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REPORT

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King's Lynn Compressor Station Risk Workshop Report

Prepared for: National Grid PLC

Prepared by: [redacted]

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ABBREVIATIONS

CAPEX	Capital Expenditure
C&I	Control and Instrumentation
CSRP	Control System Restricted Performance
DLE	Dry Low Emissions
HV	High Voltage
GT	Gas Turbine
MCPD	Medium Combustion Plant Directive
MM	Million
NTS	National Transmission System
OPEX	Operating Expenditure
RIIO	Revenue=Incentives+Innovation+Outputs
RR	Rolls-Royce
SCR	Selective Catalytic Reduction
UKPN	UK Power Networks
VSD	Variable Speed Drive

HOLDS LIST

HOLD	SECTION	DESCRIPTION

1.0 EXECUTIVE SUMMARY

The King's Lynn Compressor Station Risk Workshop was held on Thursday 26th May 2022 at National Grid's offices in Warwick. The purpose of this report is to document the details, methodology, results and outcome of the King's Lynn Compressor Station Risk Workshop.

At the concept design stage, a semi-quantitative method was employed, which provides a risk-adjusted expected value of the project and the key uncertainties associated with the development options. The process aims to achieve the following:

- Coherently identify and address key uncertainties present in the current design/project plan across the scope of the proposed modifications and project boundaries;
- Assess and quantify the risk for each of the options;
- Ascertain a view on **key project risks** that require active onwards risk management;
- Identify the spread of risk across different project parameters (e.g., CAPEX, OPEX, schedule, availability) and where significant degrees of risk manifest;
- Identify any key risks which may justify modification of the options or immediate design changes to mitigate.

The technical options considered during the Risk Workshop were as follows:

New Build (Replacement of RR Avon) Options:

a) New Gas Turbine (GT) Driven Compressor (single and or dual units);

b) New Electric Variable Speed Drive (VSD) Compressor (single and or dual units).

RR Avon Retrofit Options:

a) Upgrade the combustion system on the existing RR Avon to a dry low emissions (DLE) system;

b) Use of Control System Restricted Performance (CSRP);

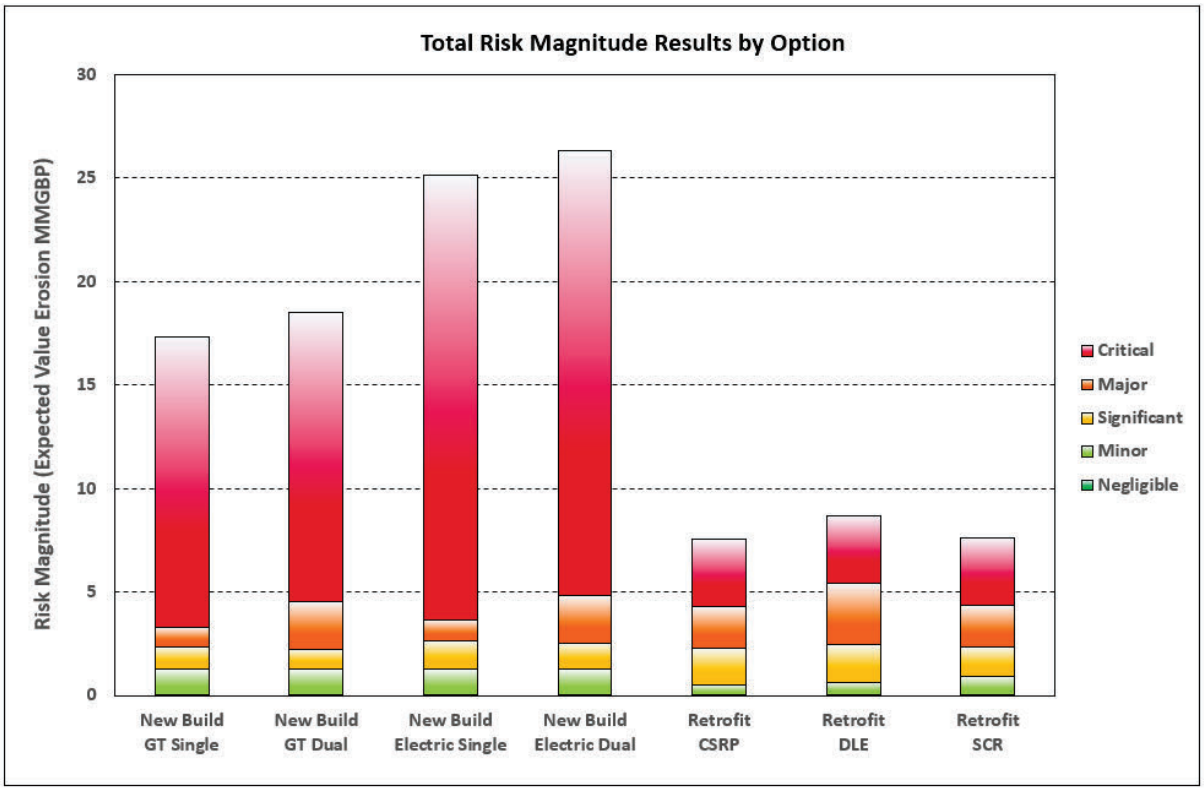
c) Installation of a Selective Catalytic Reduction (SCR) unit.

Figure 1-1 provides a summary of the total risk magnitude by option, as calculated from the sum of the individual risks identified in the risk register (provided in Appendix A). These results should be used as an indicative comparison of the options only, as they are based on indicative risk impact ranges and probabilities.

For dual unit options, a hybrid approach can also be adopted (i.e., one new unit plus one retrofit option). In this case, the risk magnitudes can be considered to be the sum of the individual options.

From Figure 1-1 for the new build options, the Electric VSD Compressor option carries the highest risk magnitude. This is attributed to the risk concerning the HV grid connection requirement. At present, this scope is unknown / undefined and reliant on a third party (UKPN) executing the works within a timely manner. Early engagement with UKPN, prior to a final investment decision, will help to mitigate this risk. For the Retrofit options, the Dry Low Emissions (DLE) option carries the highest risk magnitude (although only marginally) as it is considered a new technology for National Grid. Test bed Trials are currently ongoing, which may help to mitigate future operability concerns.

Figure 1-1 Total Risk Magnitude and Risk Breakdown of the Options



The majority of the risks identified concern CAPEX increase or schedule delay, with a smaller number of risks concerning production outage and availability issues. Therefore, it can be surmised at this stage of the project that cost and schedule increase is one of the primary areas of concern and onwards risk management focus.

The following summarises the **critical** risks that have been identified during the risk assessment process:

- **HV Connection Scope and Extension** – The Electric VSD Compressor Option requires a HV grid connection. As this scope is unknown / undefined and reliant on a third party (UKPN) executing the works within a timely manner, there is a potential for cost and schedule escalation to enable a HV grid connection. Schedule is therefore the primary impact area due to potential third party delays.
- **Coordination and Alignment with External Stakeholders** – As part of the project phase gate milestones, coordination with external stakeholders is required (Ofgem etc.,). For the New Build Options, there may be a potential delay in gaining alignment on a preferred option and as a result, a schedule delay (initial engagement between Ofgem and National Grid indicate a strong preference from Ofgem for Retrofit Options).
- **Coordination and Alignment with Internal Stakeholders** – As part of the project phase gate milestones, coordination with internal stakeholders is required. For the Retrofit Options, there may be a potential delay in gaining alignment on a preferred option and as a result, a schedule delay (currently the New Build Options are the preferred option for internal stakeholders).

- **Network Outage Scheduling and Coordination** – The planned network outage period for construction/ commissioning activities (e.g., tie-ins) on the project is assumed to be 6 months (April – September) [Ref. 3]. For the New Build Options, there is a greater risk of potential schedule delay (based on longer outage duration requirements for tie-ins) due to the allowed outage period being shorter than anticipated or at less optimum time for construction.
- **Geopolitical Issues** – For all Options, there are country specific and worldwide geopolitical issues affecting equipment supply and workforce. However, for the New Build Options in particular, a major risk has been identified regarding potential cost escalation.

The following summarises the **major** risks that have been identified during the risk assessment process:

- **Refurbishment Scope for Avon Unit** – For the Retrofit Options, a major risk was identified around the Avon Unit refurbishment scope. As this is a conceptual phase project, no in-depth condition assessment surveys have been carried out for the existing Avon Unit B. Therefore, there is uncertainty in the 're-life' scope modifications currently identified and whether all areas of concern have been captured. There is potential for 're-life' component scope growth and as a result, CAPEX increase. This risk can be mitigated by undertaking detailed condition assessments and facilities surveys prior to project execution.
- **New Technology Reliability** – For the DLE Retrofit Option, the technology being implemented is considered new for National Grid. As a result, there are potential unknown operability issues (e.g., wider system dynamic issues) which may arise. If these operability issues / teething troubles are discovered during the initial operating period, this may result in poor availability. However, test bed trials are currently ongoing which may help to mitigate / alleviate these concerns.
- **Space in Existing Cable Trenches** – All options require the routing of new cables via existing trenches, however, there is variation in volume and type of cabling required between options. The existing trench space is currently unknown and cable routes may already be at capacity, therefore, adequate segregation may not be possible. For the New Build Options, this has been ranked as a major risk as these options are likely to have issues with separation distances.

  Post Workshop Note: National Grid has provided additional information on separation distance requirements between cables (both power and C&I). As a result, the following basis shall be adopted in the next phase of engineering:

  - *New trenches will be required for any new unit options.*
  - *Existing trenches have adequate space for all the retrofit options (although this may require the removal of redundant cable to free up space).*
- **Land Use / Extension** – For the New Build Options, the existing site boundary requires extension to meet the 39m target separation distance for natural gas facilities, as outlined T/SP/G/37 [Ref. 1]. To facilitate this, permitting and consent is required, alongside environmental and commercial negotiations. This could result in potential scheduling delays with managing multiple stakeholders and gaining consent. However, this is a greater risk for the two-unit New Build Options, as a larger footprint is required. Although the additional land ownership is within the National Grid land ownership boundary, it is at the limit [Ref. 4]. If further detailed studies indicate a greater site boundary extension is required, then additional land ownership will be required which has not been accounted for.

- **Geopolitical Issues** – For all Options, there are country specific and worldwide geopolitical issues affecting equipment supply and workforce. For the Retrofit Options in particular, a major risk has been identified regarding cost escalation based on potential scope growth of unknown additional brownfield modifications.

All other risks are classified as either **significant**, **minor** or **negligible** and are detailed in full (including identified opportunities) within the risk register provided under Appendix A.

The purpose of the risk register is to highlight differential risks between the options and thus allow the information to be used as part of selecting the preferred MCPD compliance option for King's Lynn Compressor Station. Therefore, no further updates to the Risk Register will be made during this phase of the project.

It is recommended that at the beginning of the next phase, the risk register is filtered to show just the identified potential risks for the selected MCPD compliance option. Then, all relevant risks identified as critical, major or significant are subject to onwards risk management and development of risk action plans and appropriate mitigations under future phases of the project.

2.0 INTRODUCTION

2.1 General Background

The Medium Combustion Plant Directive (MCPD) requires that existing plant between 1 MW and 50 MW net thermal input must not exceed specified operational emission limit values or be taken out of service before 1 January 2030. This legislation impacts the Rolls Royce Avon driven compressor units on the gas National Transmission System (NTS) including units at King's Lynn and Peterborough Compressor Stations. Investment is required to ensure the capability, that the network requires, can be maintained beyond 1 January 2030. Investment may include various combinations of the following options and the investment must be assessed against network capability requirements predicted under various future energy scenarios to ensure the most cost-effective solution for end consumers, for operation till and beyond 2050.

- Upgrading non-compliant units to bring emissions within acceptable legislative limits
- Replacement of non-compliant units with new low emissions compressor sets or compression drivers;
- Taking non-compliant units out of service;
- Restrict the performance of non-compliant units through control system restriction such that operational emissions are limited to within legislative limits;
- Limit the use of non-compliant units to a maximum of 500 hours per year under an emergency use derogation as defined in the MCPD legislation;
- Upgrading units to ensure available asset life is in compliance with National Grid requirements.

National Grid submitted a compressor emissions compliance strategy paper to Ofgem in 2019 within which compliance options for each site impacted by the incoming MCPD legislation were presented. Due to the uncertainty around the optimum solution for the King's Lynn Compressor Station it was agreed that further review of options would be conducted with the optimum solution presented to Ofgem in a Final Options Selection Report. Agreement on the optimum solution would then allow the project to progress to the next phase of development prior to final funding allowances being agreed via an uncertainty mechanism under the RIIO regulatory framework.

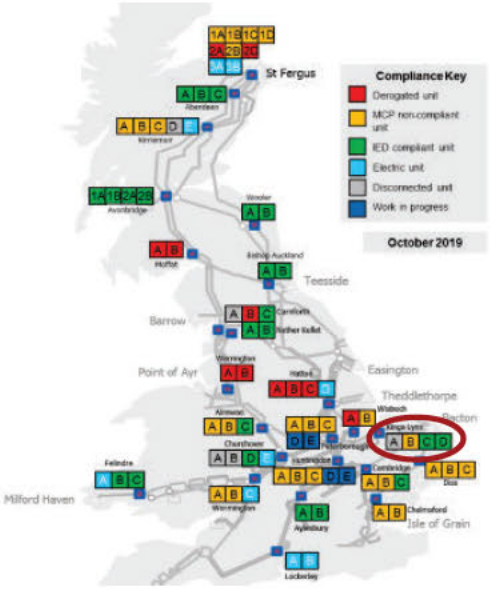
2.2 Site Background

The King's Lynn Compressor Station is located in the East of England and its location on the NTS is shown on the schematic below. A brief outline of the site is provided in the section below to put the project scope into context.

Figure 2-1 King's Lynn Compressor Station

King's Lynn

Unit A – Decommissioned Avon
Unit B – RR Avon
Unit C, D – Siemens SGT400



2.3 King's Lynn Compressor Station

The King's Lynn is a bi-directional compression station which is used to resolve supply/demand imbalance for South-East England and currently has:

- 2 off Siemens SGT400 driven compressors (C, D) which operate as lead units;
- 1 off Rolls-Royce (RR) Avon Gas driven compressor (B) which operates as partial back-up to C and D;
- 1 off Rolls-Royce Avon Gas driven compressor (A) which is disconnected and partially dismantled.

Unit B compressor does not comply with MCPD and does not provide sufficient back-up capacity. Design capacity cannot be achieved with C and D unavailable.

2.4 MCPD Legislation Compliance Project Options

The technical options being considered to meet MCPD legislation at the existing King's Lynn Compression Station are as follows:

<u>New Build (Replacement of RR Avon) Options:</u>

c) New Gas Turbine (GT) Driven Compressor (single and or dual units);
d) New Electric Variable Speed Drive (VSD) Compressor (single and or dual units).

<u>RR Avon Retrofit Options:</u>

d) Change out of Avon engine to a Dry Low Emissions (DLE) unit;
e) Use of Control System Restricted Performance (CSRP);
f) Installation of a Selective Catalytic Reduction (SCR) unit.

2.5 Document Objectives

A Risk Workshop was held with the aim of identifying and assessing uncertainty and risk associated with each of the potential options for the King's Lynn Compressor Station MCPD Project. The risk assessment results serve as input to onwards mitigation discussions and wider project risk management activities.

The objective of this report is to document the details, methodology, results and outcome of the King's Lynn Compressor Station Technical Risk Workshop.

2.6 Document Structure

This document is structured as follows:

Section 1.0 Executive Summary.

Section 2.0 Introduction.

Section 3.0 Workshop Details.

Section 4.0 Workshop Objectives and Methodology.

Section 5.0 Risk Register and Results.

3.0 WORKSHOP DETAILS

3.1 Workshop Date and Location

The King's Lynn Compressor Station Risk Workshop was held on Thursday 26th May 2022 at National Grid's offices in Warwick. Attendees in remote locations dialled in via Teams.

3.2 Workshop Agenda and Presentation

The agenda observed during the workshop is as follows:

09:00	Kick Off, Take 5 and Introductions	[redacted]
09.10	Workshop Objectives and Methodology	
09.30	Options Descriptions / Scope	
10:00	Risk Identification – Compressors and Modifications	All
10.30	***BREAK***	
10.40	Risk Identification – Compressors and Modifications	All
12:00	***LUNCH***	
12.45	Risk Identification – Supporting Utilities and Modifications	All
14.15	***BREAK***	
14.30	Risk Identification – Other Offsites Modifications	All
15.15	Risk Identification – HSSE, Commercial, Political, Organisational, Other	All
16:00	***WRAP UP AND CLOSE***	

The workshop presentation is provided in Appendix B.

3.3 Workshop Attendees

The workshop attendees are provided under Table 3-1.

Table 3-1 Workshop Attendees

Name	Company	Project Role
[redacted]	National Grid	Project Director
		Project Manager
		Design Coordinator
		Investment Engineer (Emissions Portfolio)
		Technical Safety Lead
		Rotating Equipment Lead
		Economics Officer
		Environmental Lead
		Operations Team Lead
	[redacted]	Risk Specialist and Facilitator
		Project Manager
		Design Manager
		Mechanical Lead
		Piping and Layouts Lead

4.0 WORKSHOP OBJECTIVES AND METHODOLOGY

The approach and methodology employed for the King's Lynn Compressor Station MCPD Project Risk Assessment is summarised under the following sections.

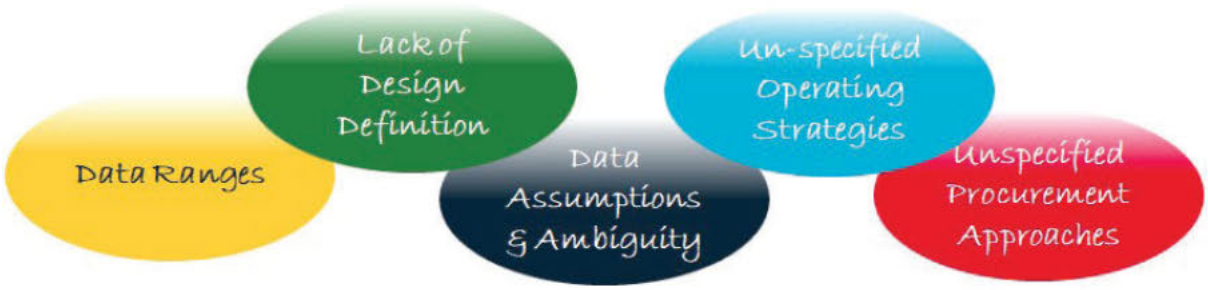
4.1 Methodology Overview and Objectives

Deterministic estimates generated during the Concept Design Stage typically form the initial basis for assessing the value and economic viability of the development options and determining an overview of project costs.

Figure 4-1 Example Deterministic Estimates

However, deterministic estimates and financial metrics are not the only data that should be used to assess project value. At any point in the asset life cycle, there will be a significant number of uncertainties, including data uncertainties, project execution uncertainties (e.g., installation issues, procurement approach) as well as other uncertainties, such as commercial, operational, political and organisational aspects.

Figure 4-2 Typical Project Uncertainties



These uncertainties result in a possibility that the deterministic project value is impacted:

- A potentially negative impact is described as a **risk** or **threat**;
- A potentially positive impact is described as an **upside** or **opportunity**.

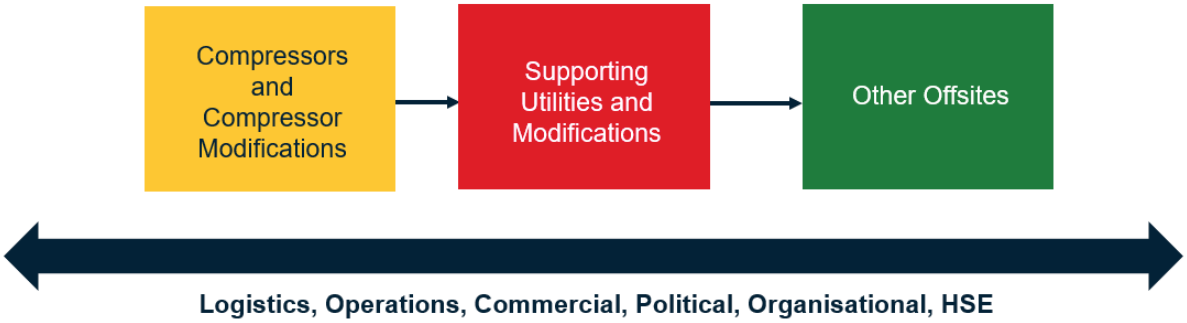
At the Concept Design Stage, it is recommended that a semi-quantitative method is employed, which provides a risk-adjusted expected value of the project and the key uncertainties associated with each development option. The process aims to achieve the following:

- Coherently identify and address key uncertainties present in the current design/project plan across the scope of the proposed modifications and project boundaries;
- Assess and quantify risk for each option;
- Ascertain a view on **key project risks** that require active onwards risk management**;**
- Identify the spread of risk across different project parameters (e.g., CAPEX, OPEX, schedule, availability) and where significant degrees of risk manifest;
- Identify any key risks which may justify modification of the options or immediate design changes to mitigate.

4.2 Risk Assessment Structure

The Concept Design Stage risk assessment methodology utilises a structured brainstorming approach. Under this methodology, the development options are broken down into a logical progression of blocks, from start to finish, to enable a structured brainstorming of risks. Each block is then discussed systematically, to ensure that no key uncertainties or risks are missed and all potentially differentiating uncertainties between options are identified. The flow of system blocks used for the risk assessment is shown in Figure 4-3.

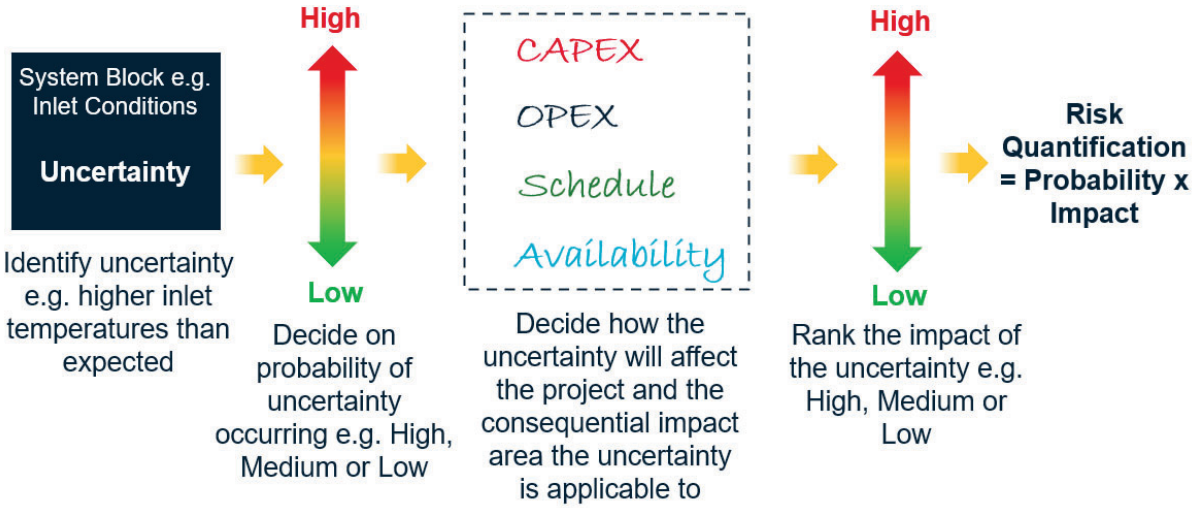
Figure 4-3 System Block Breakdown



4.3 Risk Quantification

Within each system block, a wide range of uncertainties will be identified which are relevant to that part of the system/development options. For each of the uncertainties identified, the risk presented to the project will be described and quantified using the methodology shown under Figure 4-4.

Figure 4-4 Risk Quantification Process



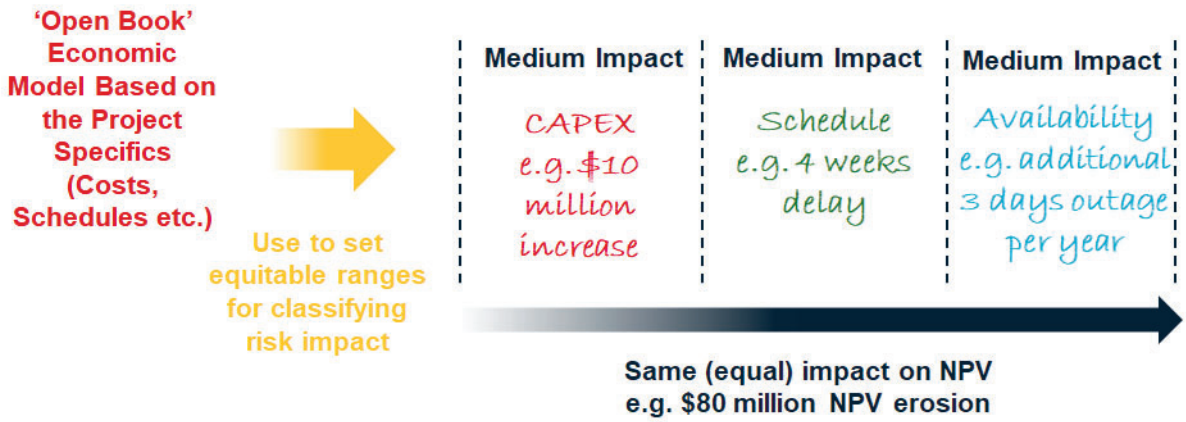
This process identifies a wide variety of risks, spread across the various impact areas (CAPEX, OPEX, availability, schedule etc.). This consequently presents the challenge of ranking the different types of risk on an equitable basis e.g., ensuring that a medium schedule impact provides the same overall (total) risk contribution as a medium CAPEX impact when summing risks and comparing options. To address this issue, NPV is used as a common denominator, as illustrated under Figure 4-5.

Figure 4-5 NPV as a Common Denominator

NPV is common denominator between variables

To set equitable ranges for impact variables (CAPEX, OPEX, schedule, availability etc.), an 'open book' pre-tax economic model is employed to determine the degree of variation in CAPEX, OPEX, schedule and availability which result in an equal impact on NPV, as illustrated under Figure 4-6.

Figure 4-6 Setting Equitable Impact Ranges



The risk ranges developed specifically for this project are given under Figure 4-7 and Figure 4-8.

Figure 4-7 Probability Risk Ranges

Probability				
V. Low	Low	Med	High	V.High
<2%	2% - 10%	10% - 30%	30% -70%	>70%

Figure 4-8 Impact Risk Ranges

	Impact				
	V. Low	Low	Med	High	V.High
CAPEX	<£250k	£250k - £1 MM	£1MM - £3 MM	£3MM - £10 MM	>£10MM
OPEX	<$30k/yr	30 - 130 £k/yr	130 - 450 £k/yr	0.45 - 1.3 £MM/yr	>$1.3MM/yr
Execution Schedule	<2 weeks	2 - 6 weeks	6weeks - 5 months	5 - 15 months	>15months
Availability Loss	<1 day/yr	1-3 days/yr	3-12 days/yr	12-36 days/yr	>36 days/yr
One-Off Production Outage	<1 weeks	1 - 5 weeks	5weeks - 4 months	4 - 11 months	>11months
Loss of Revenue	<£150k	£150k - £0.6 MM	£0.6MM - £2 MM	£2MM - £6 MM	>£6MM

Figure 4-9 shows the final risk quantification, which results from combining the probability with the impact to provide the expected value erosion. Note that the mid-point of each range bracket is used to calculate the expected value erosion, except for the high bracket, where 1.5 times the upper limit is employed. If a risk is identified which lies significantly outside of the impact ranges i.e., is very high, this will be quantified separately offline after the workshop as an exceptional case.

Figure 4-9 Expected Value Erosion Risk Quantification

			Composite Risk Index (P x I) in £k				
			V. Low	Low	Med	High	V.High
			<£150k	£150k - £0.6 MM	£0.6MM - £2 MM	£2MM - £6 MM	>£6MM
Probability	V. Low	<2%	1	4	13	40	120
	Low	2% - 10%	5	25	80	240	720
	Med	10% - 30%	15	80	260	800	2400
	High	30% -70%	40	190	650	2000	6000
	V.High	>70%	65	320	1110	3400	10000

To aid the workshop discussions and visualisation of the risk quantification during the workshop, the risk quantification values do not have to be shown on the workshop register, and instead a risk classification will be shown instead when the expected value quantifications are calculated e.g., **Medium Probability** x **High Impact** = **Major Risk**. The risk classification system is shown under Figure 4-10. Further calculation of the expected value erosion for each risk is then managed post-workshop.

Figure 4-10 Risk Quantification Signifiers

			Composite Risk Index (P x I) in £k				
			V. Low	Low	Med	High	V.High
			<£150k	£150k - £0.6 MM	£0.6MM - £2 MM	£2MM - £6 MM	>£6MM
Probability	V. Low	<2%	Negligible	Negligible	Negligible	Minor	Significant
	Low	2% - 10%	Negligible	Minor	Minor	Significant	Major
	Med	10% - 30%	Negligible	Minor	Significant	Major	Critical
	High	30% -70%	Minor	Significant	Major	Critical	Critical
	V.High	>70%	Minor	Significant	Major	Critical	Critical

4.4 Populating the Risk Register

The risk register is developed by working through the system blocks and identifying uncertainties that are applicable to each part of the development options. An example of the Risk Register is shown in Figure 4-11.

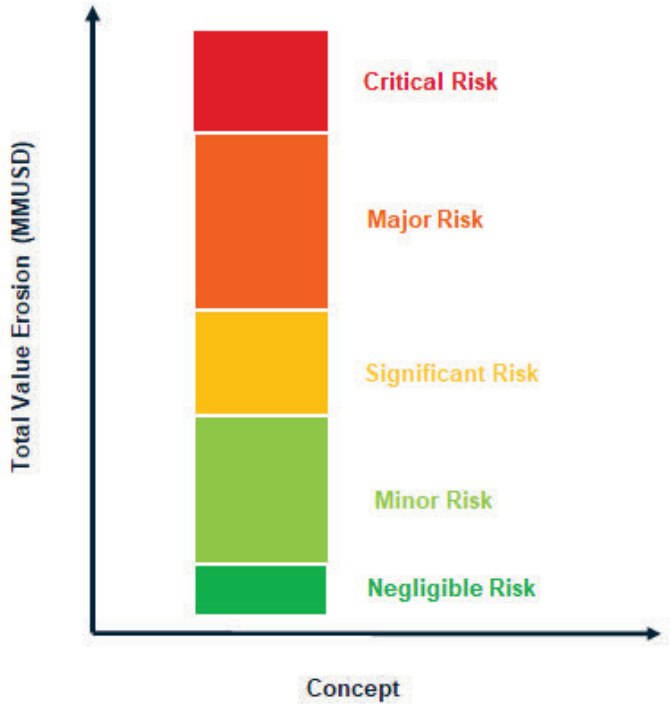
Figure 4-11 Example Risk Register

Type	No.	Uncertainty Area	Description & Possible Outcome	Key Impact Area	Opportunity (Y/N)	Risk Block	Risk Block Ranking			Comments/Mitigations
							Probability	Impact	Value Erosion	
Centralised Processing Facilities and Product Export										
CPF	1	Retrofit Riser Installation - SIMOPS	Production shutdown is required anytime an installation vessel is in close proximity to the facility. Risk that increased production shutdown will be required when vessels are in close proximity with facility.	Production Outage	N	1 - 2 New Risers at Existing Facility	H	L	Significant	
						3 New Risers at Existing Facility	H	M	Major	
CPF	2	Temporary Winch Installation	Require temporary winch installation to enable retrofit riser and umbilical operations. Locations for winch installation not currently specified. Location appears to be obstructed. Risk that temporary winch installation may be more complex than currently anticipated.	CAPEX	N	Risers at Existing Facility	M	L	Minor	
CPF	3	Installation of New Production Pipework	Tie-in point provisions and routings have been made and modelled, however, no site survey work has been completed to date, and installation of pipework from the riser slots to the existing production system may be more complex than currently expected, resulting in an extended construction schedule. Construction activities involve the lifting and installation of numerous sections of large bore pipework and hot work	Production Outage	N	Risers at Existing Facility	H	M	Major	Current design is based on yard fabrication and needs more revision for onsite construction. This risk is recommended for review following site survey activities.
CPF	4	Post Weld Heat Treatment	Post weld heat treatment required for large diameter spools. Potential schedule extension to accommodate. Risk for all options.	Schedule	N	All Options	M	L	Minor	
CPF	5	MEG System Installation	Base option is to install MEG system via deck extension. Complex work. Risk of increased schedule and production outage to install MEG system. Small risk of CAPEX increase for new MEG system installed at new facility.	Production Outage	N	MEG System at Existing Facility	H	L	Significant	Installation vessel required in close proximity with platform. High probability of production outage to allow this.
				CAPEX		MEG System at New Facility	L	L	Negligible	

4.5 Results Presentation

The risk results breakdown is presented in chart format, showing the contributing degree of different types of risk. Separate charts are produced for overall risk, CAPEX, OPEX, schedule and availability risk, if identified.

Figure 4-12 Example Results Breakdown



4.6 Consideration of HSE Risks

A number of HSE considerations may also be present as inherent uncertainties in the concept design and deterministic cost assessments, which would represent a significant impact on the expected project economics if they came to light.

An example is delay to environmental approvals creating an overall project schedule delay. The risk assessment process therefore takes into account such high-level HSE considerations, and their associated impact on the expected deterministic estimates, as appropriate and relevant to the project specific development options and uncertainties. However, the business risk assessment will not consider HSE risks in detail, consider HSE specific impacts such as loss of life, reputational damage etc., and is not in any way intended to replace or combine essential HSE assessments (safety QRA/HAZID/ENVID/HAZOP etc.).

4.7 Consideration of Opportunities and Upsides

Many uncertainties may have an 'upside', which results in a positive impact on the project as opposed to a negative impact. There may also be various opportunities that the project team may choose to implement as the project progresses.

Theoretically, all upsides and opportunities identified can be quantified based on probability and impact, as per risks. For opportunities and upsides, this will lead to a positive impact on overall project value rather than a negative erosion. However, during a risk assessment process, the natural psychological bias is towards a more extensive/thorough consideration of risk (negative impacts and threats) than upside and opportunity (positive outcomes). Consequently, unless exhaustive efforts are undertaken to ensure that upsides and opportunities are afforded equal consideration alongside risk, the final results will potentially be skewed. Realising opportunities may also be a management decision that is not ultimately pursued, or may introduce new (unidentified) risks, which have not been fully explored under the concept development stage risk assessment.

It is therefore recommended that potential upsides and opportunities are documented as they arise during the risk assessment process and considered during subsequent concept definition on a qualitative basis. However, upsides and opportunities will not be quantitatively assessed in combination with the risks. Post-workshop, all opportunities captured during the risk assessment process can be reviewed and moved to a dedicated value engineering register as appropriate for further study and management.

4.8 Relationship to Absolute Economics

Risk assessment at the Concept Design Stage has a number of known limitations:

- A high level, expected value methodology has been utilised - probability distributions and interdependent relationships between risks are not taken into account, as would be considered under detailed Monte Carlo assessment;
- Indicative, pre-tax economic factors have been employed (aligned with open book economics) as opposed to absolute economic parameters.

As a consequence, the absolute value of the risks presented will not be fully aligned with absolute project economic values, and therefore have limited meaning from a pure economic value assessment perspective. However, the process undertaken enables the following:

- An equitable and appropriately scaled quantification of risk resulting from different uncertainties;
- An appropriate indication of the magnitude of risk resulting from each uncertainty;
- Identification of key risks and potential issues for further focus under onwards project stages.

4.9 Pre-Workshop, Workshop and Post-Workshop Activities

4.9.1 Pre-Workshop Activities

Prior to the risk workshop, a starter risk register was initiated and prepared by a risk specialist with input from the project team.

4.9.2 Workshop Activities

The workshop activities focused on the review of the draft risk register produced during the preliminary risk work. During the workshop, each risk identified on the draft register was reviewed in detail, the quantification assigned to the risk discussed and modified as appropriate. Any new risks identified during the workshop were also added to the risk register and further discussed and quantified.

Once the risks had been reviewed, the opportunities identified were also reviewed, thereby completing the risk register.

4.9.3 Post-Workshop Activities

Post-workshop, the following activities have been undertaken:

- The total expected value erosion for the development options has been calculated via summation of the individual risks. Results are ultimately presented on a chart;
- The finalised risk register has been developed post-workshop for review and comment;
- The workshop methodology, workshop discussions, results charts, risk analysis and finalised risk register have been fully documented under this dedicated workshop report.

5.0 RISK REGISTER AND RESULTS

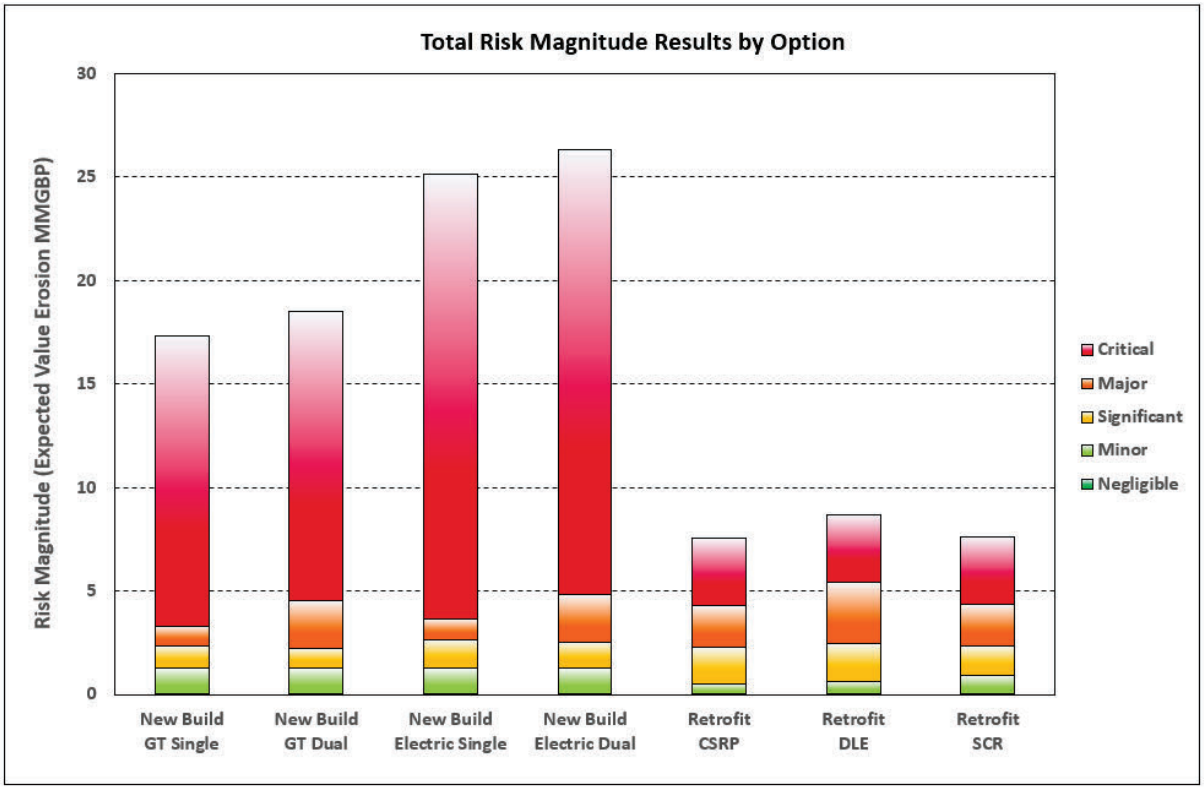
5.1 Risk Register

The full risk register is provided under Appendix A.

5.2 Risk Results Summary

Figure 5-1 provides a summary of the total risk magnitude and breakdown of risks identified by Option, as calculated from the sum of the individual risks identified in the risk register (provided in Appendix A).

Figure 5-1 Total Risk Magnitude and Risk Breakdown Results by Option



The majority of the risks identified concern CAPEX increase or schedule delay, with a smaller number of risks concerning production outage and availability issues. Therefore, it can be surmised at this stage of the project that cost and schedule increase is one of the primary areas of concern and onwards risk management focus.

The following summarises the **critical** risks that have been identified during the risk assessment process:

- **HV Connection Scope and Extension** – The Electric VSD Compressor Option requires a HV grid connection. As this scope is unknown / undefined and reliant on a third party (UKPN) executing the works within a timely manner, there is a potential for

cost and schedule escalation to enable a HV grid connection. Schedule is therefore the primary impact area due to potential third party delays.

- **Coordination and Alignment with External Stakeholders** – As part of the project milestones, coordination with external stakeholders is required (Ofgem etc.,). For the New Build options, there may be a potential delay in gaining alignment on a preferred option and as a result, schedule delay (initial engagement between Ofgem and National Grid indicate a strong preference from Ofgem for Retrofit Options).
- **Coordination and Alignment with Internal Stakeholders** – As part of the project milestones, coordination with internal stakeholders is required. For the Retrofit Options, there may be a potential delay in gaining alignment on a preferred option and as a result, schedule delay.
- **Network Outage Scheduling and Coordination** – The planned network outage period for construction/ commissioning activities (e.g., tie-ins) on the project is assumed to be 6 months (April – September) [Ref. 3]. For the New Build Options, there is a greater risk of potential schedule delay (based on longer outage duration requirements for tie-ins) due to the allowed outage period being shorter than anticipated or at less optimum time for construction.

Geopolitical Issues – For all Options, there are country specific and worldwide geopolitical issues affecting equipment supply and workforce. However, for the New Build Options in particular, a major risk has been identified regarding potential cost escalation.

- The following summarises the **major** risks that have been identified during the risk assessment process:
- **Refurbishment Scope for Avon Unit** – For the Retrofit Options, a major risk was identified around the Avon Unit refurbishment scope. As this is a conceptual phase project, no in-depth condition assessment surveys have been carried out for the existing Avon Unit B. Therefore, there is uncertainty in the 're-life' scope modifications currently identified and whether all areas of concern have been captured. There is potential for 're-life' component scope growth and as a result, CAPEX increase. This risk can be mitigated by undertaking detailed condition assessments and facilities surveys prior to project execution.
- **New Technology Reliability** – For the DLE Retrofit Option, the technology being implemented is considered new for National Grid. As a result, there are potential unknown operability issues (e.g., wider system dynamic issues) which may arise. If these operability issues / teething troubles are discovered during the initial operating period, this may result in poor availability. However, test bed trials are currently ongoing which may help to mitigate / alleviate these concerns.
- **Space in Existing Cable Trenches** – All options require the routing of new cables via existing trenches, however, there is variation in volume and type of cabling required between options. The existing trench space is currently unknown and cable routes may already be at capacity, therefore, adequate segregation may not be possible. For the New Build Options, this has been ranked as a major risk as these options are likely to have issues with separation distances.

  Post Workshop Note: National Grid has provided additional information on separation distance requirements between cables (both power and C&I). As a result, the following basis shall be adopted in the next phase of engineering:

  - *New trenches will be required for any new unit options.*

- *Existing trenches have adequate space for all the retrofit options (although this may require the removal of redundant cable to free up space).*

- **Land Use / Extension** – For the New Build Options, the existing site boundary requires extension to meet the 39m target separation distance for natural gas facilities, as outlined T/SP/G/37 [Ref. 1]. To facilitate this, permitting and consent is required, alongside environmental and commercial negotiations. This could result in potential scheduling delays with managing multiple stakeholders and gaining consent. However, this is a greater risk for the two-unit New Build Options, as a larger footprint is required. Although the additional land ownership is within the National Grid land ownership boundary, it is at the limit [Ref. 4]. If further detailed studies indicate a greater site boundary extension is required, then additional land ownership will be required which has not been accounted for.

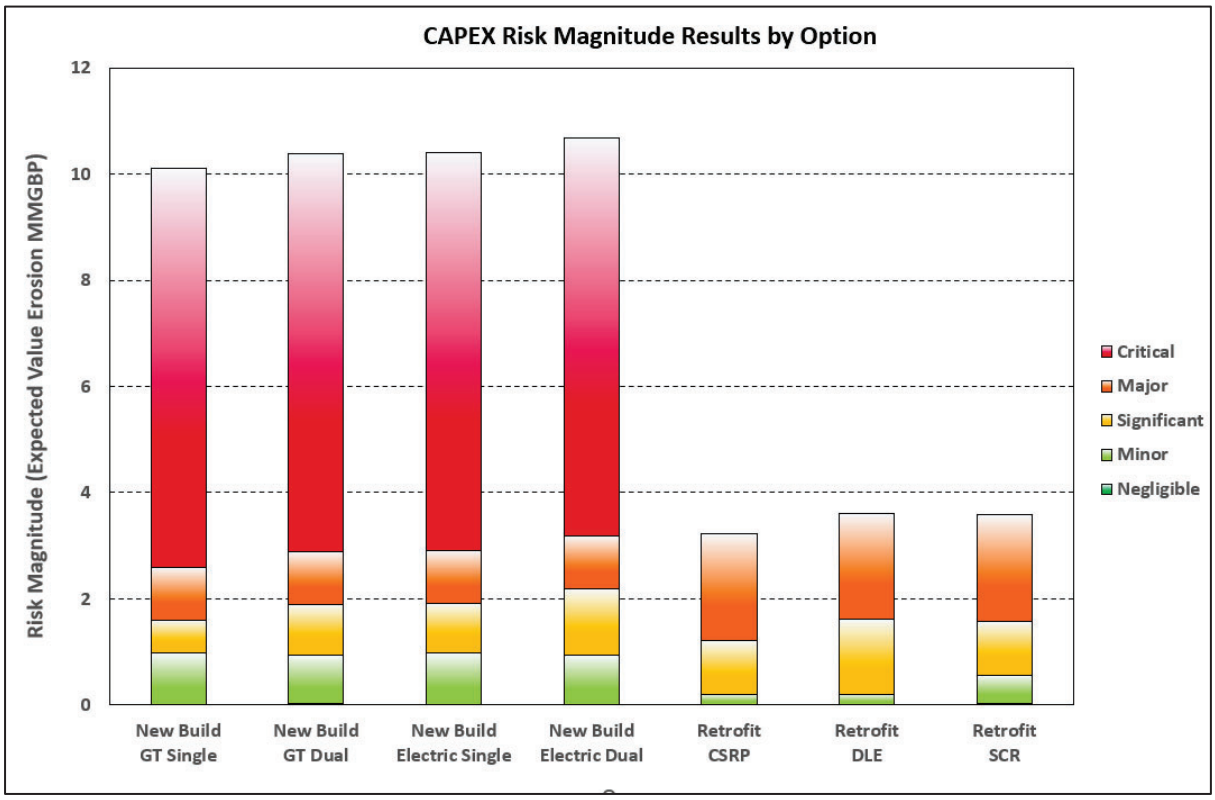
  Geopolitical Issues – For all Options, there are country specific and worldwide geopolitical issues affecting equipment supply and workforce. For the Retrofit Options in particular, a major risk has been identified regarding cost escalation based on potential scope growth of unknown additional brownfield modifications.

All other risks are classified as either significant, minor or negligible. Significant risks are described in further detail under the following sections. All minor and negligible risks and identified opportunities are detailed in the risk register provided under Appendix A.

5.3 CAPEX Risk Results

Figure 5-2 provides a summary of the total combined CAPEX specific risk per Option which has been calculated from the sum of the individual risks identified in the risk register (provided in Appendix A).

Figure 5-2 CAPEX Risk Magnitude and Risk Breakdown



The critical and major CAPEX risks identified are discussed above under Section 5.2. The following summarises the **significant** CAPEX risks that have been identified during the risk assessment process:

- **DLE Technology Cost** – For the DLE Retrofit Option, a provisional cost estimate has been provided by [redacted] [Ref. 5]. No other technologies have been considered at this stage of the project. Therefore, in future phases, there is a potential to select an alternative supplier (i.e., Siemens Technology) with an associated cost increase.
- **Capacity of Existing Instrument Air System** – The existing Instrument Air System is designed for three off Siemen SGT 400 driven compressors (two currently installed and one future). For the two-unit New Build Options and with no capacity assessment to date, there is a concern regarding sufficient capacity for one additional compressor. The current project basis is to tie-in to the existing system, as a result, there is a potential for additional instrument air package requirements, resulting in increased CAPEX.
- **SCADA Interconnections and Networking** – For all Options, the current SCADA system is due to be replaced in 2026 [Ref. 3]. However, the modifications do not include an update to the overall network. As a result, there may be potential issues with data speeds and network capacity. As a result, there may be an additional requirement to upgrade the network to accommodate the new loads imposed by the project, thus resulting in increased CAPEX.
- **New Trench for HV Cable** – For the Electric VSD Option, a preliminary new HV cabling routing has been selected as part of this project which currently crosses existing trenches and unknown/ undefined obstructions. Therefore, there may be a

requirement for scope growth/ routing deviations to accommodate the new HV cable routing and avoid obstructions, resulting in increased CAPEX.

- **Asbestos Management** – For all Options, there is potential for asbestos contamination in existing cabs and trenches. There may be a requirement for increased decontamination of equipment, resulting in increased CAPEX.
- **Failure To Meet Emissions Requirements** – For the Retrofit Options in particular, any future changes to the pollution requirements or stricter requirements applied at the permitting stage could have a significant CAPEX implication. As a result, there may be a requirement for additional modifications/ replacement of units to meet these limits, resulting in increased CAPEX.

All other risks are classified as either minor and negligible and are detailed under the risk register provided in Appendix A along with any CAPEX improvement opportunities.

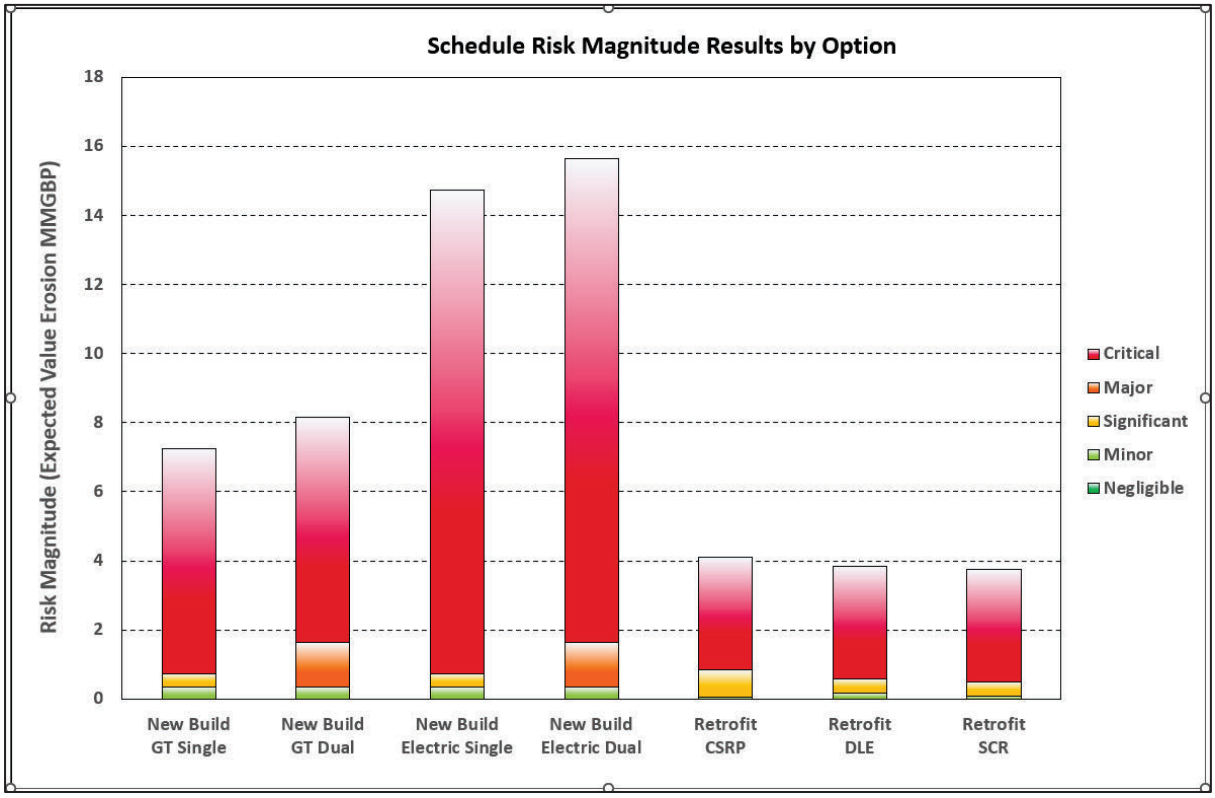
5.4 OPEX Risk Results

No critical, major or significant OPEX risks were identified under the scope of the assessment. All OPEX risks identified have been classified as either minor and negligible and are detailed under the risk register provided in Appendix A.

5.5 Schedule Risk Results

Figure 5-3 provides a summary of the total combined schedule specific risk per Option which has been calculated from the sum of the individual risks identified in the risk register (provided in Appendix A).

Figure 5-3 Schedule Risk Magnitude and Risk Breakdown



The critical and major schedule risks identified are discussed above under Section 5.2. The following summarises the **significant** schedule risks that have been identified during the risk assessment process:

- **Network Outage Scheduling and Coordination** – The planned network outage period for construction/ commissioning activities (e.g., tie-ins) on the project is assumed to be 6 months (April – September) [Ref. 3]. The planned outage is currently not confirmed and there is a risk that the allowed outage may be shorter than anticipated or at a less optimum time for construction, thus resulting in a schedule delay. Therefore, for the Retrofit Options, this has been ranked as a significant schedule risk.
- **Land Use / Extension** – For the New Build Option (Single Unit) a significant schedule risk was identified in regard to attaining the correct permitting and consent for the required site boundary extension. Potential schedule delay in managing multiple stakeholders and gaining consent.

Post Workshop Note

- **Environmental Permitting Approvals** – For the CSRP Option, a significant schedule risk was identified in regard to obtaining environmental permitting approvals. This is because the CSRP technology is currently unproven for emissions reduction and thus could result in a potential schedule delay.

All other risks are classified as either minor and negligible and are detailed under the risk register provided in Appendix A along with any schedule improvement opportunities.

5.6 Production Outage /Availability Risk Results

No critical or significant production outages / availability risks were identified. The major risk identified under this impact range is discussed in Section 5.2.

All other production outage / availability risks identified have been classified as either minor and negligible and are detailed under the risk register provided in Appendix A along with any schedule improvement opportunities.

6.0 REFERENCES

References	
Ref. 1	King's Lynn Compressor Station Layout Drawings, 203513C-001-DW-0051-0001 Rev B
Ref. 2	King's Lynn Compressor Station Basis of Design, Doc. no. 203513C-001-RT-0008-0002.
Ref. 3	King's Lynn Compressor Station Site Visit Report, Doc. no. 203513C-001-RT-0500 Rev B
Ref. 4	King's Lynn Compressor Station Layout Review Report, Doc. no. 203513C-001-RT-0250 Rev B
Ref. 5	King's Lynn Compressor Station Cost Estimate Phase 2, 203513C-001-RT-0301.
Ref. 6	King's Lynn Compressor Station Level 2 Schedules (Phase 2), 203513C-001-PLG-0301.

APPENDIX A RISK REGISTER

[redacted]

National Grid Kings Lynn Compression Station Risk Register

nationalgrid

Type	No.	Uncertainty Area	Risk Description (Cause, Effect, Consequence)	Key Impact Area	Opportunity (Y/N)	Option Block	Risk Block Ranking			Other Comments
							Probability	Impact	Value Erosion	
Compressor Modifications										
CM	1	Refurbishment Scope for Avon Unit	**Cause:** Conceptual phase engineering to date. No in-depth condition assessment survey carried out for Avon Unit B. **Effect:** Uncertainty in the 're-life' scope modifications and whether all areas of concern have been captured. Potential for 're-life' component scope growth. **Consequence:** CAPEX increase.	CAPEX	N	Avon Unit Re-Use Options	H	M	Major	Includes destruct elements. Wet seal system is elderly. Uncertainty in scope division between 'asset health' and project scope. Some scope growth may be covered under asset health rather than project expenditure. No current survey of unit and accurate understanding of refurbishment scope. External part of cab has been refurbished previously (6 - 7 years ago).
CM	2	Production Outage Window for Avon Unit Refurbishment	**Cause:** Conceptual phase engineering to date. No in-depth condition assessment survey carried out for Avon Unit B. **Effect:** May not be possible to undertake work within planned production outage window. Additional shutdown required. Loss of production. **Consequence:** Production outage.	Production Outage	N	Avon Unit Re-Use Options	M	L	Minor	Machines are currently running permanently given geo-political situation and expected to continue for next 3 - 5 years. Avon B Unit is currently preferred unit to run due to improved operational flexibility in comparison with other compressors. No fixed annual T&I to coordinate with - planned summer outage period. Can be performed over two seasons. 6 month period available over the summer, but work may take 6 months to complete as part of base schedule. Potential additional isolation considerations for continuing into winter period. Mitigation is full site survey.
CM	3	Tie-in to Existing Underground Production Piping	**Cause:** Conceptual phase engineering to date. No underground piping survey has been carried out. Potential for areas of damaged/corroded pipework. **Effect:** Potential for brownfield scope increase. May need to remove more sections of pipe that expected/replace damaged pipe. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options	M	L	Minor	Pipework for A & C has previously been removed and inspected and was in good condition.
CM	4	Re-Use of Existing Underground Production Piping	Conceptual phase engineering to date. No underground piping survey has been carried out. Requirement to re-use existing production piping infrastructure for all options. Potential for more extensive damage/lower integrity of pipework than currently expected. Requirement to replace large sections of underground pipework. All compressors currently use existing pipework. Wider site risk, not a project risk.							Data regarding site pipework to be provided.
CM	5	Increased Flows Through Site Pipework	Potential velocity limitations. Wider site review required and focused assessment for any changes to overall site capacity. Being reviewed by others. No intention for project to increase flow rates above current design limits.							Data regarding site pipework to be provided.
CM	6	Reliability of Avon Unit	**Cause:** All retrofit options rely on use of existing Avon compressor. Compressor is approximately 50 years old. **Effect:** Risk that ageing asset does not meet availability requirements (even with re-life works) and experiences a higher degree of production outages than currently anticipated. **Consequence:** Loss of availability and increased OPEX.	Availability & OPEX	N	Avon Unit Re-Use Options	L	M	Minor	Base estimates already account for reduced availability and increased OPEX of retrofit machine. RAM model and site availability model.
CM	7	Lack of Vendor Support	**Cause:** Avon Units are obsolete and no longer supported by OEM. **Effect:** Avon Units are unsupported from a maintenance perspective for the design lifetime. Become increasingly reliant on used parts, with potential issues associated with wider package support and ancillary equipment items. Risk that machine is not viable to keep in operation, resulting in a requirement to replace. **Consequence:** CAPEX impact.	CAPEX	N	Avon Unit Re-Use Options	VL	VH	Minor	Currently licensed service providers that can support. NG have other Avon units that can potentially be cannibalised.
CM	8	Existing Control Systems (DCS/ ESD/ F&G) Tie-In	Conceptual phase engineering / no extensive electrical site survey has been carried out. Existing control systems are old and/or obsolete. Ongoing plan to replace entire station control system in place. Not considered to be a project risk.							Intended to be replaced by 2026.
CM	9	Remote Control Upgrades	**Cause:** No modifications to central remote control systems currently included in scope for tie-in of new build options. **Effect:** Potential increase in scope to modify remote controls. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options	L	L	Minor	Relatively well understood - Peterborough has a precendent for new machines installation. Coms in back panels. Pre-investment has already been considered.
CM	10	HV Connection Scope and Execution	**Cause:** Electric drive compressor option requires HV grid connection. Unknown/undefined scope elements at present regarding HV connection.. **Effect:** Potential for cost and schedule escalation to enable HV grid connection. Reliant on third party executing works within timely manner. **Consequence:** Schedule and CAPEX increase. Schedule is primary impact area due to potential third party delays.	Schedule	N	New Build Electric Option	H	VH	Critical	HV grid connection currently excluded from cost and schedule basis. Reliant on planning and third party coordination. Mitigation is to progress commercial negotiations with power networks.
CM	11	Compressor Selection	**Cause:** Current basis for new compressors is a Solar Titan compressor, as per Peterborough, which has been used for generation of cost estimates. No other machines have been considered to date. **Effect:** Potential for different machine to be selected at increased cost. **Consequence:** CAPEX impact.	CAPEX	N	New Build Options	VL	VL	Negligible	Cost is conservative in terms of footprint size etc. Cost includes all National Grid compliance elements. Solar tend to be the more conservative cost compared to other vendors.
CM	12	Compressor Footprint	Conservative basis with regard to space/footprint requirement for new build compressors. Opportunity to optimise and reduce with resulting impact on fence extension requirements, foundations etc.	CAPEX	Y	New Build Options				
CM	13	New Technology Qualification	**Cause:** DLE technology is currently not proven for use on National Grid sites. **Effect:** Potential for extended qualification periods or concept recycle **Consequence:** Schedule impact.	Schedule	N	DLE Option	M	L	Minor	[redacted]
CM	14	New Technology Reliability	**Cause:** DLE is a new technology retrofit. Potential operability issues are currently unknown. Potential wider system dynamics issues. **Effect:** Operability issues/teething troubles are discovered during initial operational period leading to poor availability. **Consequence:** Availability impact.	Production Outage/Availability	N	DLE Option	H	M	Major	Field trial planned in Q3 but limited learnings from this compared with use during operation. Two potential suppliers.
CM	15	DLE Technology Cost	[redacted]	CAPEX	N	DLE Option	M	M	Significant	
CM	16	SCR Retrofit	**Cause:** SCR would need to be fitted to existing exhaust system. Current exhaust system has not been designed for SCR addition. **Effect:** Potential for increased complexity of retrofit. Potential for increased utilities requirements e.g. nitrogen and instrument air. **Consequence:** CAPEX increase.	CAPEX	N	SCR Option	M	L	Minor	
CM	17	SCR Reliability	**Cause:** Lack of familiarity with SCR operation. **Effect:** Potential operational issues and teething troubles. **Consequence:** Reduced availability.	Availability	N	SCR Option	L	L	Minor	Relatively simple system. Systems in use by other operators.
CM	18	SCR Technology Cost	[redacted]	CAPEX	N	SCR Option	L	L	Minor	
CM	19	Electrical Load Requirements	**Cause:** No full electrical load assessment to date. **Effect:** Potential for dual compressor (GTs) to exceed maximum load provisions available on site. Requirement to increase electrical load capacity. Main risk is standby generator capacity and associated requirement to replace. Potential impact on UPS back up. **Consequence:** Increased CAPEX.	CAPEX	N	New Single Unit	L	L	Minor	Planned to decommission Avon units, freeing up electrical load capacity. 400V system which may not be compatible with new machines, which are likely to be more reliant on electrical elements than older units. Action to review further. N.B. SCR has very low power requirements and is not considered to be a risk for electrical loads.
						New Dual Units	M	L	Minor	
CM	20	Area 1 Plinth Information for New Units	**Cause:** Only have data/drawings for one plinth. Current cost estimating is based on existing Avon data. **Effect:** Potential for scope growth for foundations etc. for actual installation. **Consequence:** CAPEX increase.	CAPEX	N	New Units	L	VL	Negligible	
CM	21	Re-Use of Unit A	Unit A is currently mothballed equipment. Opportunity to re-use. Potential degree of risk due to equipment integrity concerns.	CAPEX	Y					

[redacted]

Type	No.	Uncertainty Area	Description & Possible Outcome	Key Impact Area	Opportunity (Y/N)	Option Block	Risk Block Ranking			Other Comments
							Probability	Impact	Value Erosion	
Utilities and Tie-Ins										
U	1	Capacity of Existing Fuel Gas	Current basis is new fuel gas package for new build options. Opportunity to use existing package but would potentially need modification.	CAPEX	Y	New Build Options - GT				

Type	No.	Uncertainty Area	Risk Description (Cause, Effect, Consequence)	Key Impact Area	Opportunity (Y/N)	Option Block	Risk Block Ranking			Other Comments
							Probability	Impact	Value Erosion	
U	2	Capacity of Existing Instrument Air	**Cause:** Basis is to tie-in to existing package. No capacity assessments to date. **Effect:** Potential for additional instrument air package requirement. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options - 1 Unit	M	L	Minor	Instrument air package was potentially installed with capacity for one additional compressor. Peterborough uses air for separation seals as well as conventional instrument air - not accounted for under current capacity estimates, however, potential to use nitrogen instead (existing obsolete N2 package that needs replacement). Air package usually feeds N2 package.
						New Build Options - 2 Units	H	L	Significant	
U	3	Change of Avon Actuators	**Cause:** Current actuators do not use instrument air. May need to change to meet current regulations. **Effect:** Potential for additional instrument air package requirement plus change out of actuators. **Consequence:** CAPEX increase.	CAPEX	N	Avon Unit Re-Use Options	VL	L	Negligible	Instrument air package was potentially installed with capacity for one additional compressor. Opportunity to use electrically actuated valves.
U	4	SCADA Interconnections and Networking	**Cause:** SCADA system is being replaced but network isn't. **Effect:** Potential issues with data speeds and network capacity. Requirement to upgrade network to accommodate additional loads imposed by project requirements. **Consequence:** CAPEX increase.	CAPEX	N	All Options	H	L	Significant	System is already slow (existing problem). No plans to upgrade network. Project would most likely need to contribute to upgrade costs.
Site Location, Preparation and Brownfield Tie-Ins										
S	1	Site Area Preparation	**Cause:** Conceptual phase engineering to date. No in-depth underground piping survey of redundant equipment. Uncertainty in the extent of underground piping requiring removal. Uncertainty in general level of site preparation required e.g. soil contamination, other buried obstructions etc. **Effect:** Potential for additional site remediation activities. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options	M	L	Minor	Historically, there was additional Avon unit next to Unit B. Pipework is likely to still be present underground.
						SCR Option	L	VL	Negligible	
S	2	Space in Existing Cable Trenches	**Cause:** All options require routing of new cables via existing trenches, however, variation in volume of cabling required between options. Existing trench space currently unknown. Existing cable routes may be at capacity. Adequate segregation may not be possible. Unknown condition and space. **Effect:** Potential to expand trench space or remove redundant cables to make space. May need new trenches due to separation distance issues. **Consequence:** CAPEX increase.	CAPEX	N	Retrofit Options	VL	M	Minor	Potential to clear redundant cabling from A and C units to enable capacity in trenches. N.B. Unit B cabling (live) is also in trench. Large volume of existing cabling at Peterborough. New build options are most likely to have issues with separation distances due to high volume of cables and controls.
						SCR Option	L	M	Minor	
						New Build Options	H	M	Major	
S	3	Access to Existing Trenches	**Cause:** Old trenches have cast iron and concrete coverings. **Effect:** May be difficult to remove and access trench for cable works. **Consequence:** CAPEX increase.	CAPEX	N	All Options	M	VL	Minor	
S	4	New Trench for HV Cable	**Cause:** Preliminary routing for HV cable. Requirement to cross existing trenching and other obstructions. **Effect:** Potential for scope growth/routing deviation to accommodate HV cable routing and obstructions. **Consequence:** CAPEX increase.	CAPEX	N	Electric Drive Options	H	L	Significant	
S	5	Construction Near Bacton Pipeline (Feeder 27)	**Cause:** Live main feeder line for Bacton is close to Redundant Plinth Area 1. Depth of Bacton line is unknown. Excavation methods are assumed. **Effect:** Potential for mechanically assisted excavations being limited. Increased manual excavation scope. **Consequence:** Schedule impact.	Schedule	N	New Build Options	M	L	Minor	
S	6	Extension of Drainage System	**Cause:** Current existing drainage system capacity and tie-ins unknown (local surface water drainage). **Effect:** Potential for scope increase. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options - 1 Unit	VL	VL	Negligible	For 1 unit, area is not much bigger than existing drainage capacity. Conservative approach for 2 unit new build.
						New Build Options - 2 Units	L	VL	Negligible	
S	7	Tie-in to Existing Vent Structure	**Cause:** New compressor vent stack to be tied into existing vent structure. Limited structural assessment to date. **Effect:** Additional support maybe required. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options	L	VL	Negligible	Limited new pipework. Existing Avon pipework can be removed. Vent structures require some revamp work, but not expected to be significant impact.
S	8	Blowdown Capacity	**Cause:** New build unit integration impacts wider production system perfomance and blowdown scenarios. **Effect:** Potential for impact on main vent capacity and size of sterile area. Potential for vent system expansion requirement. N.B. Issues would be with main blowdown vent rather than route from individual compressors. **Consequence:** CAPEX increase.	CAPEX	N	New Build Options	L	L	Minor	Vent and wider system capacity is already sized for existing Avon units. Not expected to be a risk. Sterile area is likely to be sufficient for addition of new units. Not changing overall blowodwn capacity from design.
S	9	Construction Disruption Due to Flooding	**Cause:** Areas of site prone to flooding. **Effect:** Potential for constructuion delay due to flooding. **Consequence:** Schedule delay.	Schedule	N	SCR Option	L	L	Minor	
S	10	Subsidence	Potential on-site subsidence. Not due to construct in areas subject to subsidence. Not considered to be a project risk.							
S	11	Crossing Bacton Pipeline - Construction Activities	**Cause:** Crossing of Bacton Pipeline is required by suction and discharge lines to new compressor. **Effect:** Risk of damage during construction to existing pipeline. **Consequence:** Production outage and CAPEX increase.	CAPEX & Production Outage	N	New Build Options	VL	VH	Minor	Production outage required to lift over live plant.
Operations										
O	1	Construction SIMOPs	**Cause:** SIMOPs with ongoing operations during construction works. **Effect:** Construction disruption. **Consequence:** Schedule delay.	Schedule	N	All Options	M	VL	Minor	Geotechnical survey data available.
O	2	Operational Disruption Due to Flooding	**Cause:** Areas of site prone to flooding. **Effect:** Potential for operational disruption due to flooding. **Consequence:** Production outage.	Production Outage	N	SCR Option	VL	VL	Negligible	High level flood maps. Infrequent issue and compressors are raised on plinths. Some actuated valves within pits. Flood risk assessment to support design.

Type	No.	Uncertainty Area	Description & Possible Outcome	Key Impact Area	Opportunity (Y/N)	Option Block	Risk Block Ranking			Other Comments
							Probability	Impact	Value Erosion	

HSSE and HSSE Approvals										
HSSE	1	Ammonia On Site	**Cause:** SCR requires use of aqueous ammonia. Potential for use of anhydrous ammonia. **Effect:** On site storage of re-agents or other dangerous substances if anhydrous ammonia selected as reagant. Additional safety and waste management measures required. **Consequence:** Increased CAPEX & OPEX.	CAPEX & OPEX	N	SCR Option	L	VL	Negligible	Will need bunded area and tank, 40 m3 allowed for under design. Sizing based on 1 tanker volume. Usage is very low. Current concentration is 24.5% aqueous ammonia.
HSSE	2	Fire Water Filling	**Cause:** Water connection required to re-fill fire system bottles. No connection provision at present for new units. **Effect:** Potential cost increase to provide adequate fire water tie-ins. **Consequence:** CAPEX impact.	CAPEX	N	New Units	VH	VL	Minor	4" water ring main for supply.
HSSE	3	Excessive Noise	**Cause:** New air blowers required (80kW) for SCR option, which are source of additional noise **Effect:** HSE and regulatory/permitting limitations on acceptable noise levels. Potential requirement to install additional noise mitigation measures. **Consequence:** CAPEX impact.	CAPEX	N	SCR Option	L	VL	Negligible	Equipment will be specified to within noise limitations. Low cost additional measures. Industrial area with overall noise levels.
HSSE	4	Ammonia Release to Atmosphere	**Cause:** Full dispersion modelling and slippage of ammonia not currently quantified. Potential for higher ammonia releases to vent. **Effect:** Requirement for additional ammonia mitigation measures to remain within consent limits. **Consequence:** CAPEX increase for additional equipment.	CAPEX	N	SCR Option	L	L	Minor	
HSSE	5	Air Pollution from GT Compressor	Part of determinstic results to compare against electric compressor. Not a project risk - fundamental selection driver.							
HSSE	6	Failure to Meet Emissions Requirements	**Cause:** Future changes to pollution requirements or stricter requirements applied at permitting stage. Energy efficiency requirements may come in. **Effect:** Inability to achieve required regulatory limits with selected scheme, or requirement for additional modifications to meet limits. Cost increase for replacement machine or modifications. **Consequence:** CAPEX increase.	CAPEX or OPEX	N	New Units - GT	VL	H	Minor	All options meet current requirements. Have a lot more flexibility with new units to meet changes in requirements than for retrofit options. If changes are required, then all options would require a significant change. Electric machines would need additional electricity from green source. Regulations are not typically applied retrospectively.
						New Units - Electric	VL	H	Minor	
						Retrofit	L	H	Significant	
HSSE	7	Presence of NORMS	**Cause:** NORMs experienced in wider network. **Effect:** Potential for construction delay due to cleaning and decontamination requirements. **Consequence:** Schedule delay.	Schedule	N	New Units	H	VL	Minor	Standard procedures in place to manage this. Testing to be scheduled as part of construction planning process.
HSSE	8	Pipework Isolation and Cleaning	**Cause:** Potential for contamination due to condensate, MEG etc. carryover from incoming sources. **Effect:** Potential for increased cleaning and decontamination of equipment and pipework. **Consequence:** Schedule delay.	Schedule	N	New Units	M	VL	Minor	
HSSE	9	Asbestos Management	**Cause:** Potential for asbestos contamination in existing cabs and trenches. **Effect:** Potential for increased decontamination of equipment. **Consequence:** CAPEX increase.	CAPEX	N	All Options	H	L	Significant	Part of UAP at present - no dedicated contingency.
HSSE	10	COVID/Pandemic Disruption	**Cause:** Potential for disruption to construction activities due to COVID or other pandemic/health issues in workforce. **Effect:** Potential for increased construction schedule. **Consequence:** Schedule increase.	Schedule	N	Retrofit Options	VL	L	Negligible	Larger workforce in place for new build option. Procedures in place to deal with COVID disruption.
						New Units	VL	M	Minor	
HSSE	11	Environmental Permitting Approvals	**Cause:** The CSRP technology is currently unproven for emissions reduction. **Effect:** Potential impact on obtaining environmental permit. **Consequence:** Schedule increase.	Schedule	N	CSRP	L	H	Significant	Probability ranked low but high impact as the CSRP option has not been implemented as an emissions compliant solution and there is a risk that the Environment Agency will not approve an environmental permit to operate without run-hour restrictions. NG are due to meet with the Environment Agency to discuss permitting for retrofit options on 5 October 2022.
Commercial, Political, Organisational										
CPO	1	Crossing Bacton Pipeline - Permitting	**Cause:** Crossing of Bacton Pipeline is required by suction and discharge lines to new compressor. Permitting required from operations. **Effect:** Risk of not obtaining permit due to dropped object concerns, loss of containment etc. Risk of concept recycle. **Consequence:** Schedule delay.	Schedule	N	New Build Options	VL	H	Minor	Not currently assumed to be on critical path. May have to wait for extended period for production outage in feeder to be available. Been done for other projects.
CPO	2	Catalyst Sole Supplier	**Cause:** Single supplier for SCR catalyst. **Effect:** Tied into single supplier, with potential for increased costs, supply security issues or inability to source supplies. May need to alter unit to accommodate alternative supplier. **Consequence:** CAPEX increase & production outage.	CAPEX & Production Outage	N	SCR Option	L	L	Minor	Generic technology by catalysts may be proprietary in terms of design compatibility. Framework in ducting may not be compatible with alternative suppliers.
CPO	3	Rental of Land for Construction	**Cause:** Land rental required for construction phase for new units. Includes offices, car parking etc. to accommodate construction workforce. No cost allowance and no negotiations undertaken. **Effect:** Potential for cost escalation. Potential for schedule delay. **Consequence:** CAPEX & schedule increase.	CAPEX & Schedule	N	New Units	M	L	Minor	Have data for land requirements.
CPO	4	Increase to Station Flow Capacity	**Cause:** Potential for future increase to overall station flow capacity. **Effect:** Modifications required to accommodate capacity changes. **Consequence:** Future cost increase. General site risk. Not considered to be a project risk.							
CPO	5	Change to Hydrogen Network	Opportunity for future change to hydrogen production.	Revenue	Y	All Options				
CPO	6	Coordination with Other Projects	Potential to coordinate with decommissioning and other projects. Optimise workforce etc.	CAPEX	Y	New Build Options				
CPO	7	Coordination and Alignment with External Stakeholders	**Cause:** Coordination with external stakeholders required (ofgem etc.). **Effect:** Potential delay with regard to gaining alignment on preferred option. **Consequence:** Schedule delay.	Schedule	N	New Build Options	H	H	Critical	Ofgem are likely to require lost cost option to reduce cost to consumer.
						Retrofit Options	VL	M	Minor	
CPO	8	Coordination and Alignment with Internal Stakeholders	**Cause:** Coordination with internal stakeholders required. **Effect:** Potential delay with regard to gaining alignment on preferred option. **Consequence:** Schedule delay.	Schedule	N	New Build Options	VL	M	Minor	Original cost estimates were based on 2019 business plan - risk of issue with internal stakeholders due to cost inflation.
						Retrofit Options	H	H	Critical	
CPO	9	Network Outage Scheduling and Coordination	**Cause:** Planned network outage period is currently unknown. **Effect:** Allowed outage may be shorter than anticipated or at less optimum time for construction. **Consequence:** Schedule delay.	Schedule	N	New Build Options	H	H	Critical	Currently assuming that April - September period is available. Shorter duration required for retrofit option and more float. However, outage only required for new build option tie-ins - other work can be undertaken during production.
						Retrofit	M	M	Significant	
CPO	10	Land Use / Extension	**Cause:** New units require extension of existing site boundary. Permitting and consent requirement. Environmental and commercial negotiations. **Effect:** Potential for delays managing multiple stakeholders and gaining consent. **Consequence:** Schedule delay.	Schedule	N	New Build Options - 1 Unit	L	H	Significant	Single unit is within existing NG land ownership. Dual unit has higher footprint requirement - up to limit of existing land ownership. Can't start construction until permitting is in place. Both options needs careful planning and management.
						New Build Options - 2 Units	M	H	Major	
CPO	11	Geopolitical Issues	**Cause:** Country specific and worldwide geopolitical issues affecting equipment supply and workforce. **Effect:** Potential for cost escalation. Potential for schedule delay. **Consequence:** CAPEX & schedule increase.	CAPEX	N	Retrofit Options	H	M	Major	Economic sensitivities to be conducted.
						New Build Options	H	VH	Critical	

APPENDIX B WORKSHOP PRESENTATION

Appendix B
National Grid Risk W