production slot would delay the re-wheel and asset health programme by 12 months. This would delay all the benefits detailed above by one year and reduce the NPV of the project.

[2] This is based on predicted run hours under the 2023 Future Energy Scenario 'Falling Short'.

2. Problem Statement

2.1 Current Site Overview and Operation

9. King's Lynn compressor station has four compressor units. There are two Siemens (formerly Rolls-Royce) SGT-400s, units C and D, and these are MCPD emissions compliant and also two Avon compressors, units A and B, which are MCPD non-compliant and can breach the NOx limits imposed. Unit A was disconnected in 2017 after becoming life expired and beyond economical to continue investing in for current and future requirements. For unit B Ofgem have approved a final preferred option to comply with MCPD by 2030 following NGT's submission of the Final Options Selection Report (FOSR) in January 2023, under which we will run the unit up to 500-hour EUD. See figure 1 for the site layout.

10. The three operational units at King's Lynn can run in multiple configurations. Current compressor operating ranges has seen higher operational hours on unit B than units C and D throughout 2022 and 2023. This resulted in the hours on unit B being above the future 500-hour EUD limit.

11. In this period the NTS experienced high Bacton exports and high Isle of Grain imports. This resulted in station flows above the flow limit on a single SGT400 of 42 mscm/d, and above the minimum speed line of two SGT400's in parallel. Resulting in conditions where unit B took primary duty as unit C and D compressor wheels aren't appropriately mapped to those flow conditions. Unit B required significant support to keep it operational during this period where there are high cost repairs due to the Power Turbine which has exceeded its effective life. Re-wheeling units C and D would align the operational envelopes to more expected flow ranges and patterns going forward, enabling them to take primary duty in single unit operation. Current operational limits are further detailed in the next sections.

Figure 1 – King's Lynn Compressor Station Overview

2.2 Problem Statement

12. As part of the option selection phase of the MCPD FOSR for King's Lynn, a process study was undertaken which identified limitations with the current SGT-400 units (unit C and D) against the 2022 Process Duty Specification (PDS) points. [redacted] As a result the FOSR submission included a recommendation to re-wheel units C and D. With the preferred option of a new unit rejected by Ofgem the re-wheel will help to minimise run hours for unit B to within the 500-hour EUD.

13. Since the FOSR submission in 2023, the PDS was updated and figure 2 below shows the latest historic duty including the years of operation 2022 and 2023 (in green). The PDS points are superimposed, shown in red. The PDS gives the full operating range of the station to support exports and imports from the Bacton terminal.

14. PDS points are historic and expected operating regions represented as head and the flow combinations; where head is the pressure increase provided by the compressor and flow is the flow through the compressor station. These PDS points can be shown alongside the compressor envelope to create a PDS map which provides visual evidence to aid understanding and presentation of the compressor's operation. The compressor envelope is the optimised operating region, where operating outside of the envelope is inefficient or unstable. These PDS maps show how the compressor is performing and can be used in conjunction with a performance map to demonstrate that a suitable re-wheel should be considered to meet the performance requirements of a unit in the most cost effective/efficient way.

Figure 2: Historic Duty 2014 to 2023 with PDS Points C1-C9 superimposed

15. Figure 3 shows the current unit envelopes overlayed with the updated PDS points. The area shaded in red is outside of the compressor map for units C and D. Only unit B can currently cover operation in this area. If unit C or D was used for this point it would lead to the compressor being heavily in choke (blue dotted line). Choke is an unstable operating condition that can damage the compressor affecting its operability.

Figure 3: King's Lynn Unit C and Unit D Compressor single and parallel operating envelopes as well as backup Unit B against Process Duty Specification (PDS) Points

16. Details of the PDS inlet temperature, station flow, inlet and outlet pressure are given in Table 1. Table 2 details the high level details of when the units are required to operate in this area. Table 2 shows that after the re-wheel C2 and C4 can be supported by a single SGT400. C3 can also be met with a single SGT400 on some occasions. This will depend on the available turbine power, which is impacted by the inlet temperature. The higher the inlet temperature the lower the power capability.

Duty	Date Stamp	Inlet Pressure (Barg)	Outlet Pressure (Barg)	Station Flow (MSCM/D)	Inlet Temp. (Deg C)
[redacted]					

Table 1– Kings Lynn PDS points (updated July 2023)

Duty	Date Stamp	Narrative	Feasibility to operate with single SGT400 today	Feasibility to operate with single SGT400 after re-wheel
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 2 – PDS points narrative

**following an asset failure at nether Kellet the max flow range of the SGT400's has been reduced to 42 mscm/d to prevent a similar failure*

***depending on actual available turbine power*

17. From 2030 unit B will be restricted to 500 hours (on a rolling 5 year average with a maximum 750 hours permitted in a single year) and so would not be available when expected running hours are high post 2030. With current wheel configuration, units C and D cannot currently run within the designed envelope, and so would not be an option for the C4 duty point.

18. A re-wheel will result in more single unit running which is more efficient in terms of emissions. The re-wheel option also provides more options for back-up units, when taking running hours into account. For duty point C4, if there is no re-wheel, there is no back-up option (due to potential back-up unit out of envelope), which may result in constraints on the network and associated costs.

2.3 King's Lynn Compressor Review and Technical Proposal from Siemens

19. In September 2023 NGT approached the compressor OEM Siemens for units C and D, to undertake a preliminary feasibility review of the compressor re-wheel proposal against the latest PDS from 2023 as detailed above. Siemens provided a proposed re-wheel compressor envelope for NGT consideration.

20. The MCPD project team have had several engagements with Siemens to review the suitability of the current compressor performance against the latest PDS. [redacted]

21. The proposed compressor performance map for the re-wheel is shown below in Figure 4, which will enable the SGT400 units to meet all process duty points including C4. Note that reference to 'Half' in the naming of the points indicates where parallel running of units C and D would be required, with half duty being taken by each unit.

22. The compressor re-wheel proposal is designed around the most constraining operating points including C4 and points such as C1-B-Half, C9-B-Half and C3 being possible. The proposal will reduce the

operating margin for the outlying points C1 and C9 (high unit speed, high lift), but they can be met. The benefit of the proposal compressor re-wheel is that all operating points can be achieved by the SGT400 units, reducing reliance on unit B which will be placed on EUD from 2030. A much higher proportion of the run hours will be met by single SGT400 running.

Figure 4: Proposed Compressor Performance Map from Siemens for Units C and D at King's Lynn (preliminary and subject to detailed engineering).

23. To comply with MCPD by 2030, unit B will have a 500-hour EUD limit applied. The operating region for unit B contains the PDS point C4, which the current C and D units cannot safely meet. Re-wheeling units C and D will allow these units to meet this C4 PDS point, giving additional resilience as this point would no longer be solely covered by a unit on a 500-hours EUD. The re-wheel also allows for greater single unit operation, as some of operating regions requiring parallel running could now be met with a single unit. This would result in lower emissions, reduced run hours and higher resilience.

3. Future Requirements

3.1 Supply and Demand Scenario Discussion and Selection

24. There are two drivers for compression to operate at Kings Lynn. High supplies in the South East at Bacton and the Isle of Grain, and exports to Europe through the two interconnectors. The latest 2023 Future Energy Scenario (FES) Falling short has been used to make this assessment. This scenario was selected as it provides the worst-case demand forecast. The scenario includes progress on decarbonisation compared to today, however it is slower than in the other scenarios. As a prudent operator, we believe the system should be planned for the most appropriate supply and demand future scenario to ensure we remain compliant with our licence. The supply forecasts used is the High LNG scenario reduces the supply from the two EU interconnectors to a minimum in favour of imports via the two LNG terminals (Milford Haven and Isle of Grain). Historically both High Continental and High LNG scenarios have been considered equally likely. However, post the Russia/Ukraine war priority is given to the High LNG sensitivity with significant imports from Europe considered unlikely.

Supply

25. The gas supply landscape has changed considerably in the last 20 years. With the continued decline of UK Continental Shelf (UKCS) supplies and the need to decarbonise NGT expects gas supply patterns to continue to change and become more volatile going forwards. This includes a greater dependence on imports, Figure 5 shows the increase in imports in the Falling Short (FS) scenario.

26. 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 from continental Europe at Bacton. To ensure these import routes are not restricted under the appropriate range of supply conditions reliable and unrestricted compression at King's Lynn is critical.

27. As the UK becomes more import dependent, it is critical that the entry capability and resilience is at the required level to ensure UK and South-East Security of Supply.

28. There are limitations to the FES's supply data, with no consideration of sudden changes in market trends or geo-political events that result in significant global supply pattern changes. It is therefore important that a full range of scenarios are considered and the appropriate level of capability and resilience for either high levels of entry or exports is maintained.

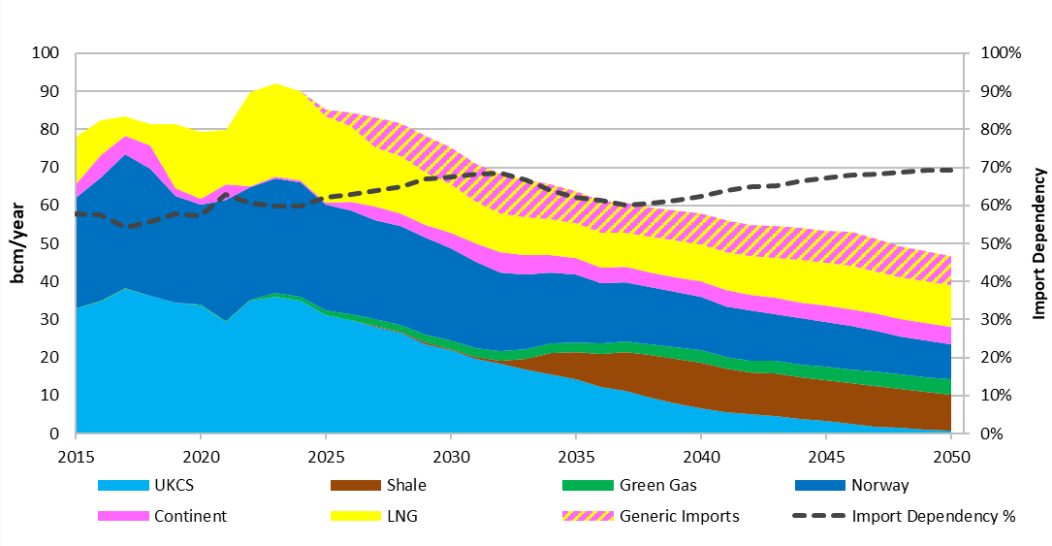

Figure 5 – Falling Short: FES 2023 Annual Gas Supply and Import Dependency

Demand

29. [redacted].

30. Figure 6 shows the forecast reduction to 2050 in IUK and BBL exports in the 2023 FS Scenario. This forecast has been used to estimate the future run hours for compression at Kings Lynn. The changes seen following the Russia/Ukraine war are now reflected in the forecast export levels, but there remains uncertainty on the magnitude and longevity of those flows. The current forecast has exports reducing below the historic average by the end of RIIO-GT3. If this did not occur the benefit of completing the re-wheels would increase from the positive level already seen in the CBA.

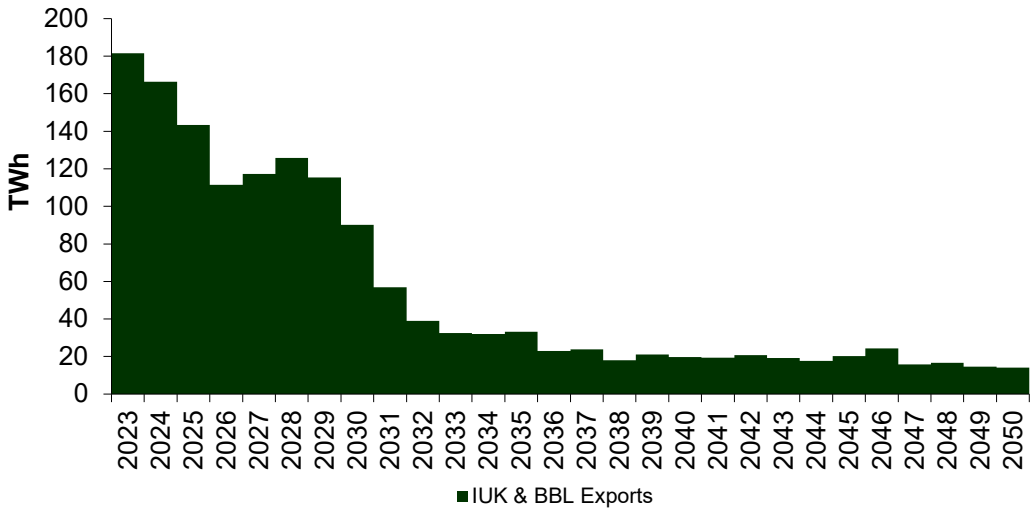

Figure 6 – IUK & BBL Export – 2023 FES Falling Short

3.2 Site Operations

31. Utilisation of the compressors at King's Lynn is directly linked to import and export at Bacton. King's Lynn compression is used to flow gas towards Bacton during high exports to Europe through the interconnectors, and to transport gas away from Bacton/SE when imports from Europe/LNG are high. King's Lynn's two SGT-400s currently operate in parallel to meet high flow requirements. The use of Kings Lynn compression is the only option available in order to achieve high exports through the Bacton interconnectors to Europe.

32. The current flow limit of 42mscm/d on the SGT400 units in single operation results in the need for parallel operation most of the time, with 80% of flows through the station above this level in 2022 and 2023.

33. Figure 7 shows how since 2021 we have seen a change in the operating behaviour of the interconnectors. Prior to this time they only exported to Europe during April to September, we are now seeing exports throughout the winter.

Figure 7 - Exports by Fiscal Month

34. Figure 8 shows the network exit capability with and without compression at Kings Lynn[3]. The orange Network Capability line is with King's Lynn compression and the purple High Resilience line is without King's Lynn compression. The use of King's Lynn increases East Midlands zone (which encompasses the interconnector export flow) exit capability significantly.

35. The capability line is based on the worst case supply scenario for the zone with supplies at the Isle of Grain and Bacton UKCS reduced to minimum levels. If supplies at those terminals are higher there is less need to move gas into the area and the capability is increased.

36. The capability is strongly linked to the National Demand level, level of UKCS supply at Bacton, and the level of supply from Isle of Grain. As national demand increases the overall export capability decreases. High supplies from Bacton UKCS would see the capability increase, low supplies would see the capability decrease. Similar with the Isle of Grain, high supplies increase the capability, but they do

[3] For details of capability charts refer to National Gas Ancar Publication Network Capability | National Gas

reduce the allowable head across the units, forcing operation into the C4 area of the PDS which can currently only be covered by unit B.

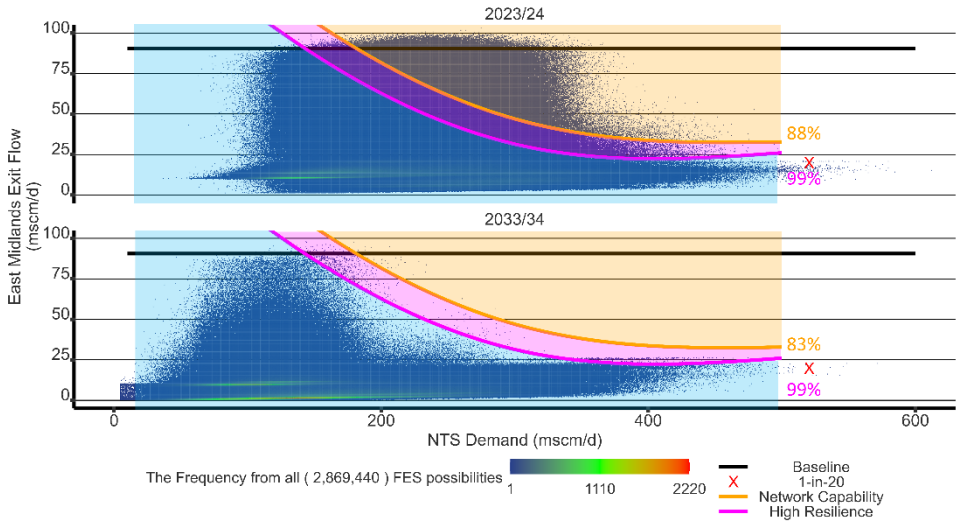

Figure 8 - East Midlands Exit Capability for 2023/24 and 2033/34

37. Figure 8 does show a decline in the expected exports over the next 10 years, with the blue dots moving back to low demand levels, as predicted in Figure 6 in the demand section. However, this is uncertain with the potential for the export flows to continue for longer depending on EU needs. This assessment has been based on the reduction predicted in FES only.

3.3 Compressor Utilisation

38. The annual (calendar year) running hours of the three operational units are shown in Table 3. Changes in the level of run hours are due to changing supply and demand levels at Bacton.

[redacted]

Table 3 – Units B, C, D Calendar Year Run Hours

39. Running hours in 2017, 2018 and 2021 were associated with higher UKCS supplies, leading to a need for higher compression to move gas away from Bacton. Isle of Grain supplies were low during these periods, if this supply from Isle of Grain had been higher, the need for King's Lynn would have been greater.

40. Running hours in 2022 and 2023 are due to the high levels of exports to Europe requiring compression to support the export pressures at the Bacton terminal. [redacted].

41. 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 (and therefore running hours) on unit B.

42. Table 4 shows the forecast run hours based on the predicted exports within the 2023 FES Falling Short. The estimate does not take account of expected reductions in UKCS supplies, which increases the required flow through the station with a subsequent increase in parallel operation required.

Table 4 – Predicted Compressor Run Hours Without Re-wheel

43. Table 5 shows the forecast run hours following the re-wheels. The flow limit could potentially increase up to 55 mscm/d, further reducing the level of parallel running; the 50 mscm/d value has been used in calculations to ensure the reduction isn't over estimated.

Table 5 – Predicted Compressor Run Hours With Re-wheel

44. With more single unit running compared to the current unit configuration, the re-wheel of units C and D would also have the benefit of increasing network resilience, with more options for back-up units being available, depending on specific flow conditions. Network resilience is impacted by the availability of candidate compressor units when they are required. Individual units are not available 100% of the time, requiring back-up units to be available to cover any short-fall. Increasing the available flow range of units C and D will improve options for unit selection, giving an improvement in overall resilience and therefore energy security.

45. Table 6 below shows how compressor unit resilience would be impacted. Currently units C and D have a maximum flow rate capability of 42mscm/d. Over 80% of flows in 2022 and 2023 were above this level, with only 34% over 50 mscm/d. The re-wheel would therefore see a 9% increase in resilience for 46% of the operating points in those years.

Table 6 - Estimated Resilience By Flow Range (mscm/d) Before and Post Re-wheel

4. Business Case

4.1 Options Considered

46. To assess the need case for Ofgem approval, the following options have been considered:

- Counterfactual – undertake only the approved asset health on the units.
- Option 1 – Counterfactual plus the re-wheel of units C and D, one unit in 2025 and the second unit in 2026.

47. Option 1, NGT's preferred option, has the below benefits:

- Reduction in emissions and increased efficiency, giving a positive net present value estimated between [redacted]
- Increased resilience – All duty points can now be met with appropriate back-up and there is a 9% increase in resilience for flows up to 50 mscm/d.
- Resilience - Unit B will only be used for back-up with a [redacted] hours.
- Resilience – A [redacted] the need for parallel operation.
- Reduced risk of incurring entry or exit constraint costs due to reduced risk of network constraints
- Delivery of greater certainty meeting import and export flow requirements in accordance with customer requirements

4.2 Options Cost Estimate Details

48. Siemens Energy, OEM for the compressors, were awarded a framework contract for both maintenance and machinery train equipment. The framework was competitively negotiated to ensure value to the consumer.

49. [redacted] in the next stage of project development (detailed design), scope will be better defined. Following detailed design, Siemens will firm up scope and cost and this will inform part of our King's Lynn re-opener submission due in April 2025, with a cost confidence of +/-15%.

51. As part of project development through the next stage, NGT will seek opportunities for efficiencies in delivery, considerations will include:

- Value Engineering of replacement/wear parts.
- Bundling of other works in construction phase (NGT project delivery team potentially delivering multiple schemes concurrently at King's Lynn compressor station).

4.3 Cost Benefit Analysis Results

52. A CBA was conducted on option 1, re-wheel of units C and D against a counterfactual of "do nothing" over a time horizon from 2026 to 2050. Asset health investment is consistent for both options so not included in this assessment. Measuring against a NPV that accounts for the difference between baseline risk, outcome risk, and option cost provides an evaluation of this investment's benefit.

53. The re-wheel option for King's Lynn units C and D allows for operational changes that can result in a reduction range of run hours on unit B and the site overall due to the decreased need to operate the site in parallel mode, resulting in a cost of carbon emissions reduction. After investment, between 2026 to 2050, analysis indicates a reduction range in carbon emissions equivalent to 37 to 52 kilotonnes CO2e. This analysis valued this cumulative carbon reduction between [redacted]

54. With a positive net present value between [redacted] this option is cost beneficial from cost of carbon emission savings alone. As can be seen in Figure 9 the NPV goes positive between the end of 2026 and 2027 based on the range of forecast reduction in run hours following the re-wheels.

55. This CBA was conducted against the BEIS reference price.

Figure 9 – Cummulative Value of the Compressor Re-wheel

5. Conclusion and Next Steps

56. The current operating range of units C and D are unable to meet the full range of historic and anticipated future operating points driven by customer and network requirements. The flow limit on the units drives the current need for parallel operation of the units. Both of these issues result in higher levels of utilisation of unit B. This unit is non-compliant with the MCPD emission legislation and will need to be derogated from 2030 thus limiting the ability to meet the expected back-up requirements at this key site.

57. Following the re-wheels units C and D will be able to fully meet the operating range required. The overall site run hours will reduce by 54%, the use of unit B will become as back-up to the lead units with run hours reducing by 44%. The resilience will improve for flows up to 50 mscm/d with only one out of three units required to operate. [redacted]

58. Based on the carbon savings alone, and the proposed work programme, the investment has a positive NPV before the end of 2026.

59. NGT is therefore requesting approval of this need case, which will allow NGT to include the funding request as part of the MCPD re-opener submission in April 2025. Following Ofgem's approval of the need case, we are aiming to secure long lead items production slot for 2024 ready for the first unit re-wheel to be completed in summer 2025. This is the most effective delivery programme completing both re-wheels ahead of the planned asset heath works on unit B in 2027. Missing the production slot would delay the re-wheel and asset health programme by 12 months. This would delay all the benefits detailed above by one year and reduce the NPV of the project.


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