nationalgrid

FEED REPORT

20840-EN-RPT-000-0006 Rev 1

WORMINGTON MCPD FEED FEASIBILITY

NATIONAL GRID

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Document Approval

Rev	Date	Description	By	Checked	Approved
A	17/03/2022	Issued for Internal Review	WA	PK	TCW
0	18/03/2022	Issued for Review (IFR)	WA	PK	TCW
1	04/05/2022	CLIENT Comments Incorporated – Final Issue	DKM	PK	TCW

CONTENTS

1. EXECUTIVE SUMMARY

1.1 Overview

This scope of this MCPD FEED Feasibility study is to:

- Identify a full set of options (the “Long List”) that will secure future emissions compliant operation of Wormington Compressor Station, meeting both current and (forecast) future capability requirements based on the process duty specification for each scenario defined by CLIENT in the PDS supplied.
- Carry out an initial screening of Long List options to identify a Short List of feasible options for to be taken forward for development
- Develop the engineering design for each shortlisted option to a suitable level of definition and use this to develop ±30% cost estimate
- Provide engineering inputs to support CLIENT in developing whole life cost benefit analysis and Best Available Techniques (BAT) assessments for each option
- Identification of key risks and assumptions including quantification and provision of evidence that they are of sound and credible basis
- Support CLIENT in responding to Ofgem queries via the supplementary question (SQ) process during the reopener window

1.2 Phase 1 Long List Options

The full set of Long List options considered were:

- 500 hrs Avon - Limiting the time using the gas turbines per year in accordance with the MPCD allowable operational options. All cases require operations for more than 500 hours per year, so this option was not considered further.
- Derated Avon turbine - Derating is when a system or component is operated below its normal operating limit by means of proper control systems. This reduces the thermal power demands and the fuel usage and therefore the NOx emissions are decreased. This is obvious from the test results as well as from the principles of combustion and energy equations. Additionally, this reduces the deterioration rate of the component which extends the component’s life in addition to enhancing the reliability.
- SCR (Selective Catalytic Reduction) - A well-established method of reducing emissions of oxides of nitrogen (NOx) from combustion gases, including gas turbine exhaust applications. Uses an ammonia injection system and catalyst to reduce NOx formation.
- Retrofit DLE - Lean premix combustion aims to reduce combustion temperatures to reduce NOx formation. Air and fuel mix ratios are carefully controlled to achieve lower combustion temperatures and reduced NOx formation. Was not previously available for Avon turbines however a recent development has changed this. A retrofit DLE Avon turbine prototype being tested in summer 2021. Potential full winter test 2022/23.
- New GT DLE - Complete new Compressor Train(s) incorporating the latest DLE technology to replace the existing Avon unit(s).
- New VSD - New compressor train to be installed to replace units A/B. This will result in next to no emissions as the power will come from electricity, however, GT back up to the existing electric VSD is required to ensure compression capability is available in the event of an electrical power outage and as a result this option has been discounted

National Grid are currently assessing a PARCA received from South Hook LNG which would increase the compression capability required at Wormington compressor station. The Western Gas project is considering different levels of investment to accommodate the flows associated with this PARCA. Wormington MCPD options are being assessed against 5 sets of process conditions which consider compression capability with and without the PARCA flows and different levels of pipeline and compressor upgrades on the wider network.

The full scope of the options included in the long list is noted in this report and may include: compressor re-wheeling; equipment uprating to accommodate additional flows associated with the Western Gas Project, and balance of plant enhancements.

In Phase 1 of the study each of the options was reviewed against a list of evaluation criteria to identify preferred option(s).

During Phase 2 of the study a deeper analysis of the fundamental issues underpinning each option was conducted in order to confirm the Phase 1 option selection or highlight any residual risks or concerns associated with each option.

1.3 Phase 2 Short List Options

Following an initial screening, the Long List of options was reduced to the following Short List to be taken forward for further development:

- Derated Avon turbine
- Retrofit DLE
- New GT DLE
- Rewheeled & uprated DLE Avon

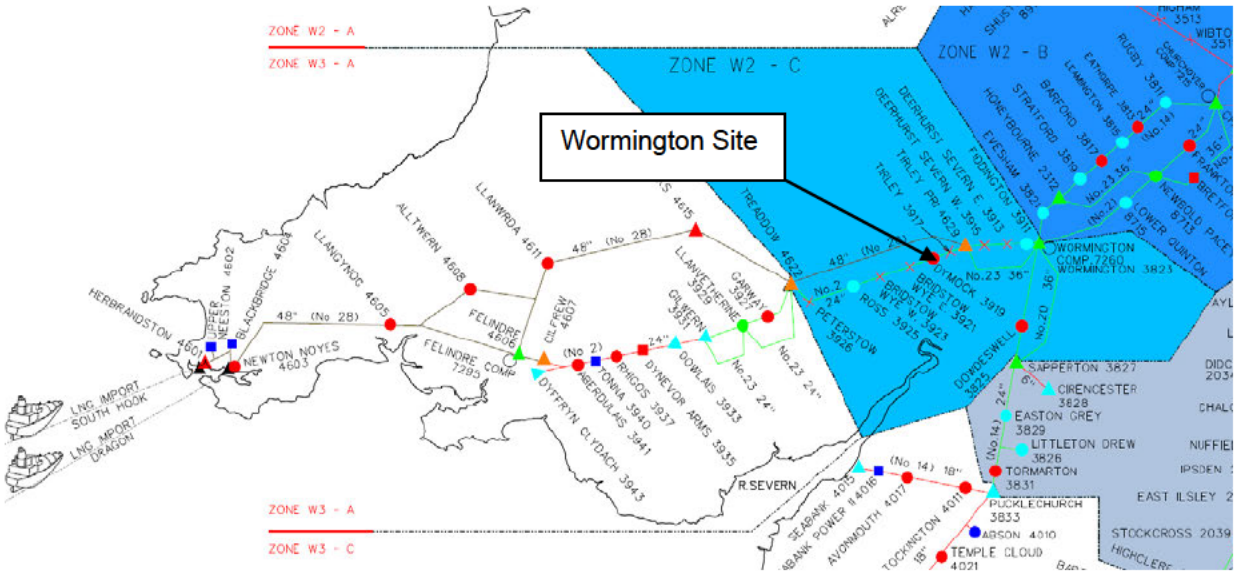
These Short List options were taken forward for further development to a suitable level of definition for use in developing a ±30% cost estimate.

Conclusions and recommendations are presented in Section 16.

2. INTRODUCTION

2.1 General

The Wormington compressor station, commissioned in 1990, is critical in transporting National Transmission System (NTS) gas entering through the Milford Haven terminal. The site is situated in Gloucestershire at the junction in the gas National Transmission System (NTS) shown in the figure below. The station maintains flow through six (6) feeders connecting at the multijunction located at the east of the Wormington site.



The station has been subject to various modifications and upgrades over the past 30 years. Notably in 2009 the station underwent modifications as part of the South West Expansion Project to support flows onto the NTS from the aggregated system entry point (ASEP) at Milford Haven Terminal which includes South Hook and Dragon LNG import terminals.

In its current configuration the site can support bi-directional flow and compression is provided by two (2) Rolls Royce (now Siemens) Avon MK1533 gas turbine driven compressor units (referred to as Units A and B) and a Siemens variable speed drive electrically driven compressor unit (Referred to as Unit C). The VSD (unit C) was commissioned in 2009 as part of the South West Expansion Project and is the lead unit on site. Units A and B are utilised either when Unit C is unavailable due to planned or unplanned outages or when the flow through the site exceeds the capacity of Unit C, typically when flow from Milford Haven ASEP is high and demand in South Wales is low.

The Compressors that drive compression for gas from the Wormington Terminal breach the Medium Combustion Plant Directive (MCPD) which come into effect from the 1st January 2030. Compliance with MCPD is the primary driver for investment at Wormington with the current compression facilities uncompliant with the new legislation based on the current operational model.

As part of the RIIO-2 process, National Grid proposed to Ofgem to install two new 15MW compressors on site. The response to these proposals recognised the need to ongoing compression, however, further work was required to refine the cost estimate associated in order to protect consumers. As such, National Grid now look to conduct a holistic options selection process and detailed cost estimate to validate the proposed solutions. The outcomes of this FEED Feasibility are to be summarised within an Ofgem Re-Opener submission in May 2022 for funding consideration.

National Grid is therefore seeking to identify the best enduring solution until 2050 as per UK's Net Zero Carbon Emissions strategy and the recent Future Energy Scenarios (FES) developed for Wormington Terminal, ensuring safe, reliable and compliant operation in line with current and future stakeholder needs.

This Service will look to address this need and seek to refine the presented BATs and consider any additional options for consideration to consider the best value option to redevelop the terminal for its current and future gas flows and use. Already identified techniques include new units, control system restricted performance, Selective Catalytic Reduction (SCR) and other abatement technologies for existing units to meet emission limits, retrofitting compliant engines along with new configurations to maximise the operational flexibility of the site. Other key areas of focus for the study include

- Single point failure for VSD,
- Compression Backup Options,
- Asset Health issues and expenditure,
- Hydrogen Resilience / Compatibility,
- Construction/Site Carbon Neutrality,
- Reuse/Recycle of Existing Equipment,
- Risk identification,
- Cost and Programme (+/-30%),
- Support to the CBA
- Feed Study Report
- Support to National Grid Re-Opener Submission and resultant Technical Queries
- Optional Scope for Procurement Support

CONSULTANT appreciate the importance of Ofgem's role in balancing the necessary investments of operators against the protection of the consumer. This means for a proposed development at Wormington to be accepted, there is a need for full demonstration that all options with potential have been considered and critically evaluated. Furthermore, the options selection needs to progress in an open-book and understandable method which is accessible to all without need for detailed commentary or explanation. The proposed methodology needs to evaluate the ideas against robust criteria so the final best value solution can be accepted.

CONSULTANT understand from our knowledge of macro issues affecting the future UK energy landscape coupled with the details from the study specifications that we need to be creative to develop a wide range of potential solutions. We recognise the need to provide a fresh approach, apply broad engineering knowledge to elaborate ideas, assess option strengths, weaknesses, and risks. As a team, we will have the empathy to assimilate key stakeholder concerns and thereby devise a solution that can respond fully to all of the imposed constraints and leverage all possible solutions.

2.2 Document Purpose

The purpose of this document is as follows:

- To summarise the work and outputs from the study and present the conclusions and recommendations identified
- To append all the supporting documentation and drawings which support the study report summary, conclusions, and recommendations

3. REFERENCES

3.1 Precedence

As per the contract between NG and Consultant the following precedence is specified:

In the event of any conflict or inconsistency between the documents making up the contract, they shall take precedence as stated below (in descending order of priority):

(i) this form of agreement;

(ii) the Contract Data - Part one;

(iii) the *conditions of contract* (including the *additional conditions of contract*);

(iv) the Scope and any documents referred to in the Scope;

(v) the Contract Data - Part two; and

(vi) any other document forming part of the contract.

3.2 Statutory Regulations

The Control of Major Accident Hazards (COMAH) Regulations

3.3 CLIENT Design Guides

See Project Execution Plan document number 20840-PM-PEP-000-0001

3.4 Codes and Standards

Design and performance shall be in accordance with the latest applicable editions of international Codes and Standards listed in the project document 20840-EN-LST-000-0001 Codes, Standards and Technical Specifications.

4. DEFINITIONS

CLIENT	National Grid
CONSULTANT	Entity appointed by the CLIENT, to carry out defined engineering duties on behalf of the CLIENT – [redacted] Limited ([redacted])
CONTRACTOR	Sub-Contractors / Specialists Contractors to be appointed by the PRINCIPAL CONTRACTOR
SUPPLIER	Supplier of Equipment or Materials

Throughout this document the following terminology is used:

"may"	signifies a feature, which is discretionary in the context in which it is applied;
"must"	signifies a legal or statutory requirement;
"shall"	signifies a requirement made mandatory by this document;
"will"	signifies a feature, which the PRINCIPAL CONTRACTOR / SUPPLIER may assume to be already present.

5. ABBREVIATIONS

The following abbreviations are used within this document:

Abbreviation	Description
AC	Alternating Current
API	American Petroleum Institute
ASEP	aggregated system entry point
BAT	Best Available Technique
BIM	Building Information Modelling
C&I	Control and Instrumentation
CAPEX	Capital expenditure
CBA	Cost Benefit Analysis
CDM	Construction Design and Management
CEMS	Continuous Emissions Monitoring System
COMAH	Control of Major Accident Hazards
CSRP	Control Systems Restricted Performance
DB	Distribution Board
DLE	Dry Low Emissions
DMP	Design Management Plan
ESD	Emergency Shut Down
F&G	Fire and Gas
FEED	Front End Engineering Design
FES	Future Energy Scenarios
FID	Financial Investment Decision
GT	Gas Turbine
HAZCON	Hazards in Construction
HAZID	Hazard Identification
HSE	Health, Safety and Environmental
HV	High Voltage
HVAC	High Voltage Alternate Current
LNG	Liquefied Natural Gas
LVAC	Low Voltage Alternate Current
MCC	Motor Control Centre
MCPD	Medium Combustion Plant Directive (MCPD)
NG	National Grid
NOx	Nitrous Oxides
NTS	National Transmission System
OPEX	Operating Expenditure
PDS	Process Design Specifications
PLC	Programmable Logic Controller
RAMS	Risk Assessment Method Statements
SCADA	Supervisory control and data acquisition
SCR	Selective Catalytic Reduction

Abbreviation	Description
SOL	Safe Operating Limits
TBE	Technical Bid Evaluation
TCS	Trip Control Supervision
UPS	Uninterruptable Power Supply
VSD	Variable Speed Drive

6. STUDY BACKGROUND

6.1 Basis & Methodology

The basis and scope of the study was defined by CLIENT within the “Project Specific Scope” (PAC1050295-01-7260-NGG-0007).

Following a detailed review of the study specifications and objectives, three logical and sequential work phases were identified to progress the study. Phase 0 work established the necessary management, design, and safety framework for the services along with the orderly assembly of data for review and use in developing the succeeding activities.

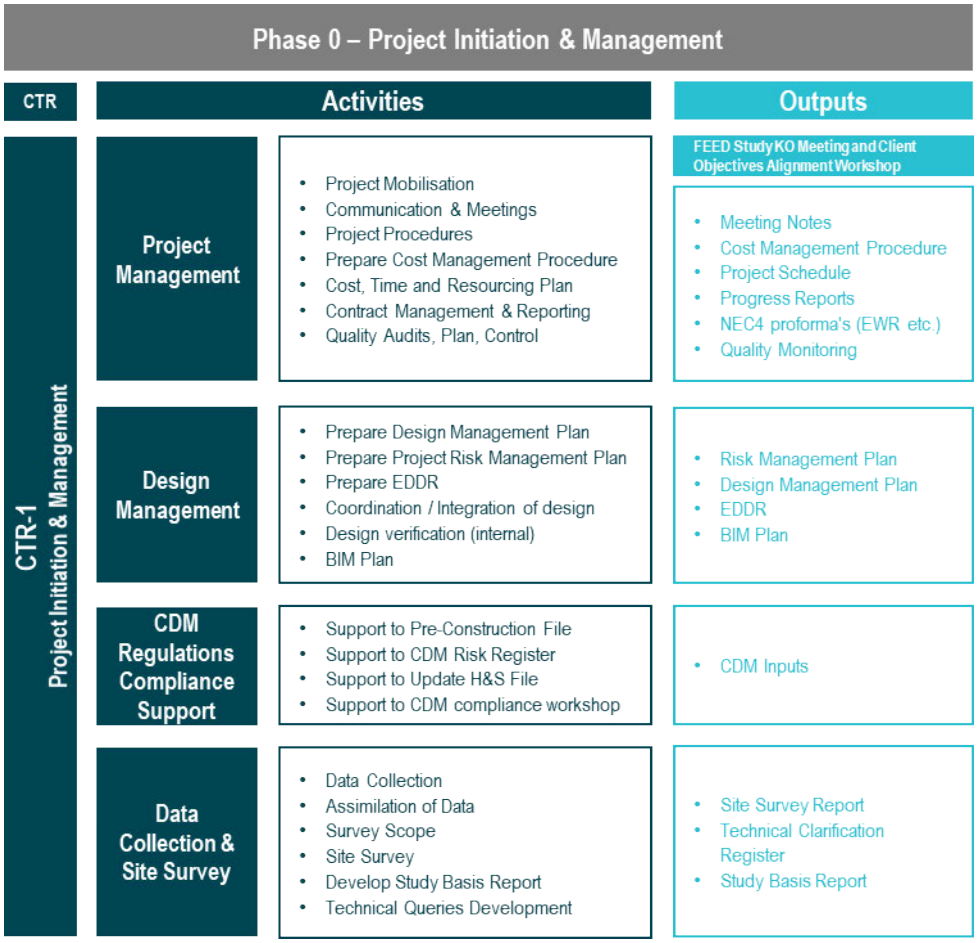


Figure 6-1: Phase 0 Workflow

Phase 1 of the study was focussed on investigation and identification of BAT Options as well as identifying new additional options and was fundamental to all further work. The level of analysis of options in phase 1 was necessarily of a coarser definition than the phase 2 conceptual engineering work, but of sufficient detail to allow a reasoned choice between the options.

At the Phase 1 evaluation workshop, a short list of options was produced and during Phase 2 these options were examined in detail. A final short list evaluation workshop was then conducted to identify the sorted listed options for the final stage of engineering.

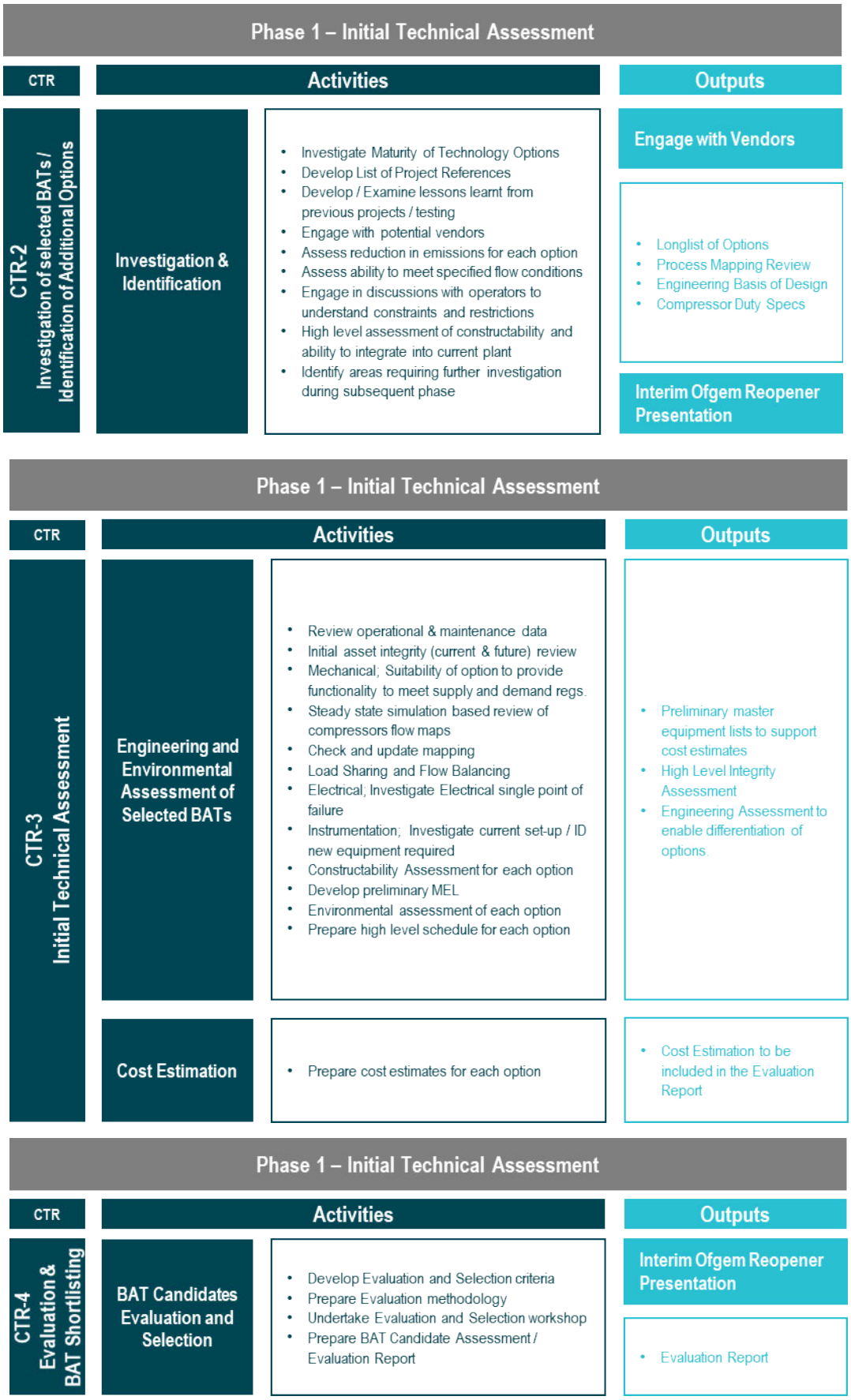


Figure 6-2: Phase 1 – CTRs Breakdown

6.2 Key Study Elements

Data was provided by CLIENT to CONSULTANT. The NG 3D model in native Autocad 3D file was provided for update for the project scope. Other specific site data has been provided by CLIENT in the form of site records of asset conditions. The Consultant conducted a site visit on 18/11/2021 for a visual survey of the areas of interest. This phase of work comprised tasks and activities concerned with the correct setting up of the project and thereafter maintaining its orderly management until project close.

Consultant held a kick-off meeting with CLIENT on 22/11/2021 where the draft schedule and planned meetings were reviewed to achieve alignment. Modifications to the schedule were agreed to allow the issue of the final project schedule following the meeting.

The following activities occurred at the kick-off meeting:

Joint review with CLIENT of key project management elements including

Safety, Joint working methods, key contacts and details, reviews and workshops planned, Schedule, deliverables listing, risk, confirmation of overall objectives for study work, validation of proposed methods to achieve them and any identified improvements, meetings, contract management and any issues, communications plan

Following award of contract, the DMP was submitted to CLIENT for review and acceptance.

The DMP sets out the structures, protocols, processes, and procedures to be followed, to meet CLIENT requirements for the FEED Feasibility as required by the scope in accordance with CLIENT standards and statutory obligations. Additionally, the DMP and its supplemented documents include procedures in order to avoid situations where there is missing information, poorly communicated information, inconsistencies between documentation, poor resource allocation and poor decision making due to inadequate information. This also includes the digital engineering activities, the BIM model, and the exchange of information.

All the required engineering and design management activities, as detailed in the CLIENT Project Specific Scope, Stakeholder and Design Activity Schedule and Schedule of Required Deliverables, were integrated within the DMP. This included the CLIENT Formal Process Safety Assessment in accordance with T/PM/HAZ/9

6.3 Design Review – Conducted on 17/02/2022

The list of Shortlisted options was discussed, with options clarified to clearly indicate where existing compressors will be maintained alongside new or modified ones. Short listed options as agreed in the design review workshop are shown below.

SHORT LISTED OPTIONS - DESIGN REVIEW 17.02.2022

			Combinations						Comments
		Initial Option Number ------>		1	2	4	5	7	
		Scenario	Existing GT/Comp	Derated Avon/ CSRP	500 hrs	Retrofit DLE	New GT/Comp	Rewheel (Note 1)	
Case 1	C10	New GT/Comp					✓ (2x50%)		VSD is backup
		Existing GT (Derated) + New GT/Comp	✓	✓ (One)			✓ (1x60%)		VSD is backup
		2 x Existing GT in parallel + Retrofit DLE	✓			✓ (Two)			VSD is backup
		2 x Existing GT in parallel + 500 hrs	✓		✓ (Two)				Case for Ofgem information only. Not for CBA. Engineering not required to develop. Will be covered in a qualitative manner in process evaluation and FEED reports. VSD is backup
	C10 ALTERNATIVE	Existing GT/Comp	✓						Proposed NEW duty case based on Process Simulation to define optimised operating points with respect to load sharing and to ensure that MCPD limits are met e.g through removal of duty point C10 which operates for 29 hours per year. Will be covered in a qualitative manner in process evaluation and FEED reports.
Case 2	P11	New GT/Comp					✓ (2x50%)		Existing VSD cannot be used as backup for this operating point. Sparing philosophy to be agreed and described in FEED report.
		Existing GT/Comp rewheel with DLE	✓			✓ (One)	✓ (1x60%)	✓	
Case 3	R2	New GT/Comp					✓ (2x50%)		Existing VSD cannot be used as backup for this operating point. Sparing philosophy to be agreed and described in FEED report.
	R2 ALTERNATIVE	Existing GT/Comp rewheel with DLE	✓			✓ (Two)		✓	Proposed NEW duty case based on Process Simulation to define optimised operating points with respect to load sharing and to ensure that MCPD limits are met. VSD is backup
Case 4	P23	Existing GT (Derated) + New GT/Comp	✓	✓ (One)			✓ (1x60%)		Will be covered in a qualitative manner in process evaluation and FEED reports. VSD is backup.
	P23 ALTERNATIVE	Existing GT (Retrofit DLE)	✓			✓ (Two)			Proposed NEW duty case based on Process Simulation to define optimised operating points with respect to load sharing and to ensure that MCPD limits are met. Will be covered in a qualitative manner in process evaluation and FEED reports. VSD is backup.
Case 5	P31	Existing GT (Derated) + New GT/Comp	✓	✓ (One)			✓ (1x60%)		Will be covered in a qualitative manner in process evaluation and FEED reports. VSD is backup.
	P31 ALTERNATIVE	Existing GT (Retrofit DLE)	✓			✓ (Two)			Proposed NEW duty case based on Process Simulation to define optimised operating points with respect to load sharing and to ensure that MCPD limits are met. Will be covered in a qualitative manner in process evaluation and FEED reports. VSD is backup.
Notes:	1. Options for compressor rewheeling to be comfired by OEM								

Figure 6-3: Revised Short Listed Options

The notes of design review are presented in MOM in APPENDIX D – DESIGN REVIEW NOTESPHASE 1 SHORT LIST OPTIONS SELECTION

6.4 Overview

The selection of techniques and practices to protect the environment should achieve an appropriate balance between benefits to the environment as a whole and the costs incurred by the operator. The final options of techniques will be evaluated and selected for short-listing by Client (National Grid) and Consultant based on Client's BAT (Best Available Technique) assessment / tool and on Consultant's multi-criteria method.

As part of the Consultant methodology a Multi-Criteria Decision Making (MCDM) technique was employed to review the initial list of options and to identify the best options against an agreed list of criteria.

The main Options that have been identified are the following:

- 500 hrs Avon - Limiting the time using the gas turbines per year in accordance with the MPCD allowable operational options. All cases require operations for more than 500 hours per year, so this option will not be considered.
- Derated Avon turbine- Derating is when a system or component is operated below its normal operating limit by means of proper control systems. This reduces the thermal power demands and the fuel usage and therefore the NOx emissions are decreased. This is obvious from the test results as well as from the principles of combustion and energy equations. Additionally, this reduces the deterioration rate of the component which extends the component's life in addition to enhancing the reliability.
- SCR (Selective Catalytic Reduction) - A well-established method of reducing emissions of oxides of nitrogen (NOx) from combustion gases, including gas turbine exhaust applications. Uses an ammonia injection system and catalyst to reduce NOx formation.
- Retrofit DLE- Lean premix combustion aims to reduce combustion temperatures to reduce NOx formation. Air and fuel mix ratios are carefully controlled to achieve lower combustion temperatures and reduced NOx formation. Was not previously available for Avon turbines however a recent development has changed this. A retrofit DLE Avon turbine prototype being tested in summer 2021. Potential full test win winter 2021/22.
- New GT DLE - Very similar system however a new compressor train to replace units A/B will be installed with the DLE technology
- New VSD - New compressor train to be installed to replace units A/B. This will result in next to no emissions as the power will come from electricity.

Additional Options

- HV supply – single point of failure
- Rewheeled & uprated DLE Avon- Re-wheeling of the compressors, included the replacement of internal parts related to the aero performance of the machine so that different process conditions are accommodated. It will be investigated at a later stage
- Recycle loop enhancement- Operational improvements, such as off-site recycling and / or other modifications, could be considered as an option for low flow cases. Will be investigated at a later stage if needed
- BoP enhancements- No systems have been identified yet in relation to the MPCD emissions compliance

- Pipeline only - This is related to network optimisation and that would be part of another study

6.5 Methodology

The Consultant issued the procedure 20840-PM-PRC-000-0002 “Shortlist Criteria & Methodology” describing the methodology for the option selection process.

The workshop for option selection consisted of three phases of work:

- Pre-Workshop
- Workshop
- Post-Workshop

6.6 Pre-Workshop

As part of the preworkshop activities a meeting was held with NG to discuss the methodology, workshop objectives and initial listing of criteria to use in the selection process. The workshop methodology is illustrated in the following figure:

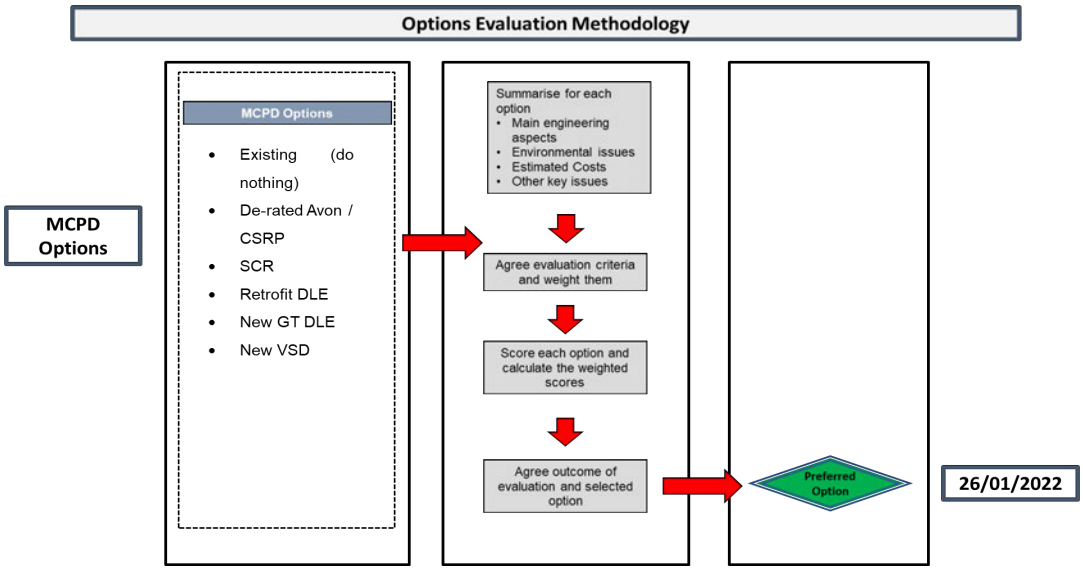


Figure 6-4: Short List Workshop Methodology

A preworkshop information pack was prepared and issued to the persons identified from both parties to attend.

The workshop date and timing were reviewed and agreed and an invitation to participants issued.

The objectives of the workshop were:

- review the concepts of the current options within the workshop
- evaluate the options using an agreed list of criteria
- identify the best option that represents the best current response to the criteria used

The workshop used a multiple criteria decision making (MCDM) methodology that is described in the procedure issued as part of the pre-workshop preparations. The workshop examines the following items

- To review each option in summary against these main elements

  - Engineering concept and risk
  - Environmental and Sustainability
  - Costs (CAPEX and OPEX)
  - Other relevant issues
- Agree a list of evaluation criteria
- Carry out a criteria-weighting process to agree the team's assessment of relative importance for this study
- Evaluate the options by each workshop team member proposing raw scores per option
- Input scores and allocate criteria weightings to arrive at an overall final weighted score per option and identification of a preferred option
- Review outcome and consider any adjustments and conclude

6.6.1 Constraints applied to the Workshop

The following constraints were identified for any acceptable idea to comply with:

- Avoid infringing the MCPD directive
- Must be able to demonstrate benefits in terms of emissions and represent 'good value'

6.7 Workshop

6.7.1 Venue

The Workshop Venue was virtual using Microsoft Teams.

6.7.2 Duration

The Workshop was held between the hours 09:00-13:30 on 26/01/2022. The time and date were discussed with CLIENT and agreed with them in pre-workshop discussions.

6.7.3 Workshop Team

The workshop team was made up of key representatives from the CLIENT and CONSULTANT. The workshop report gives a list of those invited and attending the workshop.

6.7.4 Workshop Activities

6.7.4.1 Option Review

A review of the work to date of each of the main options was presented. This was used to establish a common level of understanding for all participants prior to the MCDM phase of work. The information is shown in the presentation in the Workshop Report 20840-PM-RPT-000-0007 which is included in **APPENDIX A -** .

In summary the options being considered in the workshop were as follows:

	OPTION
0	500 hours Avon
1	Derated Avon turbine
2	SCR (Selective Catalytic Reduction)
3	Retrofit DLE (inc 1533&1535)
4	New GT DLE
5	New VSD

Figure 6-5: Phase 1 Options

6.7.4.2 Team Discussions

The presentation of work on the options to date generated useful discussions between team members and some comments are summarised below:

- Re-wheeling of Avon needs data and discussions with vendors
- Re-use of an Avon will also include major asset health work
- CONSULTANT analysis resulted in some comments as follows
  - PDS 1 – query on the gas turbine power capability at these conditions
  - PDS 2 – the existing compressors can't deliver the required duty
  - PDS 3 – case of retrofit DLE option or re-wheel to be considered
  - PDS 4 – no comments
  - PDS 5 – compressors will do duty point but emissions too close to 50MW limit
- CONSULTANT commented that the analysis results are based on data provided by CLIENT
- Layout was considered by CLIENT as a critical part of option selection; any move outside the current site boundary would cause cost and consent issues
- Site Control System will be replaced under another project by CLIENT and costs should be checked to ensure no double counting if considered in this study
-

6.7.4.3 Criteria for Evaluation

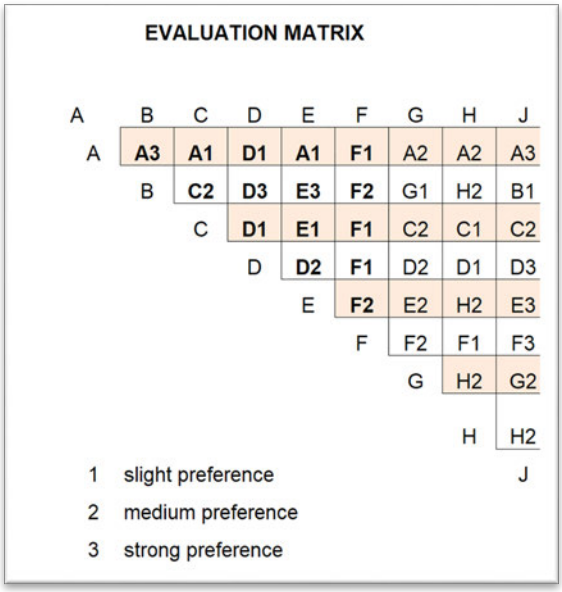
A pre-workshop list of 12 criteria was discussed and a final listing of nine items agreed following some re-wording and also deletion of items not considered relevant. The final agreed list was as follows:

A	NOx emissions
B	Environmental impact (noise, planning,etc)
C	Technical Risk (integration ease, proven, (extg. On NTS),
D	CAPEX (for ±50% range)
E	OPEX (as variances from the existing OPEX) inc fuel gas cost
F	Operational assurance (inc operational flexibility to meet PDS)
G	Asset Health issues / obsolescence
H	Constructability (Inc constn sched) / Site Carbon Neutrality
J	Future Proofing (headroom to emission limits + hydrogen compatibility + efficiency)

Figure 6-6: Workshop Agreed Criteria

6.7.4.4 Criteria Weighting

A key stage in MCDM is to weight the agreed criteria using pairs analysis. This can generate useful discussions on what and why one item is considered more important than another. The outputs from this work are shown below.



EVALUATION MATRIX

A	B	C	D	E	F	G	H	J
A	**A3**	**A1**	**D1**	**A1**	**F1**	A2	A2	A3
B		**C2**	**D3**	**E3**	**F2**	G1	H2	B1
C			**D1**	**E1**	**F1**	C2	C1	C2
D				**D2**	**F1**	D2	D1	D3
E					**F2**	E2	H2	E3
F						F2	F1	F3
G							H2	G2
H								H2
J								

1 slight preference

2 medium preference

3 strong preference

Figure 6-7: Criteria weighted following pairs analysis in workshop

Note that for criteria J a nominal vote of one was added to give it some weight. The weighted criteria are shown in the next figure.

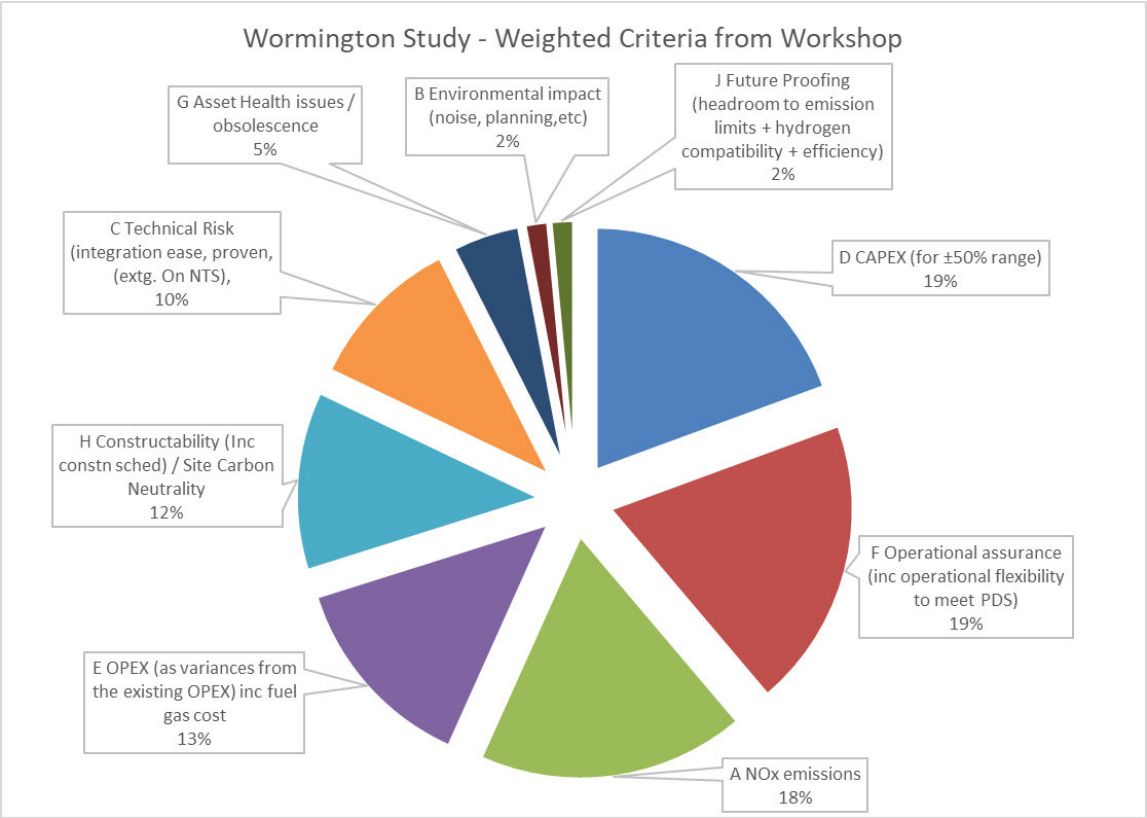


Figure 6-8: Weighted Criteria

6.7.4.5 Raw Scores

Voting slips were issued to all attendees and returned by email. These were used by the team to provide their assessment of how well each option is considered to perform against each of the criteria by assigning a score from 1 to 9. The summary average of scores (total scores per criteria / no. of voters) is shown in the next figure.

Workshop - Raw Score averages of votes cast for each option against criteria

	OPTION TITLE		NOx emissions	Environmental impact (noise, planning etc)	Technical Risk (integration aspects, proven fleet eg On NTS)	CAPEX (for ±50% range)	OPEX (ex variances from the existing OPEX) inc fuel gas cost	Operational assurance (inc operational flexibility to meet PDB)	Asset Health issues / obsolescence	Constructability (inc constrained) / Site Carbon Neutrality	Future Proofing (headroom to emission limits + hydrogen compatibility + efficiency)
0	500 hours Avon	raw score	2.36	6.55	6.91	8.64	3.91	1.55	2.27	7.18	1.45
1	Derated Avon turbine	raw score	4.45	6.82	6.64	7.00	3.73	2.64	2.64	6.36	2.09
2	SCR (Selective Catalytic Reduction)	raw score	6.36	4.82	4.09	4.64	3.36	3.91	4.00	4.09	5.18
3	Retrofit DLE (inc 1533&1535)	raw score	5.91	6.09	4.00	5.36	3.45	6.00	4.00	4.82	4.91
4	New GT DLE	raw score	7.27	5.36	7.27	2.64	5.64	7.82	6.91	5.27	7.18
5	New VSD	raw score	8.91	4.82	7.09	2.45	5.73	7.27	7.45	3.82	8.18

Figure 6-9: Summary of Team Raw Votes for Options

6.7.4.6 Overall Evaluation

The raw scores were inserted into the MCDM spreadsheet with the weighted criteria to give a final assessment of the current options as follows:

	OPTION TITLE		NOx emissions	Environmental impact (noise, planning etc)	Technical Risk (integration aspects, proven, (e.g. On NTS);	CAPEX (for ±50% range)	OPEX (ex variances from the existing OPEX) inc fuel gas cost	Operational assurance (inc operational flexibil ity to meet PDB)	Asset Health issues / obsolescence	Constructability (inc constrained) / Site Carbon Neutrali ty	Future Proofing (headroom to emission limits + hydrogen compatibility + efficiency)	otal	ranking
	Weighted Criteria		0.175	0.015	0.104	0.194	0.134	0.194	0.045	0.119	0.015		
0	500 hours Avon	weighted score	0.42	0.10	0.72	1.68	0.53	0.30	0.10	0.86	0.02	4.72	5
		raw score	2.36	6.55	6.91	8.64	3.91	1.55	2.27	7.18	1.45		
1	Derated Avon turbine	weighted score	0.80	0.10	0.69	1.36	0.50	0.51	0.12	0.76	0.03	4.87	4
		raw score	4.45	6.82	6.64	7.00	3.73	2.64	2.64	6.36	2.09		
2	SCR (Selective Catalytic Reduction)	weighted score	1.14	0.07	0.43	0.90	0.45	0.76	0.18	0.49	0.08	4.49	6
		raw score	6.36	4.82	4.09	4.64	3.36	3.91	4.00	4.09	5.18		
3	Retrofit DLE (inc 1533&1535)	weighted score	1.06	0.09	0.42	1.04	0.46	1.16	0.18	0.58	0.07	5.06	3
		raw score	5.91	6.09	4.00	5.36	3.45	6.00	4.00	4.82	4.91		
4	New GT DLE	weighted score	1.30	0.08	0.76	0.51	0.76	1.52	0.31	0.63	0.11	5.97	2
		raw score	7.27	5.36	7.27	2.64	5.64	7.82	6.91	5.27	7.18		
5	New VSD	weighted score	1.60	0.07	0.74	0.48	0.77	1.41	0.33	0.46	0.12	5.98	1
		raw score	8.91	4.82	7.09	2.45	5.73	7.27	7.45	3.82	8.18		

Figure 6-10: Overall Option Evaluation Sheet

6.8 Post Workshop

The results from the evaluation resulted in the following ranking of each option:

Option Number	Option	Workshop score	Rank
5	New VSD	5.98	**1**
4	New GT DLE	5.97	**2**
3	Retrofit DLE (inc 1533&1535)	5.06	**3**
1	Derated Avon turbine	4.87	**4**
0	500 hours Avon	4.72	**5**
2	SCR (Selective Catalytic Reduction)	4.49	**6**

Table 6-1: Phase 1 Option Ranking

In reviewing the results, the workshop evaluation showed a narrow band of scores covering all the options with the two top ranked ones only 0.01 different.

It was agreed that these results suggested that a greater definition of the options was necessary to make a better judgement.

Other comments were summarised as:

- SCR option needs equipment installed within the site boundary
- SCR should have minimum extra work
- What can be done within the existing site footprint?
- PDS scenarios may need to be considered for each option to help refine layouts and CAPEX
- Better definition of the ‘problem’ required including possibly consideration of the wider network

These observations were used in shaping the remaining work for Phase 2 including the addition of some further options.

7. ENGAGEMENT WITH VENDORS

During the project, CONSULTANT engaged with four different vendors as agreed with CLIENT for new GT and VSD driven compressors, The list of vendors with contact details is as shown in the list below. CLIENT was copied in all major exchange of information with vendors.

Vendor	Contact Names	Email Addresses (Key contacts)	Telephone Numbers
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

7.1 Requests for 50% Estimate

The initial request to these vendors was for a budgetary quotation (+/- 40 or 50%) with an estimate lead time as per below specific cases indicated below. Cost effectiveness and especially the MCPD compliance were the key factors to take into account. At that stage of the project, two scenarios were identified:

- PDS Case 2: Replace the two existing gas turbine driven compressors with a new GT driven compressor or VSD driven compressor. In this case if the net thermal power is more than 50 MW, then VSD was the only viable solution, to meet the MPCD requirements. GT Drivers (1 or 2 x 50% trains to be selected so that the MPCD legislation requirements are met) or VSD drive (1 or 2x50% trains depending on which is more cost effective) could be selected.
- Other PDS Cases: Replace one of existing gas turbine driven compressors with a new GT driven compressor or VSD driven compressor. The net thermal power was predicted to not be higher than 50 MW

7.2 Responses for 50% estimates

7.2.1 [redacted]

[redacted] provided different options of machines for cases 2 and 5 and the performance curves which is shown below. They estimated a lead time of 18-24 months.

Gas Turbine combinations	Cost (million euros)	Rating (MW)
[redacted]	[redacted]	30
[redacted]	[redacted]	33
[redacted]	[redacted]	35
[redacted]	[redacted]	
[redacted]	[redacted]	

Table 7-1: Case 2 (Required Power 30405kW)

[redacted]

Gas Turbine Combinations	Cost (million euros)	Rating (MW)	Comments
[redacted]	[redacted]	22.7	[redacted]
[redacted]	[redacted]	16.3	[redacted]
[redacted]	[redacted]	16.5	[redacted]

[redacted]

[redacted] provided GA dimensions of the proposed units.

The suitability of installation of new units on existing berths has been checked at a basic level during the engineering. However, work that is more detailed will be required at the next design stage when the selected options and the sizing of the machines will be finalized. There are also hazards related to the age and the condition of the existing bases. The structural integrity and suitability of existing compressor bases will be checked in the next design stage – see also Ref. 26 in the design risk register of the document 20840-EN-RPT-000-0004 “Design Process Safety Report”

7.2.2 [redacted]

According to the preliminary data sheets and information provided, [redacted] has advised the following (delivery time of 14 months):

- 2x T250+C753 (option 1)
- 2x Spartan EMD (30KHp) + C752 (Option 2)

[redacted]

Quantity	Scope	Unit Price (£'M)	Total Price (£'M)
2	[redacted]	[redacted]	[redacted]
2	[redacted]	[redacted]	[redacted]

7.2.3 [redacted]

[redacted] proposed MOPICO compressors. This type of machine has been operated successfully for many years. The Gas Turbines in their inventory are not large enough to meet the specified duty (in KW standpoint) therefore the proposal includes VSD's only.

Case 2 P11 Design

[redacted]

Compressor coupling power ~ 15.4 MW (per machine)

Budgetary price and delivery

Scope of Supply

Two (2) Compressor packages, including:

- [redacted] installed on a single lift base frame including cooling gas loop and instrumentation
- AMB controls
- VFD

- Transformer
- Quality assurance and inspection according to manufacturer standard
- Factory Acceptance Test including API 617 mechanical test and PTC10 type 2 performance test

Indicative Price for above scope of supply: £ [redacted]

Delivery: [redacted] months

Case 5 P31 Design

1x100% [redacted]

[redacted] motor

Compressor coupling power ~ 17.1 MW

Budgetary price and delivery

Scope of Supply

One (1) Compressor package, including:

- [redacted] installed on a single lift baseframe
- including cooling gas loop and instrumentation
- AMB controls
- VFD
- Transformer
- Quality assurance and inspection according to manufacturer standard
- Factory Acceptance Test including API 617 mechanical test and PTC10 type 2 performance test

Indicative Price for above scope of supply: £ [redacted]

Delivery: [redacted]

[redacted]

[redacted] were requested to provide a quotation for the “Re-wheeling” option of the existing Gas Compressors. They estimated it would be roughly £700k ± 20% per compressor and a lead time of around 12 months. To review the latest process conditions to see whether the duty will fit a revamp within the existing compressors, it will require doing a paid engineering study costing roughly £ [redacted] and with lead time of 10-12 weeks for completion. The revamp study excludes any review of the drive train and will focus on the compressor only.

7.3 Request for +/- 30% Quote

On 23rd February the process duty specification (see 20840-EN-SPC-000-0002, Compressors Duty Specification) was sent with a request for +/- 30% quotes. Given to the vendors was the following:

7.4 Responses

7.4.1 [redacted]

[redacted] advised that it is not possible to cover all operating point within a single envelope if Point C3 remains as is. [redacted] proposed two possible solutions to overcome this:

Run C3 operating 1x100 or Run C3 in full recycle mode

A further clarification meeting discussed various options, e.g.:

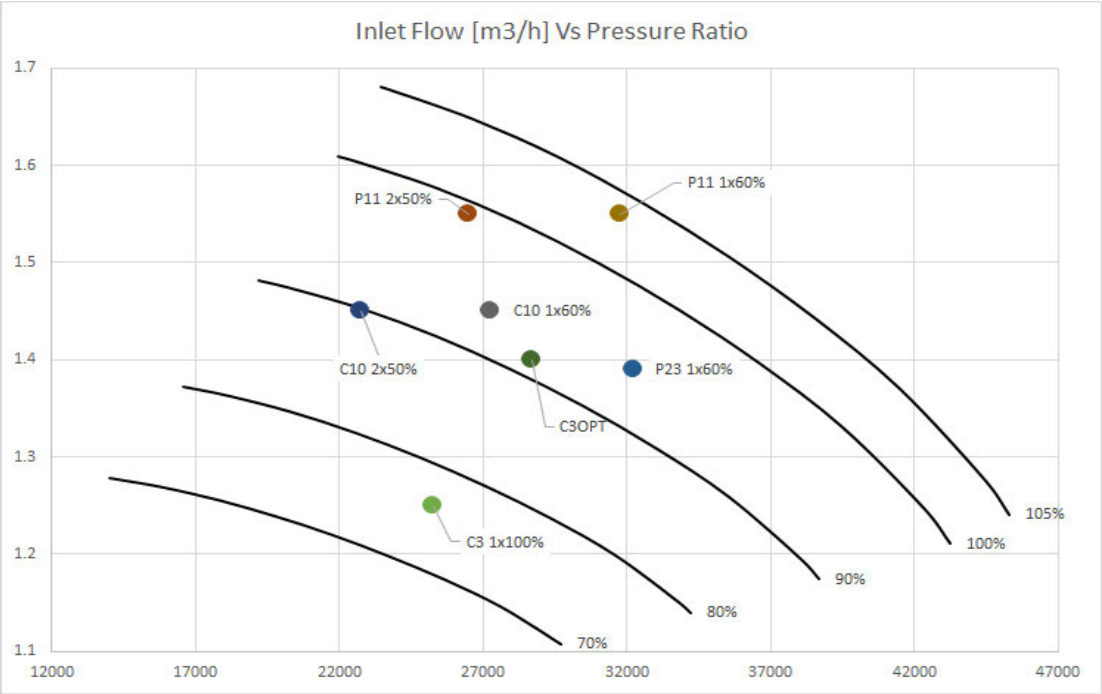
- Increase pressure ratio so that C3 @ 1x 100% configuration is near other operating points. The proposed optimised operating point is within the driver capability.
- Operating at 2 x 50% however this goes beyond the surge line.
- Recycle- not recommended.
- One machine covers operating points C3 and C10, one machine to cover the rest.
- Hot or cold bypass to push C3 up the operating curves.

The final recommendation is shown as C3 optimal on the performance curves

Case	P11 (1x60%)		P23 (1x60%)		C10 (1x60%)	
Absorbed power (kW)	18,344		18,967		17,122	
Technology	Gas turbine	Electric motor	Gas turbine	Electric motor	Gas turbine	Electric motor
Machine selection	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Machine power (MW)	30	35	30	35	30	35
Budget price (M€)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Budget Lead time	[redacted]					

Case	P11 (2x50%)		C10 (2x50%)	
Absorbed power (kW)	15,104		14,298	
Technology	Gas turbine	Electric motor	Gas turbine	Electric motor
Machine selection	[redacted]	[redacted]	[redacted]	[redacted]
Machine power	16.3	16.5	16.3	16.5
Budget price (M€)	[redacted]	[redacted]	[redacted]	[redacted]
Budget Lead time	[redacted]			

Case	C3 (1x100%)		C3 Optimal (1x100%)	
Absorbed power (kW)	10,526		16,147	
Technology	Gas turbine	Electric motor	Gas turbine	Electric motor
Machine selection	[redacted]	[redacted]	[redacted]	[redacted]
Machine power (MW)	12.3	12.5	16.3	16.5
Budget price (M€)	[redacted]	[redacted]	[redacted]	[redacted]
Budget Lead time	[redacted]			



An additional enclosure ("enclosure in the enclosure") is something [redacted] does not recommend because it will potentially introduce other issues, e.g. double the ventilation system to feed air in both enclosures, the firefighting is impacted plus the maintenance has lot of additional constraints etc.

7.4.2 [redacted]

For the +/-30% quote [redacted] provided the following:

Base Price (2x50%): [redacted] for 2 [redacted] compressor set

Base Price (1x60%): [redacted] for 1 [redacted] compressor set

Options to the Base Price:

- Anti-surge recycle valve: 16 Inch Noise Attenuating Ball Valve 1 per [redacted] Compressor-
- Dynamic Simulation Study
- Training

An extra enclosure over the existing offering is not included. According to [redacted], it is a more complex offering and needs some inputs and additional data from site such as a noise survey etc. This option is typically a significant proportion in relation to the overall budgetary price.

[redacted] estimates a lead time of around 12 months

7.4.3 [redacted]

[redacted] proposed a [redacted] (electric motor compressor) in the previous stage of the project. The use of an electric motor has been discounted, so this would not be taken forward onto the +/- 30% stage.

7.4.4 [redacted]

1 compressor design to cover all 3 CNEW (2x50%) duty points.

Cost: 20 million euros

Notes:

- The [redacted] (15 MW) is a good fit but it is a little short on power for Case 2 Point C11
- There is still the issue of Case 1 Point C3 which is only 35% GT load
- Using the [redacted] (24 MW) to cover Case 2 Point C11 makes Case 1 Point C3 worse (20% GT load)

1 compressor design to cover all 4 alternative (1x60%) duty points

Cost: 15 million euros

Notes:

- This would fit the [redacted] (24 MW)
- There is still the issue of Case 1 Point C3 which is only 25% GT load

[redacted] estimate a lead time of 13-14 months.

A TBE has been produced following the latest quotations and it is included in the next page. The quote from [redacted] had been evaluated as the best technically.

[redacted]

National Grid - Wormington MCPD Compliance FEED Study Project

nationalgrid

TECHNICAL BID EVALUATION - GAS TURBINE COMPRESSORS

Job No.:	Doc. No.						
Client: **NATIONAL GRID**	Req'n No.						
Location: **WORMINGTON**	Service					17.03.22	C
Specification: **20840-EN-SPC-000-0002**	Tag No.	CNEW (2 X 50%)				14.03.22	B
	Tag No.	CNEW Alt (1 X 60%)				11.03.22	A
						Date	Rev

DRIVER	[redacted]	[redacted]	[redacted]	[redacted]	REMARKS
GENERAL				#	
MODEL / FRAME DESIGNATION	[redacted]				
MECHANICAL / GENERATOR APPLICATION	Mechanical Drive Application	Mechanical Drive Application	Mechanical Drive Application		
SIMPLE CYCLE / REGENERATIVE / COMBINED CYCLE	Simple Cycle	Simple Cycle	Simple Cycle		
DLN / DLE CAPABILITY	Yes, SOLONOx	Yes, DLE	Yes, DLE		
Scope as per 20840-EN-SPC-000-0002 with exclusions as below	Yes	Yes	Yes		
Exclusions	Special Tools	TBC	Civil works, earth/Grounding connections cables, utilities required for operation, any site activities (erection, installation)		
Optional Scope as per 20840-EN-SPC-000-0002 (enclosure with inlet and exhaust systems)	Yes	TBC	No		
GAS TURBINE PERFORMANCE:					
FUEL TYPE (Natural Gas)	Confirmed	Confirmed	Confirmed		
ABSORBED POWER / MACHINE POWER (2 x 50%)	[redacted]				
ABSORBED POWER / MACHINE POWER (1 x 60%)					See Notes below
Nox EMISSIONS (MCPD applies)	Confirmed (below MCPD Limits)	Confirmed (below MCPD Limits)	Confirmed (below MCPD Limits)		
Nox EMISSIONS - Expected	25 ppmV from 40 to 100% load	15 - 25 ppmV	25ppm NOx down to 50% load. Depending on site conditions this range can be extended to lower loads and 15ppm		
Starter Type	Direct Drive AC Motor Driven Start System	VSD (Electrical)	Electric hydraulic starting system and barring motor		
NOISE:					
TOTAL PACKAGE - NOISE PRESSURE	85 dBA (at 1 m)	85 dBA (at 1 m)	85 dBA (at 1 m)		
Technical Documentation supplied with the quote	Very good	Limited information			
DELIVERY / LEAD TIME :	Approx 12 months .	18 to 24 months	13-14 months		
COST :	[redacted]	[redacted]	[redacted]		
OTHER OPTIONS TO THE BASE PRICE					
Antisurge valve 16" - price per valve (2 for 2x50% or 1 for 1x60%)	[redacted]				
Dynamic study					
Training					
[redacted]					

8. PHASE 2 SHORT LIST OPTIONS - ENGINEERING

8.1 Overview

The short list of options, as recommended by [redacted] and agreed with the CLIENT in the design review (after the short listed options workshop), are listed below:

SHORT LISTED OPTIONS - DESIGN REVIEW 17.02.2022

			Combinations					
		Initial Option Number ------>		1	2	4	5	7
		Scenario	Existing GT/Comp	Derated Avon/ CSRP	500 hrs	Retrofit DLE	New GT/Comp	Rewheel (Note 1)
Case 1	C10	New GT/Comp					✓ (2x50%)	
		Existing GT (Derated) + New GT/Comp	✓	✓ (One)			✓ (1x60%)	
		2 x Existing GT in parallel + Retrofit DLE	✓			✓ (Two)		
		2 x Existing GT in parallel + 500 hrs	✓		✓ (Two)			
	C10 ALTERNATIVE	Existing GT/Comp	✓					
Case 2	P11	New GT/Comp					✓ (2x50%)	
		Existing GT/Comp rewheel with DLE	✓			✓ (One)	✓ (1x60%)	✓
Case 3	R2	New GT/Comp					✓ (2x50%)	
	R2 ALTERNATIVE	Existing GT/Comp rewheel with DLE	✓			✓ (Two)		✓
Case 4	P23	Existing GT (Derated) + New GT/Comp	✓	✓ (One)			✓ (1x60%)	
	P23 ALTERNATIVE	Existing GT (Retrofit DLE)	✓			✓ (Two)		
Case 5	P31	Existing GT (Derated) + New GT/Comp	✓	✓ (One)			✓ (1x60%)	
	P31 ALTERNATIVE	Existing GT (Retrofit DLE)	✓			✓ (Two)		

Notes: 1. Options for compressor rewheeling to be comfired by OEM

The engineering requirements mainly for the option 5 (New GT driven compressor) are included in the BOD document number 20840-EN-SPC-000-0001.

The initial option number 3 (SCR) is currently on HOLD, as another report by third-party is expected. Assessment and conclusions will be included in the next revision of this FEED report if the SCR report is available.

Option 1 (derated Avon) and option 4 (retrfofit DLE) have been based substantially on other reports, e.g. Appendix E “Avon DLE and Avon Control Systems Restricted Performance (CSRP) Provisional Innovation Study Outputs” of the original ITT package and the “Avon DLE Technical Note” document number PAC1050295-01-7260-NGG-0032 (19.01.2022).

8.2 Asset Health

An assessment of the condition various equipment which are related to this project scope of the Wormington compressor station has been made based upon the information provided by CLIENT and upon the CONSULTANT's analysis and assessments. The conclusions for current asset integrity and future asset integrity are included in the report Asset Integrity Review, document number 20840-EN-RPT-000-0001.

Based on the initial site visit to Wormington facility and the desktop review carried on the existing instrument & control and electrical systems associated with compressor and turbine, in addition to field hardware and associated accessories at the facility, it is evident that a considerable percentage of associated instrumentation and electrical systems although currently operating are indeed at the end life phase of the product life cycle.

The typical life cycle for average instrumentation ranges between 15- 20 years depending on the instrument. Taking the fact that majority of the instrument have been operating online for more than 30 years, it is only logical to conclude that the majority of these instruments are either at the end of life phase or indeed already obsolete.

As such regardless of the option being evaluated the main backbone driving the scope will always be obsolescence. The asset health works will be required for all options that keep the existing compressor trains driven by Avon gas turbines .

The list of recommended refurbishment, repairs and replacement works is included in the report Asset Integrity Review, document number 20840-EN-RPT-000-0001. As part of the continuous refurbishment and upgrades, the following activities have been identified by CLIENT and they are included in the Asset Integrity Review Report:

- Power turbine major overhaul. Engagement with original OEMs will be needed to define the feasibility and the extent of works.
- Power Turbine upgrade (if required for new operating cases, e.g. for PDS point C10 when the use of the existing compressor trains is selected as an option). For this point, the required shaft power is higher than the capacity of the Avon 1533 gas turbine and an upgrade will be required to drive the compressor. Engagement with original OEMs will be needed for the next stage of the project to define the feasibility and the extent of works.
- GT major overhaul. Engagement with original OEMs will be needed to define the feasibility and the extent of works.
- GT power upgrade from Avon 1533 to 1535 derivative (if required for new operating cases, e.g. for PDS point C10 when the use of the existing compressor trains is selected as an option). For this point, the required shaft power is higher than the capacity of the Avon 1533 gas turbine and an upgrade to Avon 1535 derivative will be required to drive the compressor. Engagement with original OEMs will be needed for the next stage of the project to define the feasibility and the extent of works.
- Compressor re-wheel (if required for new operating cases, e.g. for PDS Case 2 where an existing compressor train, which currently cannot meet the required outlet pressure, is selected as an option to work in parallel with a new compressor train). Engagement with original OEMs will be needed for the next stage of the project to define the feasibility and the extent of works.
- Replacement of the fuel gas system conditioning to maintain the reliability of operations
- Replacement of Instrumentation cabling between unit control system and field instruments to maintain the reliability of operations

- Replacement of Instrumentation/telemetry cabling between unit control system and station control system to enhance the reliability of operations
- Replacement of Compressor Unit Control system including unit instrumentation and junction boxes to enhance the reliability of operations
- Install a new electric pump for the fire suppression system replace existing Hi-Fog system to maintain the safety and the reliability of operations
- Replace unit Fire & Gas detection system including all sensors and junction boxes to maintain the safety and the reliability of operations
- Replacement of the anti surge valves to maintain the reliability of operations
- Replacement of Compressor Unit Electrical equipment (lighting, dist. boards, switchboards, DSEAR non-compliances, UPS, chargers etc.) to maintain the safety and the reliability of operations R
- Refurbishment of the exhaust stacks to maintain the structural integrity and the reliability of operations
- Refurbishment of the air intakes to maintain the structural integrity and the reliability of operations
- Refurbishment of general compressor cab including corrosion repairs to maintain the structural integrity and the reliability of operations

8.3 Options 1 (Derated Avon), 2 (work with 500 hrs limit), 3 (SCR) and 4 (retrofit DLE), which are presented below, require the Asset Health works in order to re-life the existing Compressor Machinery Trains and associated equipment. The relevant costs have been included in the cost estimateOption 1 – Derated Avon / CSRP

8.3.1 Option 1 – General

This is an option to limit Avon NOx emissions to comply with MCPD (150 mg/Nm3) requirements, through software control system modifications, such as using feedback from a Predictive Emissions Management System (PEMS) to restrict running at power levels with NOx output around the permitted maximum in legislation.

Operation with Derated Avon / CSRP may be considered where the currently installed equipment:

- Is not capable of delivering the required discharge pressure at specified flowrate and station inlet pressure where that duty is stipulated as a controlling operating scenario but the discharge pressure may be delivered at a reduced flowrate and
- Required power input at the GT is lower than the MCPD 50 MW upper limit and NOx emissions are below the 150 mg/Nm³ limit imposed by the MCPD legislation at the revised flowrate.

In principle, this is a simple solution to implement but would require changes to control and instrumentation, increasing the complexity of these systems.

The analysis through process modelling has demonstrated that this is viable option for one of the existing compressor trains only when this is combined with a new compressor train. In this scenario, the balancing will be such that the new compressor train will contribute to approximately 60% of the overall demand, while the existing train in a derated / CSRP mode will contribute approximately 40% of the overall demand. Therefore, for the worst case (point C10 of the PDS), the installed equipment (only one of the two) is capable of delivering the PDS points, as the maximum required shaft power of a compressor train under a derated / CSRP mode will be no more than 11.4 Mw, which means 43.9 MW Net Thermal Input and 140 mg/Nm^3 NO_x emissions.

8.3.2 Option 1 – Mechanical

Apart from asset health related works, there are no other associated mechanical works

8.3.3 Option 1 – Piping

Apart from asset health related works, there are no other associated mechanical works

8.3.4 Option 1 – Civil and Structural

Apart from asset health related works, there are no other associated mechanical works

8.3.5 Option 1 – C & I

The scope is mainly focused on software modification & configuration of the engine control and compressor control systems to assure the new operating requirements are achieved. There may be a requirement for additional instrumentation and i/o cards. As such generally the I&C Scope associated with the De-rating of the machines is summarized as follows:

- Modification of Compressor logic (Hardware & Software) to suit the new operating Limits of the machine and operation envelop.
- Modification of TCS Logic (Hardware & Software) to suit the new SOL Safe Operating Limits of the engine and operation envelop.
- Station Control PLC software modification /configuration/re-mapping)

Replacement of all instruments and cabling and indeed new unit control systems will be driven by Asset Health works – see previous Section 8.2 Option 1 – Electrical

Apart from asset health related works, there are no other associated electrical works.

8.4 Option 2 – 500 hours

8.4.1 Option 2 – General

Operation restricted to less than 500 hours per year may be considered where the currently installed equipment:

- Is capable of delivering the specified duty (required discharge pressure at specified flowrate and station inlet pressure) where that duty is stipulated as a controlling operating scenario and
- Required power input at the GT is lower than the MCPD 50 MW upper limit but NOx emissions exceed the 150 mg/Nm³ limit imposed by the MCPD legislation.

To establish the capabilities of the existing installed compressors, steady-state process simulation models have been set-up. These models have been based on supplied performance curves for compressors C201 A/B (Unit A & B) and C2301A (Unit C). Note that C201A/B are GT driven compressors while C2301A is electrically driven and has a VSD.

Inspection of the PDS Cases supplied by CLIENT has determined the most onerous (controlling) duty points (operating scenario) in terms of compressor flow and/or head requirements. The identified duty points were then used in the process simulation model to assess the capabilities of the currently installed compressors.

The PDS Cases also state number of hours operation per annum for each of the duty points defined. On a cumulative operating hours basis, there are no operating scenarios covering the use of only one GT / Compressor combination that has less than 500 hours per annum and as such, on a qualitative basis alone, this option cannot be considered a solution and an alternative approach will need to be adopted.

8.5 Option 3 – SCR

8.5.1 Option 3 – General

SCR may be considered where the currently installed equipment:

- Is able to deliver the specified duty (required discharge pressure at specified flowrate and station inlet pressure) where that duty is stipulated as a controlling operating scenario and
- Required power input at the GT is lower than the MCPD 50 MW upper limit but NOx emissions exceed the 150 mg/Nm³ limit imposed by the MCPD legislation.

To establish the capabilities of the existing installed compressors, steady-state process simulation models have been set-up. These models have been based on supplied performance curves for compressors C201 A/B (Unit A & B) and C2301A (Unit C). Note that C201A/B are GT driven compressors while C2301A is electrically driven and has a VSD.

Inspection of the PDS Cases supplied by CLIENT has determined the most onerous (controlling) duty points (operating scenario) in terms of compressor flow and/or head requirements. The identified duty points were then used in the process simulation model to assess the capabilities of the currently installed compressors. Where the GT / Compressor meets the above criteria, a SCR could be specified as an option for consideration.

SCR is a well-established method of reducing emissions of NOx from combustion gases, including gas turbine exhaust applications. From a technical perspective, SCR is a relatively proven technology for retrofitting to existing gas turbines to achieve NOx emissions performance which will comply with emissions directives. A typical SCR system may consist of:

- Exhaust modifications, including stack demolition, installation of expansion joint and insulated ducting
- Air blowers
- Ammonia injection grid
- Catalyst housing, with catalyst bed
- Self-supporting exhaust stack and silencer
- Ammonia storage and pumping system
- Ammonia vaporisation system, including hot air fans
- Sampling grid and test ports
- Continuous Emissions Monitoring System (CEMS)
- PLC control and data acquisition systems
- Ammonia tanker unloading system, and horizontal storage tank in bund with shelter

Using SCR technology a reduction in NOx concentration of up to 90% can be achieved, dependent up on having a uniform ammonia : NOx distribution in the exhaust stream. It is also feasible to achieve NOx reductions of up to 95% if increased ammonia slip is allowed. However, a challenge for GT driven compressor systems is that they do not typically operate under steady load, and may cycle on and off quite frequently, and consequently exhaust temperatures, pressures and flow rates may change rapidly, which may challenge the performance of SCR resulting in transient NOx or ammonia emissions.

Initial engineering work has revealed that there are plot space and construction restraints due to the required height of the exhaust stack and the space needed for the supporting equipment and ammonia loading operations.

At the time of writing, a study is currently undergoing by a third party. For this reason, no further development of this option will be carried out.

Should SCR be deemed as a viable option in the future, asset Health works will be required to re-life the existing Avon(s).

8.6 Option 4 – Retrofit DLE

8.6.1 Option 4 – General

A retrofit DLE may be considered where the currently installed equipment:

- Is able to deliver the specified duty (required discharge pressure at specified flowrate and station inlet pressure) where that duty is stipulated as a controlling operating scenario and
- Required power input at the GT is lower than the MCPD 50 MW upper limit but NOx emissions exceed the 150 mg/Nm³ limit imposed by the MCPD legislation.

To establish the capabilities of the existing installed compressors, steady-state process simulation models have been set-up. These models have been based on supplied performance curves for compressors C201 A/B (Unit A & B) and C2301A (Unit C). Note that C201A/B are GT driven compressors while C2301A is electrically driven and has a VSD.

Inspection of the PDS Cases supplied by CLIENT has determined the most onerous (controlling) duty points (operating scenario) in terms of compressor flow and/or head requirements. The identified duty points were then used in the process simulation model to assess the capabilities of the currently installed compressors. Where the GT / Compressor meets the above criteria, a retrofit DLE shall be specified as an option for consideration.

Note that for this case, where there is no mechanical limitation of the system that restricts performance in terms of delivering the specified duty, other solutions (e.g. DLE operation in parallel with new compressor train.) may also be valid and therefore considered for reduction of NOx emissions.

Although there are no modifications currently commercially available, two suppliers ([redacted] and [redacted]) are developing technology which is expected to be available in 2023. Both suppliers have now carried out prototype tests of their equipment and have shared the results with CLIENT.

There is one key difference between the approaches that the suppliers have taken. [redacted], who are the OEM of the Avon gas turbine, have based their DLE modification on the latest, highest power output, version of the Avon, known as the 1535. If implemented, it is expected that this modification could produce nominal 15MW of shaft power to each compressor unit. [redacted], who are an independent service provider, are developing their DLE technology through a contract with CLIENT and have therefore based their design on the CLIENT fleet, which is the 1533 variant of the Avon and produces 12.34MW of power (ISO rated).

The difference in power also results in a large difference in the cost and effort required to implement the different variants. The CLIENT Avon fleet is currently all Avon 1533s so the modified [redacted] engine will only require a new DLE fuel system and associated control system modification, whereas the [redacted] modified engine will require a power turbine upgrade and possibly a re-wheel of the compressor to accommodate the increased power output from the Avon 1535.

Both DLE combustor designs are based on existing proven technology, and the prototype tests have produced encouraging results, so there is a low risk of failure of these projects. [redacted] are currently building a full engine to be tested on a test bed, and [redacted] are carrying out further prototype tests to try to further reduce the emissions before building a full engine.

For the current project, the modification and the scope of [redacted] has been considered in the cost estimate, as the Retrofitted option is combined with a new compressor and at a load sharing of 60% for the new machine and for 40% of the existing machine to be retrofitted resulting in estimated shaft power which is within the capability of the existing Avon 1533.

Two retrofitted DLE Avons are capable of delivering PDS Case 1 for all points except C10. All other PDS cases cannot be delivered with this configuration.

In case two machines are selected to be retrofitted, then optimised operating conditions for the PDS point C10 are recommended so that the existing Avon 1533 will be able to drive the compressors. If Point C10 must be included as an operating point, then the Avon 1535 power upgrade will be required.

8.6.2 Option 4 – Mechanical

Apart from asset health related works and works within the scope of [redacted], there are no other associated mechanical works

8.6.3 Option 4 – Piping

Apart from asset health related works and works within the scope of [redacted], there are no other associated mechanical works

8.6.4 Option 4 – Civil & Structural

Apart from asset health related works and works within the scope of [redacted], there are no other associated mechanical works

8.6.5 Option 4 – C & I

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The scope is mainly focused on software modification & configuration of the engine control and compressor control systems to assure the new operating requirements are achieved. There may be a requirement for additional instrumentation and i/o cards. As such generally the I&C Scope associated with the De-rating of the machines is summarized as follows:

- Modification of Compressor logic (Hardware & Software) to suit the new Operating Limits of the machine and operation envelop.
- Modification of TCS Logic (Hardware & Software) to suit the new SOL Safe Operating Limits of the engine and operation envelop.
- Station Control PLC software modification /configuration/re-mapping)
- Integration of new Continuous Emissions Monitoring System (CEMS)(Field + System) + New PLC control and data acquisition system to the station control PLC
-

Replacement of all instruments and cabling and indeed new unit control systems will be driven by Asset Health works – see previous section 9.2.

8.6.6 Option 4 – Electrical

Apart from asset health related works and works within the scope of [redacted], there are no other associated electrical works

8.7 Option 5 – New GT / Compressor

8.7.1 Option 5 – General

New GT / Compressor(s) will need to be considered where the currently installed equipment:

- Cannot deliver the specified duty (required discharge pressure at specified flowrate and station inlet pressure) where that duty is stipulated as a controlling operating scenario or
- Required power input at the GT is too close to or exceeds the MCPD 50 MW upper limit

In the context of this feasibility study, where new compressor or compressors are being considered, it automatically requires a new GT driver. Note that the MCPD NOx emission limit of 150 mg/Nm³ is not a consideration for evaluation of GT performance under Option 5 due to the technology used on modern machines.

To establish the capabilities of the existing installed compressors, steady-state process simulation models have been set-up. These models have been based on supplied performance curves for compressors C201 A/B (Unit A & B) and C2301A (Unit C). Note that C201A/B are GT driven compressors while C2301A is electrically driven and has a VSD.

Inspection of the PDS Cases supplied by CLIENT has determined the most onerous (controlling) duty points (operating scenario) in terms of compressor flow and/or head requirements. The identified duty points were then used in the process simulation model to assess the capabilities of the currently installed compressors and thus identify which duty points would require a new GT / Compressor to be specified based on the above criteria.

Six different layouts have been developed for this option. The layouts are described below:

Layout 1 New Compressors (two or one) in Greenfield area (North of feeder 23)	Layout 2 New Compressors (two or one) in Greenfield area (South of feeder 23)	Layout 3 New Compressor (one) in Brownfield area with a new control building in the south side of the plant (existing control building to be demolished)	Layout 4 New Compressors (two or one) in brownfield area with a new control building in the south side of the plant (existing control building and aftercoolers to be demolished)	Layout 5 New Compressors in brownfield area (existing compressor berths)	Layout 6 New Compressors in brownfield area (existing compressor berths) with a new control building in the south side of the plant (existing control building to be demolished)

8.7.2 Option 5 – Mechanical

The mechanical scope of work is related to the specification and selection of new compressor trains. Following the engagement with vendors and the issue of the Duty Specification, a TBE has been produced – see section 8. The quote from [redacted] had been evaluated as the best technically and there are no outstanding issues.

8.7.3 Option 5 – Piping

Layout 1

This layout consists of 2 Nos. New Compressors located in greenfield area.

Proposed location of New Compressors is based on following consideration:

- Location of compressors has been based on safety distances mentioned in National Grid Specification, Document No. T/SP/G/37. Safety distance circles have been marked on the Plot Plan to highlight the distances between Compressor and occupied building and outermost fence
- Space requirement for future project modifications. Optimum space has been utilized leaving space for future expansion
- Minimum / No Shut down requirement. Greenfield option enables option of construction of new compressors without disturbances to existing facilities
- Materials handling requirements. Sufficient space has been left so that crane and other equipment can access the area for material handling.
- Operations and maintenance requirements using access roads around the new compressors.
- Constructability requirements. Security gate and laydown area for construction activities have been shown in Plot Plan. These facilities can be expanded based on construction methodology which will be finalized at the next stage of design
- Environmental requirements as these have been identified in the design and layout reviews
- Cost impact, as minimum area and compact modules which can be prefabricated have been foreseen.

New Compressors proposed location shall be at North side of existing feeder line by demolition of existing fence along with lighting poles. New fence shall be placed at South side of existing feed line near the existing road to substation. Area at South side of existing fence is already acquired by Nation Grid.

Location of new compressor have been reviewed as per CLIENT Specification, Document No. T/SP/G/37 in layout review and HAZID.

Existing Compressors Unit A and Unit B shall be demolished along with piping.

Piping has been designed based on concept to have all piping underground in order to minimize hazards. All valves shall be placed in valve pits. The concept will be verified in the next design stage considering that T/SP/CE/4 June 2021 update includes the following in cl 2.3: "wherever practical the use of pits shall be avoided in scheme designs due to additional hazards and risks associated with their use”

Suction and discharge header has been considered as 36” API 5L X 65 having 20.6mm thickness same as existing suction and discharge headers. Vent line has been considered as 8” SS material and vent stack location is nearby location of existing vent stack. Vent line will also be underground.

he tie-ins location on existing systems so as to minimize or avoid shutdowns. Discharge header shall be tie-in at upstream of existing Air Cooler isolation valve and suction header shall be tie-in at downstream of existing Flowmeter.

The tie-ins have been located to accessible areas. The execution strategy for the tie-ins will be finalized at next design stage, keeping in mind that existing compressors will be in operation and that suction and discharge lines shall be laid while existing facilities are in operation. To avoid shutdown, hot tapping and other possible options shall be explored. Discharge header shall be tie-in at upstream of existing Air Cooler isolation valve and suction header shall be tie-in at downstream of existing Flowmeter.

An updated 3D model has also been produced for this layout.

Layout 2

This is similar to Layout 1. The only difference is that the new Compressors proposed location shall be at South side of existing feeder line and that the plot will be extended towards the South with a new fence

This layout requires the new piping to cross feeder 23, which add extra requirements related to crossing of pipelines and robust construction execution strategies.

One of the first actions for the next design stage will be the topographical and buried services surveys so that the coordinates and the elevation of the pipeline of feeders 23, as well as any other underground services in the area are known accurately, in order to define the type of crossings, the elevations and the runs including any protective structures that might be required.

The following procedures define the safe working practices required when working in the vicinity of pipelines:

- T/MP/SSW/2 V11 – Management Procedure for Safe Working And Development In The Vicinity Of National Grid Gas Pipelines And Associated Installations / Requirements For National Grid Gas
- T/SP/SSW/22 Apr 20 - Specification for safe working in the vicinity of National Grid high pressure gas pipelines and associated installations - requirements for third parties
- T/SC/CE/12 – specification for the design, construction and testing of civil and structural works part twelve: protection works over steel pipelines

Layout 3

It consists of 1 No. New Compressor located in brownfield area.

Proposed location of New Compressor is based on following consideration:

- Location of compressors has been based on safety distances mentioned in National Grid Specification, Document No. T/SP/G/37. Safety distance circles have been marked on the Plot Plan to highlight the distances between Compressor and occupied building and outermost fence. New control building location has been proposed based on safety distances and location of existing feeder line.
- Space requirement for future project modifications. Optimum space has been utilized for new compressor and control building leaving space for future expansion
- Minimum / No Shut down requirement. The option enables option of construction of new compressors without significant disturbance to existing facilities. Detail execution strategy shall be developed at next design stage for exploration of minimum possible disturbances to existing facilities while planning construction activities in parallel/sequence.
- Materials handling requirements. Sufficient space has been left so that crane and other equipment can access the area for material handling.
- Operations and maintenance requirements using access roads around the new compressors and new control building.
- Constructability requirements. Security gate and laydown area for construction activities have been shown in Plot Plan. These facilities can be expanded based on construction methodology which will be finalized at the next stage of design.

- Environmental requirements as these have been identified in the design and layout reviews
- Cost impact, as minimum area and compact modules which can be prefabricated have been foreseen.

New Compressor proposed location shall be at location of existing Control Building. Existing Control Building shall be demolished, and proposed location of New Control Building will be at South side of existing feeder line. Existing fence along with lighting poles will be demolished. Access road has been provided for new Control Building. New fence will be placed at South side of existing feed line near the existing road to substation. Area at South side of existing fence is already acquired by CLIENT.

. .As a new compressor will be installed one of the existing will not be needed and therefore the existing compressor Unit A is proposed to be decommissioned. The reason for selecting Unit A for decommissioning is its proximity to the new installed unit and the potential interference in the suction and exhaust air flows. Unit B is at a further distance and a potential interference in the air flows is less likely.

Piping has been designed based on concept to have all piping underground in order to minimize hazards. All valves shall be placed in valve pit with extended handwheel so that valves can be operated from ground.

Suction and discharge header has been considered as 36” API 5L X 65 having 20.6mm thickness same as existing suction and discharge headers. Vent line has been considered as 8” SS material and vent stack location is nearby location of existing vent stack. Vent line will also be underground.

The tie-ins have been located to accessible areas. The execution strategy for the tie-ins will be finalized at next design stage, keeping in mind that existing compressors will be in operation and that suction and discharge lines shall be laid while existing facilities are in operation. To avoid shutdown, hot tapping and other possible options shall be explored. Discharge header shall be tie-in at upstream of existing Air Cooler isolation valve and suction header shall be tie-in at downstream of existing Flowmeter.

Layout 4

It consists of 2 Nos. New Compressor located in brownfield area.

Proposed location of New Compressor is based on following consideration:

- Location of compressors has been based on safety distances mentioned in National Grid Specification, Document No. T/SP/G/37. Safety distance circles have been marked on the Plot Plan to highlight the distances between Compressor and occupied building and outermost fence. New control building location has been proposed based on safety distances and location of existing feeder line.
- Space requirement for future project modifications. Optimum space has been utilized for new compressor and control building leaving space for future expansion
- Minimum / No Shut down requirement. The option enables option of construction of new compressors without significant disturbance to existing facilities. Detail execution strategy shall be developed at next design stage for exploration of minimum possible disturbances to existing facilities while planning construction activities in parallel/sequence.

- Materials handling requirements. Sufficient space has been left so that crane and other equipment can access the area for material handling.
- Operations and maintenance requirements using access roads around the new compressors and new control building.
- Constructability requirements. Security gate and laydown area for construction activities have been shown in Plot Plan. These facilities can be expanded based on construction methodology which will be finalized at the next stage of design.
- Environmental requirements as these have been identified in the design and layout reviews
- Cost impact, as minimum area and compact modules which can be prefabricated have been foreseen.

1 No. New Compressor shall be installed at the location of existing Control Building and 1 No. New Compressor shall be installed at the location of existing Air Cooler. Existing Control Building and existing Air Cooler shall be demolished. Proposed location of New Control Building will be at South side of existing feeder line. Existing fence along with lighting poles will be demolished. Access road has been provided for new Control Building. New fence will be placed at South side of existing feed line near the existing road to substation. Area at South side of existing fence is already acquired by Nation Grid.

Location of new compressor have been reviewed as per CLIENT Specification, Document No. T/SP/G/37 in layout review and HAZID.

Existing Compressors Unit A and Unit B shall be demolished along with piping.

Piping has been designed based on concept to have all piping underground in order to minimize hazards. All valves shall be placed in valve pit with extended handwheel so that valves can be operated from ground.

Suction and discharge header has been considered as 36” API 5L X 65 having 20.6mm thickness same as existing suction and discharge headers. Vent line has been considered as 8” SS material and vent stack location is nearby location of existing vent stack. Vent line will also be underground.

The tie-ins have been located to accessible areas. The execution strategy for the tie-ins will be finalized at next design stage, keeping in mind that existing compressors will be in operation and that suction and discharge lines shall be laid while existing facilities are in operation. To avoid shutdown, hot tapping and other possible options shall be explored. Discharge header shall be tie-in at upstream of existing Air Cooler isolation valve and suction header shall be tie-in at downstream of existing Flowmeter.

Layout 5

Layout 5 consists of 2 Nos. New Compressor located in brownfield area.

Proposed location of New Compressor is based on following consideration:

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- Although the location of compressors is not in compliance with the safety distances required in National Grid Specification, Document No. T/SP/G/37, protection measures like blast walls could mitigate the risks. Safety distance circles have been marked on the Plot Plan to highlight

the distances between Compressor and occupied building and outermost fence. Any protection measures for mitigation will be decided in the next design stage.

- Space requirement for future project modifications. No new space has been utilized for new compressor and control building leaving space for future expansion
- Construction. Although there are challenges like lifting over live plants, outage constraints etc, a final decision including detailed assessment of risks and challenges shall be done in the next design stage. Detail execution strategy shall be also developed at next design stage for exploration of minimum possible disturbances to existing facilities while planning construction activities in parallel/sequence.
- Environmental requirements as these have been identified in the design and layout reviews
- Cost impact, as minimum area and compact modules which can be prefabricated have been foreseen.

New Compressors shall be installed at the location of existing Compressors Unit A and Unit B. Existing Compressors Unit A and Unit B shall be demolished along with piping.

Location of new compressor have been reviewed as per CLIENT Specification, Document No. T/SP/G/37 in layout review and HAZID.

Piping has been designed based on concept to have all piping underground in order to minimize Hazid. All valves shall be placed in existing valve pit with extended handwheel so that valves can be operated from ground. Piping arrangement shall be same as existing piping

Suction and discharge header has been considered as 36” API 5L X 65 having 20.6mm thickness same as existing suction and discharge headers. Vent line has been considered as 8” SS material

The tie-ins are at same location as existing to the suction and discharge headers. Vent Line shall be tie-in to existing vent lines. The execution strategy for the tie-ins will be finalized at next design stage,

Layout 6

Layout 6 consists of 2 Nos. New Compressor located in brownfield area.

Proposed location of New Compressor is based on following consideration:

- Location of compressors has been based on safety distances mentioned in National Grid Specification, Document No. T/SP/G/37. Safety distance circles have been marked on the Plot Plan to highlight the distances between Compressor and occupied building and outermost fence. New control building location has been proposed based on safety distances and location of existing feeder line.
- Space requirement for future project modifications. No new space has been utilized for new compressor leaving space for future expansion
- Construction. Although there are challenges like lifting over live plants, outage constraints etc, a final decision including detailed assessment of risks and challenges shall be done in the next design stage. Detail execution strategy shall be also developed at next design stage for exploration of minimum possible disturbances to existing facilities while planning construction activities in parallel/sequence.
- Environmental requirements as these have been identified in the design and layout reviews

- Cost impact, as minimum area and compact modules which can be prefabricated have been foreseen.

New Compressors shall be installed at the location of existing Compressors Unit A and Unit B. Existing Control Building will be demolished, and proposed location of New Control Building shall be at North side of existing feeder line. Existing fence along with lighting poles shall be demolished. Access road shall be provided for new Control Building. New fence shall be placed at South side of existing feed line. Area at South side of existing fence is already acquired by Nation Grid.

Location of new compressor have been reviewed as per CLIENT Specification, Document No. T/SP/G/37 in layout review and HAZID.

Existing Compressors Unit A and Unit B shall be demolished along with piping.

Piping has been designed based on concept to have all piping underground in order to minimize Hazard. All valves shall be placed in valve pit with extended handwheel so that valves can be operated from ground. Piping arrangement shall be same as existing piping

Suction and discharge header has been considered as 36" API 5L X 65 having 20.6mm thickness same as existing suction and discharge headers. Vent line has been considered as 8" SS material

The tie-ins are at same location as existing to the suction and discharge headers. Vent Line shall be tie-in to existing vent lines. The execution strategy for the tie-ins will be finalized at next design stage,

The 3D model was updated for this layout.

8.7.4 Option 5 – Civil & Structural

Details for construction scheduling, execution strategy and works shall be defined in the next design stage in accordance with the CDM:2015 requirements.

The risks whilst working on a live compressor station need to be considered – see also Section 8.7.7 below.

Layouts 1 and 2:

New Compressors have been proposed in green field area.

Based on piping and equipment layout finalized by piping based on the consideration listed in respective section, required foundation for below items has been planned.

- 2 no's of new compressor
- New lighting pole required along the fence and road-approx. 21 no's
- New pipe support for above ground piping nearby compressor foundation-approx. 10no's
- New roads to access compressor during maintenance -
- New fence to increase the plant area. Foundation for fence has been considered at 3m c/c
- Demolition of existing fence and road – 6no's of light pole and 165m of existing fence

Following consideration was kept in mind during foundation layout

- Underground existing facilities - As new compressor foundation has to be constructed, clashes with underground existing facilities such as cables, pipe, near by foundation etc need to be checked in line with constructability requirement of foundation

- Existing drainage system - The existing gravity drainage has to be carefully re-routed and new drainage from compressor area to be connected in existing system. The adequacy of existing drainage system in new layout will need to be checked in the next design stage.
- Proximity of nearby foundation and facilities - Clashes with existing foundation to be checked in the next design stage to provide safe and constructible design
- Cost and economic design.
- Maintenance accessibility - All areas are easily accessible and there is space for modifications which might be required in future
- Construction feasibility for proposed facilities and related issues
- Cable trenches for electrical, Instrumentation and telecom include any crossing requirement for existing buried facilities
- Requirement of pile for compressor foundation in line with existing foundation.

Special attention was paid while considering foundation to minimize the impact on the existing facilities

Layouts 3 and 4

New Compressors have been proposed at existing control building location or existing control building and aftercoolers

Based on piping and equipment layout finalized by piping based on the consideration listed in respective section, required foundation for below items has been planned.

- 1 or 2 no's of new compressor
- New lighting pole required along the fence and road-approx. 21 no's
- New pipe support for above ground piping nearby compressor foundation-approx. 10no's
- New roads to access compressor during maintenance -
- New fence to increase the plant area. Foundation for fence has been considered at 3m c/c
- Demolition of existing fence and road – 6no's of light pole and 165m of existing fence
- Demolition of existing control building plan area 463sq m
- New control building size 42m x 22m– layout has been finalized based on
    - HSE requirement
    - No of personal offices
    - Electrical, instrumentation & Telecom room requirement
    - HVAC requirement
    - Environmental requirement
    - Ergonomics requirement
    - Equipment & cabinet room

Following consideration was kept in mind during foundation layout

- Underground existing facilities - As new compressor foundation has to be constructed, clashes with underground existing facilities such as cables, pipe, near by foundation etc need to be checked in line with constructability requirement of foundation

- Existing drainage system - The existing gravity drainage has to be carefully re-routed and new drainage from compressor area to be connected in existing system. The adequacy of existing drainage system in new layout will need to be checked in the next design stage.
- Proximity of nearby foundation and facilities - Clashes with existing foundation to be checked in the next design stage to provide safe and constructible design
- Cost and economic design.
- Maintenance accessibility - All areas are easily accessible and there is space for modifications which might be required in future
- Construction feasibility for proposed facilities and related issues
- Cable trenches for electrical, Instrumentation and telecom include any crossing requirement for existing buried facilities
- Requirement of pile for compressor foundation in line with existing foundation.
- New building shall be accessible from all around and in case of any hazard ,personal can easily evacuate from inside to outside master point

Special attention was paid while considering foundation to minimize the impact on the existing facilities

Layout 5

New Compressors to be installed at the existing compressor foundations with modifications to accommodate the skid base and meeting the required design requirement i.e.

- Frequency separation to avoid resonance
- Amplitude separation at skid base
- Pile capacity

The suitability of installation of new units on existing berths has been checked at a basic level during the engineering. However, work that is more detailed will be required at the next design stage when the selected options and the sizing of the machines will be finalized. There are also hazards related to the age and the condition of the existing bases. The structural integrity and suitability of existing compressor bases will be checked in the next design stage – see also Ref. 26 in the design risk register of the document 20840-EN-RPT-000-0004 “Design Process Safety Report”

Based on piping and equipment layout finalized by piping based on the consideration listed in respective section, required foundation for below items has been planned.

- New lighting pole required along the fence and road-approx. 21 no’s
- New pipe support for above ground piping nearby compressor foundation-approx. 10no’s

Following consideration was kept in mind during foundation layout

- Underground existing facilities
- Existing drainage system
- Proximity of nearby foundation and facilities.
- Cost and economic design.
- Maintenance accessibility
- Construction feasibility for proposed facilities and related issues

Special attention was paid while considering foundation to minimize the impact on the existing facilities.

Following consideration was kept in mind during foundation layout

- Underground existing facilities – As the existing foundation will be used, its adequacy need to be checked in the next design stage
- Cost and economic design.
- Maintenance accessibility
- Construction feasibility for proposed facilities and related issues

Layout 6

New Compressors to be installed at the existing compressor foundations with modifications to accommodate the skid base and meeting the required design requirement i.e.

- Frequency separation to avoid resonance
- Amplitude separation at skid base
- Pile capacity

The suitability of installation of new units on existing berths has been checked at a basic level during the engineering. However, more detailed work will be required at the next design stage when the selected options and the sizing of the machines will be finalized. There are also hazards related to the age and the condition of the existing bases. The structural integrity and suitability of existing compressor bases will be checked in the next design stage – see also Ref. 26 in the design risk register of the document 20840-EN-RPT-000-0004 “Design Process Safety Report”

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Based on piping and equipment layout finalized by piping based on the consideration listed in respective section, required foundation for below items has been planned.

- New lighting pole required along the fence and road-approx. 21 no’s
- New pipe support for above ground piping nearby compressor foundation-approx. 10no’s
- New fence to increase the plant area. Foundation for fence has been considered at 3m c/c
- Demolition of existing fence and road – 6no’s of light pole and 165m of existing fence
- Demolition of existing control building plan area 463sq M
- New control building size 42m x 22m– layout has been finalized based on
    - HSE requirement
    - No of personal offices
    - Electrical, instrumentation & Telecom room requirement
    - HVAC requirement
    - Environmental requirement
    - Ergonomics requirement
    - Equipment & cabinet room

Following consideration was kept in mind during foundation layout

- Underground existing facilities – As the existing foundation will be used, its adequacy need to be checked in the next design stage
- Underground existing facilities – As a new building has to be constructed, the clashes with underground existing facilities such as cables, pipe, near by foundation etc need to be checked in line with constructability requirement of foundation
- Existing drainage system- The existing gravity drainage has to be carefully re-routed and new drainage from control building area to be connected in existing system. The adequacy of existing sewage drainage system will need to be checked in the next design stage.
- Proximity of nearby foundation and facilities. Clashes with existing foundation to be checked properly to provide safe and constructible design
- Cost and economic design.
- Maintenance accessibility
- Construction feasibility for proposed facilities and related issues
- Cable trenches for electrical, Instrumentation and telecom include any crossing requirement for existing buried facilities

- New building shall be accessible from all around and in case of any hazard, personal can easily evacuate from inside to outside master point

Special attention was paid while considering foundation to minimize the impact on the existing facilities.

8.7.5 Option 5 – C & I

The C&I scope for this option is focused on the installation of new engine and compressor. The assumption is that both the engine control & the compressor control and associated field instrumentation and any associated interfaces shall be supplied as a package.

The instrument scope associated with the new GT and compressor option includes but not limited to the following:

- New compressor and turbine control package inclusive of instrumentation.
- Integration of new compressor and engine control system (TCS) with station Control & 3rd party systems.
- New interface cables between new TCS and existing station control system.
- Integration of new GT & Compressor package FGS & ESD to existing plant FGS & ESD.

8.7.6 Option 5 – Electrical

Layout 1

As part of the MCPD FEED feasibility project the following electrical works will be carried out for Layout 1. In Layout 1 two new compressor train 1 and 2 located in north side of the existing feeder pipeline. These compressors will have new LVAC Distribution board, MCC, Lighting Distribution board and required other accessories in line with the manufacturer recommendations.

The Electrical power will be tapped from the Existing LV AC spare feeders for each new compressors and if required the spare feeder will be modified to the present technical / standard's. The existing power supply will be fed to the new LVAC DB for the New compressor train 1 and 2 local requirements. The new LVAC DB, Lighting DB, DC UPS, AC UPS and MCC as required by the compressor manufacturer will be supplied and installed for the new compressors and connected to the respective applications.

The Lighting system with fittings and required sockets will be installed for the new road layout and to the new compressor area.

New earthing system will be installed for the new compressors.

Small power and multicore cables for the new compressors will be installed.

In the existing GT locations during the course of refurbishment the required indoor / outdoor light fittings will be revisited, and new fittings will be installed as required. The earthing system in the existing GT area will be revisited and updated with respect to the recommendations of earthing survey and condition report. The earthing survey will be carried out by others.

Layout 2

As part of the MCPD FEED feasibility project the following electrical works will be carried out.. In this Layout two new compressor train 1 and 2 will be installed in south side of the existing feeder pipeline. These compressors will have new LVAC Distribution board, MCC, Lighting Distribution board and required other accessories in line with the manufacturer recommendations.

The Electrical power will be tapped from the Existing LV AC spare feeders for each new compressors and if required the spare feeder will be modified to the present technical / standard. The existing power

supply will be fed to the new LVAC DB for the New compressor train 1 and 2 local requirements. The new LVAC DB, Lighting DB, DC UPS, AC UPS and MCC as required by the compressor manufacturer will be supplied and installed for the new compressors and connected to the respective applications.

The Lighting system with fittings and required sockets will be installed for the new road layout and to the new compressor area.

New earthing system will be installed for the new compressors.

All the small power and multicore cables for the new compressors will be installed.

In the existing GT locations during the course of refurbishment the required indoor / outdoor lighting will be revisited, and new fittings will be installed as required. The earthing system in the existing GT area will be revisited and updated with respect to the recommendations of earthing survey and condition report. The earthing survey will be carried out by others.

Layout 3

As part of the MCPD FEED feasibility project the following electrical works will be carried out for Layout 3. In this Layout the existing control room will be demolished and new compressor train 1 will be installed in this location and the existing GT unit B will be retained. The new control room will be built in north side of the existing feeder pipeline. In this option the Auxiliary Transformer will be relocated adjacent to the new control room and the 11kV cable between NOC substation to the Auxiliary Transformer and from Auxiliary Transformer to the LVAC board in the new control room to be replaced with new cables and terminated.

The existing power supply will be fed to the new LVAC DB for the New compressor train 1 and existing unit B local requirements. The new LVAC DB, Lighting DB, DC UPS, AC UPS and MCC as required by the new compressor train manufacturer will be supplied and installed for the new compressor train 1 and connected to the respective applications. The existing GT unit B electrical connections will be checked and if required will be replaced with new systems in line with the most upto date standards.

The Light fittings, required sockets, earthing, small power and multicore cables will be installed for the new compressor train 1.

In the existing GT unit B location during the course of refurbishment the required indoor / outdoor lighting will be revisited and new fittings will be installed as required. The earthing system in the existing GT unit B area will be revisited and updated with respect to the recommendations of earthing survey and condition report. The earthing survey will be carried out by others.

Layout 4

As part of the MCPD FEED feasibility project the following electrical works will be carried out for Layout 4. In this Layout the existing control room will be demolished and New compressor train 2 will be installed in this location and second new compressor train 1 will be installed adjacent to the existing GT's unit A and B. The new control room will be built in north side of the existing feeder pipeline. In this option the Auxiliary Transformer will be relocated adjacent to the new control room and the 11kV cable between NOC substation to the Auxiliary Transformer and from Auxiliary Transformer to the LVAC board in the new control room to be replaced with new cables and terminated.

The existing power supply will be fed to the new LVAC DB for the New compressor Train 1 and 2. The new LVAC DB, Lighting DB, DC UPS, AC UPS and MCC as required by the new compressor Train 1 and 2 manufacturers will be supplied and installed for the new compressor train 1 and 2 and connected to the respective applications.

The Light fittings, required sockets, earthing system, small power and multicore cable will be installed for the new compressor train 1 and 2.

Layout 5

As part of the MCPD FEED feasibility project the following electrical works will be carried out for Layout 5. In this Layout the existing GT Unit A and B location will be reused.

The existing power supply will be fed to the new LVAC DB's for the New compressor train 1 and 2 in the existing unit A and B location and to their local requirements. The new LVAC DB, Lighting DB, DC UPS, AC UPS and MCC as required by the new compressor train 1 and 2 manufacturer will be supplied and installed for the New units and connected to the respective applications.

In the existing GT unit A and B location during replacing with new compressor train 1 and 2 the required indoor / outdoor lighting, sockets will be revisited and new fittings will be installed as required. The earthing system in the existing area will be revisited and updated with respect to the recommendations of earthing survey and condition report.

Layout 6

As part of the MCPD FEED feasibility project the following electrical works will be carried out for Layout 6. In this Layout new compressors train 1 and 2 will be installed in the existing GT Unit A and B location.

The existing power supply will be fed to the new LVAC DB's for the New compressor train 1 and 2 in the existing unit A and B location and to their local requirements. The new LVAC DB, Lighting DB, DC UPS, AC UPS and MCC as required by the new compressor train 1 and 2 manufacturer will be supplied and installed for the new compressor train 1 and 2 and connected to the respective applications.

In this Layout the existing control room will be demolished, and new control room will be built in north side of the existing feeder pipeline. In this option the Auxiliary Transformer will be relocated adjacent to the new control room and the 11kV cable between NOC substation to the Auxiliary Transformer and from Auxiliary Transformer to the LVAC board in the new control room to be replaced with new cables and terminated.

In the existing GT unit A and B location during replacing with new compressor train 1 and 2 the required indoor / outdoor lighting, sockets will be revisited and new fittings will be installed as required. The earthing system in the existing area will be revisited and updated with respect to the recommendations of earthing survey and condition report. The earthing survey will be carried out by others.

8.7.7 Option 5 – Construction Notes

Note: The general positives and negatives of all the site locations, have been reviewed during the site location and layout review in accordance with the pre-populated sheets (see the email sent at 22.02.2022) so that an informed decision can be made as to the best layout option.

Layout 1

- First construction task would be to install the new fence line
- Temporary lay down area constructed in southern fenced in area south of Feeder 23
- Construct temporary office, welfare and plant facilities
- Construct new road infrastructure within existing plant fence line & external of fence as is practical.
- Construct firewall around generator
- Piping spool fabrication
- Steel erection / pipe supports
- Commence piping installation as far as practical prior to Machine installation
- Cable routing / JB / marshalling cabinet placement
- Remove existing Southern boundary fence in part to allow road completion
- Install compressor & major foundations civils
- Install new Compressors

- Complete piping, ME&I installation, tie-ins
- Pre-commissioning Completions ME&I, Mechanical Completion
- Commission new systems
- Decommission obsolete units & facilities
- Reinstate areas & removal temporary facilities
- Operational Handover

For works in the existing site, like tie-ins, vent stack etc, see the notes below:

- SIMOPS requirements
- Consider operational schedule / demand for time frame for SIMOPS scenario
- Lifting over 'Live' Plant
- Commission machine whilst station operational, interfaces, trip potentials.
- Scheduling of construction pre-works / installation ahead of any decommissioning to shorten removal / installation timing within Low Demand window.
- Equipment / manning levels
- Lifting Plans, placement areas
- Construction work areas, access / egress.
- Consider requirement "dropped object" design
- Existing underground service locations
- HAZCON study and requirements
- Existing Plant Operation to Project interfaces
- Permits to work control, isolation procedures, restricted areas
- Outline schedule commencement through commissioning to operational handover
-

Layout 2

Siting New Compressors South of feeder 23 extends the site boundary considerably further South requiring extensive tree and shrub removal. This will likely cause a longer planning / environmental approval process. Additional environmental surveys required plus time windows for removals time limits / focusing on seasonal nesting, breeding seasons

This layout requires the new piping to cross feeder 23, which add extra requirements related to crossing of pipelines and robust construction execution strategies.

One of the first actions for the next design stage will be the topographical and buried services surveys so that the coordinates and the elevation of the pipeline of feeders 23, as well as any other underground services in the area are known accurately, in order to define the type of crossings, the elevations and the runs including any protective structures that might be required.

Construction similar process to Layout 1 with the addition of works in the vicinity of pipelines as per the standards below:

- T/MP/SSW/2 V11 – Management Procedure for Safe Working And Development In The Vicinity Of National Grid Gas Pipelines And Associated Installations / Requirements For National Grid Gas
- T/SP/SSW/22 Apr 20 - Specification for safe working in the vicinity of National Grid high pressure gas pipelines and associated installations - requirements for third parties

- T/SC/CE/12 – specification for the design, construction and testing of civil and structural works part twelve: protection works over steel pipelines

For works in the existing site, like tie-ins, vent stack etc, see the notes below:

- SIMOPS requirements
- Consider operational schedule / demand for time frame for SIMOPS scenario
- Lifting over 'Live' Plant
- Commission machine whilst station operational, interfaces, trip potentials.
- Scheduling of construction pre-works / installation ahead of any decommissioning to shorten removal / installation timing within Low Demand window.
- Equipment / manning levels
- Lifting Plans, placement areas
- Construction work areas, access / egress.
- Consider requirement "dropped object" design
- Existing underground service locations
- HAZCON study and requirements
- Existing Plant Operation to Project interfaces
- Permits to work control, isolation procedures, restricted areas
- Outline schedule commencement through commissioning to operational handover

Layout 3

-
- SIMOPS requirements
- Consider operational schedule / demand for time frame for SIMOPS scenario

- Lifting over 'Live' Plant
- Potential for excessive spurious trips / alarms
- Plant on-line take out one machine / train & install new
- Commission machine whilst station operational, interfaces, trip potentials.
- Review existing unit design re: decommissioning, package component / modular removals.
- Scheduling of construction pre-works / installation ahead of any decommissioning to shorten removal / installation timing within Low Demand window.
- Equipment / manning levels
- Lifting Plans, placement areas
- Construction work areas, access / egress.
- Consider requirement "dropped object" design
- Existing underground service locations
- HAZCON study and requirements
- Existing Plant Operation to Project interfaces
- Permits to work control, isolation procedures, restricted areas
- Outline schedule commencement through commissioning to operational handover
- Demolition requirements of existing control building
- Existing still required to be in service, therefore new control building would need to be operational, but tied to existing in the interim until new machine & facilities installed.

Layout 4

- As Per Layout 3
- More existing plant demolition, with consequential ME&I isolations interfacing.
- Plant, structures, ME&I removals.
- More civils remedials / reinstatement requirements

Layout 5

- SIMOPS requirements
- Consider operational schedule / demand for time frame for SIMOPS scenario

- Lifting over 'Live' Plant
- Potential for excessive spurious trips / alarms
- Plant on-line take out one machine / train & install new
- Commission machine whilst station operational, interfaces, trip potentials.
- Review existing unit design re: decommissioning, package component / modular removals.
- Scheduling of construction pre-works / installation ahead of any decommissioning to shorten removal / installation timing within Low Demand window.
- Equipment / manning levels
- Lifting Plans, placement areas
- Construction work areas, access / egress.
- Consider requirement "dropped object" design
- Existing underground service locations
- HAZCON study and requirements
- Existing Plant Operation to Project interfaces
- Permits to work control, isolation procedures, restricted areas
- Outline schedule commencement through commissioning to operational handover

Layout 6

-
- Similar issues to layout 5 for installation of new compressors
- Demolition requirements of existing control building
- Existing still required to be in service, therefore new control building would need to be operational, but tied to existing in the interim until new machine & facilities installed

8.8 Option 6 – New VSD

8.8.1 Option 6 – General

A VSD compressor would be considered for replacement of the two existing GT driven compressors (Unit A & B).

The main advantage of this solution is the almost complete elimination of NOx emissions at Wormington Compressor Station as a direct result of removal of the two mentioned GT drivers and use of an electrical drive replacement.

A concern expressed by CLIENT related to power supply availability and overall reliability of the existing VSD compressor (Unit C) and the length of time that the unit is unavailable due to reliability issues and the time that the machine is physically off-site for repair in the supplier's workshops is of concern and could possibly contribute to unexpected failure of compression capability at Wormington and therefore negatively impact the gas transmission network.

Also, a new VSD option was discounted due to the fact that, were it to be adopted then Wormington Compressor Station would be totally reliant on HV electricity supply for gas compression and this introduces the potential for a single point of failure.

For this reason, a solution involving a new VSD has not been explored further.

8.8.2 Option 6 –Future Electrical Recommendation

In the NOC compound there two nos 66/11kV Transformers – Distribution Network Organisation (DNO), which provide a redundant power to CLIENT Gas Station at Wormington. The present arrangement is shown in the figure below

The following Switchgear needs to be added to the present arrangement for feeding to the New VSD system,

- Busbar extension
- 1 Future VSD feeder
- 1 Harmonic Filter feeder

This needs to be fitted in the existing switchgear room and connected through the busbar to the existing Switchgear, the existing switchgear type is available in the market, hence we don't have any major issues for replacing with new switchgears.

Installation of additional Switchgear should be considered in the earlier extension of the Switchgear room. When this requirement arises, it should accommodate fitting the additional Switchgears. This arrangement is given in the below.

The related LV Distribution Board, 11kV cable, Multicore cables, Termination, Earthing, Lighting and other accessories needs to be replaced or modified to these requirements.

8.9 Option 7 – Rewheel

For case 2 P11, the existing compressors cannot meet the duty point however, if one of the existing compressors is rewheeled (change the internal components of the compressors) in combination of retrofit and DLE and a new compressor train then the requirements for increased pressure at the outlet of the compressors can be met.

For this case, the existing Avon is capable to drive the re-wheeled compressor and no other works will be required apart from the removal and re-installation of the compressor, the Asset Health works and software updates for the compressors balancing.

The removal and re-installation of the compressor will be in accordance with established procedures on site.

Rewheeling is technically doable as confirmed by the OEM however, more studies will be required mainly from the OEM at the next stage of the project.

9. COST ESTIMATE

9.1 General

As part of the FEED scope of works is to produce cost estimates. A +/- 50% estimate that was produced for the Long List items is in document 20840-PM-COE-000-0001.

As the FEED Study has evolved and developed further new estimates were required for the Short-Listed Options with an accuracy of +/- 30%. The +/- 30%. Estimate is in document 20840-PM-COE-000-0002.

Both documents mentioned above are included in Appendix B

A summary for the +/- 30%.estiamte is included in the next page.

9.2 Estimate +/- 30% Summary

Cost Summary Level 1	PDS Case 1					PDS Case 2				PDS Case 3	PDS Case 4				PDS Case 5			
	Option 5 New GT	Option 1 Derated Avon	Option 4 Retrofit DLE (2 No)	Asset Health plus Overhaul (2 No)	TOTAL	Option 5 New GT	Option 4 Retrofit DLE (1No)	Asset Health plus Re - wheeling (1No)	TOTAL	Option 5 New GT	Option 5 New GT	Option 1 Derated Avon	Asset Health plus Overhaul (1 No)	TOTAL	Option 5 New GT	Option 1 Derated Avon	Asset Health plus Overhaul (1 No)	TOTAL
Retrofit DLE plus 1 x 60% for PDS Case 2 (1 No) Standalone for PDS Case 1 (2No).	[redacted]																	
New GT/Comp Layout 1 2 x 50%																		
New GT/Comp Layout 1 1 x 60%																		
New GT/Comp Layout 2 2 x 50%																		
New GT/Comp Layout 2 1 x 60%																		
New GT/Comp Layout 3 1 x 60%																		
New GT/Comp Layout 4 2 x 50%																		
New GT/Comp Layout 5 2 x 50%																		
New GT/Comp Layout 6 2 x 50%																		

Upgrading of existing gas turbines is appliable only for PDS Case 1 point C10. However the recommendation in the FEED Report is to optimise the operating conditions instead of upgrade.
The cost of asset health plus upgrading gas turbines for this point calculates to [redacted] see Option B in the analysis.

10. SCHEDULE FOR OPTIONS

Schedule for Options 1, 4 & 5 has been developed. See subsections below.

Basis for development of these schedules is:

- Award of Contract – 01-Feb-23
- Tendering Phase – 6 Months post award.
- Overall Construction, Precommissioning, Mechanical Completion, Commissioning & Handover is based on delivery of the Compressor to work site (Retrofit / Derating / New).
- After delivery of the Compressor to work site, 5-6 Months to complete the commissioning & handover works.
- Based on the option selected, to commence construction activities early; site preparation, civil, structural (shop & worksite), piping (shop & worksite), electrical & instrumentation. This is to achieve the readiness before the receipt of Compressor at work site.
- Upon receipt of Compressor outstanding activities; tie-ins, termination of cables, updation of system etc. to be completed to make it ready for Commissioning & Operation Handover.
- Parallel activities to be performed for the as built documentation and to be finished by 1 Month from completion of Operation Handover.

10.1 Schedule For Option 1

[redacted]

20840- Wormington FEED EPC Schedule

DERATED AVON

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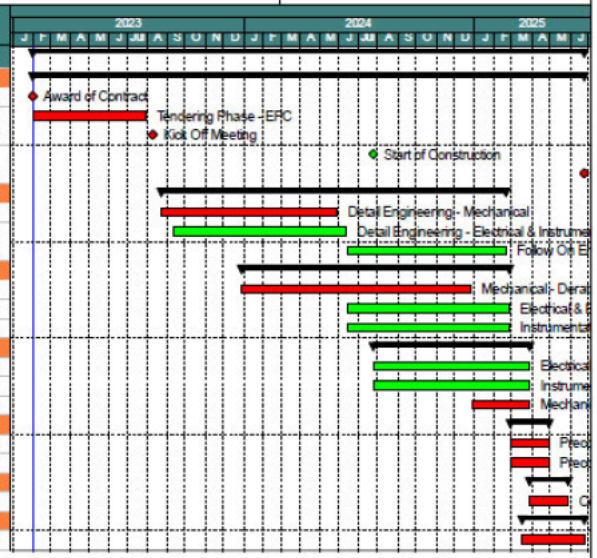
Activity ID	Activity Description	Original Duration	Start	Finish
20840-5	20840 - FEED EPC Schedule - Derated AVON Rev 1	693	01-Feb-23	23-Jun-25
20840-5.1	MILESTONES	693	01-Feb-23	23-Jun-25
A1000	Award of Contract	0		01-Feb-23
A1010	Tendering Phase - EPC	129	01-Feb-23	31-Jul-23
A1170	Kick Off Meeting	0		09-Aug-23
A1180	Start of Construction	0	24-Jul-24	
A1190	Overall Project Completion	0		23-Jun-25
20840-5.2	ENGINEERING	390	24-Aug-23	19-Feb-25
A1210	Detail Engineering - Mechanical	198	24-Aug-23	27-May-24
A1230	Detail Engineering - Electrical & Instrumentation	198	11-Sep-23	12-Jun-24
A1020	Follow On Engineering	180	13-Jun-24	19-Feb-25
20840-5.3	PROCUREMENT & DELIVERY	363	29-Dec-23	24-Feb-25
A1030	Mechanical - Derated AVON	312	29-Dec-23	26-Dec-24
A1060	Electrical & Bulks	220	13-Jun-24	24-Feb-25
A1070	Instrumentation & Bulks	220	13-Jun-24	24-Feb-25
20840-5.4	CONSTRUCTION	214	24-Jul-24	29-Mar-25
A1120	Electrical Works	214	24-Jul-24	29-Mar-25
A1130	Instrumentation Works	214	24-Jul-24	29-Mar-25
A1090	Mechanical Works	80	27-Dec-24	29-Mar-25
20840-5.7	PRE COMMISSIONING & MECHANICAL COMPLETION	52	27-Feb-25	28-Apr-25
A1140	Precommissioning Works & Mechanical Completion - Mechanical	52	27-Feb-25	28-Apr-25
A1260	Precommissioning Works & Mechanical Completion - Electrical & Instrumentation	52	27-Feb-25	28-Apr-25
20840-5.5	COMMISSSIONING & HANDOVER	52	29-Mar-25	28-May-25
A1150	Commissioning Works & Operational Handover	52	29-Mar-25	28-May-25
20840-5.6	AS-BUILT	70	17-Mar-25	23-Jun-25
A1160	As Built Documentation	70	17-Mar-25	23-Jun-25



Normal
Actual Work
Current Milestone
Critical Milestone
Critical Remaining Work
Summary

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Date	Revision	Checked	Approved
13-Apr-22	Rev 1		
16-Mar-22	Rev 0		

10.2 Schedule For Option 4

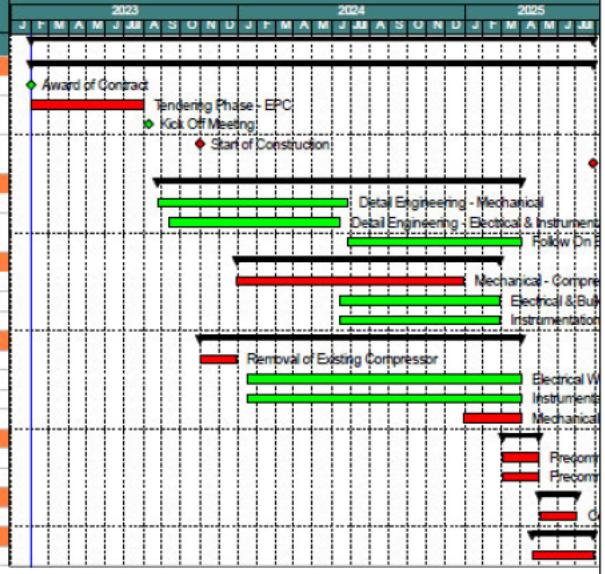
[redacted]

20840- Wormington FEED EPC Schedule

RETROFIT DLE

Page : 1 of 1

Activity ID	Activity Description	Original Duration	Start	Finish
20840-4	20840 - FEED EPC Schedule - Retrofit DLE Rev 1	720	01-Feb-23	28-Jul-25
20840-4.1	MILESTONES	720	01-Feb-23	28-Jul-25
A1000	Award of Contract	0		01-Feb-23
A1270	Tendering Phase - EPC	129	01-Feb-23	31-Jul-23
A1170	Kick Off Meeting	0		09-Aug-23
A1180	Start of Construction	0	31-Oct-23	
A1190	Overall Project Completion	0		28-Jul-25
20840-4.2	ENGINEERING	420	24-Aug-23	02-Apr-25
A1210	Detail Engineering - Mechanical	220	24-Aug-23	26-Jun-24
A1230	Detail Engineering - Electrical & Instrumentation	200	11-Sep-23	14-Jun-24
A1020	Follow On Engineering	200	27-Jun-24	02-Apr-25
20840-4.3	PROCUREMENT & DELIVERY	364	30-Dec-23	26-Feb-25
A1030	Mechanical - Compressors Updation (Workshop Works)	314	30-Dec-23	30-Dec-24
A1060	Electrical & Bulks	220	15-Jun-24	26-Feb-25
A1070	Instrumentation & Bulks	220	15-Jun-24	26-Feb-25
20840-4.4	CONSTRUCTION	446	31-Oct-23	02-Apr-25
A1080	Removal of Existing Compressor	52	31-Oct-23	29-Dec-23
A1120	Electrical Works	380	16-Jan-24	02-Apr-25
A1130	Instrumentation Works	380	16-Jan-24	02-Apr-25
A1090	Mechanical Works	80	31-Dec-24	02-Apr-25
20840-4.7	PRE COMMISSIONING & MECHANICAL COMPLETION	52	03-Mar-25	01-May-25
A1140	Precommissioning Works & Mechanical Completion - Mechanical	52	03-Mar-25	01-May-25
A1260	Precommissioning Works & Mechanical Completion - Electrical & Instrumentation	52	03-Mar-25	01-May-25
20840-4.5	COMMISSSIONING & HANDOVER	52	02-May-25	01-Jul-25
A1150	Commissioning Works & Operational Handover	52	02-May-25	01-Jul-25
20840-4.6	AS-BUILT	70	21-Apr-25	28-Jul-25
A1160	As Built Documentation	70	21-Apr-25	28-Jul-25



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Critical Milestone
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Summary

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Date	Revision	Checked	Approved
13-Apr-22	Rev 1		
16-Mar-22	Rev 0		

10.3 Schedule For Option 5

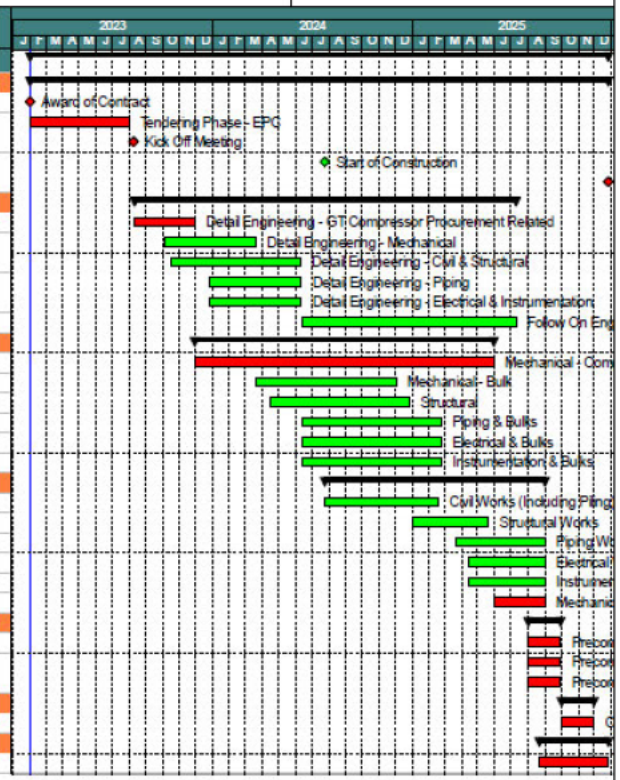
[redacted]

20840- Wormington FEED EPC Schedule

NEW GT COMPRESSOR

Page : 1 of 1

Activity ID	Activity Description	Original Duration	Start	Finish
20840-3	20840 - FEED EPC Schedule - New GT Compressor Rev 1	841	01-Feb-23	25-Dec-25
20840-3.1	MILESTONES	841	01-Feb-23	25-Dec-25
A1000	Award of Contract	0		01-Feb-23
A1270	Tendering Phase - EPC	129	01-Feb-23	31-Jul-23
A1170	Kick Off Meeting	0		09-Aug-23
A1180	Start of Construction	0	24-Jul-24	
A1190	Overall Project Completion	0		25-Dec-25
20840-3.2	ENGINEERING	500	10-Aug-23	09-Jul-25
A1200	Detail Engineering - GT Compressor Procurement Related	80	10-Aug-23	29-Nov-23
A1210	Detail Engineering - Mechanical	120	05-Oct-23	20-Mar-24
A1010	Detail Engineering - Civil & Structural	170	17-Oct-23	10-Jun-24
A1220	Detail Engineering - Piping	120	28-Dec-23	12-Jun-24
A1230	Detail Engineering - Electrical & Instrumentation	120	28-Dec-23	12-Jun-24
A1020	Follow On Engineering	280	13-Jun-24	09-Jul-25
20840-3.3	PROCUREMENT & DELIVERY	470	30-Nov-23	30-May-25
A1030	Mechanical - Compressors	470	30-Nov-23	30-May-25
A1240	Mechanical - Bulk	220	21-Mar-24	02-Dec-24
A1040	Structural	220	16-Apr-24	27-Dec-24
A1050	Piping & Bulks	220	13-Jun-24	24-Feb-25
A1060	Electrical & Bulks	220	13-Jun-24	24-Feb-25
A1070	Instrumentation & Bulks	220	13-Jun-24	24-Feb-25
20840-3.4	CONSTRUCTION	347	24-Jul-24	01-Sep-25
A1080	Civil Works (Including Piling)	180	24-Jul-24	18-Feb-25
A1100	Structural Works	120	01-Jan-25	20-May-25
A1110	Piping Works	140	22-Mar-25	01-Sep-25
A1120	Electrical Works	120	15-Apr-25	01-Sep-25
A1130	Instrumentation Works	120	15-Apr-25	01-Sep-25
A1090	Mechanical Works	80	31-May-25	01-Sep-25
20840-3.7	PRE COMMISSIONING & MECHANICAL COMPLETION	52	01-Aug-25	30-Sep-25
A1140	Precommissioning Works & Mechanical Completion - Mechanical	52	01-Aug-25	30-Sep-25
A1250	Precommissioning Works & Mechanical Completion - Piping	52	01-Aug-25	30-Sep-25
A1260	Precommissioning Works & Mechanical Completion - Electrical & Instrumentation	52	01-Aug-25	30-Sep-25
20840-3.5	COMMISSSIONING & HANDOVER	52	01-Oct-25	29-Nov-25
A1150	Commissioning Works & Operational Handover	52	01-Oct-25	29-Nov-25
20840-3.6	AS-BUILT	90	22-Aug-25	25-Dec-25
A1160	As Built Documentation	90	22-Aug-25	25-Dec-25



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13-Apr-22	Rev 1		
16-Mar-22	Rev 0		

11. FORMAL PROCESS SAFETY ASSESSMENT

11.1 General

The FPSAs were carried out in compliance with CLIENT Procedure T/PM/HAZ/9 'Application of Formal Process Safety Assessments During Engineering Design and Project Delivery Phases'. The information provided includes:

- Site Location and Layout Review Report Doc. No 20840-EN-RPT-000-0002
- HAZID1 Report Doc. No 20840-EP-RPT-000-0003
- Design Process Safety Report Doc. No 20840-EN-RPT-000-0004

The reports above are included in APPENDIX F – FORMAL PROCESS SAFETY ASSESSMENTS

11.2 Site Location & Layout Review

The purpose of the Layout Review was to identify all the possible hazards presented by each layout option such that CLIENT can use this information as part of the decision-making process when deciding which option is the one to progress forward. The Layout Review was carried out following the requirements as defined in the CLIENT 'Specification for Site Location and Layout Studies and Reviews' T/SP/G/37.

All of the Action record sheets were issued to both CLIENT and Consultant for each company to further issue these internally to the responsible engineer. Each responsible engineer is then required to provide a suitable method by which each of their action(s) can be closed.

A further meeting was held on 02/03/2022 with all parties to table and agree the action responses for all options and what is documented in the record sheets has been agreed. All actions / worksheets have been agreed and signed by the Site Location & Layout Review Chairperson.

The current status of the raised actions is:

Actioner	Actions	Fully Closed
CONSULTANT	10	10
CLIENT	1	0
Next Phase Contractor	5	0

11.3 HAZID

The scope of the HAZID1 study was to identify potential hazards arising from the design. The HAZID1 study was carried out in accordance with the CLIENT standard T/SP/HAZ/8 as a structured assessment technique using guidewords.

All of the Action record sheets were issued to both CLIENT and Consultant for each company to further issue these internally to the responsible engineer. Each responsible engineer is then required to provide a suitable method by which each of their action(s) can be closed.

A further meeting was held on 02/03/2022 with all parties to table and agree the action responses for all options and what is documented in the record sheets has been agreed. All actions / worksheets will need to be agreed and signed by the HAZID Chairperson.

The status of the raised actions is:

Actioner	Actions	Fully Closed	Transferred to the Technical Risk Register
CONSULTANT	6	6	6
CLIENT	8	0	0
Next Phase Contractor	7	0	0

12. ENVIRONMENT & SUSTAINABILITY

12.1 Project Requirements

12.1.1 Carbon

The Project Specific Scope (PSS) Service Objectives requires the Wormington Gas Compressor Station Refurbishment project to be Carbon Neutral construction[1].

The cost of achieving this vs "standard" construction must be well documented in the service study report to present to OFGEM.

NG GT has a RIIO T2 Supply Chain Responsible Business Commitments to "Achieve carbon neutral construction for major projects by 2025/26 by further implementing PAS2060 and PAS2080, supported by an offsetting policy and based on current business assumptions."

Carbon emissions committed to offset in the T2 business plan are major schemes in 2025/26: [redacted] (Milford Haven, Bacton, Wormington, plus additional compressors projects from T1). For major schemes, Bespoke FEED and contractor carbon footprints are required.

The FEED contractor will produce carbon footprints for each option under consideration (Building upon NG CAt data and aligned to NG carbon management template)[2].

The Contractor shall estimate the carbon footprint for the options considered as part of the Service.

The carbon footprint shall be included as a factor in the Cost Benefit Analysis (CBA) and option selection process.

The Contractor can use the Client's Carbon Impact Tool (CIT) provided in Appendix G (HOLD) or their own footprinting tool, the scope and functionality of which shall be verified by the Client.

12.1.2 Sustainability

The Sustainability targets and reporting section of the Generic Scope is not applicable.

For Sustainability the PSS refers to the Generic Scope (GS), which requires the following activities:

- Apply the PAS2080 standard to Cap Carbon[3]
- Provide a baseline
- Maximise reductions
- Achieve Biodiversity Net Gain (BNG) of +10%
- Adopt Best Availability Technologies (BATs) and Innovations where possible.
- Log measures taken

[1] Carbon (or climate) neutrality is defined as balancing greenhouse gas (GHG) emissions with removals. For carbon neutrality, the boundary of the calculation covers Scope 1 and 2 emissions (under direct control), with Scope 3 (supply chain) being a voluntary addition.

[2] The Detailed Design FEED Contractor needs to set the baseline for reduction through the remaining stages. It is not possible to set a baseline for the entire project at the Optioneering FEED stage due to the resolution of the design information being produced. Assume the CIT is aligned to the carbon management template.

[3] Cap Carbon = Capital Carbon. It is defined as the carbon embedded in in the demand for goods, materials, services and covers stages A0-A5 of the PAS 2080 stages of emissions. (please see Appendix H for details of the PAS 2080 Process and associated standards.

12.2 Scope of Sustainability

The scope of sustainability on the project is outlined in the Generic Scope and encompasses:

- Carbon
- Materials - Waste Minimisation in line with good practice principles of the waste hierarchy
- Biodiversity - Biodiversity Net Gain (BNG)
- Neighbour/Environment/Public Nuisance
    - Noise
    - Light pollution
    - Litter
    - Dust
- Water Management
    - Mitigation of Flood Risk
    - Mitigation of pollution to Waterbodies including containment of concrete and other cement-based products from washout to natural watercourses and interception of drainage from refuelling areas.
- Contaminated land

12.3 Other CLIENT Corporate Commitments

Wormington FOS forms part of wider long-term sustainability strategy for CLIENT (Economic, Environmental, Social) and the UK (Energy Security and Decarbonisation).

CLIENT reports performance using the GRI Reporting methodology in its Responsible Business Report. Aspects covered are reproduced in the figure below.

Figure 1: Material issues for GRI reporting purposes

The environment	Our communities	The economy	Our people	Our governance
• Enabling the clean energy system • Our own emissions and energy consumption • Air quality • Compliance • Land use • Circular economy/ waste management • Water	• Network reliability and resilience • Service affordability • Public safety • Developing STEM skills for the future • Customer satisfaction • Human rights • Compliance	• Right tax • Economic contribution • Investment (long-term/ regional) • Supply chain • Compliance	• Employee health, safety and well-being • Fair pay • Skills development • Inclusion & diversity • Social mobility • Employee rights	• Board representation & role • Business ethics/ bribery & corruption

Figure 12-1: Global Reporting Initiative issues in NG Responsible Business report

As part of this CLIENT has a number of KPIs aligned to the Sustainable Development Goals that include

- SDG 3 & SDG11 Air quality targets
- SDG 7 Affordable Clean Energy
- SDG 8 Decent Work and Economic Growth – a good employer and lever of economic growth
- SDG 13 Greenhouse Gas emissions

SDG		National Grid Activities and Programmes
5	Achieve gender equality and empower all women and girls.	We have established multiple commitments in our RBC relating to improving diversity of all kinds within our company and supply chain.
7	Ensure access to affordable, reliable, sustainable and modern energy for all.	Our Purpose is to 'bring energy to life' and through the development and management of energy infrastructure, our role in the transition to clean energy systems, and our Net Zero commitment, we act in support of SDG 7.
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.	We aim to provide the clean, affordable and reliable supply of energy that underpins economic growth whilst, through our Grid 4 Good programme, we support young people from disadvantaged backgrounds to develop the skills to find employment in the clean energy transition.
9	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	We invest in building, maintaining and innovating energy networks that will be resilient in the face of climate change, and deliver the clean energy to power sustainable industrialisation in the communities we serve.
13	Take urgent action to combat climate change and its impacts.	As well as playing a central role in enabling the clean energy transition, we have committed to deliver Net Zero greenhouse gas emissions by 2050, while strengthening the ability of our assets to withstand the impacts of climate change.

Figure 12-2: SDGs in the Responsible Business report

Under **Greenhouse Gases** the following are the reporting commitments:

- Scope 1 and 2 Greenhouse Gas (GHG) emissions (Scope 2 location based)
- Scope 1 GHG emissions
- Scope 2 GHG emissions - market based
- Scope 2 GHG emissions - location based
- Scope 3 emissions - total scope 3 emissions
- Scope 3 GHG emissions - US Cat 3 (Fuel & Energy Related Activities)
- Scope 3 GHG emissions - US Cat 11 (Use of Sold Products)
- Scope 3 GHG emissions - UK & US Cat 1 (Purchased Goods and Services)
- SF6 emissions

Under **Air Quality** the following are KPIs

- Air quality - Emissions from stationary sources (NOx)
- Air quality - Emissions from stationary sources (SOx)
- Air quality - Emissions from stationary sources (PM)
- GHG emissions from air travel
- Total miles from air travel

KPIs in relation to **SDG7 and Communities** relate to keeping energy affordable:

- Electric: Average Customer Bill (Low Income Customers Excluded)- affordability
- Gas: Average Customer Bill (Low Income Customers Excluded)- affordability
- Electric: Average Low Income (only) Customer Bill- affordability
- Gas: Average Low Income (only) Customer Bill- affordability
- Contribution of CLIENT's UK's transmission costs to consumer bills – affordability

CLIENT is a user of the CEEQUAL rating scheme for demonstrating sustainability in infrastructure. While not included in the brief, consultations with the Client revealed a desire to align with this in the gas infrastructure side also.

Therefore, a review of the scheme proposals against the CEEQUAL scheme is included in Appendix G (HOLD) to enable the Client to articulate CEEQUAL aspirations through the design and procurement stages, ensuring that the scheme remains CEEQUAL-ready.

12.4 Carbon

Capital carbon is currently considered to be a good proxy for resource efficiency.

Greatest savings are made at the project inception/brief. Potential decreases thereafter.

Early-adopter sectors (water, highways) report that saving carbon emissions saves costs and stimulates innovation.

Scope of Carbon Emissions on the Project

The Client has set an ambitious target to achieve net zero construction on all major construction projects by 2025/26 in accordance with PAS2080 (infrastructure carbon). This aims to reduce the emissions to air during the whole life cycle of the project.

Principles of PAS2080 are to be applied to maximise the % reduction in carbon, between baseline and delivered design, contributing to the attainment of Net Zero construction emissions on major schemes by 2025/26.

The Carbon Interface Tool (CIT) provided is to be populated throughout the project and reductions achieved captured.

The Client has an aspiration to ultimately capture at least 96% of embodied emissions in the final project.

Components specifically included in the CIT are listed below, with a requirement for Carbon Stages A1-3 as a minimum to be estimated.

- Pipes
- Flanges
- Elbows
- Reducers
- Equal Tees
- Insulation Joints
- Compressors
- Pig Traps
- Diesel Generators
- Transformers
- Valves
- Actuators
- Cables
- Demolition
- Earthworks
- Equipment Foundations
- Roads & Hardstandings

- Fences
- Buildings and Foundations – limited to Steel-clad building w/foundation – standard design, bricks, steel cladding, doors.
- Trenches & Ducts
- Services – water, pipework, tank, firefighting, generator bund
- Other (basic material)
- Additional Items not listed

The PAS 2080 Stages are explained in the next section.

PAS 2080 Essentials

PAS 2080 adopts the LCA stages of BS EN 15978. This breaks the lifespan of a material into the different stages of use for computation at that stage. The stages are (see Figure 12-3 below):

Capital Carbon or Cap Carbon

This considers the carbon embedded in the fabric of the design from the design stages (A0) where the Client and design team use energy to work, meet and visit the site to determine the form the project will take, materials that will be used and how they will be used.

Stages A1-A3 cover the extraction of the raw material and transport to plant for processing. A3 includes processing to the factory gate.

A4 covers transport of the material to the site; it also covers other transport associated with the site that is attributable to this product – the construction site staff commuting to site, for instance. If the manufacturer uses a distribution centre, the distance from the factory to the distribution centre will typically be included on the Environmental Product Declaration for the product. Stage A5 then covers the energy used for installation on site.

Stages A0-A5 are called Capital Carbon – or Cap Carbon, for short.

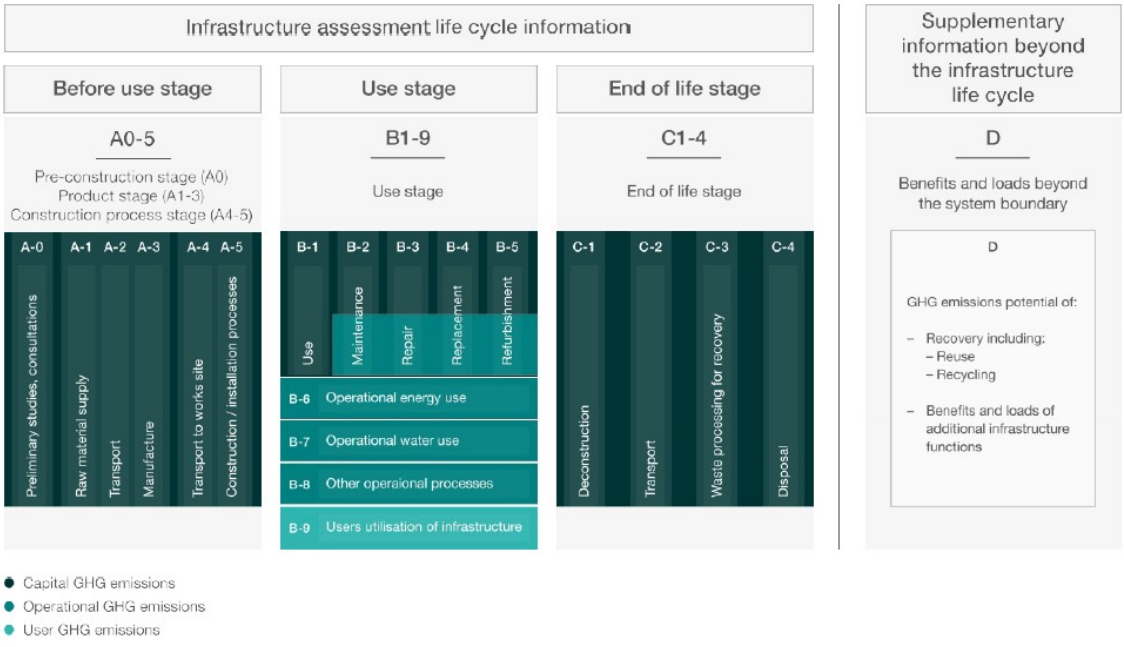


Figure 12-3: PAS2080 Stages

The B Stages of a product's lifecycle covers the emissions associated with the use and operation of the product throughout its lifetime. This covers and process or other direct emissions (or absorption) of carbon on site, emissions of those maintaining, repairing, refurbishing it, as well as the material carbon they are using. Operational energy and water (which generally uses energy) associated with the product consider the emissions off-site due to energy used on site. These stages are known as the Operational Carbon or Op Carbon.

The most recent addition to this section is User Carbon. This is the increase or saving in carbon that is enabled by this infrastructure – for instance railways enable a saving in user carbon on personal vehicle emissions.

Likewise, Wormington inevitably has – over the course of its lifetime – enabled a transition from coal or oil-fired power generation to cleaner natural gas. It is potentially still on that journey. However, as a compressor station, the extent of this will be difficult to estimate, as Wormington is simply boosting existing supply as needed.

The Final Stages (C and D) cover the end of the material's life (EoL) – the energy used to demolish/deconstruct, transport the material for transformation, reintroduction to the circular economy or to its final resting place. Material re-used or recycled, that displaces carbon embedded in new products, can lay claim to that carbon saving and deduct it from the material's WLC budget. This requires than an energy saving is made through re-use. (Stage D)

PAS2080 Context

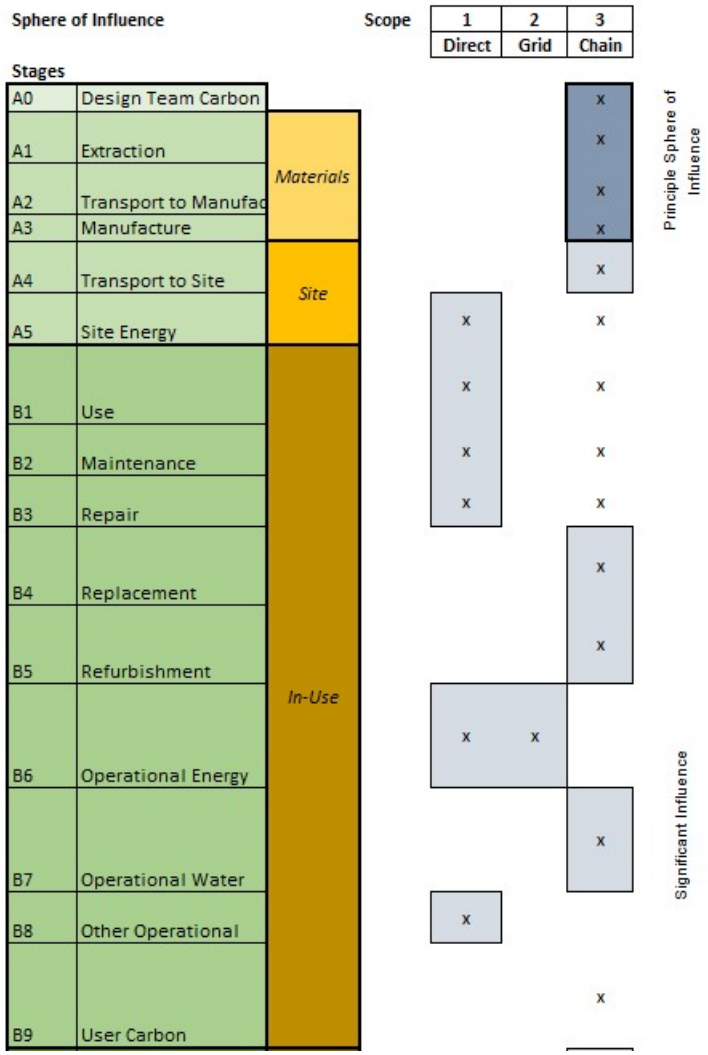
Companies report emissions in terms of their "Scope" – this is essentially the point of emissions and/or degree of control over the emissions. Scope 1 is emissions directly occurring on the or journeying to site within the control of the Client or Client's agents. Scope 2 is emissions elsewhere demanded by the Client or Client's agents – typically grid electricity. Scope 3 occurs in the supply chain, over which the Client has some but limited control.

The scope of carbon reporting on this FEED study is on Stages A1-3 of the supply chain (**Figure 12-4**), but the design tries to minimise carbon elsewhere in the lifecycle through design and facilitate minimisation at other stages. The degree to which the project can influence carbon at other stages of the lifecycle through the design is indicated in **Figure 12-5** below.

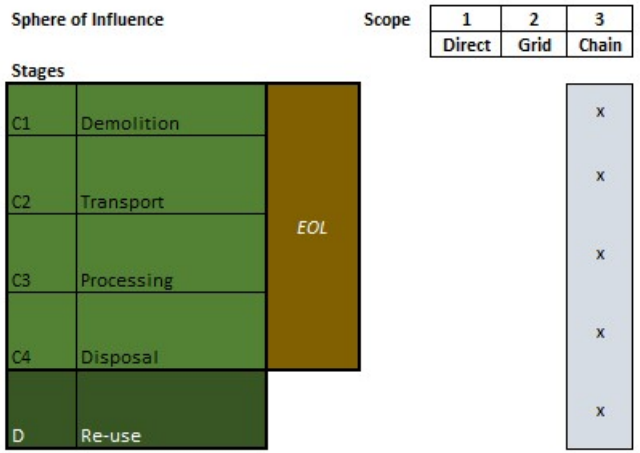
Context of Wormington

Stages			Scope 1 Direct	Scope 2 Grid	Scope 3 Chain
A0	Design Team Carbon				x
A1	Extraction	*Materials*			x
A2	Transport to Manufact				x
A3	Manufacture				x
A4	Transport to Site	*Site*			x
A5	Site Energy		x		x
B1	Use	*In-Use*	x		x
B2	Maintenance		x		x
B3	Repair		x		x
B4	Replacement				x
B5	Refurbishment				x
B6	Operational Energy		x	x	
B7	Operational Water				x
B8	Other Operational		x		
B9	User Carbon				x
C1	Demolition	*EOL*			x
C2	Transport				x
C3	Processing				x
C4	Disposal				x
D	Re-use				x

Figure 12-4: Context of this project in terms of the PAS2080 Stages for the asset



Wormington FEED Project	Opportunity to Reduce Carbon Remaining
Emits this	None - it is what it is
Mostly determines this	None for specialised equipment that is completely spec'd Some scope for sourcing of generic equipment/materials
Partially determines this through big equiment choices of recommended works and layout choices	Some scope for sourcing of generic equipment/materials Some scope for contractor to reduce through methods, source and practices
Design and equipment selection determines the process emissions in use, including staff required on site,	Some scope for reducing staff transport emissions and process efficiency
Design partially determines the maintenance effort required	Some scope for client to require reduced supply chain emissions
Design partially determines the maintenance effort required	Some scope for client to require reduced supply chain emissions
Design fully determines lifespan of major equipment	Scope for contractor to improve general durability; and client to ensure care of site extends life of components
Design fully determines lifespan of major equipment and ability of equipment to be refurbed	Some scope for client to require reduced supply chain emissions
Design largely determines operational energy	Some scope for contractor to reduce further through selection/procurement and further scope for client to reduce through site good practices and energy sourcing
Design largely determines operational water requirement	Some scope for contractor to reduce further through selection/procurement and further scope for client to reduce through site good practices and water recycling
Design largely determines other operational emissions	Some scope for client to reduce through good management practices
Design determines capability to facilitate user reductions of carbon downstream, if facilitating switch from solid and liquid hydrocarbons	Client determines service capability



Scope	1	2	3
	Direct	Grid	Chain
Significant Influence	x	x	x
	x	x	x
	x	x	x
	x	x	x
	x	x	x

Wormington FEED Project	Opportunity to Reduce Carbon Remaining
Mostly determined by design	Some scope for contractor to reduce waste by retention and reuse on site
Mostly determined by design	Some scope for contractor to reduce waste by retention and reuse on site and choice of transport/service
Mostly determined by design	Some scope for contractor to reduce waste by retention and reuse on site and how demolition has been done
Mostly determined by design	Some scope for contractor to reduce waste by retention and reuse on site, how demolition has been done and choice of waste handler
Mostly determined by design	Some scope for contractor to reduce waste by retention and reuse on site, how demolition has been done and choice of waste handler

Figure 12-5: PAS2080 Stages of the Design that can be influenced at the FEED stage and Carbon remaining that can be influenced by the construction project

While PAS2080 is typically applied to a project, with the CapCarbon supplied for the A stages, in practice Wormington is an asset with a long lifetime.

In context of the asset lifetime, the carbon emitted on this project is Stages B4 and B5 – part of the asset management cycle of the project. This is mentioned in order to avoid later double-counting in apportioning carbon over the lifecycle of the asset.

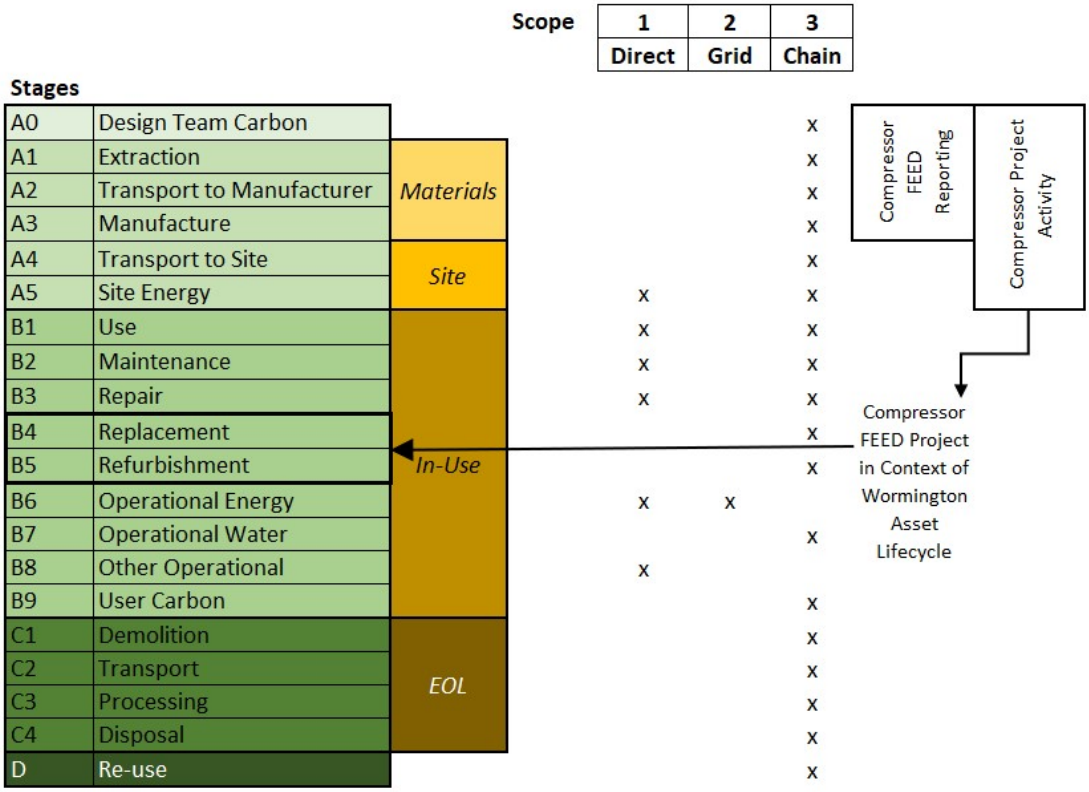


Figure 12-6: Context of this project in terms of the PAS2080 Stages for the asset

PAS2080 Data Sources

Carbon accounting is data driven – good data is essential.

For the most part, data for this project is drawn from the NG GT CIT Tool. Where it is not included in the tool, there is a hierarchy of data quality.

The manufacturer is the next best source of information. Often, they will have produced the information on embedded carbon of a product in standardised form as an Environmental Product Declaration (EPD).

Production of EPDs, showing the environmental impact per unit of a product across all of the stages of the life cycle, is increasing among manufacturers, with many of the household name suppliers having approximately 30% of their product ranges independently certified.

An EPD for the exact product that is to be installed is the gold standard in terms of data input to a PAS 2080 WLC calculation.

Where these do not exist, there are a number of reputable databases of similar product ensembles or materials from which the component can be sourced.

PAS 2080 Process

A typical process of PAS2080 on projects goes through cycles of developing baselines, target setting, quantification, tracking and improvement.

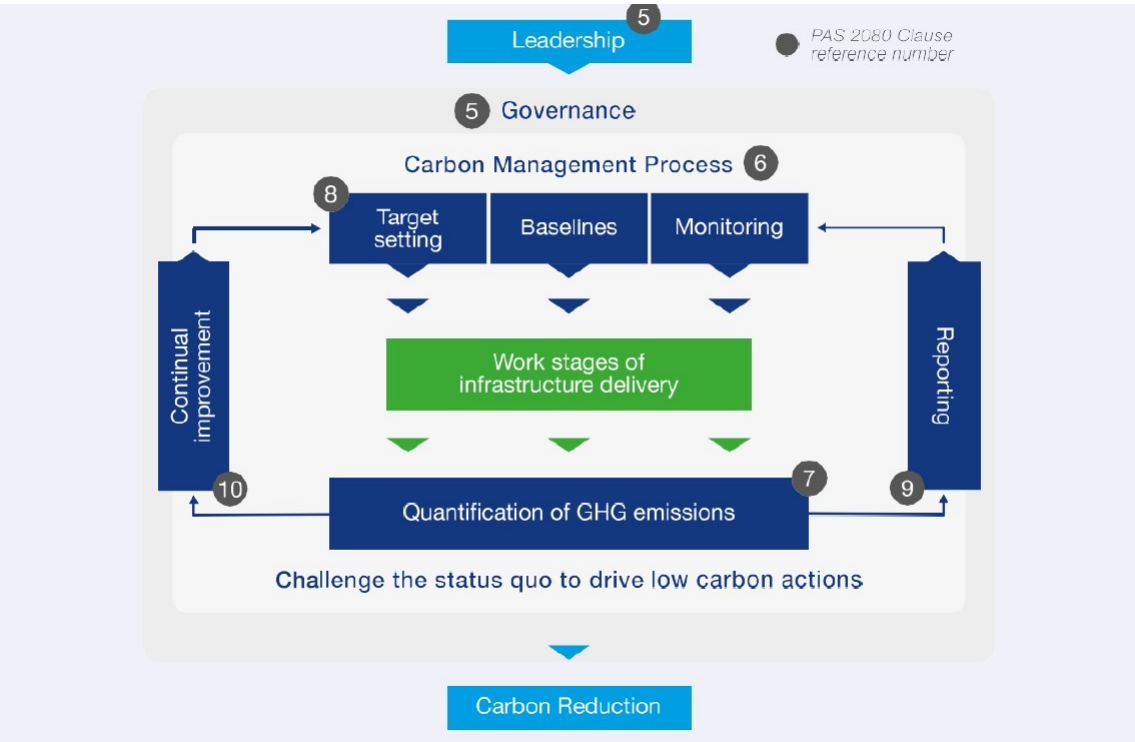


Figure 12-7: PAS2080 Process

There are a number of benefits and limitations to estimating carbon at the early stages of a project:

1- The greatest gains, biggest and quickest wins are achievable in the early stages, following the Getting to Net Zero Hierarchy:

   a) Build nothing

   b) Build less

   c) Build Clever

   d) Build Efficiently

2- However, the data for many components and stages are at their lowest accuracy because the details on which carbon data relies is simply not available. Equipment, materials and quantities are not specified in such a level of detail at the early stages to allow the embodied emissions to be calculated from scratch, where a product does not already carry an Environmental Product Declaration.

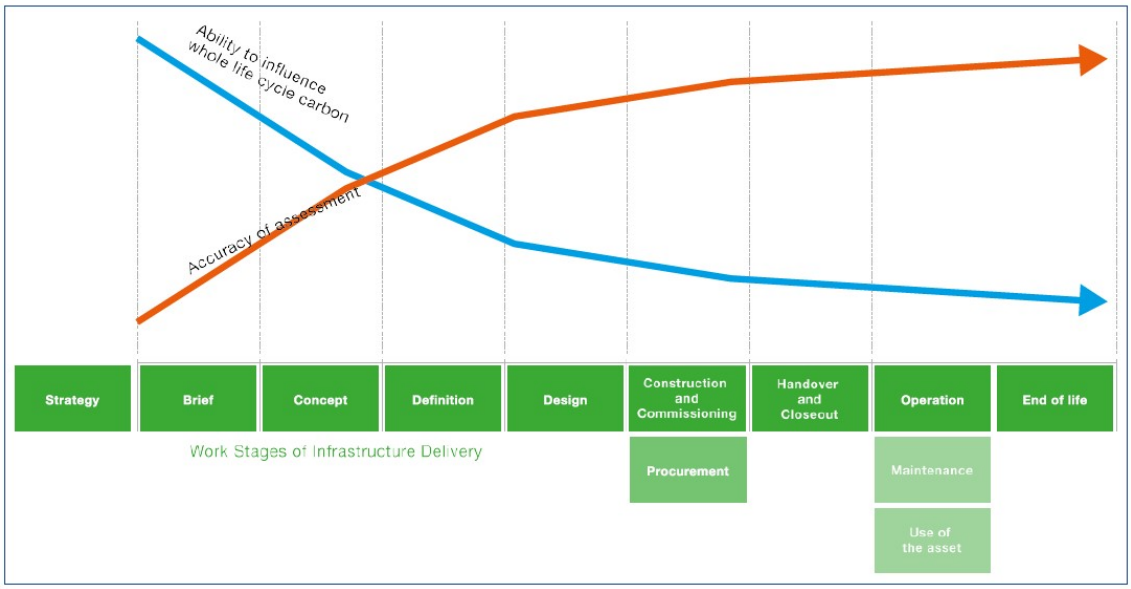


Figure 12-8: PAS2080 Workstages

Key Features & Concepts of PAS2080 applicable to this project

In order to compare options like-for-for like, PAS2080 makes the following requirements for equivalence:

System Boundary – When comparing options for WLC carbon emissions, the boundary of the system in both space and time is required to be constant for all options compared.

- In this instance the physical boundary is taken as the maximum site boundary (Existing + Greenfield). Emissions considered here related to activities taking place within this boundary only. That said, there is currently no mechanism at this scale for considering the contribution of a green field.

The boundary in time is as yet unclear. This must be equivalent for all options. Where retrofit or rewheeling deliver plant with a shorter lifetime, this cannot be compared directly with new GTs, because there is essentially more carbon to come for the retrofit options to cover the remaining lifetime of the new GTs. This may be further retrofit or new GTs.

Here the primary comparison is between new GT options.

Functional Units – The functional unit is a plant that can deliver the required compression, PDS point performance and NOx emissions compliance. Again, plant that does not do these things is are not directly comparable.

The Goal of Boundaries and Functional Units – of boundary and functional unit determination is to engineer a situation where carbon is genuinely a determinant between options. Where the boundary and functional units are not the same, there is some other driver of decision-making that is likely to be greater than carbon. Carbon savings cannot be made readily with this approach.

Data Resolution – Data are broadly aligned to the cost plan resolution, although this has certain limitations.

Data Limitations – At the feasibility stage, cost planning itemises large components only; with strategic elements and details approximated using established rules of thumb for the context.

Specifications of equipment are outline at this stage. Smaller components are typically bulk estimated as a percentage cost, rather than specification and quantity. Such benchmarks are scarce for carbon at this stage and potentially sector specific.

Where generic product data is not available, either at this scale or at all; and an Environmental Product Declaration for the component or a similar component; embodied emissions estimates can – in theory - be made from the basic materials of that product. However, for this a breakdown of proportions of the materials in the product is needed.

The location of the manufacturing plant plays a significant role, where the material has undergone substantial transformation. The fuel/energy basket powering this transformation will significantly influence the emissions embodied in the finished product.

Rules of thumb used here should be interpreted with caution. By and large they originate from the building construction industry from which emissions data has been collected over the last 25 years. Use of these in this exercise is confined to guidance issued on superstructure and sub-structure studies only.

Baselines & Improvement – PAS 2080 advocates developing a baseline and seeking to improve on it within the same design stage.

However, in practice, by the stage that the data are sufficiently robust and accurate to base design decisions with financial implications, the time to exert significant influence over the design would well have passed (as shown in Figure 12-8 above).

The drive to automate WLC assessment through BIM is a necessary step to enable key early design decisions to be made based on carbon.

On the other hand, following the natural progression of the design stages, design information gets more detailed and accurate as the design progresses. This means that baselines derived from earlier designs will be missing large quantities of information that is below the data resolution available at that stage of design. The total carbon of the project accountable at the FEED stage will then be artificially low.

This means that a benchmark cannot be developed at the FEED stage on which contractors can reasonably improve, if all components are not included and fully specified.

It is essential therefore that benchmarks are generated from real data for infrastructure projects – in line with those available for buildings – to enable rapid early assessments.

For the purposes of this stage of the project we consider that the comparison of carbon on a like-for-like basis between options fulfils the function of developing a baseline and seeking improvements.

Within the cycle itself a number of small improvements have also been made, nonetheless, there remains much scope for improvement in the FEED stage through the detailed design, specification and consideration of O&M. A number of ideas have been presented in the Sustainability Section which can be explored further by the contractor in the next stage.

It should be noted that the emissions associated with materials is a rapidly changing landscape, as companies begin to chart their own paths to net zero. The emissions of some materials – and therefore their optimal relative proportions – is sensitive to the timing of procurement.

For instance, pipe supports and reinforced concrete bases – the steel and concrete industries are on separate paths to net zero. Lower carbon concrete is already available with a product that is 30% of standard emissions on track to emerge by 2030. On the other hand, companies such as Arcelor Mittal have committed pledged to produce a net zero steel product by 2025.

Works Avoided – Works avoided in this case can be considered to be new GTs if the retrofit options are selected. However, the timelines of the two options need to be aligned to ensure works avoided are not merely works deferred, and the carbon advantage of deferral clarified.

Methodology –

The primary comparison is between New GT options.

The options area as shown below:

	Layout 1		Layout 2		Layout 3	Layout 4		Layout 5	Layout 6
Compressor Option									
1 New GT Compressor	•		•		•	•			
2 New GT Compressors		•		•			•	•	•
+ Location Option									
Greenfield North of F23	•	•							
Greenfield South of F23			•	•					
East-West Arrangement			•	•					
Brownfield on site of Existing Compressors								•	•
Brownfield on Existing Control Room					•				
Brownfield on Existing Control Room & Aftercoolers site						•	•		
+ Control Room Option									
New Control Room South					•	•	•		•

Treatment By Stage

12.4.1 A0 Design

It is understood that this is not a requirement of this particular study – NG to confirm.

12.4.2 A1-3 Materials

Most of the data for modules A1-3 derives from the CIT itself.

12.4.3 A4 Construction Site Transport.

It is understood that estimates are not required at this stage. It is actually difficult to estimate, btu some benchmarks exist for building construction.

12.4.4 A5 Construction Site Carbon

It is understood that estimates are not required at this stage. It is actually difficult to estimate, but some benchmarks exist for building construction.

No benchmarks exist yet for emissions on site of methane due to venting prior to cutting into pipework. Since the plant will be operational when the works are done, it is understood that this component will be very small. This will be reviewed by the contractor.

12.4.5 B1+ In-Use Emissions

It is understood that this is to be done via the BAT Tool.

12.4.6 C1-C4 & D End of Life Benchmarks

It is understood that this is not required at this stage. As for the other construction site-related carbon, this is difficult to estimate at this stage, but over time contractors required to account for this will build benchmarks from their data that will allow this to be assessed earlier in the design process.

12.4.7 Results

Pending further review Tuesday 22/03/22

GHG Savings

Target areas where significant carbon savings may be made.

12.5 Sustainability

(Pending review 22/03/22)

12.5.1 Sustainability Measures

A Sustainability Register was not supplied to the project on this occasion. Opportunities for introducing sustainable practices have been identified in order to inform setting the brief for the main construction contract.

(Pending review 22/03/22)

12.5.2 CEEQUAL Overview

CEEQUAL has been widely adopted as a way of quantifying the sustainability performance of infrastructure projects in the UK. It was developed by the Institute of Civil Engineers and sold to BRE Ltd. to join their family of BREEAM Assessment products. It has been adopted as a requirement by a large number of public and private sector clients including, CLIENT. The scope of CEEQUAL is provided at the end of this doc.

There is currently no requirement for it on the project but there is considerable enthusiasm within the Client body for implementing infrastructure development good practices such as CEEQUAL certification. This section provides a review and some guidance against CEEQUAL to ensure that the project will be CEEQUAL-ready further down the line.

A brief assessment has been made of the current situation in Appendix G (HOLD).

This describes the credits and how they are achieved. Our review confirms what credits appear possible at this stage.

Stages where action is needed have been marked: this relates mainly to agreement of terms, development of policy documents for the project and inclusion of requirements in tender and contract documents.

12.6 Planning permissions

The requirements are included in section 7.1.1 of the Environment and Sustainability report. A summary of the planning risks for each layout of option 5 is shown below:

Layout	Planning Risk
1	Planning permission required, as works would be outside existing planning boundary.

Layout	Planning Risk
	Schedule II development under the EIA Regulations, but works more than likely would require an EIA. Pre-application advice required from LPA regarding the requirement for an environmental impact assessment (EIA) and for a Scoping Opinion.
2	Planning permission required, as works would be outside existing planning boundary. Schedule II development under the EIA Regulations, but works more than likely would require an EIA. Pre-application advice required from LPA regarding the requirement for an environmental impact assessment (EIA) and for a Scoping Opinion.
3	Planning permission required, as works would be outside existing planning boundary. Schedule II development under the EIA Regulations. EIA may be required due to move of compressors within the site and small change in location of exhaust stacks, and small increase of curtilage of the site due to relocated Control Room. Pre-application advice required from LPA regarding the requirement for an environmental impact assessment (EIA) and for a Scoping Opinion.
4	Planning permission required, as works would be outside existing planning boundary. Schedule II development under the EIA Regulations. EIA may be required due to move of compressors within the site and small change in location of exhaust stacks, and small increase of curtilage of the site due to relocated Control Room. Pre-application advice required from LPA regarding the requirement for an environmental impact assessment (EIA) and for a Scoping Opinion.
5	Option with the least planning risk as replacing “like with like” is unlikely to require planning permission. Assumes installation of plant or machinery does not exceed 15m in height.
6	Planning permission required, as works would be outside existing planning boundary Schedule II development under the EIA Regulations. EIA may be required due to replacement compressors within the site and relocation of Control Room, and small increase of curtilage of the site due to relocated Control Room. Pre-application advice required from LPA regarding the requirement for an environmental impact assessment (EIA) and for a Scoping Opinion.

13. CDM

CLIENT, as the Principal Designer will take ownership of the CDM risk register to be developed and updated throughout the project.

CONSULTANT has supported by issuing a CDM risk register and a Pre-Construction Information pack, which can be used as starting points or as inputs to the CDM documentation.

Consultant's input to the CDM risk register is included in Appendix B.

14. REGISTERS

14.1 Technical Risk Register

Technical risks relating to the project have been recorded throughout the project and a combined technical risk register has been completed for all options No residual actions from the design FPSA studies have been transferred to the technical risk register.

Following project completion, any residual open actions will be handed over to CLIENT Operations. The status of the register has been shared and all open entries will be managed in the next design phase. Refer to Appendix A of document 20840-EN-RPT-000-0004 which is included in APPENDIX F – FORMAL PROCESS SAFETY ASSESSMENTS.

14.2 CDM Risk Register

CLIENT, as the Principal Designer will take ownership of the CDM risk register to be developed and updated throughout the project.

Consultant's input to the CDM risk register is included in Appendix B.

15. CONCLUSIONS AND RECOMMENDATIONS

15.1 Conclusions

The conclusions of this study into appropriate solutions to address the NOx limits introduced by the Medium Combustion Plant Directive (MCPD) are as follows:

- Derated Avon / CSRP – This is a viable solution for PDS Cases 1, 4 & 5 if combined with one new compressor train, although further investigation to include an analysis of the distribution network covering operational areas such as line-packing and, potentially, peak-shaving and associated demand-supply balances would be required. On this basis, it cannot be ruled out at this stage.
- 500 hrs – This is not a viable solution as there are no operating scenarios having less than 500 hours operation per annum for any Compressor / GT. Should CLIENT modify or change the definition of PDS Cases as part of future evaluation of the distribution network then this option may need to be re-evaluated.
- SCR – As stated, this option cannot be evaluated, as another study is on-going by a third party, which make it impossible to assess the effectiveness of this either as a standalone solution or one to be used in conjunction with other solutions.
- Retrofit DLE – This is a viable solution for those PDS Cases where the Compressor / GT is able to meet the required process duty but NOx emissions exceed the 150 mg/Nm³ limit imposed by the MCPD legislation. The analysis through process modelling has demonstrated that this is viable option for one of the existing compressor trains only when this is combined with a new compressor train. In this scenario, the balancing will be such that the new compressor train will contribute to approximately 60% of the overall demand, while the existing train will contribute approximately 40% of the overall demand. Therefore, for the worst case (point C10 of the PDS), the installed equipment (only one of the two) under the modified load balancing scheme is capable of delivering the PDS points, as the maximum required shaft power of a compressor train will be no more than 11.4 MW, which means 43.9 MW Net Thermal Input and 140 mg/Nm^3 NO_x emissions. No upgrade will be required to the power turbine.
- New GT / Compressor – This is the only viable solution where the compressor cannot deliver the specified duty or the required power input at the GT is too close to or exceeds the MCPD 50 MW upper limit.
- New VSD - A VSD compressor would be considered for replacement of the two existing GT driven compressors (Unit A & B). The main advantage of this solution is the almost complete elimination of NOx emissions at Wormington Compressor Station as a direct result of removal of the two mentioned GT drivers and use of an electrical drive replacement. Due to issues related to HV power supply availability, a solution involving VSD has not been explored further. For further details see Section 8.8.
- Re-Wheel - For PDS Case 2, the existing compressors cannot deliver the specified duties. However, if one of the existing compressors is rewheeled (change the internal components of the compressors) in combination of retrofit and DLE and a new compressor train then the requirements for increased pressure at the outlet of the compressors can be met. Rewheeling is technically doable as confirmed by the OEM however, more studies will be required at the next stage of the project.

The options taken forward for further, more detailed analysis in preparation for production of a +-30% cost estimate were:

- Derated Avon / CSRP
- Retrofit DLE
- New GT / Compressor

These are all viable options to address the MCPD directives while also addressing the CLIENT's duty points as defined in the PDS.

The final, selected options will be identified after the CBA has been carried out.

To avoid introducing a single point of failure into the compressor station operation, the sparing philosophy for the compressor station should be reviewed and updated.

Any solution that involves installation of new Compressor / GT drives and that relies upon the VSD compressor as the operational backup machine should be reviewed ensure that flows can be balanced across all operating machines such that performance parameters (curves) are not compromised.

The results of the ongoing RAM study being carried out at CLIENT compressor stations are likely to have an impact on the solution adopted and may dictate compressor / driver replacement due to minimum operational on-stream requirements thus superseding the MCPD NOx emissions limits.

15.2 Recommendations

Starting with a defined Long List of potential solutions to address the limits on NOx emission levels introduced by the MCPD legislation, this study has identified several viable options that could be adopted as a solution.

Before making a decision on which, if any, of the Short-Listed options to select, a formal Cost Benefit Analysis (CBA) needs to be completed. This will provide a quantitative ranking for the Short List options and this ranking should be further reviewed based on the Risk Register developed in support of the Wormington MCPD FEED Feasibility project. The Risk Register provides a qualitative assessment of potential risk and this, when overlaid on the CBA ranking will provide CLIENT with an informed basis upon which to select options to take forward for further development in the next phase of the project.

It is strongly recommended that the current state of the Wormington asset health is taken into account and that the additional costs potentially associated with modifying an ageing installation (e.g. requirement for piling, asset condition at interface points worse than expected etc.) are carefully assessed. All the issues related to asset health have been investigated – see section 9.2 Asset Health

If a decision is made to purchase and install new compressors, then the risk to the project becomes identification of land/space (potentially outside of the current station boundaries) and then being able to obtain any required planning permission. Although the current study has not included areas outside of the existing land ownership boundaries, planning permissions for the greenfield areas (layouts 1 and 2) will need to consider the fence relocation and the new builds on previously green areas – see also section 7.1.1 of the Environment and Sustainability report.

There will be opportunities arising from this project related to economies of scale for the gas transmission network that CLIENT can capitalise on. For example, adopting a common approach to definition of compressor/compression requirements across the network will provide Procurement and supply chain (warehousing) opportunities for CLIENT that could result in significant operational savings where common replacement units are procured.

By identifying and implementing any changes in a timely manner, it may be possible to defer or cancel planned asset health activities where they can be identified as no longer required due to proposed changes thus resulting in financial savings.

It is also recommended that, before any decision is made regarding capital expenditure, a holistic study of the gas distribution network is carried out with a focus on considering options such as line-packing and supply-demand balancing as a route for reducing compression power requirements and therefore NOx emissions.

APPENDIX A - LIST OF DOCUMENTS

20840-PM-PEP-000-0001	Project Execution Plan
20840-QA-PLN-000-0001	Project Quality Assurance Plan
20840-EP-PLN-000-0001	Project Design Management Plan
20840-EP-PLN-000-0002	Project BIM Plan
20840-PM-PRC-000-0001	Cost Estimation Procedure
20840-DC-MDR-000-0001	Project MDR
20840-PM-SCH-000-0001	Project Schedule
20840-PM-RPT-000-0001	Progress Report- December
20840-PM-RPT-000-0002	Progress Report- January
20840-PM-RPT-000-0003	Progress Report- February
20840-PM-RPT-000-0004	Progress Report- March
20840-EN-LST-000-0001	Codes, Standards, Technical Specifications List
20840-PM-TEN-000-0001	Technical Note: Options Under Consideration
20840-EN-SPC-000-0001	Engineering Basis of Design
20840-EN-SPC-000-0002	Compressor Duty Specification
20840-EN-LST-000-0003	Equipment List (All Options - superceeds Preliminary Equipment List)
20840-PM-PRC-000-0002	BAT / Shortlist Criteria & Methodology
20840-PM-RPT-000-0007	Long List to Short List Evaluation Workshop Report
20840-EN-RPT-000-0001	Asset Health Report
20840-PR-SPC-000-0001	Process Simulation Report
20840-EL-SLD-000-0001	Single Line Diagram - HV System Upgrade
20840-EL-SLD-000-0002 1 of 4	Single Line Diagram - New GT Compressors
20840-EL-SLD-000-0002 2 of 4	Single Line Diagram - New VSD Greenfield
20840-EL-SLD-000-0002 3 of 4	Single Line Diagram - New GT Existing Berth
20840-EL-SLD-000-0002 4 of 4	Single Line Diagram - New GT Greenfield
20840-EL-SLD-000-0003 1 of 2	Single Line Diagram - Sheet 1- Existing GT Compressors (Retrofit & Derated Options)
20840-EL-SLD-000-0003 2 of 2	Single Line Diagram - Sheet 2 Existing GT Compressors (Retrofit & Derated Options)

20840-EL-SLD-000-0004	Single Line Diagram - New VSD Compressors
20840-PR-PFD-000-0001 1 of 2	Process Flow Diagram. Compression - Cases 1,4 & 5 **(Updated ELD)**
20840-PR-PFD-000-0002 2 of 2	Process Flow Diagram. Compression - Cases 1,4 & 5
20840-PR-PFD-000-0003 1 of 2	Process Flow Diagram. Compression - Cases 2 & 3 **(Updated ELD)**
20840-PR-PFD-000-0004 2 of 2	Process Flow Diagram. Compression - Cases 2 & 3
20840-PI-LST-000-0001 1 of 2	Tie-In List - New GT Existing Berth
20840-PI-LST-000-0001 2 of 2	Tie-In List - New GT Greenfield
20840-PEN-WO-00-M1-M-0000-S3-P01 1 of 2	3D Model - New GT Existing Berth
20840-PEN-WO-00-M1-M-0000-S3-P01 2 of 2	3D Model - New GT Greenfield
20840-PI-XKY-000-0001 Sheet 1	Plot Plan Layout 1 New GT Compressors Sheet 1
20840-PI-XKY-000-0001 Sheet 2	Plot Plan Layout 2 New GT Compressors Sheet 1
20840-PI-XKY-000-0001 Sheet 3	Plot Plan Layout 3 New GT Compressors Sheet 3
20840-PI-XKY-000-0001 Sheet 4	Plot Plan Layout 4 New GT Compressors Sheet 4
20840-PI-XKY-000-0001 Sheet 5	Plot Plan Layout 5 New GT Compressors Sheet 5
20840-PI-XKY-000-0001 Sheet 6	Plot Plan Layout 6 New GT Compressors Sheet 6
20840-PI-XKY-000-0002 1 of 2	Plot Plan Layout 1. New VSD Compressors Sheet 1
20840-PI-XKY-000-0002 2 of 2	Plot Plan Layout 1. New VSD Compressors Sheet 2
20840-PEN-WO-00-DR-P-0000-S3-P01 Sheet 1	Piping Layout 1 - New Compressors Sheet 1
20840-PEN-WO-00-DR-P-0000-S3-P01 Sheet 2	Piping Layout 1 - New Compressors Sheet 2
20840-PEN-WO-00-DR-P-0000-S3-P01 Sheet 3	Piping Layout 3 - New Compressors Sheet 3
20840-PEN-WO-00-DR-P-0000-S3-P01 Sheet 4	Piping Layout 4 - New Compressors Sheet 4
20840-PEN-WO-00-DR-P-0000-S3-P01 Sheet 5	Piping Layout 5 - New Compressors Sheet 5
20840-PEN-WO-00-DR-P-0000-S3-P01 Sheet 6	Piping Layout 6 - New Compressors Sheet 6
20840-IC-XBK-000-0001 1 of 4	C&I Block Diagram - Avon DLE (Alba & XXXXXX)
20840-IC-XBK-000-0001 2 of 4	C&I Block Diagram - CSRP Derated Avon
20840-IC-XBK-000-0001 3 of 4	C&I Block Diagram - New GT Existing Berth

20840-IC-XBK-000-0001 4 of 4	C&I Block Diagram - New GT Greenfield
20840-CI-XGE-000-0001 1 of 2	Building Elevation Dwgs - New GT Existing Berth
20840-CI-XGE-000-0001 2 of 2	Building Elevation Dwgs - New GT Greenfield
20840-CI-XGA-000-0001 1 of 2	Building Layouts - New GT Existing Berth
20840-CI-XGA-000-0001 2 of 2	Building Layouts - New GT Greenfield
20840-EN-LST-000-0002	Long Lead Item Identification
20840-EN-TNO-000-0002	Design Review Note (inc Stakeholder Engagement)
20840-EN-RPT-000-0002	Layout Review Report
20840-EN-RPT-000-0003	HAZID Report
20840-EN-RPT-000-0004	Design Process Safety Report
20840-PM-SCH-000-0002	Option Schedules
20840-PM-COE-000-0001	Long List Option - Cost Estimate Report
20840-EN-RPT-000-0005	Environmental and Sustainability Report
20480-PM-COE-000-0002	Cost Estimate Report +- 30%
20840-EN-RPT-000-0006	FEED Report
PAC1050295-01-7260-NGG-0030	BAT Tool
20840-EN-EVL-000-0001	Pre-Workshop Information Pack
20840-EP-RPT-000-0001	CDM Pre Construction Information Pack

APPENDIX B - Consultant's Input to CDM Risk Register

Technical Risk Register

Project Title:	WORMINGTON MCPD FEED Feasibility
Document No:	Input to CDM Risk Register
Person Responsible for Risk Register:	[redacted]
Designer	[redacted]

nationalgrid

Risk Register Issue No.	Issue Date	Issued By	Comments (Only show last 3 revisions, hide previous revisions)
IR1	01/04/22	[redacted]	
IR2			[redacted]
IR3			

Ref No.	Hazard and Location	Action No.	Design Actions	Current Status	Info Source	Construction / Commissioning Action	Current Status	Residual Hazard	Residual Risk Scores (Likelihood	Residual Risk Level (H, M,	Action No.	Operational Action	Current Status
	GENERAL CDM COMPLIANCE REQUIREMENTS												
28	ASBESTOS-CONTAINING MATERIALS (ACMs)		The asbestos survey carried out covers a single building only and no soil sampling or overall building / pipework / installation survey has been provided. Design considerations should ensure ensure new works do not disturb ACMs where practicable. Where impracticable, it should be ensured that sufficient information is provided to all persons carrying out investigative or construction activities that may damage or disturb ACMs so that location, type, quantity and condition are known and procedures established for their safe removal, control and subsequent monitoring.	Open		Managed within Construction Phase Plan		Managed in next design stage	3x5	High		Items on the asbestos register must be monitored at appropriate periods.	Open
29	GROUND / AIR CONTAMINANTS / COSHH		Ground and air monitoring surveys to identify radioactive materials and contaminants including coal tar products and others with associated harmful / carcinogenic potential have not yet been carried out. Lead-based paints, asbestos, natural gases and hydrocarbon fuels/oils may be present. The design stage considerations shall include arrangements to identify, locate, safely remove, encapsulate / make safe or avoid disturbing such materials as practicable in keeping with the safety principles of prevention. Licensed disposal contractors shall be used where necessary. Safe working procedures and PPE requirements shall be reviewed and made clear in the CPP (Construction Phase Plan).	Open		Managed within Construction Phase Plan		Managed in next design stage	3x5	High		N/A	Open
30	GROUND STABILITY / CAPACITY / FLOODING		See also section Nos 7 and 8 above. The site is predominantly lime-rich loamy and clayey coils with impeded drainage, consisting of soft ground with a high-water table. The EA Flood Map for Planning (FMfP) indicates that the entire Site is located within Flood Zone 1 (although there may be conflicting zone 2 /3 information on record), classified as land with less than a 0.1% probability of flooding from rivers or the sea in any given year. Surface water flood risk is the key flood risk to the Site. Surface water flood risk mapping results indicate surface water flood risk within the current operational area of the Site and in the southwest portion of the Site. Surface water flood risk must be considered for both the brownfield and the greenfield options. Assessment of flood risk from other sources of flooding has indicated a low risk from all of these to the Site. Soil load bearing capacities etc have not yet been established and detailed designs can not be finalised without this information. The designs of civil works and foundations etc shall be carried out by a competent	Open		Construct / install as designed.		Managed in next design stage	2x4	Med		N/A	Open
31	BURIED / SITE SERVICES		The operational area of the site is likely to contain significant buried services. This design risk register revision did not have the listed electrical services drawings available to it or details / locations of other services. Detailed designs can not be finalised without this information.	Open	Drawings 726003	The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x5	High		N/A	Open
32	OVERHEAD SERVICES		No overhead services drawings or surveys are so far available. Detailed designs can not be finalised without this information.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x5	High		N/A	Open
33	BURIED STRUCTURES / VOIDS		Buried structure information is limited to there being no known mines or underground cavities below the site. There is no survey information regarding buried pits, silos, bunkers etc. Detailed designs can not be finalised without this information.	Open	mapapps2.bgs.ac.uk, British Geological Survey	The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x5	High		N/A	Open
34	ADJACENT STRUCTURES / FACILITIES REMAINING		The National Grid Site Information Document identifies several installations that shall / may remain functional during new construction / installation and must not be adversely affected. Design decisions shall accommodate such installations and ensure they remain unaffected, taking into account stresses / limitations to avoid collapse / fracture. There are also fire-related services that must be maintained without fail. No assessment of structural considerations has so far been concluded. Detailed designs	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x5	High		N/A	Open

Ref No.	Hazard and Location	Action No.	Design Actions	Current Status	Info Source	Construction / Commissioning Action	Current Status	Residual Hazard	Residual Risk Scores (Likelihood	Residual Risk Level (H, M,	Action No.	Operational Action	Current Status
35	COVID-19		All face-to-face meetings associated with the project (design & construction phases) shall be conducted as per the current Government guidelines regarding hygiene and the control of infection transmission as available on https://www.gov.uk/coronavirus . All organisations shall maintain practical protocols including social distancing, use of PPE and testing to comply with such guidance.	Open		The CPP shall include suitable arrangements.		N/A	2x1	Low		N/A	Open
36	DECOMMISSIONING (INCLUDING PREPARATORY SURVEYS / INSPECTIONS / ACCESS ETC)		The induction and permit-to-work system for this top-tier COMAH operational site must be adhered to. A safe procedure for each decommissioning or existing process interruption should be developed to ensure that the closing off or disconnection etc of plant, equipment, supplies or services etc do not cause potential hazards arising from the compromising of existing operations or loss of key monitoring / alarm / safety systems. Access to areas / buildings / structures etc should be prior risk assessed especially in respect of confined spaces and hazardous substances. The design team shall consider the safety aspects of decommissioning / interruption processes within a specific Hazid process and the Construction Phase Plan shall reflect the safe working procedures required.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x5	High		N/A	Open
37	PLANNED DEMOLITION / REMOVAL		See section No.25 above. 2No. concrete bases are identified for possible demolition and there may be other such structures including buildings. Identify any potential hazards associated with unplanned collapses prior to controlled demolition and any need for exclusion zones. Consider the potential effects of demolition on adjacent areas and structures including services and the potential liberation of hazardous substances.	Open		Design risk registers shall consider the effects of demolition, rendering them tolerable. The CPP shall include suitable arrangements to ensure compliance with all legislation and guidance in force on the Wormington site and to control all residual risks.		Managed in next design stage	4x5	High		N/A	Open
38	EXISTING OPERATIONAL PLANT ASPECTS		A formal Health & Safety File for the existing plant affected is unlikely to exist. As a result, the design stage processes associated with the new construction should consider the safety repercussions of each stage and element carefully. The rules for site access and movement shall be adhered to including for the need for access, parking, breakdown towing, large plant escort, fuel types and fire protection	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x5	High		N/A	Open
39	LIGHTNING STRIKE / EARTHING		The condition of the earthing and lightning protection system is unknown. Ensure interim safeguards / safe working arrangements are in place for personnel, especially during adverse weather and that repairs / upgrades / replacements remain under consideration. Mobile plant shall also be earthed as practicable.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	4x5	High		Maintenance of lightning protection and earthing facilities	Open
40	STAKEHOLDERS / LOCAL AMENITY		Consideration should be given to any unwanted effects upon indigenous site operations not already covered. A stakeholder register may be advised. Also adjacent parties including local residents and businesses, those associated with churches and schools, holiday parks and farms etc should have their safety and environmental needs and the maintenance of their facility considered. Additionally, effects upon the natural and other resources associated with wildlife including bats, woodland areas, other areas of outstanding natural beauty and listed buildings and items of historical value must be considered in the design process including the potential liberation of windblown pollutants.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	2x1	Low		Protection of local amenity remains a duty during operation	Open
41	FIRE / EXPLOSION / EMERGENCY		Codes of practice for fire precautions and fire protection require that generic fire protection elements including fire water tanks and ring mains etc must remain operationally unaffected as must critical status monitoring, fire detection, alarm and control /suppression systems. The design process and the construction phase plan should acknowledge the need to protect such facilities as a high priority. All requirements of any site Emergency & Environmental Plans should be adhered to for all emergency situations including for bomb threat. The existing plant operation may vent natural gas to atmosphere, therfore design and construction stage processes should allow for safe equipment (including being ATEX rated where required) and safe working procedures taking into account site rules, the above documents, DSEAR risk assessments and COMAH requirements in its formal HAZID deliberations including those arising from security / arson issues. The site contains fuel storage and natural gas assets which must remain unaffected by hazards arising from survey, decommmissioning or contruction work etc. Radio frequency ignition risk should be assessed as part of the existing plant's risk assessment process. Hazardous zone limitations, spark arrestor and Chalwyn valve overspeed requirements shall be observed where necessary as per National Grid requirements. Arrangements must be made to allow for safe working adjacent to points of potential leakage of in-line seals and the risks of over-pressure in gas handling systems and all other risks associated with flammable gases, other flammable materials and their potential ignition. Contractors must fully familiarise themselves with the	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	4x5	High		Maintenance of fire and explosion protection remains crucial during operation	Open

Ref No.	Hazard and Location	Action No.	Design Actions	Current Status	Info Source	Construction / Commissioning Action	Current Status	Residual Hazard	Residual Risk Scores (Likelihood	Residual Risk Level (H, M,	Action No.	Operational Action	Current Status
42	NOISE		See also section No.11 above. High noise venting events from exisiting operations may be a potential hazard to site personnel (and shall be dealt with via control methods in the Construction Phase Plan) No design input required (unless similar new plant falls within this scope).	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	2x2	Med		N/A	Open
43	ELECTRICAL		Electrical equipment shall be designed as intrinsically safe where required for ATEX zones etc and shall satisfy fire risk and DSEAR assessments and COMAH regulations. Exposure to electrical hazards during construction work shall be mitigated via risk assessments and safe systems of work within the Principal Contractor's Construction Phase Plan. Similarly, any prior survey work shall carry their own pre-assessments and control methods to ensure safe working at all times.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	4x5	High		Maintenance of electrical systems remains crucial during operation	Open
44	SITE SECURITY & ACCESS		Persons accessing the site for survey work during the design phase or for construction phase activities shall be required to comply with the strict access and security requirements in force. Construction vehicles and mobile plant etc are required to follow the standing site instructions as outlined at the site induction. Where construction work requires that existing perimeter fencing be penetrated, replaced or extended, security shall be re-established through the provision of security fencing to an agreed specification. All Client, designer, contractors and visitors to the Wormington facility are required to undertake the site safety induction and to comply with the site rules for control of sources of ignition such as matches, mobile telephones, key fobs etc. Smoking aterials must be deposited at the gatehouse. Smoking is not permitted anywhere on site or other construction site area within perimeter fenced areas, except where specifically designated. Mobile telephones and laptops may be brought in to limited areas only with prior approval of the Site Management. All delivery vehicles and their drivers must be positively identified prior to entry to site and remain under the control of the nominated site person. All vehicles on site for construction functions shall be under the control of an appropriate permission document. Large construction plant such as excavators and cranes or smaller vehicles with driver vision or reversing limitations will require an escort / banksman at all times of use. Large plant shall adopt a plan agreed with the site operator regarding routes and shall identify and risk assess overhead lines, buried services, voids and all other hazards. All site movements and operations of plant shall be in accordance	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed during construction phase	3x3	Med		N/A	Open

Ref No.	Hazard and Location	Action No.	Design Actions	Current Status	Info Source	Construction / Commissioning Action	Current Status	Residual Hazard	Residual Risk Scores (Likelihood	Residual Risk Level (H, M,	Action No.	Operational Action	Current Status
45	GENERIC / COMMON ASPECTS OF CONSTRUCTION ACTIVITIES		The residual safety risks remaining following the finalisation of the design stage processes shall transfer, where tolerable and manageable by a competent Principal Contractor, from this and other design risk registers to the control of the Principal Contractor for incorporation in their CPP (Construction Phase Plan) which shall sufficiently and suitably control all typical, generic and other remaining risks. Existing operational site requirements (and any additional requirements imposed by specific construction site requirements) as outlined in inductions and safety training minimum standards shall be adhered to or exceeded. The Principal Contractor shall agree with the client before the commencement of the works which specific guidance and controls shall be predominant for the duration of the works where there may be any conflict between the Client's or other party's and the PC's own risk assessments and safe working procedures. This may include National Grid's Good Practice Guidance: PAC3721-14-99-00-1211-NGG-0017; Banned Tools Risk Assessment: PAC3721-14-70-00-1211-NGG-0022; various permit requirements such as the Permit to Pump: PAC3721-14-59-00-1211-NGG-0032; Hazardous Areas: PAC3721-14-67-00-1211-NGG-0103; PAC3721-14-99-00-1211-NGG-0152 and RAMS etc (such as the DSEAR risk assessment) arising as part of the design stage process. Special consideration will be applied by all parties to design changes during the construction phase and to any temporary works design requirements to ascertain whether revisions to risk assessments and safe working procedures may be required. Temporary works and design changes during construction shall not be considered generic or common aspects of construction but shall receive full design re-consideration by the designers / Principal Designer in a Hazid	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next construction stage	4x4	Med		N/A	Open
46	COMPETENCY		Throughout the design, construction, commissioning and operational stages, competence of all parties (designers and contractors) shall be sufficiently ascertained by the Client, the Pricipal Designer / Designers and the Principal Contractor as appropriate in compliance with the CDM regs 2015.	Open		The Principal contractor shall ensure the competence of all other contractors.		Managed in next design stage	3x3	Med		N/A	Open
47	CALIBRATION		All measuring and monitoring equipment requiring calibration shall be inspected, tested, maintained and certificated as per current regulatory requirements and best practice guidance.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	3x3	Med		Calibration of sensor / monitoring equipment etc remains crucial during plant operation	Open

Ref No.	Hazard and Location	Action No.	Design Actions	Current Status	Info Source	Construction / Commissioning Action	Current Status	Residual Hazard	Residual Risk Scores (Likelihood	Residual Risk Level (H, M,	Action No.	Operational Action	Current Status
48	CONFINED SPACES		The creation of and the need to access confined spaces shall be minimised during the design process. The Hazid processes shall identify and minimise the number of confined spaces and the Principal Contractor shall create and maintain a list of identified and potential confined spaces from information provided in the PCI and shall, within the Construction Phase Plan, lay out the safe working procedures and permit systems in place to control the associated hazards.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage and construction phase	4x5	High		Management of residual confined spaces remains crucial during plant operation	Open
49	COMMISSIONING OF NEW PLANT & SERVICES		The project design team shall carry out HAZID / HAZOP studies to ensure that the removal / interruption / commissioning of existing, new or altered plant and equipment shall be carried out in a controlled and carefully monitored sequence that shall not have negative effects upon the safe running of that plant or other adjacent plant and equipment or systems.	Open		N/A		Managed in next design stage	5x5	High		N/A	Open
50	WELFARE		The provision of suitable welfare facilities for site workers is the responsibility of the Client and arrangements shall be made through the Principal Contractor.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed during construction phase	2x1	Low		N/A	Open
51	STATUTORY AUTHORITY REQUIREMENTS		The design process shall ensure that all requirements of statutory authorities including the Local Authority planning department, the Environment Agency, the Health & Safety Executive and other relevant statutory bodies shall be highlighted and satisfied. In particular the HSE shall be notified of the commencement of the construction where notifiable under CDM Regulations and engaged with on an ongoing basis as required.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI. An F10 notification shall be maintained on the man site noticeboard.		Managed in next design stage	3x3	Med		Compliance with statutory authority requirements remains crucial during plant operation	Open
52	TEMPORARY WORKS		Where temporary works are required (as described by the HSE here: https://www.hse.gov.uk/foi/internalops/sims/construct/2_10_04.htm are required, the Client shall ensure that competent persons such as a Temporary Works Co-ordinator ensures that the safety requirements as outlined in BS5975 are satisfied. Such works include, but are not limited to: trenches, excavations, temporary slopes and stockpiles; formwork, falsework, propping, edge protection, scaffolding, temporary bridges, site hoarding and signage, site fencing, cofferdams; plant foundations such as tower crane bases, supports, anchors and ties and groundworks to provide suitable locations for plant location / erection. Earthworks - trenches, excavations, temporary slopes and stockpiles. Structures - formwork, falsework, propping, façade retention, needling, shoring, edge protection, scaffolding, temporary bridges, site hoarding and signage, site fencing, cofferdams. Equipment/plant foundations - tower crane bases, supports, anchors and ties for construction hoists and mast climbing work platforms (MCWPs), groundworks to provide suitable locations for plant erection, eg	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	5x5	High		N/A	Open
53	ENVIRONMENTAL		All sensitive ecological receptors and habitats shall receive due consideration. An aspects and impacts report shall be prepared during the design phase.	Open		The CPP shall include suitable arrangements based upon the information to be provided within the PCI.		Managed in next design stage	N/A	Low		The management of environmental issues remains an important requirement during plant operation	Open
54	OTHER		It is required that the principles and practices of National Grid's current Standards & Specifications are understood and adopted. Where any party wishes to establish their own procedures, approval for this must be expressly received in advance and any conflict with NG standards and specifications resolved in advance.										