REPORT

[redacted]

Peterborough Compressor Station FEED Summary Report

Prepared for: **National Grid PLC**

Prepared by: [redacted]

Project Title: **King's Lynn & Peterborough Compressor Station MCPD FEED Project**

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Contents

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Figures & Tables

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ABBREVIATIONS

AACEI	Association for the Advancement of Cost Engineering International
ADEPT	Asset Development, Evaluation and Planning Tool
AG	Above Ground
BAT	Best Available Techniques
BNG	Biodiversity Net Gain
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CEM	Cost Estimating Methodology
CS	Carbon Steel
CSRP	Control System Restricted Performance
DB	Distribution Board
DCS	Distributed Control System
DLE	Dry Low Emissions
DNO	Distribution Network Operator
D/S	Downstream
EPC	Engineering, Procurement and Construction
ERP3	Emissions Reduction Phase 3
ESD	Emergency Shutdown
F&G	Fire and Gas
FEED	Front End Engineering Design
FV	Full Vacuum
GBP	Great Britain Pounds
GG	Gas Generator
GTC	Gas Turbine Compressor
GT	Gas Turbine
HAZOP	Hazard and Operability
HSSE	Health, Safety, Security, and Environment

HVAC	Heating, Ventilating and Air Conditioning
IA	Instrument Air
IED	Industrial Emissions Directive
I/O	Input/Output
LER	Local Equipment Room
LV	Low Voltage
MCPD	Medium Combustion Plant Directive
MTO	Material Take-Offs
MTOD	'Material Take Off Driven' (Proprietary software tool developed by [redacted]
MV	Medium Voltage
NTS	National Transmission System
PAU	Pre-Assembled Unit
PCC	Point of Common Coupling
PDS	Process Duty Specification
PMS	Power Management System
PT	Power Turbine
RAM	Reliability, Availability and Maintainability
RIIO	Revenue=Incentives+Innovation+Outputs
RR	Rolls-Royce
SCR	Selective Catalytic Reduction
SIMOPS	Simultaneous Operations
SWBD	Switchboard
SWGR	Switchgear
TBC	To Be Confirmed
TCPA	Town and Country Planning Act
UG	Underground
UCP	Unit Control Panel

UKPN	UK Power Networks
USFM	Ultrasonic Flowmeter
U/S	Upstream
VFD	Variable Frequency Drive
VSD	Variable Speed Drive

HOLDS LIST

HOLD	SECTION	DESCRIPTION
1		Deleted.

1.0 EXECUTIVE SUMMARY

1.1 General

The Medium Combustion Plant Directive (MCPD) requires that existing plant between 1 MW and 50 MW net thermal input must not exceed specified operational emission limit values or be taken out of service before 1 January 2030 or operate under 500 hour emergency use derogation (EUD). This legislation impacts the Rolls Royce Avon driven compressor units on the gas National Transmission System (NTS) including units at Peterborough and Huntingdon Compressor Stations.

The Peterborough Compression Station is used primarily for bulk transmission of gas to support demand and currently has:

- 3 off Rolls-Royce Avon gas driven compressors (A, B, C) existing that do not meet emissions limits;
- 2 off Solar Titan gas driven compressors (D, E) in process of being installed to become lead units. These are part of the ERP3 project which is due for commissioning Q4 2022.
- Installation of 3rd Solar Titan was originally planned as part of the ERP3 project but was not completed. However, some civils construction was completed, and pre-investment was included in utility and support systems for a 3rd new unit.

Peterborough and Huntingdon compressor stations have a significant interaction on the National Transmission System (NTS) gas network in a range of supply and demand conditions. They are both centrally located with connections to multiple feeders. Both sites primary function is to move gas from the north of the NTS into the south.

The Huntingdon Compression Station is used primarily for bulk transmission of gas to support demand and currently has:

- 3 off Rolls-Royce Avon gas driven compressors (A, B, C) existing that do not meet emissions limits;
- 2 off Solar Titan gas driven compressors (D, E) in process of being installed to become lead units. These are part of the ERP3 project which is due for commissioning Q3 2023.

Note, no technical assessment or evaluation was performed by [redacted] on the Huntingdon Compressor Station. As Huntingdon forms part of the CBA options jointly being considered for Peterborough and Huntingdon, Huntingdon information has been included for completeness.

Unit A, B and C compressors at both Peterborough and Huntingdon do not comply with MCPD (Medium Combustion Plant Directive). One of these units may be used to provide resilience after commissioning of Units D and E, but need to be replaced/modified or derogated by 2030.

1.2 MCPD Legislation Compliance Options

The technical options being considered to provide required MCPD compliant compression capability to meet forecast requirements meet MCPD legislation at the existing Peterborough Compression Station are as follows:

Do nothing:

a) Retain Avon with run hours restricted 500 hour per year on a 5 year rolling average per the emergency use derogation allowed in MCPD;

RR Avon Retrofit Options

a) Retrofit emissions compliant DLE combustion system to Avon gas generator;

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

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

New Build (Replacement of RR Avon) Options

a) New Gas Turbine Driven Compressor;

b) New Electric Variable Speed Drive (VSD) Compressor.

Based on the preliminary information, the existing Avon Unit A is the preferred unit for the retrofit options as it is considered to be the most reliable unit of three existing Avon units. The unit to be retained will be confirmed based on further surveys and assessments. This study has proceeded on the premise that Unit A is the selected unit for retention.

As part of the ongoing ERP3 project, there has been significant pre-investment in the plinth F area located immediately alongside compressor units D and E to the North, providing a location for potential new build compressor unit, with foundations and underground services partially in place.

Figure 1-1: Peterborough Station Layout (Key Site Equipment)

[redacted]

Figure 1-2: Huntingdon Station Layout (Key Site Equipment)

[redacted]

1.3 Study Execution Methodology

Cost Benefit Analysis (CBA) and BAT Assessments shall be used to help inform the preferred MCPD Compliance Option. National Grid will perform the CBA and BAT assessments. [redacted] is responsible for providing the input data for the analysis / assessment. The study execution methodology is illustrated by Figure 1-3.

The study was executed in two phases. During Phase 1, a preliminary assessment and screening of new build and retrofit options was undertaken in order to shortlist the options. The options were screened based on project development cost, project execution schedule, safety, environmental impact, constructability and impact on existing operations considerations. Based on the assessment, the New Build Electric VSD drive option was screened out and not carried forward to Phase 2. Refer to Section 7.4 for details for details of the assessment and rationale for screening out of the New Build Electric VSD drive option.

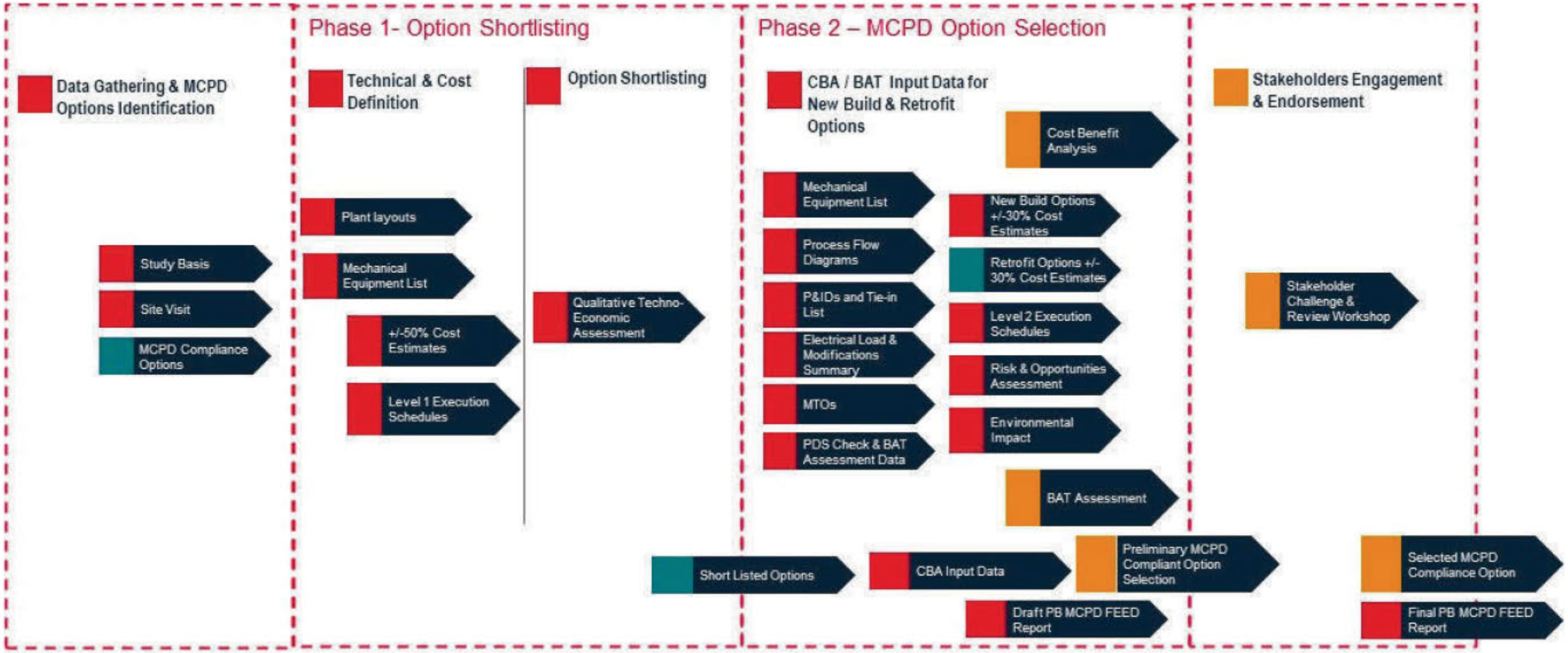
During Phase 2, the input data required for the CBA and BAT assessment was generated for all MCPD Compliant options carried forward from Phase 1. A summary of the input data is provided by Table 1-1. National Grid will perform the CBA and BAT Assessments on the short listed MCPD legislation compliance options and use the results to help inform the preferred option.

Table 1-1: Peterborough CBA & BAT Assessment Input Data

Assessment Criteria	MCPD Compliance Option						Notes
	Counterfactual ("Do Nothing")	New Build GT Unit	CSRP Retrofit	DLE Retrofit	SCR Retrofit	Decommission Avon	
Project Development Cost	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	Includes re-life costs for "Do Nothing" and retrofit options.
Project Development Schedule	All options can achieve the MCPD target date. Retrofit options have more float and thus less schedule risk. The estimated completion date for a new build 1Q2029. The estimated completion date for retrofit options is 4Q2027.						
Risk Exposure	N/A	Higher exposure than all retrofit options due to extent of project scope.	Carries lowest risk exposure.	Less risk exposure than SCR. Technology is not proven within National Grid.	Highest exposure of the retrofit options due to planning and project extent.	N/A	Risk Exposure relates to risks associated with required mods / upgrades
Process Duty Specifications	N/A	Designed to satisfy required operating envelope.	Compromises flexibility available from Avon unit, but can meet achieve PDS with mitigations	Can achieve PDS with mitigations for the most onerous cases. Mitigations required are fewer than that required with CSRP retrofit.		N/A	
Emissions Assessment	All options are compliant with the relevant MCPD emission limits.						
Embodied Carbon Emissions	N/A	Highest embodied carbon emissions.	Offers minimal embodied carbon emissions relative to other options.		Highest embodied carbon of the retrofit options.	N/A	Emissions relate to required mods / upgrades
Environmental Impact	N/A	Able to meet Biodiversity Net Gain targets.	No impact on Biodiversity		Able to meet Biodiversity Net Gain targets.	N/A	Impact relates to required mods / upgrades

[redacted]

Figure 1-3: Study Execution Methodology



[redacted] Activity [redacted] / NG Activity NG Activity

2.0 INTRODUCTION

2.1 General Background

The Medium Combustion Plant Directive (MCPD) requires that existing plant between 1 MW and 50 MW net thermal input must not exceed specified operational emission limit values or be taken out of service before 1 January 2030 or operate under 500 hour emergency use derogation (EUD). This legislation impacts the Rolls Royce Avon driven compressor units on the gas National Transmission System (NTS) including units at the Peterborough and Huntingdon Compressor Stations. Investment is required to ensure the capability, that the network requires, can be maintained beyond 1 January 2030. Investment may include various combinations of the following options and the investment must be assessed against network capability requirements predicted under various future energy scenarios to ensure the most cost-effective solution for end consumers.

- Upgrading non-compliant units to bring emissions within acceptable legislative limits;
- Replacement of non-compliant units with new low emissions compressors;
- Taking non-compliant units out of service;
- Restrict the performance of non-compliant units through control system restriction such that operational emissions are limited to within legislative limits;
- Limit the use of non-compliant units to a maximum of 500 hours per year under an emergency use derogation as defined in the MCPD legislation (i.e. do nothing).

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

2.2 Site Background

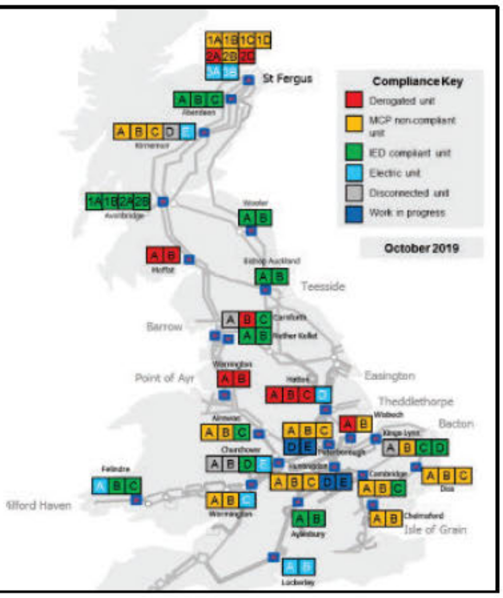
Peterborough and Huntingdon Compressor Stations are located in the East of England and their location on the NTS is shown on the schematic below. A brief outline of the Peterborough and Huntingdon sites is provided in the section below to put the project scope into context.

Figure 2-1: Peterborough & Huntingdon Compressor Stations Locations

Peterborough / Huntingdon

Unit A, B, C – RR Avon

Unit D, E – Solar Titan 130



2.2.1 Peterborough Compressor Station

The Peterborough Compression Station is used primarily for bulk transmission of gas to support demand and currently has:

- 3 off Rolls-Royce Avon gas driven compressors (A, B, C) existing that do not meet emissions limits;
- 2 off Solar Titan gas driven compressors (D, E) in process of being installed to become lead units. These are part of the ERP3 project which is due for commissioning Q4 2022.
- Installation of 3rd Solar Titan was originally planned but was not completed. However, some civils construction was completed, and pre-investment was included in utility and support systems for a 3rd unit.

The A, B and C compressors do not comply with MCPD (Medium Combustion Plant Directive). One of these units may be used to provide resilience after commissioning of Units D and E, but it needs to be replaced/ modified by 2030.

2.2.2 Huntingdon Compressor Station

The Huntingdon Compression Station is used primarily for bulk transmission of gas to support demand and currently has:

- 3 off Rolls-Royce Avon gas driven compressors (A, B, C) existing that do not meet emissions limits;
- 2 off Solar Titan gas driven compressors (D, E) in process of being installed to become lead units. These are part of the ERP3 project which is due for commissioning Q3 2023.

The A, B and C compressors do not comply with MCPD (Medium Combustion Plant Directive). One of these units may be used to provide resilience after commissioning of Units D and E, but it needs to be replaced/ modified by 2030.

2.2.3 Peterborough & Huntingdon Compressor Stations Operation

Peterborough and Huntingdon compressor stations have a significant interaction on the National Transmission System (NTS) gas network in a range of supply and demand conditions. They are both centrally located with connections to multiple feeders. Both sites primary function is to move gas from the north of the NTS into the south.

Peterborough is a critical site in moving gas around the network supporting multiple operational strategies, predominately to support movement of gas into the south where the bulk of the demand exists. Huntingdon is very similar however operates downstream of Peterborough and typically forms a compressor chain (working in unison with Peterborough to meet Southern demand), this also makes Huntingdon a critical site for supporting South East and South West demand).

Peterborough and Huntingdon cannot always be used to cover each other. During high demand scenarios, such as a common winter demand day, the NTS requires 2 units at each site (4 units online) to ensure that the network can operate.

The central location of the sites mean they are also used for a wide range of other purposes including:

- Moving gas towards the North West and West Midlands under high North West storage injection scenario;
- Supporting movement of gas from the North East into Southern parts of the network;
- Providing resilience as back-up compressor stations to Hatton or Wisbech;
- Facilitating maintenance and planned outages in the central and southern parts of the network.

2.3 Document Objectives

Cost Benefit Analysis (CBA) and BAT Assessments shall be used to help inform the preferred MCPD Compliance Option. National Grid will perform the CBA and BAT assessments . In order to perform the CBA and BAT Assessment, key technical and cost information is required as input. This report presents a summary of the input data generated for the CBA and BAT Assessments as well as key findings and recommendations resulting from the activity.

Note, no technical assessment or evaluation was performed by [redacted] on the Huntingdon Compressor Station. As Huntingdon forms part of the CBA options jointly being considered for Peterborough and Huntingdon, Huntingdon information has been included for completeness.

2.4 Document Structure

This document is structured as follows:

Section 3.0 summaries the main data and assumptions used for technical development of the alternative MCPD compliance options.

Section 4.0 presents a technical summary of the MCPD compliance options.

Section 5.0 presents a summary of the study execution approach.

Section 6.0 highlights whether the MCPD compliance options are able to achieve the required Process Duty Specifications (PDS).

Section 7.0 summaries the preliminary screening of the build MCPD compliance options.

Section 8.0 presents the findings of the HSE assessments performed for the MCPD compliance options.

Section 9.0 presents the estimated +/-30% project development costs for the MCPD compliance options.

Section 10.0 summaries the Level 2 project execution schedules developed for the MCPD compliance options.

Section 11.0 presents the main risks and opportunities identified at this stage for the MCPD compliance options.

Section 12.0 provides a summary of the main conclusions resulting from this phase plus recommendations for future project phases.

Section 13.0 lists the supporting documents produced during this study and also other key references used in the execution of the study.

3.0 STUDY BASIS

Key Reference Documents

203513C-002-RT-0008-0002	Peterborough Basis of Design [Ref. 1]
203513C-002-RT-0500	Peterborough Compressor Station Site Visit [Ref. 2]
203513C-000-RT-0300	Cost Estimating Methodology [Ref. 3]
203513C-002-RT-0008-0001	Peterborough Compressor Station Process Description [Ref. 16]

3.1 General

The study Basis of Design [Ref. 1] catalogues relevant detail and assumptions employed over the course of this study.

The Peterborough Compressor Station features five gas turbine driven units with associated equipment including filtration, metering, fuel gas pressure reduction and venting, associated pipework and control systems. A high-level illustration of the station is provided in Figure 3-1.

The station sits between pipeline feeders F2, F4, F9, F18 and F22 as summarised below.

Table 3-1: Station Feeder Pipeline Summary

Feeder	To / From	Nominal Pipe Size (mm)
F2	Wisbech Nene West / Duddington	900
F4	Wisbech Nene West / Tixover	900
F9	Hatton / Huntingdon	1050/900
F18	Lutton	1050
F22	Silk Wiloughby	1050

Table 3-2 summarises details associated with the station compressor units. The D and E Solar Titan T130 compressors are currently under commissioning as part of the Emissions Reduction Phase 3 (ERP3) project, and will be the lead units for operation in single or parallel modes. Units A, B and C will provide resilience when one or more of the Solar Titan driven units are not available due to planned or un-planned outages.

Unit A, B and C compressors do not comply with MCPD (Medium Combustion Plant Directive). One of these units will be used to provide resilience after commissioning of Units D and E, but it needs to be replaced/modified by 2030.

Based on the preliminary information (Ref. 2), the existing Avon Unit A is the preferred unit for the retrofit options as it is considered to be the most reliable unit of the three existing Avon units. The unit to be retained will be confirmed based on further surveys and assessments during later project stages. This study has proceeded on the premise that Unit A is the selected unit for retention.

Figure 3-1: Peterborough Compressor Station Schematic

[redacted]

The ERP3 project has modified and replaced station systems, utilities, pipework and buildings. The schematic is representative of the station on completion of the ongoing installation.

Table 3-2: Existing Operating Compressors Specifications

Unit	Engine	Comp.	ISO Power (MW)	Installed	Min. Flow (MSCM/D)	Capacity (MSCM/D)
A	RR / 1533	Dresser Clark 36x36	12.4	1973 (GT Major Overhaul 2018)	14	73
B	RR / 1533	Dresser Clark 36x36	12.4	1973	16	73
C	RR / 1533	Siemens Delaval PV30/30	12.4	1978	7	73
D(1)	T130	Solar C65	15.3	2021	TBC (3)	TBC (3)
E(1)	T130	Solar C65	15.3	2021	TBC (3)	TBC (3)
Para(2)	Note 2	-	24.7	-	-	140 (3)

1. Compressor under commissioning.
2. Parallel operation between one of A / B / C and one of D / E.
3. Based on the National Grid Process Description, the station design capacity is 140 MSCM/D. Datasheets for units D and E were not available during thus study to confirm the design capacities of these units.

3.2 Design Operating Cases

Demand on the compressor station varies throughout the year reflective of the various factors contributing to supply and demand variation on the wider grid. Operating points to be met by the station are summarised in Table 3-3 with varying operating mode as follows:

- Mode 1 – single compressor unit operation;
- Mode 2 – parallel operation between two compressor units;
- Mode 3 – station capacity.

Note that Mode 3 Station Capacity specifications are relevant to unit operations and components out with the individual compressor units.

Table 3-3: Process Design Cases

Case	Operating Mode	P Suct. (Barg)	P Dis. (Barg)	Std Flow (MSCM/D)	T Suct. (°C)
C1	2	51.63	64.46	94.80	7.73
C2	1	52.64	61.10	58.80	8.01
C3	1	51.78	62.30	50.57	15.49
C4	2	54.82	67.20	84.42	8.68
C5	2	59.25	67.80	105.04	11.04
C6	2	59.22	65.80	73.89	10.01
C7	1	51.98	58.30	34.93	15.22
C8	1	46.43	55.79	27.40	10.50
C9	1	50.46	63.13	46.78	9.04
S1	2	58.36	66.68	132.16	5.00
S2	2	46.95	56.38	109.70	6.00
2050	3	37.9	75.00	140.00	-

3.3 Site Status

A site visit has been undertaken as part of the project with associated report detailing outcomes and findings of significance (Ref. 2). Refer to Section 3.6 for the main findings from the site visit.

3.4 Site Layout

The station is divided into general areas that feature specific unit operations and equipment. Figure 3-2 provides station layout overview.

Figure 3-2: Peterborough Station Layout Overview

[redacted]

Major site piping is predominantly underground. Site buildings include old and new Control Buildings towards the South-East. The old building primarily houses original control systems and MV switch room with the new building housing all other essential services. Navigation between site areas is facilitated by an asphalt road network and a security fence stands around the site perimeter, featuring remotely operated gates for access and egress.

Immediately north of the new D and E compressor units is a space that had been reserved for a further compressor, unit F, however, during design development, the third new unit was removed from the scope.

3.5 Layout Specifications

Site areas are classified as Class 1, 2, 3 or 4 as summarised in National Grid's Site Location and Layout Specification T/SP/G/37 [Ref. 9] with the Peterborough Compressor Station comprising areas as follows:

- Class 4;
  - Gas scrubbers, K-101A/ B;
  - Condensate tank, V-10 2;
  - Compressor units, A-E;

- Class 3;
    - Fuel Gas pressure reduction area;
- Class 2;
    - FE-11001/12001 Ultrasonic Flowmeter;
    - Inlet / Outlet manifolds;
    - Pig Traps.

Based on site maximum operating pressure of 75 barg, the required minimum separation distances across the site are as summarised in Table 3-4.

Table 3-4: Minimum Separation Distances from Hazardous Equipment

Plant Area Category	Minimum Separation Distance (m)		
	Essential / Hazardous Equipment	Occupied Building	Outermost Security Fence
4	32	39	39
3	16	20	19
2	5	6	5
1	3	3	5

3.6 Site Condition

Condition across site is generally good with many systems and areas having been replaced as part of the ERP3 project, however, there is notable deterioration at specific locations. Further detail can be found within the Peterborough Site Visit Report [Ref. 2]. For the Retrofit Options, as well as the upgrades required to meet the MCPD requirements, additional 're-life' modifications / upgrades are required to the existing Avon Unit A Gas Turbine Compressor to ensure the requisite design life is achieved. The re-life modifications are part of the MCPD project scope, they form part of the on-going National Grid's Asset Health Plan. Refer to Reference 27 for full details of the asset health plans.

3.7 Fleet RAM Study

A National Grid Gas Transmission (NGGT) Fleet RAM Study [Ref. 20] by [redacted] was performed to forecast the expected Compressor Train availability to provide necessary capacity during periods of demand for the entire fleet of National Grid Compressor Trains. Note, this RAM Study is a generic assessment and does not specifically reflect the condition of the existing facilities at the Peterborough Compressor Station.

The study reviewed both electric and gas turbine driven systems used on the National Grid network.

The main objective of the RAM study was to:

- Forecast expected availability;
- Identify main contributors to unavailability and itemise individual sub-unit contributions;
- Identify potential areas of availability improvement in the operation and maintenance of the compressor train.

The following observations were made in regard to the biggest contributors to the Avon Compressor Train's unavailability:

- Failures of the Safety / Protection / ESD sub-unit were the largest contributor to the availability loss;
- The second largest loss-contributor to availability is trips and failures of the Control System. The majority of losses attributed to this sub-unit were caused by major failures with long-lead times;
- The third largest contributor to the availability loss was the Compressor sub-unit;
- Contributions from miscellaneous and Power Turbine sub-units were also significant and like other sub-units, most of the losses were attributed to major and minor failures when spare parts are not available.

The conclusions from the RAM Study (although a generic assessment of the Avon Unit fleet) are consistent with the re-life requirements presented in Reference 27. As a minimum, the following upgrades are required as part of the Avon Unit B 're-life' modifications to ensure the requisite design life is achieved:

- Safety / Protection/ ESD Systems;
- Control Systems;
- Compressor Package Overhaul.
- Better understanding of the spare parts inventory and overall obsolescence issues.

3.8 New Build Unit Location

As part of the ongoing ERP3 project, there has been significant pre-investment in the plinth F area located immediately alongside compressor units D and E to the North, providing a potential location for a new build compressor unit with foundations and underground services already partially in place.

3.9 Design Life

The design life of each element of the compressor installation shall as a minimum, comply with the asset life requirements listed in Table 3-5 [Ref. 1].

Unit upgrades or life extension reviews (i.e., retrofit options highlighted in Section 1.2) shall also comply with the asset design life requirements shown below.

[redacted]

Table 3-5: Design Life Requirements

Asset	Life (Years)
Compressor	40
Gas Generator	20
Power Turbines	25
Pipework and Valves	30
Protection and Control Systems	15
Enclosures and Buildings	60

3.10 Maintenance Requirements

As a minimum, the design shall comply with the requirements of National Grid's maintenance policy T/PL/MAINT/99. The design shall facilitate safe isolation and accessibility to enable maintenance activities to be undertaken safely.

There are no total station shutdowns at Peterborough for maintenance purposes. Each compressor unit is shutdown as required for routine maintenance activities etc. For any major station modifications, this study is premised on the basis that the station can be shut down for approx. 6 months, April to September inclusive, as long as this is planned in advance. The actual durations permitted may vary in practise.

3.11 New Build Compressors

For the purposes of this study, the design and footprint for the new build units is based on the footprint of the Solar Titan T130 units recently installed at the Peterborough Compressor Station (i.e., 60m long x 22m wide) as part of the ERP3 project. This footprint is for a GT driven compressor including the associated cab, plus it also caters for the space requirements for the associated ancillaries (i.e., inlet / outlet isolation valves and piping, recycle valve and piping, fuel gas skid, dry seal gas skid, lube oil system, LER for local LV switchgears and control panels, fire suppression skid). The allocated footprint is considered to be generous / conservative as there is significant scope to optimise the layout and size of the compressor cab etc.

It should be noted that for an electric driven VSD compressor, the main differences to the footprint / layout requirements are as follows:

- The compressor cab would be smaller by approx. 3.5m, as the electric motor occupies less space than a gas turbine;
- No fuel gas skid is required;
- There is no requirement to provide cut-outs on the compressor cab for gas turbine air intake incl. filters and exhaust. Although the cab cut-outs are on the cab roof, there is an opportunity to optimise the compressor cab dimensions;

- A separate LER is required for the VFD unit transformers / harmonic filters etc., Based on preliminary vendor information, the size of this LER would be 13.3m (L) x 1.6m (W) x 2.6m (H). The water-cooling system for the VFD is integrated into the VFD unit LER;
- A new LER for 11kV switchgear that would tie-into the new electrical incomer that is required from UKPN. However, this would be installed adjacent to the existing control building / electrical room and therefore is not part of the compressor unit footprint requirements.

Given the plot plan allocated footprint for the compressor unit is generous / conservative, the same footprint is also considered adequate for an electric driven compressor.

There are opportunities to optimise the package layout (e.g. quantity of structural steel etc.) and this can be carried out during the latter stages of design.

3.12 Utilities

Utility Systems at Peterborough are well defined having been replaced or as-built during the ERP3 project. Detail associated with critical utility systems is summarised in the following sub-sections.

3.12.1 Fuel Gas

Dedicated skid mounted fuel gas conditioning packages, W204 and W205, are in place corresponding to each of compressor units D and E respectively. Each package incorporates filter / coalescer, lube oil heat integration, electric heater and pressure let-down to achieve the specifications in Table 3-6. Where considering a new build compressor equivalent to units D and E installed as part of the ERP3 project, a fuel gas package equivalent to W204/ W205 is included.

Table 3-6: W204/ W205 Fuel Gas Package Specifications

Parameters	Min	Max	Design
Molar Flow (Nm3/h)	1230	4500	-
Mass Flow (kg/h)	990	3630	-
Inlet Pressure (barg)	44.8	75	80
Inlet Temperature (°C)	7	11	-26 / 53
Outlet Pressure (barg)	24.5	34.47	34.5
Outlet Temperature (°C)	26	83	-26 / 93

Fuel gas supply to the Avon compressor units is via separate dedicated system. Gas is heated and pressure is let-down via reduction manifold for supply to each unit with the following components:

- Domestic hot water HEX, H1103;
- Compressor supply filters;

- Supply meter, FM102A/B/C.

The only retrofit option that requires modifications to the existing Avon unit fuel gas system is the DLE retrofit option. These modifications are performed as part of the DLE Retrofit Option scope.

3.12.2 Instrument Air

The ERP3 project has installed an instrument air package, housed within dedicated building, 7220-W702, comprising conditioning and compression unit operations for supply to the compressor units designed as part of the project. Package specifications are summarised in Table 3-7 and are understood to be based on supply to the originally planned three GT driven Solar Titan T130 compressor units. Installation of and supply to a new compressor unit is therefore considered to be within the capacity of the existing utility system.

Table 3-7: Instrument Air Operating and Design Conditions

Parameters	Min	Max	Normal	Design
Discharge Pressure (barg)	9	10	-	13
Discharge Flow (Nm^3/h)	140	520	280	
Discharge Temperature (°C)	10	52	-	-14 / 65
Inlet Pressure	Atmospheric			13
Ambient Temperature (°C)	-13.4	32.9	9.8	-14 / 65
Discharge Dew Point (°C)	-40			

3.12.3 Potable/ Service Water

The station water ring main runs local to compressors D and E. It is assumed that tie-ins to the water ring main are feasible for the potable / service water supply to the new build compressor option.

3.12.4 Effluent / Drainage

The Peterborough site comprises of two separate networks: "Foul Water Sewer" and "Surface Water Drains". It is assumed sufficient capacity is available to tie into the existing networks for the new build compressor options.

3.12.5 Relief

A new vent array has been constructed as part of the ERP3 project featuring five identical stacks corresponding to each of the site compressor units and three larger stacks for each of station suction, discharge and separator service. Re-purposing of an existing Avon unit vent to service a new build compressor has been assumed and the capacity of common stacks considered sufficient for station upgrade options.

3.12.6 Electrical Power Supply

Main power for the Peterborough compressor station is supplied from National Grid at 11kV via underground cable(s). The incoming supply is stepped down to 400V via a 11/0.4kV transformer, which feeds the Main LV Switchboard in the New control room which was installed as part of the ERP3 scope. 400V power is distributed to units D & E via newly installed cable trenching which can be utilised for providing low voltage power to new compressor options.

The original MV switchboard at the old control room receives power via the New LV Switchboard installed during ERP3 scope. The original LV switchboard facilitates the power distribution to the Avon compressors and their auxiliaries.

Figure 3-3: Existing Peterborough Power Distribution System Overall SLD

[redacted]

3.13 Cost Estimating Methodology

Two levels of cost estimates were required for this study. +/-50% and +/-30%.

Full details of the Cost Estimating Methodology are provided by Reference 3.

3.13.1 +/-50% Cost Estimating Method

To achieve the required accuracy for the +/-50% cost estimate, the brownfield cost estimates are be based on high level MTOs (Material Take Offs) estimates. For expediency, a hybrid cost estimating method is used, whereby cost elements are classified as greenfield, simple brownfield and complex brownfield. For greenfield and simple brownfield cost elements, a semi-automated MTO method is applied using the [redacted] ADEPT cost estimating tool. For complex brownfield, where more rigorous MTOs are required, the [redacted] MTOD (Material Take Off Driven) tool is used.

ADEPT (Asset Development, Evaluation and Planning Tool) is a proprietary software tool developed by [redacted] The ADEPT output cost is the P50 cost estimate including contractor and National Grid indirects costs.

The MTOD tool is a proprietary software tool developed by [redacted] developed over more than 20 years. It allows for rapid, accurate, consistent, credible and fully transparent estimation of complex brownfield cost estimates based on a MTO approach in accordance AACEI (Association for the Advancement of Cost Engineering International) requirements. The MTOD output cost is the P50 cost estimate including contractor indirects and National Grid indirects costs.

3.13.2 +/-30% Cost Estimating Method

To achieve the required accuracy for the +/-30% cost estimate, the cost estimates are solely based on MTOs (Material Take Offs) using the [redacted] MTOD (Material Take Off Driven) tool. The tool uses the following method:

- This model assumes a PAU (Pre-Assembled Unit) with a final tie-in approach to construction or a stick-built approach;
- The +/-30% Cost estimate is a “bottom-up” cost estimate, deriving as much detail as is practicable and useful, from the engineering information produced by the engineering team;
- New build compressor unit procurement costs are supported by budget quotations. This data will be augmented by in-house cost data, using information from a large number of similar current or recent projects;
- Supplier budget quotes used for all major equipment (e.g. SCR).
- Re-life costs and compressor demolition costs based on National Grid's RIIO-T2 unit cost schedule.

The Cost Estimate will be prepared in accordance with the AACEI (Association for the Advancement of Cost Engineering International) requirements.

3.13.3 Exclusions

The following cost elements are excluded from the cost estimates and are developed separately by National Grid:

- Operating expenditure (OPEX).

The following costs are omitted from the estimate:

- Forward escalation;

- Financing costs;
- Cost of future exchange rate fluctuations;
- Import duties, Customs charges;
- Customs duties and local taxes;
- Licenses and consents;
- Disposal and decontamination costs;
- Re-sale value of any destructed / removed equipment and bulk materials from demolition scope;
- National Grid's Approved for Expenditure Contingency (Management reserve).

4.0 OPTION DESCRIPTIONS

Key Reference Documents

203513C-002-RT-0503	Peterborough Compressor Station Option Review Report (Phase 1) [Ref. 7]
203513C-002-RT-0250	Peterborough Compressor Station Layout Review Report (Phase 1) [Ref. 6]
203513C-002-DW-0051-0001	Peterborough Layout Drawings [Ref. 17]
203513C-002-RT-1600-0001	Peterborough Compressor Station Electrical Modifications Summary [Ref. 18]
203513C-002-EL-0260	Peterborough Compressor Station Mechanical Equipment List (Phase 1) [Ref. 8]
203513C-002-EL-0261	Peterborough Compressor Station Mechanical Equipment List (Phase 1) [Ref. 8]
203513C-002-PFD-0010-0001	Peterborough Process Flow Diagrams [Ref. 19]

4.1 Options Overview

The Peterborough Compressor Station has five compressor units. At present, RR Avon Units A, B and C are operational, with Solar T130 Units D and E undergoing commissioning as part of the ERP3 project. Currently, the Peterborough Compressor Station primarily operates units A and B in single or parallel operating modes according to the flow levels required. Note, as observed during the Site Visit [Ref. 2] Unit A and B are generally run together. Unit C has a different compressor and seal oil system design. Unit C is larger and there are load sharing issues if it is run with Unit A or B.

When operational, Unit D and E will become the lead units with either Unit A, B or C (prior to 2030) providing resilience when one or more of the Solar Titan driven units are not available due to planned or un-planned outages. Further information is provided in the Peterborough Basis of Design [Ref. 1]. Given the Avon Compressor Units do not comply with MCPD, various options are being considered to upgrade or replace a single unit to provide the station with adequate capacity and resilience post 2030.

The options considered to upgrade or replace the RR Avon Unit is as follows:

- New Gas Turbine Driven Compressor (Option A);
- New Electric Variable Speed Drive (VSD) Compressor (Option B);
- Retrofit emissions compliant DLE combustion system to Avon gas generator (Option C);
- Use of CSRP (option D);
- Installation of a SCR unit (Option E).

As part of the ERP3 Project, a third unit was planned (Unit F), and limited construction activity and enabling works were completed, but this has since been descoped. The area around the new compressors has been raised and stoned to aid construction. This is due to be scraped out and a final concrete finish will be installed.

The following infrastructure and enabling works are available to aid installation of a third unit:

- Piles have been installed to accommodate the third unit;
- Foundations have been cast for the suction/discharge pipework and platforms;
- Existing draw pit available to extend to third unit with cable openings stubbed;
- Surface water drainage available to extend to third unit with pipe opening stubbed;
- An area adjacent to the proposed location would need to be prepared to position a crane;
- An existing construction road exists to facilitate access to the plinth F.

All three Avon units are currently operational, however, the following differentiating observations were made about their condition:

- The operator advised that the enclosures of units A and B had been refurbished in 2014;
- A major overhaul of the Unit A power turbine was performed in 2018;
- Unit A is the most reliable unit. It starts first time. There are defects with Units B and C. Unit C is better at higher loads;
- Compressors A & B work better in conjunction than any other combination as C can "starve" as it is at the end of the suction line;
- The Avon units have dedicated fuel gas supply skids. The fuel gas control valves for Unit B are defective. The Unit A filters, valves, piping and instruments are in good condition. However, the common fuel gas heaters (Ham Worthy Boilers) are over 40 years old and in poor condition and need replacing.

Therefore, based on the preliminary information identified above, the existing Avon Unit A is the preferred unit for the retrofit options as it is considered to be the most reliable unit of three existing Avon units. The unit to be retained will be confirmed based on further surveys and assessments in later project stages. This study has proceeded on the premise that Unit A is the selected unit for retention for the retrofit options.

For the purposes of this study, the design and footprint of the new build unit is based on the Solar Titan T130 units D & E (i.e., 60m long x 22m wide). This footprint is for a GT driven compressor including the associated cab, plus it also caters for the space requirements for the associated ancillaries (i.e. inlet / outlet isolation valves and piping, recycle valve and piping, fuel gas skid, dry seal gas skid, lube oil system, LER for local LV switchgears and control panels, fire suppression skid). The allocated footprint is considered to be generous / conservative as there is significant scope to optimise the layout and size of the compressor cab etc.

It should be noted that for an electric driven VSD compressor, the main differences to the footprint / layout requirements are as follows:

- The compressor cab would be smaller by approx. 3.5m, as the electric motor occupies less space than a gas turbine;
- No fuel gas skid is required;

- There is no requirement to provide cut-outs on the compressor cab for gas turbine air intake incl. filters and exhaust. Although the cab cut-outs are on the cab roof, there is an opportunity to optimise the compressor cab dimensions;
- A separate LER is required for the VFD unit transformers / harmonic filters etc., Based on preliminary vendor information, the size of this LER would be 13.3m (L) x 1.6m (W) x 2.6m (H). The water-cooling system for the VFD is integrated into the VFD unit LER;
- To provide sufficient supply capacity, a new 11kV incomer is required from UKPN transformer compound located external to site, alongside corresponding extension to the existing 11 kV panel located within the site control building.

For the purposes of input to the option screening, the following main technical definition was developed for each option:

- Site layout;
- Process Flow Diagrams;
- Interface Schematic and Register, plus Tie-in List and P&ID mark-ups;
- Major equipment requirements including discipline specific considerations i.e., Mechanical, Electrical and Control and Instrumentation.

4.2 New Build Options

4.2.1 Site Layout Review

Based on the pre-investment made as part of the ERP3 project in the construction of Plinth F, immediately North of compressor units D and E, this is the sole location considered for the new compressor options. Plinth F adheres to site layout requirements with all separation distances met, see Figure 3-2, avoiding the requirement for additional land acquisition.

The existing site equipment and process is illustrated by Figure 4-1.

Figure 4-1: Existing Peterborough Station PFD

[redacted]

High level separation distances for the Plinth F location and the prospective MCPD new build option are provided in Table 4-1 based on detail developed as part of the Layout Review (Ref. 6). As highlighted, each of the ERP3 compressor plinths comply with separation requirements from buildings and hazardous equipment.

Table 4-1: New Compressor Unit Separation Distances

Compressor Location Option	Proposed Distance (m)		
	Distance to Buildings (Note 1)	Distance to Essential / Hazardous Equipment (Note 2, 3)	Distance to Outermost Security Fence
Plinth D	77	>32	85
Plinth E	89	>32	66
Plinth F	103	>32	50

Notes:

1. The nearest building on site is the old control building and distances shown are to this building.

2. Distance to Existing mobile Pig Trap Location C [PT (C)]. A layout review undertaken for Peterborough ERP3 Project (Ref. 9) has confirmed that the separation distance between the compressor enclosures and PT (C) is greater than 32m.
3. The other essential hazardous equipment on site is the Suction Scrubbers, AGI Pipework & Valving, Existing Pig Traps and existing Avon Compressors. The distance to these items is greater than 32m.
4. The distances shown is the governing / worst case scenario distance from the compressor location.

4.2.2 Interface Schematic and Register

Critical interfaces with existing site facilities for the single new build compressor options include:

- Disconnection and demolition of Avon Units A, B, and C.
- Destruction of natural gas suction header with suction and discharge pipework tie-ins to existing station underground piping network;
- Compressor discharge vent relief route construction incorporated as part of Avon compressor B vent stack;
- Potable water supply to water mist package via existing underground ring main;
- LP and HP Air supply to instrument air actuated valves and compressor seals via existing skid adjacent to the compressor units D and E;
- Electrical supply to new compressor via existing cable trench network extension for GT driven. For the electric VSD unit, a new cable trench plus 11 kV incomer required to power a new VFD unit. The main LV import switchboard at the New Control Room has spare equipped cubicles which could be modified to support additional feeders as required.
- Integration with station Control and Instrumentation systems, including control and safety panel installation in new control building, and inter-connection with DCS, ESD, F&G at compressor LER and enclosure.
- New compressor recycle stream to interface with the existing common recycle header.
- Existing fuel gas pipework to interface with replacement fuel gas heater unit.

  Note, modification to the station fuel gas heating system as part of the MCPD project is to be confirmed following confirmation of the current fuel gas heating replacement project.

The interface schematics for the GT and electric driven VSD compressor options are shown in Figure 4-2 and Figure 4-3 below. The associated interface register is presented in Table 4-2.

Figure 4-2: New GT Driven Compressor Interface Schematic

[redacted]

Figure 4-3: New Electric Driven VSD Compressor Interface Schematic

[redacted]

Table 4-2: Interface Register

Interface No.	Description	Notes
COMMON INTERFACE POINTS FOR BOTH GT AND ELECTRIC DRIVEN COMPRESSORS		
IP-A1 / IP-B1	Control Signal Interface	Control signals (DCS, UCP, ESD, F&G) from new build compressor package interfacing with existing station control & safety systems (Dual ICSS Network / Hardwired Trips) via a new central control room station control panel. Control cables utilise existing cable trenching.
IP-A2 / IP-B2	HP Instrument Air Interface	Interface with existing instrument air system at Instrument air pressure reduction skid. New piping constructed to supply HP IA to the new build compressor. Piping to run parallel to LP instrument air supply.
IP-A3 / IP-B3	LP Instrument Air Interface	Interface with existing instrument air system at Instrument air pressure reduction skid. New piping constructed to supply LP IA to the new build compressor. Piping to run parallel to HP instrument air supply.
IP-A4 / IP-B4	400V Electrical Supply Cabling Interface	Cabling to interface with existing electrical switch room to provide power for Turbine auxiliaries and control cabling. Existing cable trench utilised.
IP-A5 / IP-B5	Avon Comp. A/B/C Suction Destruct	Disconnection and destruction of Avon Units A, B, and C. Destruct natural gas suction header, Compressor associated process and utility piping, and control and electrical cabling. Note, extent of destruct scope to be defined in the next engineering phase. Depiction in Figure 4-2 and Figure 4-3 is limited.
IP-A6 / IP-B6	Avon Comp. A/B/C Discharge Destruct	Disconnection and destruction of Avon Units A, B, and C. Destruct natural gas suction header, Compressor associated process and utility piping, and control and electrical cabling. Note, extent of destruct scope to be defined in the next engineering phase. Depiction in Figure 4-2 and Figure 4-3 is limited.
IP-A7 / IP-B7	New Comp. Suction Header Interface	Interface point with existing compressors D & E suction header tie-in point.
IP-A8 / IP-B8	New Comp. Vent Stack Interface	New compressor vent line to tie into existing, former Avon B Vent stack.
IP-A9 / IP-B9	New Comp. Discharge Header Interface	Interface point with existing compressors D & E discharge header tie-in point.
IP-A10 / IP-B10	New Comp. Recycle Header Interface	Interface point with existing compressors D & E recycle header tie-in point.
IP-A11 / IP-B11	New Comp. Potable Water Interface	New potable water piping to interface with Potable Water (PW) ring main for supply to the new compressor water mist cabinet.
ELECTRIC DRIVEN VSD COMPRESSOR OPTION		
IP-B12	11kV Electrical Supply Cabling Interface	Interface with new 11 kV switchgear via the new 132kV/ 11kV transformer. New cabling and cable trenching required from Control room to new electric VSD compressor package.

4.2.3 Major Equipment: Mechanical, Electrical and C&I

Major equipment items comprising the new compressor installation are detailed in the associated equipment list (Ref. 8, 21). Differences between the electrical scope for the GT driven and electric driven VSD compressor options are highlighted below.

For the GT driven compressor, the electrical system interfaces are illustrated by Figure 4-4 below.

Figure 4-4: Electrical Tie-in Schematic (Construct/ Destruct) for a new build GT Driven Compressor

[redacted]

As per units D and E installed as part of the ERP3 project, a local LER housing a 120 VDC UPS, MCC and General Small Power and Lighting Distribution Board (DB) is included as part of the new build GT driven compressor option. Therefore, for tie-in to the existing system, a single main feeder cable to the new compressor package is required, which will then be distributed internally by the Vendor. This electrical power distribution system design minimises the number of electrical tie-ins required within the existing facilities.

With the electric driven VSD compressor option, the new electric motor proposed is 15 MW controlled via a new VFD. The tie in voltage for this option is at 11 kV and the existing supply connection has insufficient capacity to support this level of load, so UKPN is required to install a significant amount of infrastructure to supply this power to the facility. There is also a requirement to extend the existing 11 kV switchboard to distribute the power to the new VFD and to the existing facility. The power supply for the new turbine hall and compressor package auxiliaries has been assumed to follow the same philosophy as the existing compression units, i.e., a new main power feeder from existing LER/ Control building. There will also be main control cables from the existing LER/ Control building to the new turbine hall. The tie-in details are illustrated in Figure 4-5 below.

Figure 4-5: Electrical Tie-in Schematic (Construct/ Destruct) for a new build Electric Driven VSD Compressor

[redacted]

For the Control and Instrumentation scope in respect to a new GT or electric VSD driven compressor, the following modifications / new equipment are required as shown below and in Figure 4-6:

- Station control and safety system expansion / modification:
  - Distributed Control System (DCS);
  - Emergency Shutdown System (ESD);
  - Fire & Gas (F&G).

- Offsite control system expansion / modification:
  - Warwick remote control centre.
- New Field / Local equipment room:
  - Compressor / Driver Unit control panels;
  - Compressor Balance of Plant integration;
  - Interfaces to Station control and safety system;
  - Fire & Gas detection / extinguishant;
  - Public Announcement Extension;
  - Telephone Extension.

Note, it is assumed the existing or new station control and safety systems have the expansion capacity capability. Limitations of obsolescence and technical support associated for expansion of these system are not considered.

Figure 4-6: C&I Sketch - New Build Compressor Package

[redacted]

For new build options, there is a potential to decommission the old control room as the existing Avon units, which interface with the room, are demolished. No detailed assessments of this potential were undertaken during this study and there may be other existing systems / interfaces that would require relocation to the new control room in order to decommission the old control room.

The following sub-sections provide detail associated with each option and associated differentiating factors.

4.2.4 Option A

Illustrations depicting Option A are available in Figure 4-7 and Figure 4-8; layout and PFD [Ref. 19] respectively. This includes a new GT Driven compressor unit in the Plinth F area.

Figure 4-7: Option A, New Build Compressor Layout

[redacted]

Figure 4-8: New Build Compressor PFD - (GT / VSD Driven Compressor)

[redacted]

Option A differs from B as follows:

- Electrical scope;
    - Limited to 400 V connection from local cable trench.
- Process scope;
    - Dedicated fuel gas skid located adjacent to compressor unit.

4.2.5 Option B

Depictions of Option B differ from A with the addition of new 132 kV incomer to site plus installation of a 11 kV cable trench as per Figure 4-9, connecting to the new Electric VSD driven compressor unit at Plinth F.

Figure 4-9: Option B: New Build Compressor Location – Electric VSD Compressor

[redacted]

Refer to the new build compressor PFD, Figure 4-8, which is identical for option A and B.

Option B differs from alternative A as follows:

- Electrical scope;
    - Installation of a separate LER for the VFD unit transformers / harmonic filters etc.
    - Installation of a new 132 kV incomer to site as the existing electrical power supply and distribution switchgear at Peterborough is not considered adequate to accommodate incremental design load;
    - Installation of infrastructure required for new 11kV incomer including switchboard extension;
    - New dedicated trench is required to route the 11kV cable from switchgear to compressor location;

4.3 Retrofit Options

4.3.1 Retrofit Option – Site Layout Review

The Peterborough Retrofit Options for a Single Unit are detailed in Table 4-3. The retrofit options being considered will upgrade an existing Avon unit with the latest technology to ensure MCPD compliance. Based on the combination of condition (Section 3.6) and performance capability (Section 6.3), the existing Avon unit selected for retention and retrofit is Unit A.

Table 4-3: Peterborough Compressor Retrofit Options

Option	Location	Technology Detail
C	Existing Comp. A	Retrofit emissions compliant DLE combustion system to Avon gas generator
D	Existing Comp. A	Retrofit Control System Restricted Performance (CSRP)
E	Existing Comp. A	Install Selective Catalytic Reduction (SCR) unit

Figure 4-10 shows the location of Avon Unit A, plus the plot space required by the SCR facilities including ammonia storage and unloading facilities which will be situated across the road from compressor A. For the DLE and CSRP options, no additional equipment is installed outside of the Avon Unit A Compressor Building.

A horizontal unit as opposed to vertical SCR unit is preferred as it will limit the weight imposed on the existing Cab and thus support structures required to support the SCR unit.

Note: The configuration (horizontal vs vertical) and best location of the SCR should be confirmed at more defined stage of engineering if this option is selected for MCPD project.

Figure 4-10: Retrofit Options (SCR) Location

[redacted]

For the SCR option, it is necessary to install ammonia storage and ammonia unloading facilities which introduces a new toxic hazard to the site. The T/SP/G/37 (Ref. 9) target separation distances are not applicable to chemical equipment, thus there are no target separation distance requirements specific to ammonia containing equipment. The likely selected ammonia concentration of 24.5% considered benign and carries limited risk to site personnel and low potential for offsite impact.

The ammonia offloading facilities are located such that the existing road network can be utilised and there is direct access to the main gate. However, the SCR facilities and potential equipment could clash with ERP3 project installed draw pits which carries project and environmental risk, see Section 11.2.

The SCR related ammonia facilities to be installed as far away as possible from other process facilities and as far away from the security fence as possible to minimise the potential for escalation (although not a domino effect) should an accidental hydrocarbon fire occur and to limit potential for offsite public and environmental impact.

Table 4-4, shows that the compressor A location meets the recommended distances to building and other hazardous process areas. All the existing Avon units do not meet the recommended distance to the security fence. A small section of the security fence would need to be moved further away to meet the recommended distance. There is not sufficient land within the existing National Grid land ownership boundary to meet the separation distance requirement. Land acquisition would be required to meet the separation distance requirement. Without land acquisition, the separation distance that can be achieved to the relocated security fence is 37m, which is slightly shorter than the required 39m. Given that these are existing units that currently do not meet the recommended separation distance to the security fence, this non-compliance is not expected to be an issue and no site fence modification is envisaged.

Note: Further review of the potential ammonia hazards will be necessary should this option be adopted.

Table 4-4: Retrofit Options Separation and Spacing Distances

Compressor Unit	Proposed Distance (m)				
	Distance to Buildings (Note 1)	Distance to Essential / Hazardous Equipment (Note 2)	Distance to Outermost Security Fence (Without Modification) (Note 3)	Distance to Outermost Security Fence (After Modification) (Note 4)	Distance to Outermost Security Fence (After Modification) (Note 5)
A	95	33	29	37	39

Notes:

1. The nearest building on site is the old control building and distances shown are to this building.
2. Above ground Scrubber Pipework.
3. Distance to fence for all 3 existing Avon's.
4. Fence modified without land acquisition.
5. Land acquisition required to meet 39m.

4.3.1 Retrofit Option - Interface Schematic and Register

Critical interfaces with existing site facilities for the compressor retrofit options include:

- Integration with station Control and Instrumentation systems, including control and safety panel installation in existing control building, and inter-connection with DCS, ESD, F&G at compressor LER and enclosure.
- 400 VAC power supply for the existing turbine unit A will be retained as it is for all retrofit options. Power requirement for Avon Unit A Re-life to tie into existing local circuits. Note, there may be reliability and obsolescence issues with using the older MV switchboard. It is recommended that during the next phase of engineering, if a retrofit option is adopted, the tie-in location should be confirmed following detailed assessment of cable and load schedule.
- Additional new feeders are required to support SCR package auxiliaries, heating, and compression. Power cabling to SCR package only to interface with spare equipped cubicles of the new 400 VAC Main LV Switchboard (installed in ERP3 scope and supplies compressors D & E).

The interface schematics for the retrofit only options are shown in Figure 4-11, Figure 4-12 and Figure 4-13. The associated interface register is presented in Table 4-5.

Figure 4-11: Option C: DLE Retrofit Interface Schematic

[redacted]

Figure 4-12: Option D: CSRP Retrofit Interface Schematic

[redacted]

Figure 4-13: Option E: SCR Retrofit Interface Schematic

[redacted]

Table 4-5: Retrofit Interface Register

Interface No.	Description	Notes
COMMON INTERFACE POINTS FOR RETROFIT OPTIONS		
IP-C1 / IP-D1	Control Signal Interface (Common Except SCR)	Control signals (UCP) from retrofit option interfacing with existing station control & safety systems (Hardwired Trips & DCS/UCP Comms & ESD/DCS) via a new central room station control panel. Control cables utilise existing cable trench. It should be noted that compressor's new control system will be installed as part of the asset health scope.
IP-C5 / IP-D2 / IP-E5	'Fuel Gas Heater Replacement	Existing fuel gas line to interface with replacement fuel gas heater unit. Note, modification to the station fuel gas heating system is not part of the MCPD Project, it will be delivered as part of the RIIO-T2 works (by 2025). Interface depiction for information only.
OPTION C – DLE RETROFIT OPTION		
IP-C2	DLE - Turbine Power Interface	DLE unit interface with existing power supply. Power supply for the existing turbine hall retained as is.
IP-C3	Turbine - DLE Interface	Retrofit of DLE unit to Avon compressor A.
IP-C4	DLE Fuel Gas Interface	Modification of existing fuel gas piping, downstream of new Fuel Gas Heater, to interface with new piping constructed to supply FG to the DLE package.

OPTION D – CSRP RETROFIT OPTION		
IP-D3	CSRP - Turbine Power Interface	CSRP unit interface with existing 400V power supply. Power supply for the existing turbine hall retained as is. Additional feeders to support the new CSRP package have been included.
OPTION E – SCR RETROFIT OPTION		
IP-E1	Control Signal Interface	Control signals (UCP) from SCR retrofit option interfacing with existing station control & safety systems (Hardwired Trips & DCS/UCP Comms & ESD/DCS) via a new central room station control panel. Fire & Gas detectors signal (F&G) from SCR package interface directly with existing station C&I systems. Control cables utilise existing cable trenching.
IP-E2	SCR - Turbine Power Interface	SCR unit interface with existing power supply. Power supply for the existing turbine hall retained as is. New SCR package requires several power feeders to support a variety of pumps, blowers, fans, and control panels.
IP-E3	Turbine - SCR Interface	Avon Unit A Area SCR Retrofit. Flue Gas from Avon Compressor Unit A Stack to new SCR Package.
IP-E4	Instrument Air Interface - IA Package	Interface with existing instrument air system at Instrument air pressure reduction skid. New piping constructed to supply IA to the SCR Unit via existing pipe rack.

4.3.1 Retrofit Option – Major Equipment: Mechanical, Electrical and Control and Instrumentations

Major equipment items for the retrofit options are detailed in the associated equipment list (Ref. 8).

As part of the SCR package, new civil foundations and surface drainage facilities will be provided as required. It is necessary to install ammonia storage and unloading facilities. This introduces a new toxic hazard to the site. The selected ammonia concentration for the SCR facilities is 24.5% (Ref. 6). Ammonia solution concentrations between 10%-35% carries limited risk to site personnel and very low potential for offsite impact. At these concentrations, it is still a corrosive hazard but is managed / handled with gloves and a mask. The process flow diagram for the SCR option is shown in Figure 4-14. Note, as the DLE and CSRP Options do not feature changes to process equipment (modifications limited to existing equipment within the compressor cab), Process Flow Diagrams have not been created for these options.

Figure 4-14: Retrofit Options PFD (SCR) [Ref. 19]

[redacted]

Detailed requirements for the Electrical and Control and Instrumentations scope are listed below for each Retrofit Option. Note, it is assumed that the existing or new station control and safety systems have the modification capacity capability. Limitations of obsolescence and technical support associated for expansion of these system are not considered.

For the retrofit options, the old control room will need to be maintained as it houses the equipment supporting the Avon unit. Therefore, additional costs will be incurred to maintain the building plus the systems housed inside.

4.3.1.1 Option C: DLE

Option C considers a DLE Engine Retrofit to the existing Avon Unit A package. Therefore, as this is a modification to an existing package, assuming like for like change out of components, there will not be any major new electrical equipment within this option. Power supply for the existing turbine hall from the original MV switchboard will be retained.

For the Control and Instrumentation scope, the following modifications / new equipment are required as shown below and in Figure 4-15:

- Station control and safety system modification
  - DCS;
  - ESD;
  - F&G.

- Offsite control system modification
  - Warwick remote control centre.
- New Unit Control panels
  - DLE Unit control panel/s;
  - Interfaces to station control and safety system;
  - Unit Control panel field cabling installation;

Figure 4-15: C&I Sketch - Option C DLE Retrofit

[redacted]

4.3.1.2 Option D: CSRP

Option D considers a CSRP upgrade to the existing Avon Unit A package. Therefore, as this is a modification to an existing package, there will not be any new major electrical equipment within this concept. Power supply for the existing compressor machinery train will be retained from the original MV switchboard as it is.

For the Control and Instrumentation scope, the following modifications / new equipment are required as shown below in Figure 4-16.

- Station control and safety system modifications:
  - DCS;
  - ESD;

- F&G.

- Offsite control system modification
  - Warwick remote control centre.
- New Unit Control panels
  - CSRP Unit control panel/s;
  - Interfaces to Station control and safety system;
  - Unit Control panel field cabling installation.

Figure 4-16: C&I Sketch - Option D CSRP Retrofit

[redacted]

4.3.1.3 Option E: SCR

Option E considers a major modification to the existing Avon Unit A package, addressing installation of a new SCR package. The power supply for the existing Avon Compressor A turbine hall has been assumed to be retained in line with the current philosophy. The new SCR package requires several power feeders to support a variety of pumps, blowers, fans and control panels. These have been allocated to existing spare equipped cubicles of the New LV Switchboard in the new control room, which will be modified to suit the connected load. The increase in total connected load is within the current carrying capacity of the new Switchboard and the infeed protection device.

Figure 4-17 illustrate the electrical tie-ins required for the SCR Retrofit Option.

Figure 4-17: Option E SCR Tie-ins Main LV SWBD

[redacted]

For the Control and Instrumentation scope, the following modifications / new equipment are required as shown below in Figure 4-18.

- Station control and safety system modification
  - DCS;
  - ESD;
  - F&G.
- Offsite control system modification
  - Warwick remote control centre.
- New Unit Control panels
  - SCR Unit control panel/s;
  - CEMS Unit Control panel/s
  - Interfaces to station control and safety system;
  - Unit Control panel field cabling installation;
  - Ammonia Storage/delivery system integration;
  - F&G detection - (e.g. confined space CO detection as necessary) / cabling installation.

[redacted]

Figure 4-18: C&I Sketch - Option E SCR Retrofit

[redacted]

Further details on the electrical scope including preliminary load summaries can be found within Reference 19.

5.0 STUDY EXECUTION METHODOLOGY

5.1 General

The study was executed in two phases:

- Phase 1: A preliminary assessment and screening of new build and retrofit options was undertaken in order to short list the options.
- Phase 2: For short-listed options from Phase 1, input data required for the CBA and BAT assessment was generated in order to assist National Grid to select a preferred MCPD compliant option for the Peterborough Compressor Station.

The study execution methodology is illustrated by Figure 1-3.

5.2 Phase 1 Option Screening

The short-listing of the MCPD compliance options was based on preliminary cost estimates (i.e., +/-50% accuracy), preliminary project execution schedules (i.e., Level 1) and a qualitative techno-economic assessment.

The methodology used for the preliminary screening was a qualitative traffic light based assessment, performed against the following key project execution / development criteria:

- Project Development Cost:
  i.e. what is the relative development cost of each option.
- Project Execution Schedule:
  i.e. is the target date for MCPD achievable.
- Impact on existing Operations:
  i.e. duration of total site shutdowns and/or unavailability of back-up compression facilities.
- Safety Assessment:
  i.e. does the location comply with plant separation criteria recommended by National Grid Specification for Site Location and Layout Studies and Reviews T/SP/G/37.
- Environmental Impact:
  i.e. are there any significant environmental impacts associated.
- Constructability:
  i.e. what is the relative construction complexity of each option with regards to the number of brownfield modifications required, access to the construction location etc.
- Technical Maturity / Risk:

  i.e. what is the relative technical maturity / risk associated with adopting the technology. It should be noted that the compressor driver options being considered for the new unit options are proven and technically mature, therefore technical maturity / risk is not a differentiator for them and hence not considered for the qualitative assessment. So this criteria has only been considered for the retrofit options.

The following traffic light grading / classification was used:

Traffic Light	Grading / Classification
	Meets the specified criteria and / or offers the best option for the criteria.
	Marginally fails to meet the specified criteria and / or is slightly worse against the criteria than the best option.
	Fails to meet the criteria and / or is significantly worse against the criteria than the best option.

As the new build compressor unit and retrofit options are not directly comparable, the qualitative assessment was performed separately. Refer to Section 7.0 for the results of the screening.

5.3 Phase 2 Option Development

In order to help inform the preferred MCPD compliant option, a detailed Cost Benefit Analysis (CBA) and BAT Assessments will be performed by National Grid for MCPD compliance options carried forward from Phase 1, using the following information:

- Development cost (i.e., +/-30% Cost Estimates). Refer to Section 9.0 for details;
- Development schedule (i.e., Level 2 Project Execution Schedules). Refer to Section 10.0 for details;
- Risk and opportunities associated with each option. Refer to Section 11.0 for details;
- Ability of the Options to comply with required Process Duty Specifications. Refer to Section 6.0 for details;
- Site Layout Review. Refer to Section 8.2 for details;
- Assessment of the embodied carbon emissions associated with the construction of the options. Refer to Section 8.3 for details;
- BAT Assessment. Refer to Section 8.4 for details;
- Environmental impact (i.e., impact on site biodiversity) of the options. Refer to Section 8.5 for details;

6.0 STATION DUTY SPECIFICATIONS

Key Reference Document

203513C-002-RT-0008-0001 Peterborough Compressor Station Process Description [Ref. 16]

6.1 General

This section presents a summary of the findings with regards to whether the gas turbine compressor (GTC) packages installed at the Peterborough Compressor Station can achieve the defined site Process Duty Specification (PDS) operating duties in current and / or potentially modified configurations post the MCPD project implementation. The PDS operating points are presented in Section 3.2, full assessment including basis and assumptions is presented by Reference 17.

Table 6-1 provides a summary of the CBA options and it also provides a cross-reference to the MCPD compliance options described in this report.

Table 6-1: Peterborough CBA Options

CBA Option No.	Description
1	Counterfactual (Do Nothing) + One 500 Hour EUD
2	One Derated (CSRP) Avon
3	One 1533 DLE retrofit
4	One SCR Retrofitted Avon (based on 1533)
5	One New GT (Brownfield) + Decommission Avon
6	Decommission Avon

6.2 Compressor Package Design Configuration

The following gas turbine driver and compressor packages were considered in the Compressor Performance Review. New build units will be specified and designed to achieve the required process duty specifications and therefore no performance assessment is necessary.

Titan 130 Options

Titan 130 (T130-20502S rating), as installed.

The T130 performance is based on the Solar Turbine's Web FASTE performance desk, considering; typically, 100mmWG inlet and 100mmWG exhaust losses, typical network gas composition for fuel gas and default NOx & CO emissions limits for both options.

Avon Options

The following Avon Unit options were reviewed as part of the performance calculations:

a) Avon (1533 rating & GEC EAS 133 Power Turbine (PT)), as installed;

b) Avon (1533 rating & GEC EAS 133 PT), fitted with Selective Catalytic Reduction (SCR) unit;

c) Avon (1533 rating & GEC EAS 133 PT), fitted with Control System Restricted Performance (CSRP);

d) Avon (1533 rating & GEC EAS 133 PT) fitted with [redacted] Power or Siemens Dry Low Emissions (DLE) combustion upgrade.

For the SCR unit option, the addition of the SCR to the exhaust system will increase the exhaust system pressure losses. The National Grid / [redacted] SCR Pre-FEED Study [Ref. 5], suggests the exhaust system loss increase can be mitigated to a negligible level (3 to 7mmWG increase only), by replacing the existing exhaust silencer with an optimised silencer. As a conservative approach, the total exhaust pressure loss is assumed to increase to 300mmWG, based on experience and discussion with the SCR vendor (CECO Environmental). The increased exhaust pressure loss is considered to reduce the maximum power output by 1.22%, based on performance of similar gas turbines.

The CSRP option performance is based on the installed unit site performance, with the maximum power output limited to ensure NOx emission remain <150 mg/Nm3. Including a margin for test inaccuracy, the NOx limit will be set at 144 mg/Nm3, equivalent to maximum power output factored by 0.934, based on National Grid's predicted Avon performance.

The power output for the Avon, with either the [redacted] or [redacted] DLE upgrade fitted, is assumed unchanged to installed unit site performance.

After completion of the ERP3 scope, existing on site there will be 3 different compressor packages, all included as part of performance calculations, detailed in Table 6-2.

Table 6-2: Existing Peterborough Compressor Package Details

Compressor Unit(s)	GT Driver	Compressor
A & B	Dresser Clark 36x36	Avon
C	Delaval PV30/30	Avon
D & E	Solar C65	T130

<u>Relocated Avonbridge Unit</u>

There is an Ex Avonbridge/ Bathgate Compressor Station SGT-400 available that could be relocated to Peterborough and used instead of retrofitting of the Avon Unit A.

However, it was determined that the Peterborough operating points are not a good match for the Avonbridge compressor unit. The Peterborough PDS duties require greater flow and less head, than the original Avonbridge duties the compressor was selected for. The differences are too significant that even a compressor re-wheel will not make its use viable. The Peterborough design duty point flows are approximately twice the Avonbridge unit design duties. Additionally, given the considerably higher actual volumetric flowrate duties require at Peterborough, it is considered that inlet and outlet compressor nozzles sizes etc. will also be too small for the required duties.

Hence, due to the Avonbridge compressor being unsuitable in its current configuration, its use was not considered further. Use of the existing Avonbridge gas turbine driver with a new compressor package has also not been considered due to concerns with performance guarantee issues with the use of a used gas turbine driver package.

6.3 Compressor Train Performance Summary

Table 6-3 provides a summary of the required compressor power demand vs available GT power for the different compressor package configurations of for each PDS duty. Results for operation of two compressor units are based on the operation of one Solar T130 (unit D / E) in parallel with the unit specified for the results point: parallel Solar T130, retained Avon Dresser Clark 36x36 package (unit A or B), or Avon Delaval PV30/30 package (unit C).

Results show that the retrofit options on the Avon Units A & B (with Dresser Clark 36x36 compressor) can provide greater resilience than Avon Unit C (with Delaval PV30/30 compressor) in the event one or more of the T130 driven units D & E being unavailable.

Considering current site operational preferences and previous site performance reports, it is recommended that Unit A train be used as the backup unit in preference to the Unit B train. *Note: This recommendation is based by the site performance reports from 1995, and hence if the train performances now differ from these reports, this preference should be reviewed.*

Table 6-3: Peterborough Performance Summary

PDS Duty	No. Units Oper.	T130	AVON 1533	AVON 1533 SCR	AVON 1533 CSRP	AVON 1533 DLE	AVON 1533	AVON 1533 SCR	AVON 1533 CSRP	AVON 1533 DLE
Compressor		C65	Dresser Clark 36x36				Delaval PV30/30			
C1	2	✓	✓	✗	✗	✓	✗	✗	✗	✗
C2	1	✓	✓	✓	✓	✓	✓	✗	✗	✓
C3	1	✓	✓	✓	✓	✓	✓	✓	✗	✓
C4	2	✓	✓	✓	✓	✓	✓	✓	✓	✓
C5	2	✓	✓	✓	✓	✓	✓	✓	✓	✓
C6	2	✓	✓	✓	✓	✓	✓	✓	✓	✓
C7	1	✓	✓	✓	✓	✓	✓	✓	✓	✓
C8	1	✓	✓	✓	✓	✓	✓	✓	✓	✓
C9	1	✓	✓	✗	✗	✓	✗	✗	✗	✗
S1	2	✓	✓	✓	✓	✓	✗	✗	✗	✗
S2	2	✓	✓	✓	✗	✓	✗	✗	✗	✗

[redacted]

C1 Alt	2	✓	✓	✓	✓	✓	✓	✓	✓	✓
S1 Alt	2	✓	✓	✓	✓	✓	✓	✓	✓	✓
S2 Alt	2	✓	✓	✓	✓	✓	✓	✓	✓	✓

Power Margin Key:	Achievable >6% power margin	Potentially Achievable <6% power margin	Not Achievable

The assessments show the 36x36 and Avon train configuration, as installed, or with DLE upgrade fitted, is able to achieve all PDS operating points. Although, the gas turbine power margin for C1, C9 and S2 duties, is <6%. This margin is considered insufficient to ensure the duties can be achieved, once the gas turbine overhaul/ manufacturing power output tolerances and unit degradation between overhauls are considered. In mitigation, as the C9 duty is for a single unit operation only, for which it may be preferable to operate the standby C65 and T130 train. The standby C65 and T130 train is anticipated to be statistically available, if required, as the C9 duty is only required for 25 to 75 hours per year. The C1 and S2 duties, are two unit operating duties, and can be mitigated by rebalancing compressor flows as alternative C1 Alt and S2 Alt duties reviewed (decreasing 36x36 flow and increasing C65 flow), to achieve acceptable power margin.

The reduced available power from the Avon with the SCR fitted, decreases the available power margin for all duties, reducing the train's operational flexibility, and would prevent the C1 and C9 duties being achieved, and S2 duty achieved with 6% power margin. In mitigation the C1 Alt and S2 Alt duties can still be achieved with acceptable margin, and the standby C65 and T130 train could be used to provide backup to C9 duty.

The limited Avon performance with CSRP upgrade, reduces the operational flexibility the 36x36 and Avon train can provide, by the greatest margin, being unable to provide ensured back-up to C1, C3, C9 and S2 duties. This reduced flexibility may still be acceptable, as duties C1 and S2 are two-unit operating duties, for which the alternative C1 Alt duty provides acceptable margin and S2 Alt duty a reduced 3.8% margin (for a duty only required 25 hours per year, as outlined in Table 2 1), and duties C3 & C9 are single unit operating duties only, for which operating the spare C65 and T130 train, is expected to be the preferred approach to provide resilience for these duties. The total requirement for C3 and C9 duties is 125 to 175 hours per year (as outlined in Table 2 1), hence it is anticipated the spare C65 and T130 train will typically be available, if required.

Based on the assessment, the following is concluded:

- All new build options will meet specified PDS points, while Avon retrofit options require some mitigation to meet specified performance;
- The Avon Units A & B (with Dresser Clark 36x36 compressor), can provide greater resilience, compared to Avon Unit C (with Delaval PV30/30 compressor);
- Based on current site operating preferences and site performance reports (dating from 1995) Unit A train is recommended as the back-up unit in preference to Unit B train;

- The 36x36 + Avon train configuration, as installed, with SCR fitted or with DLE upgrade fitted, is able to achieve all PDS operating points, with acceptable power margin, if mitigations for C1, C9 and S2 duties are considered;
  - For C1 and S2, proportionally increasing C65 + T130 train configuration flow duties;
  - For C9 duty, utilise spare C65 + T130 train for 25 to 75 hours per year when is required;
- The reduced Avon output, with CSRP upgrade fitted, compromises the operationally flexibility the 36x36 + Avon train configuration can offer, but this may be acceptable, if mitigations for C1, C3, C9 and S2 duties are considered;
  - Proportionally increasing C65 + T130 train configuration flow for C1 and S2 duties;
  - Utilising spare C65 + T130 train for 125 to 175 hours per year, when C3 and C9 duties are required.

7.0 OPTIONS SCREENING

Key Reference Documents

203513C-002-RT-0300	Peterborough Compressor Station Cost Estimates (Phase 1 +/-50%) [Ref. 4]
203513C-002-PLG-0300	Peterborough Compressor Station Level 1 Schedules (Phase 1) [Ref. 5]
203513C-002-RT-0250	Peterborough Compressor Station Layout Review Report (Phase 1) [Ref. 6]
203513C-002-RT-0503	Peterborough Compressor Station Options Review (Phase 1) [Ref. 7]

7.1 General

As detailed in Section 5.0, a phased approach was adopted for the screening of the MCPD compliance options. The options under consideration are indicated below.

New Build Compressor Unit Options (Refer to Section 4.2):

- Option A: GT driven unit located on available plinth F area;
- Option B: Electric VSD unit located on available plinth F area;

Retrofit Options (Refer to Section 4.3):

- Option C: Change out of Avon engine to a DLE unit;
- Option D: Use of CSRP;
- Option E: Installation of a SCR unit;

A preliminary assessment and screening of new build and retrofit options was undertaken in order to short list the options. The short-listing of the MCPD compliance options was based on preliminary cost estimates (i.e., +/-50% accuracy), preliminary project execution schedules (i.e., Level 1) and a qualitative techno-economic assessment, as detailed in the sections below.

The screening was individually performed for the new build options (Gas Turbine vs Electric Variable Speed Drive) and the retrofit options, in order to allow screening and shortlisting of the options for Phase 2. New Build versus retrofit options were not compared during Phase 1. It is considered that more detailed assessments, including economics and BAT etc., need to be undertaken for screening between these option types.

7.2 Cost Estimates

The Phase 1 Cost Estimate Report (Ref. 4) provides detailed cost breakdown between the options. Table 7-1 summarises the total P-50 CAPEX associated with new build and retrofit options, with a +50%/-50% accuracy. Refer to Section 3.13 for details of the Cost Estimation Methodology (CEM).

Table 7-1: Phase 1 Cost Estimates (+/-50%)

Option	P-50 CAPEX Cost Estimate (kGBP)
New Build Unit Options	
A	[redacted]
B	[redacted]
Retrofit Compressor Options	
C	[redacted]
D	[redacted]
E	[redacted]

The development cost for Option B is approx. 25% higher than Option A. This difference is predominately due to the new 132kV incomer that would be required for the electric driven VSD compressor. The new incomer cost is based on historical information and probably conservative as it was based on a 35 MW rated incomer versus the 15 MW required for this project. Hence, the cost differential between the two options may be smaller.

The development costs for the SCR option (Options E) is significantly greater relative to the other compressor retrofit options, however, all retrofit options require substantially less investment than new compressor options.

It should be noted that Phase 1 costs are superseded by the more detailed costs estimates produced as part of Phase 2. Refer to Section 9.0.

7.3 Execution Schedules

The Level 1 Schedules (Phase 1) Report (Ref. 5) provides the basis and an activity-based schedule for the options. Section 10.2 also provides a summary of the basis used. Table 7-2 provides a summary of the estimated project completion dates.

Table 7-2: New Build Unit & Retrofit Compressor Options Level 1 Schedules

Option	Project Completion Date
New Build Unit Options	
A	1Q2029
B	1Q2030
Compressor Retrofit Options	
C	4Q2027
D	4Q2027
E	4Q2027

The schedules indicate that the project completion by 2030 can be achieved and that there is also some schedule float, except for Option B.

For Option B, information available as the time of the Level 1 Schedules development showed that the installation of the new 11 kV incomer to site by the UKPN is on the critical path and pushes the project completion date out by one year compared to Option A. Thus, potentially not meeting the MCPD target date. This represents a significant schedule risk, and the UKPN construction activities may need to be started earlier, if possible, (e.g. at the same time as the onsite FEED activities) to minimise this risk.

More recent information received from UKPN indicates that new incomer can be installed within a 2 year period, which removes it from the critical path. However, it still represents a schedule risk as works are performed by a 3rd party.

For the retrofit options, the project completion date is the same. Therefore, project execution schedule is not a differentiator between them.

It should be noted that Phase 1 Execution Schedule are superseded by the more detailed schedules produced as part of Phase 2. Refer to Section 10.0.

7.4 New Build Unit Qualitative Assessment

The qualitative assessment of the new build unit options is presented by Table 7-3. Refer to Section 5.2 for details of the methodology and explanation of the traffic light-based assessment.

Table 7-3: New Compressor Unit Options Qualitative Assessment

Assessment Criteria	Option A (GT Driven)	Option B (Electric Motor VSD driven)
Project Development Cost		
Project Development Schedule		
Impact on Existing Operations		
Safety Assessment		
Environmental Impact		
Constructability		

The major differentiators between new build options are summarised below:

- Option B development cost is approx. 25% higher than Option A, predominately due to the required new 11kV incomer for the electric driven VSD compressor.
- The project execution schedule for Option B is significantly longer (one year) than Option A. The prelim. execution schedules show that Option B only just achieves completion by the MCPD target date of 2030, driven by the duration required for connection agreement with UKPN plus time required for a new supply from the 11 kV overhead lines to site. The duration assumed is 4 years and is based on historical information, which is conservative. Latest information from UKPN indicates the duration is 2 years. However, Option B still carries more risk due to the additional interface with a 3rd party.
- Both units are built in the same location on site and require the same tie-ins to the existing facilities and hence there is no difference between them in terms impact during construction. The VSD drive will offer better availability than a GT driven unit but as this new build unit will be used as a back-up to the other new units (D and E), this is not seen as a significant differentiator. However, use of an electric driven VSD unit will not offer operational benefits related to commonality with new units (D and E) currently being installed at Peterborough, e.g. holding of spares, operating procedures etc Therefore, the electric driven unit is considered to be marginally worse for this criteria.
- Both options can meet the plant separation criteria recommended by National Grid Specification for Site Location and Layout Studies.
- For both options, the units are constructed within the existing site boundary and site extensions are not required. The electric motor driven option does not introduce any additional incremental site environmental emissions under normal operation and is thus ranked the better. As the unit will primarily be used as a back-up unit to the existing new units, i.e. not used continuously, this advantage is not considered significant.
- Both options are achievable from a construction point of view and the tie-in scope for both options are similar. The electric driven option requires an additional 11kV switchgear and a new cable trench for 11kV supply to be routed through existing plant areas. Although, this can be managed, it is ranked slightly worse due the additional scope.

Based on the above assessment, the following is concluded / recommended:

- Option B (electric motor driven) does not offer significant advantages over Option A (GT Driven). It has significant development cost and execution schedule disadvantages.
- A GT driven unit also offers operational benefits related to commonality with new units (i.e. D and E) currently being installed at Peterborough, e.g. holding of spares, operating procedures etc.
- Compressor F will be used as a backup to the two newly installed GT driven units (Units D & E), therefore from an operability point of view Option B is not preferred as it does not complement the GT compressors. Installing new and different technology to a compressor array which will run as backup/in parallel will complicate operations.
- Option B does ranks better for environmental impact, this advantage alone does not make Option B more attractive than Option A.

Therefore, Option B (electric motor driven) was not carried forward to Phase 2 of the study. Hence, only Option A (GT Driven) was carried forward to Phase 2 in order to allow a detailed assessment against the retrofit options.

7.5 Retrofit of Compressor Unit A Qualitative Assessment

The qualitative assessment of the retrofit options is presented by Table 7-4. Refer to Section 5.2 for details of the methodology and explanation of the traffic light-based assessment.

Table 7-4 – Retrofit Options Qualitative Assessment

Assessment Criteria	Option C (DLE Engine Retrofit)	Option D (CSRP Retrofit)	Option E (SCR Retrofit)
Project Development Cost			
Project Development Schedule			
Impact on Existing Operations			
Safety Assessment			
Environmental Impact			
Constructability			
Technical Maturity / Risk			

The major differentiators between the retrofit options is summarised as follows:

- The development costs for the SCR option is significantly greater than the other option (approx. 100%). The DLE and CSRP costs are similar with CSRP currently estimated to be slightly more. *Note: the CSRP costs have been updated as part of the Phase 2 activities, and this option is now lower cost than the DLE option.*
- All options are able to achieve the MCPD target date of 2030.

- For the SCR option, new chemical facilities will be required on site and hence new operating procedures will need to be developed. Additionally, the SCR stack / catalyst section will block an existing site road and therefore impact site access. However, other adjacent site roads are still available. Hence, the SCR option is ranked slightly worse than the other two options for impact on existing operations.
- All options are similar with regards to meeting the plant separation criteria. However, the SCR option introduces a new toxic hazard to the site (i.e. ammonia). The proposed ammonia solution concentration of 25.5% carries limited risk to site personnel and very low potential for offsite impact. At these concentrations, it is still a corrosive hazard but is managed / handled with gloves and a mask. Thus, the SCR option is ranked as being slightly and not significantly worse than the other options with regards to safety.
- No options require additional plot space outside of the existing security fence line. However, the SCR option requires use of plot space not currently used for process plant and the ammonia storage plus tanker offloading facilities present additional potential spillage and on-site land contamination. All options are able to achieve the required MCPD emissions targets. However, the SCR technology offers the potential for greater emissions reduction, i.e. is able to achieve lower values than required targets. Hence, this advantage balances the above onsite disadvantage and the SCR option is ranked the same as the other options for environmental impact.
- All options are achievable from a construction point of view and the tie-in scope for all options is similar. However, the SCR option requires additional civils works to be undertaken, plus additional equipment to be installed. New ammonia tanker offloading facilities plus storage facilities are required. Thus greater construction / operations SIMOPs coordination will be required. Hence, it is ranked as being slightly worse than the other options with respect to constructability.
- The SCR and CSRP are both technically mature and therefore carry little technical risk. Although not currently used at National Grid facilities, they are industry proven. Hence, they are ranked the best. The DLE option is still to undergo field trials to confirm feasibility and also it is not currently used by National Grid. The technology is not a step change as it is based on proven engines used in new machines. Hence, no significant technical risk is anticipated. Thus, the DLE option is ranked slightly worse than the other two options for technical maturity / risks.

Based on the above assessment, the following is concluded / recommended:

- Option C (DLE) and Option D (CSRP) are assessed to be very similar for all assessment criteria. Therefore, both options were carried forward to Phase 2 of the study in order to allow a detailed assessment against preferred new build unit option (i.e. GT Driven).
- Although, the Option E (SCR) does not offer any significant advantages over the other options and is ranked lowest for all assessment criteria except one, it is still recommended it should be carried forward to Phase 2 of the study. It is only marginally worse for most criteria than the other options and does offer one significant advantage, i.e. the potential for greater emissions reduction as it is able to achieve lower values than required MCPD targets. During Phase 2 of the study, the detailed cost benefit analysis can be used to do a more detailed screening of the option.

8.0 HSE ASSESSMENT OF OPTIONS

Key Reference Documents

203513C-002-RT-6200-0002	Peterborough Carbon Interface Tool Summary Report Phase 2 [Ref. 12].
03513C-002-CN-6200-0001	Peterborough Compressor Station BAT Input Sheet (Phase 2) [Ref. 13].
203513C-002-RT-6200-0001	Peterborough Compressor Station Biodiversity Net Gain Assessment [Ref. 14].
203513C-002-RT-0250	Peterborough Compressor Station Layout Review Report (Phase 1) [Ref. 6]

8.1 General

This section details the key outputs from site layout reviews and environmental assessments undertaken to support the options screening plus the cost benefit analysis. For options carried forward to Phase 2, the environmental assessments that were undertaken include Carbon Interface Tool, BAT Input Proforma and Biodiversity Net Gain.

With regards to health and safety, it was confirmed that no formal assessments (e.g., HAZID) were required at this conceptual phase of the project, however, a layout review was performed to check compliance with the guidelines provided in the National Grid Specification for Site Location and Layout Studies and Reviews T/SP/G/37 (Ref. 9). Additionally, safety issues that may present a significant business risk were identified as part of the Risk Workshop, refer to Section 11.0 for further details. No significant safety issues were identified as part of the Risk Workshop.

8.2 Site Layout Review

T/SP/G/37 (Ref. 9) provides target separation distances for natural gas facilities and is applicable to new installations or modifications to existing installations with an inlet pressure above 7 bar.

For the Peterborough MCPD project, as the new facilities will be installed at an existing site, a site location review has not been performed. All options use available space within the current site security fence for locating new equipment, except for the two compression units options. Additionally, all location options considered avoid the requirement for additional land acquisition. Therefore, there is no fundamental change to the operations and functionality of the Peterborough site, which would require a site location review.

Refer to Section 4.0 for the site layouts associated with each option.

The site layout was performed to:

- Justify that the layout selected is the one that gives the best protection to manned areas on site and to the general public:
- Minimise the likelihood of escalation on site between hazardous inventories:

- Ensure where-ever possible that the principles of inherent safety are utilised in the layout and set-up of new plant and equipment, in order to eliminate hazards, as opposed to controlling them.

The site layout review (Ref: 15, 18) concluded the following:

- Separation and Spacing:

New build options are able to meet the recommended distances to buildings, hazardous process areas and the security fence.

For the retrofit options, the existing Avon Units do not meet the recommended distance to the security fence. Thus, this is not considered to be an issue and therefore no site fence modification is envisioned. The location of the ammonia storage facilities is not expected to be a concern as T/SP/G/37 (Ref. 9) target separation distances are applicable to hydrocarbon containing facilities and not chemical equipment.

- Positioning of Hazardous Plant:

All new hazardous plant is separated from non-hazardous and other existing hazardous facilities and therefore minimising any incremental safety risk. No additional vessels containing hazardous fluids are being introduced, thus any potential domino effects are also minimised.

For the SCR option, it is necessary to install ammonia storage and ammonia unloading facilities. This introduces a new toxic hazard to the site. T/SP/G/37 (Ref. 9) target separation distances are not applicable to chemical equipment, thus there are no target separation distance requirements specific to ammonia containing equipment. The selected ammonia concentration for the SCR facilities is 24.5%. Ammonia solution with concentrations between 10% – 35% carries limited risk to site personnel and very low potential for offsite impact. At these concentrations, it is still a corrosive hazard but is managed / handled with gloves and a mask.

The SCR related ammonia facilities have been installed as far away as possible from other process facilities and also as far away from the security fence as possible to minimise the potential for escalation (although not a domino effect) should an accidental hydrocarbon fire occur and to limit potential for offsite impact. Further review of the potential ammonia hazards will be necessary should this option be adopted.

Additionally, for all options, the new hazardous plant is located within the existing site boundaries and within the existing National Grid land ownership boundary. This also ensures that any impact on public, i.e. local towns, roadways, pathways, third parties etc. should be negligible. Hence, there should be no significant impact on existing site planning and operating permits.

- Maintenance and Access:

Existing site road networks are used where possible plus extended, if required. All new road extensions are within the existing site boundary. The main access route to site remains unchanged. Therefore, all options have good access for construction, maintenance and incident response etc.

- Emergency Access and Escape:

The access to site for emergency (e.g. firefighting) and other services will remain unchanged from the current arrangement, i.e. via the main gate located at the South East corner of the site.

As noted above, existing site roads will be extended, where necessary, for vehicular access to the new facilities locations.

The routes for escape from site will also remain unchanged from the current operations, i.e. either via the main gate or emergency gates located in the security fence. Therefore, there is no change to the current evacuation philosophy.

No major safety concerns were identified for any of the options; therefore health and safety is not considered to be a major driver for the MCPD project option selection.

8.3 Carbon Interface Tool Assessment

An assessment of the embodied carbon emissions associated with the construction of the design for each of the options being considered was undertaken using National Grid's Carbon Interface Tool (CIT), 2020 version. Use of the CIT supported the calculation of embodied carbon emissions in alignment with the PAS2080 - Carbon Management in Infrastructure standard. The CIT considers A1-A5 embodied carbon emissions. i.e. raw material supply (A1), transport within supply chain to final factory gate (A2) and manufacturing (A3) plus site construction (A5) and transport to the construction site (A4).

Figure 8-1 and Figure 8-2 (Ref. 12) provide a high-level comparison of the embodied carbon associated with each of the new build and retrofit options being considered:

Figure 8-1: PAS 2080 A1-A3 Carbon Comparison of Options

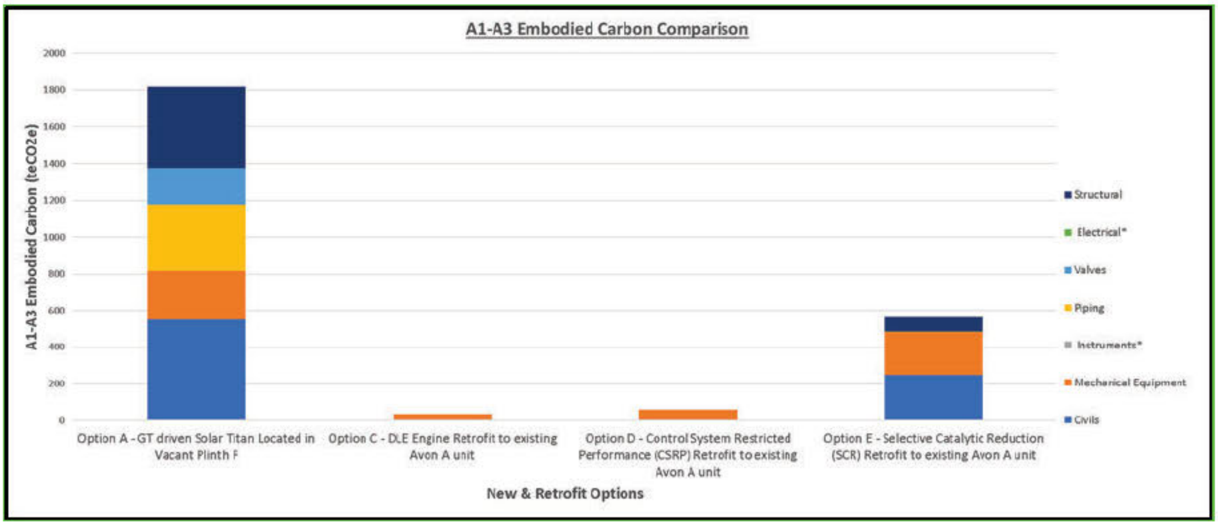
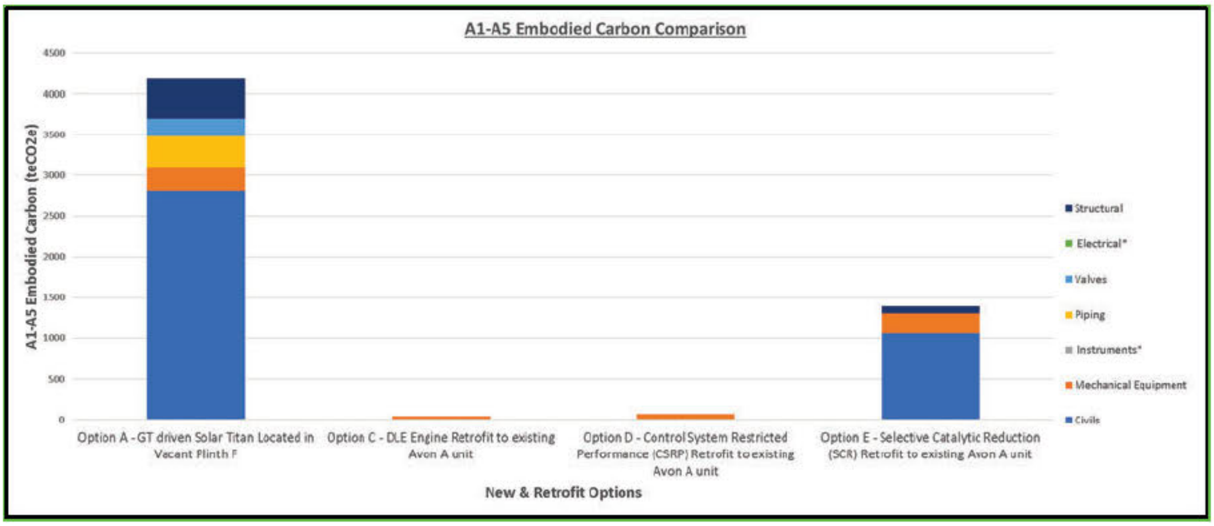


Figure 8-2: PAS 2080 A1-A5 Carbon Comparison of Options



From the results above, it can be concluded that:

- Considering A1-A3 emissions for options A & E (options with the two largest associated embodied carbon), civils, piping and structural steel items contribute the most to the carbon emissions associated with option A, whereas for option E, the main contributors are civils, structural steel and mechanical equipment.
- Considering A1-A3 emissions for retrofit options C & D, the bulk of associated embodied carbon is associated with mechanical equipment.
- All retrofit options (C, D & E) offer significantly lower A1-A5 emissions compared to the new-build option (A).
- Retrofit options C & D have the lowest A1-A5 carbon emissions, whilst retrofit option E (SCR) has notably higher A1-A5 carbon emissions associated mainly with civil and mechanical equipment emissions.

8.4 BAT Input Proforma

To support with the compressor machinery train BAT assessment being completed by National Grid, the BAT Assessment Data Collection Proforma (Ref 13) was completed for the different options being considered.

- Net thermal input (MW) power usage at site conditions
- Direct mass emissions (g/s) of CO_2, CO and NOx.

The design cases assessed (five in total) included two existing Solar T130s (lead units) with either one back-up existing Avon (counterfactual, < 500 hours) or retrofitted Avon unit (retrofitted DLE/SCR/CSRP options), and another arrangement in which two existing Solar T130s (lead units) are supported by one new Solar T130 in the event one of the lead units is unavailable.

Table 8-1 summarises the relevant MCPD NOx emission limits, the existing permitted emission limits for NOx and CO (where applicable), and the emission concentrations used to calculate the mass emissions rates input into the BAT Proforma. Refer to Reference 13 for full details of the source data and assumptions applied in calculating the required input data. Refer to Section 6.0 of the different design cases assessed when the lead units are available/unavailable.

Table 8-1: Emission Concentrations – MCPD, Permitted, Assessed

Unit [1]	Applicable MCPD NOx Limit (mg/Nm^3) [2]	Current Permit NOx Limit (mg/Nm^3) [3][4]	NOx Conc. of Proforma Input Data (mg/Nm^3)	Current Permit CO Limit (mg/Nm^3) [3][4]	CO Conc. of Proforma Input Data (mg/Nm^3)
Existing Avon	150	170	154 [10]	600	595 [10]
CSRP Avon	150	170	144 [10]	600	595 [10]
DLE Avon	150	170	51.3 [6]	600	387 [6]
SCR Avon	150	170	[8]	600	[9]
Existing T130s	50 [5]	50	30 [7]	40	30 [7]
New T130	50	n/a	30 [7]	n/a	30 [7]

[1] Concentrations stated at MCPD reference conditions: 273.15 K, 101.3 mbar, 15% O_2, dry gas.

[2] Emission limits as per the MCPD (Ref. 21), applicable unless < 500 hours operation proposed.

[3] Emission limits as per current ERP permit for Unit A Avon and Solar T130s (Ref. 22).

[4] For Avon retrofit options, emission limit values stated are for the existing permitted Unit A Avon, prior to any retrofit works having been implemented.

[5] The existing Solar T130s are considered new MCPs as first put into operation after 20 December 2018.

[6] Converted from ppm (Ref. 23) to mg/Nm^3 at MCPD reference conditions. Assumed dry gas. CO concentration based on the worst case CO concentration (at low %NTI) assessed.

[7] Confirmed in BAT Proforma Meeting Minutes (Ref. 24)

[8] SCR emissions were calculated on a mass emissions basis (90% NOx reduction compared to Existing Avon mass emission rates). On this basis, it is reasonable to assume the NOx concentrations achieved will be compliant with the MCPD limit.

[9] SCR CO emissions calculated on mass basis using Existing Avon emission curves and inputting [redacted] calculated NTIs. Based on SCR unit requiring slightly higher NTI across PDS points compared to Existing Avon, and decreasing CO concentration with increasing NTI, it is anticipated that CO concentration will not breach permitted limit of 600 mg/Nm3. However, it is advised that this is confirmed with the SCR vendor.

[10] Highest concentration determined across all PDS points for given unit.

To illustrate some differences in the emissions calculated for the different options and PDS points assessed, a comparison of the aggregated CO_2, CO and NOx mass emission rates calculated for the units operational in the three PDS points selected (C4, S2-Alt, S2 in order of increasing aggregate NTI is presented in Figure 8-3 to Figure 8-5.

The data presented below is for the scenario in which the lead unit is unavailable, on the basis that when the lead units are available (single or two Solar T130s), the emissions from each option are the same, and differences are only presented once one of the lead units are unavailable and the back-up unit (e.g. retrofit Avon) is required to operate to help meet the PDS duty point.

Please note, the S2-Alt case only applies to the Avon retrofit and counterfactual options, hence, no data is presented below for Option 4 for S2-Alt.

Figure 8-3: Comparison of Aggregated CO_2 Emissions – Lead Unit Unavailable

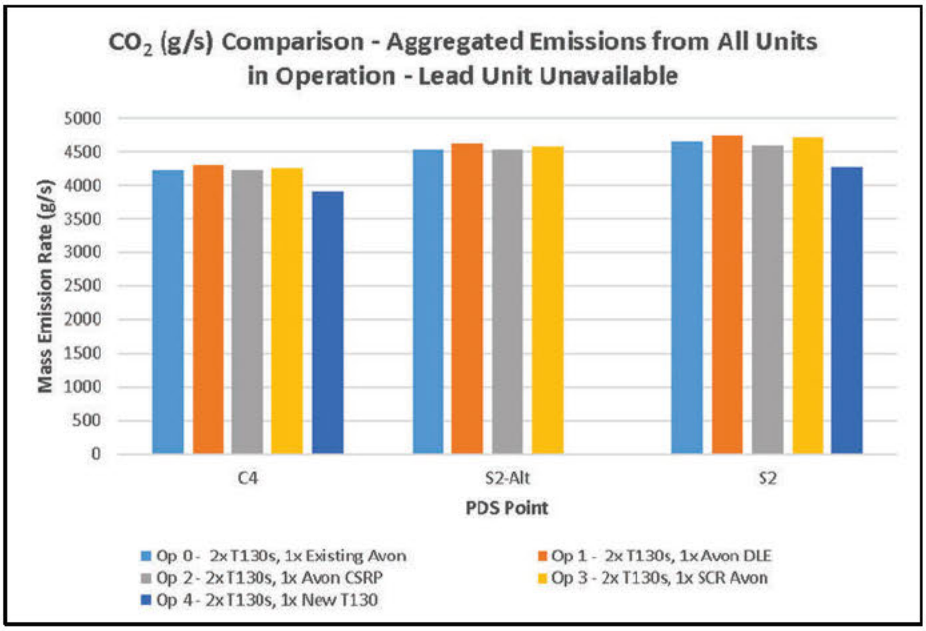
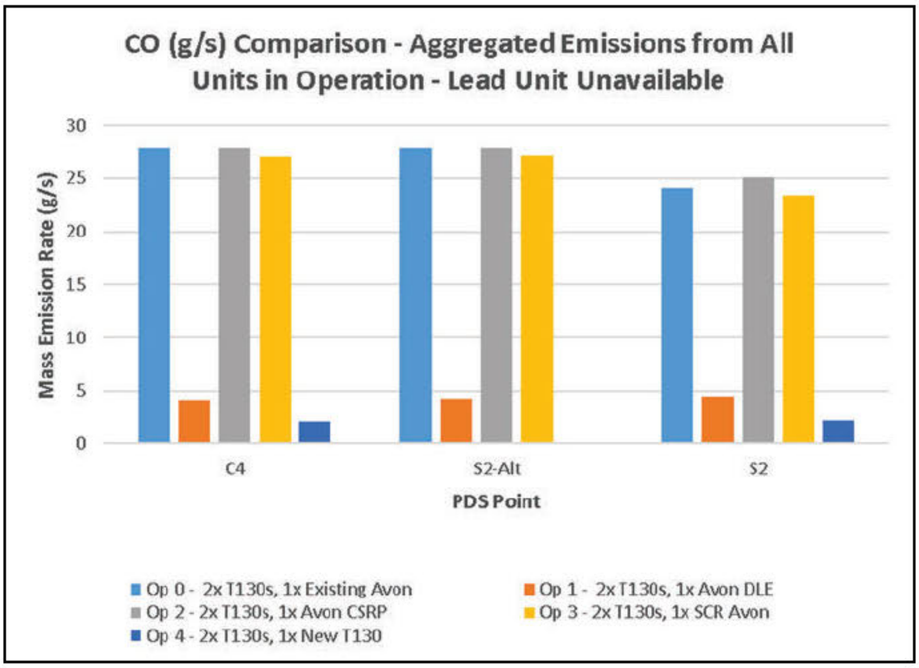
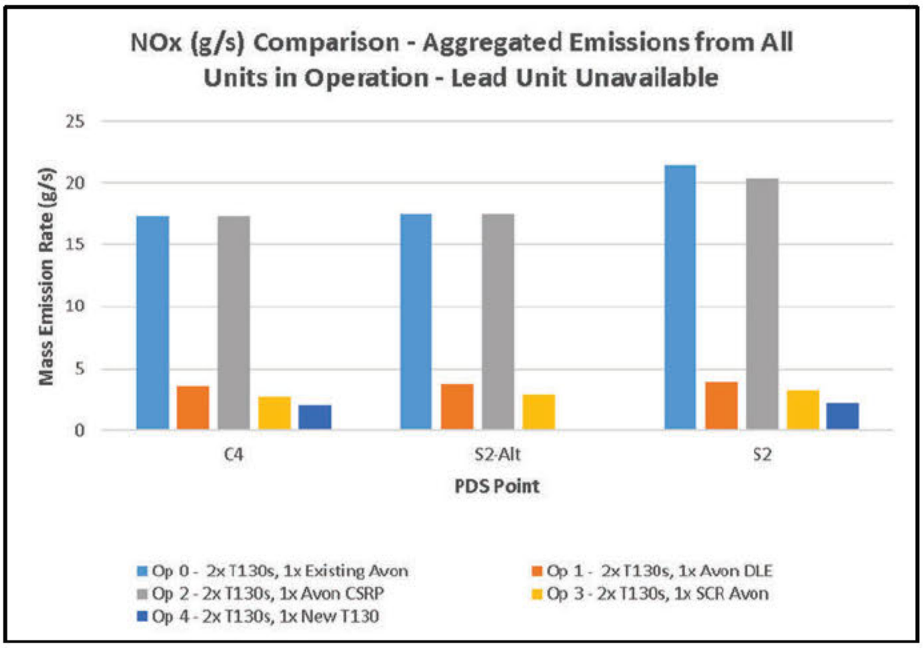


Figure 8-4: Comparison of Aggregated CO Emissions – Lead Unit Unavailable



[redacted]

Figure 8-5: Comparison of Aggregated NOx Emissions – Lead Unit Unavailable



It is evident from the data presented above that there are differences in the CO_2, CO and NOx emission rates calculated for each PDS point across the operational scenarios assessed. However, the patterns identified above are not consistent across each option and pollutant, and rather than reviewing the mass emission rates in isolation, the data should be considered alongside the operational hours of each individual unit across all PDS points.

Consideration of impact of operational hours on total mass emissions released was excluded from this scope. It is assumed that the data presented in the BAT Proforma will be considered in the wider context of what is considered BAT for the installation when used by National Grid to inform the BAT assessment being undertaken.

As summarised in Table 8-1, each of the units (counterfactual, existing retrofitted and new) assessed are compliant with the relevant MCPD emission limit for NOx based on the base data used to assess their emissions.

[redacted]

8.5 Biodiversity Net Gain Assessment

In line with the Town and Country Planning Act (TCPA) 1990 as amended by the Environment Act 2021, any National Grid construction project with a temporary or permanent impact on the natural environment must achieve a minimum of 10% Biodiversity Net Gain (BNG).

A BNG assessment was completed (Ref. 14) using the National Grid Net Gain Assessment Matrix to score the impact of each option based on the type of development and availability of National Grid land. Please refer to the BNG assessment report (Ref. 14) for full details of the assessment completed. A summary of the assessment results for all single unit options (new build and retrofit) is shown in Table 8-2.

Table 8-2: Options BNG Assessment

Option	Impact Score	Delivery Score	BNG Score	Summary
A	Low (1)	Some National Grid land available / small offsite requirement (2)	2	Impact scored as Low (1) as new compressor will impact on grassland at a single National Grid site, and temporary impact on adjacent farmland is expected to be minimal given this land has already previously been used for construction activities during the ERP3 project. Works are not within/ will not directly impact any formally designated sites. No sensitive ecological receptors/habitats were identified in the consultation boundary around site (up to 700 m away). Delivery scored as "Some National Grid land available / small offsite requirement (2)" as there is limited opportunity within the National Grid site or adjacent land owned by National Grid for providing an overall BNG, thus off-site BNG is likely to be required.
C	0	0	0	As Option C involves retrofitting existing systems and either has no additional footprint or footprint on existing hard standing, this option has no impact on biodiversity. According to Biodiversity Metric 3.1, areas of hard standing or otherwise sealed surfaces have little or no biodiversity value and can be scored zero. No BNG required.
D	0	0	0	As Option D involves retrofitting existing systems and either has no additional footprint or footprint on existing hard standing, this option has no impact on biodiversity. According to Biodiversity Metric 3.1, areas of hard standing or otherwise sealed surfaces have little or no biodiversity value and can be scored zero. No BNG required.
E	Low (1)	Some National Grid land available / small offsite requirement (2)	2	Although total footprint of land required for Option E is less than for Option A, the difference is not significant enough to score them differently according to the National Grid matrix. Impact scored as Low (1) as creation of new hardstanding for ammonia truck unloading will impact on grassland at a single National Grid site, and temporary impact on adjacent farmland is expected to be minimal given this land has already previously been used for construction activities during the ERP3 project. Works are not within/ will not directly impact any formally designated sites. No sensitive ecological receptors/habitats were identified in the consultation boundary around site (up to 700 m away). Delivery scored as "Some National Grid land available / small offsite requirement (2)" as there is limited opportunity within the National Grid site or adjacent land owned by National Grid for providing an overall BNG, thus off-site BNG is likely to be required.

Option A (new build unit) and Option E (retrofitting SCR to existing Unit A Avon, with additional land requirements) have a BNG score of 2 and a low impact on biodiversity. Options C and D (retrofitting existing units) have a BNG score of 0 and no impact on biodiversity.

Amongst the two options with a low impact on biodiversity, Option A has the greatest footprint and would require the largest area of permanent land clearance (300 m^2 total compared to 150 m^2 total for Option E). Despite this, the difference is not significant enough to score them differently according to the National Grid matrix and thus they have the same overall BNG score.

[redacted]

As Options C and D have no impact associated with land use, they are the most favourable options from a biodiversity perspective.

It can be concluded that there is no significant difference between the options with a low impact on biodiversity. Both options require an area of permanent land use within the National Grid site, as well as temporary land use out with the National Grid site that has been used for construction activities in the past. In addition, the difference between the total permanent footprint required for each option is relatively small.

There is limited opportunity within the National Grid site for providing an overall BNG, and therefore off-site replacement of lost habitats will likely be required for all options with a low BNG score.

The additional cost for the replacement of lost habitats cannot be estimated at this stage. The habitat assessment for the Peterborough site is required to be updated to understand the environmental value of the affected land before exploring options for achieving BNG. It may not be necessary to acquire new land to achieve this, for example, National Grid projects have contributed to local schemes in the past. Given the area and type of habitat impacted by each option, and with Local Planning Authority strategies / mechanisms in place, it is likely that all of the options could reasonably achieve 10% BNG in line with the TCPA.

When the final development options have been determined, BNG requirements will be further refined and updated including establishing baseline conditions, better quantification of the impacts, as well as development and implementation of enhancement and mitigation plans.

If a retrofit option is selected, then detailed safety studies (i.e. QRA) are required to confirm that a site fence extension is not necessary. If a site fence extension is required, the BNG impact will be higher than stated in this report as there is a water course that may be impacted by the fence relocation.

9.0 PHASE 2 OPTIONS COST ESTIMATES

203513C-002-RT-0301	Peterborough Compressor Station Cost Estimates (Phase 2 +/-30%) [Ref. 10]

9.1 General

For the Peterborough Compressor Station, Class 4 +/-30% P-50 CAPEX estimates were developed for the options carried into Phase 2, i.e. new build GT driven compressor and Avon Unit A retrofits. The basis and methodology for the estimates are detailed in Section 3.13.2.

The electric driven VSD compressor option (Option B) was screened from Phase 2 consideration as outlined in Section 7.0.

Below is a cost summary of the options under consideration by National Grid in their CBA for the Huntingdon Compressor Station. These options have been included in the cost estimate summary based on retrofit costs developed for equivalent Peterborough options and site specific inputs from National Grid regarding Asset Health requirements.

Note, the Phase 1 +/- 50% Cost Estimates are superseded by Phase 2 +/- 30% Cost Estimates presented in this Section.

9.2 Peterborough +/-30% Cost Estimates

A summary of the +/-30% Cost Estimates for each option is provided in Table 9-1 (Ref. 10). Although Option A benefits from the pre-investment in the Plinth F area as part of the ERP3 project, however, it has significantly higher associated costs compared with the retrofit options, featuring more equipment for design, purchase and installation. Of the retrofits, the SCR unit is the outlier featuring the higher quantity and complexity of new equipment and associated construction and civil scope. In order to provide an indication of the project size and scale for each option, Table 9-1 also provides a summary of material tonnages associated with each option.

Table 9-1: Peterborough Summary +/-30% Cost Estimates

DESCRIPTION	OPTION A: NEW BUILD GT UNIT	OPTION C: DLE RETROFIT	OPTION D: CSRP RETROFIT	OPTION E: SCR RETROFIT	COUNTERFACTUAL (DO NOTHING)	DECOMMISSION AVON
Total Installed Cost P-50 Estimate (kGBP)						
+/-30% Cost Estimates	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Material Tonnage Estimates (Tonnes)						
Equipment	201.3	Note 5	Note 5	9.2	N/A	Note 5
Piping	175.8	Note 5	Note 5	1.4	N/A	Note 5
Valves	96.0	Note 5	Note 5	0.0	N/A	Note 5
Electrical	Note 4	Note 4	Note 4	Note 4	N/A	Note 5
Instruments	Note 4	Note 4	Note 4	Note 4	N/A	Note 5
Civil Works	Note 4	-	-	25.3	N/A	Note 5
Structural Steel	216.3	-	-	38.0	N/A	Note 5

Notes:

1. Cost are total installed cost including procurement, off-site fabrication. onsite construction / installation, commissioning, contract in-directs. Logistics, National Grid costs etc. Refer to Reference 10 for full details of the scope of each option plus breakdown of costs.
2. Costs include, as appropriate, relief / asset health costs for options that require continued use of the Avon A unit. Asset health re-life scope and associated costs are based on recent National Grid 2022/23 estimates [Ref. 25].
3. Costs include, as appropriate, demolition costs for Avon A unit for options that do not require continued use of the unit. Demolition costs for Avon B and C units are not included as cost for this are allocated as part of the ERP3 project.
4. Tonnage for Civil Works, Instruments, and Electrical components quantified in estimate using non-Mass measurements e.g. No. of units or m3, therefore, tonnage not shown.
5. Tonnage in relation to Avon Compressor Re-life or Destruction scope not included in this estimate.
6. The SCR Option equipment weights exclude the SCR facilities equipment weights as only cost information was provided by technology supplier.

9.3 Huntingdon +/-30% Cost Estimates

A summary of the +/-30% Cost Estimates for each option is provided in Table 9-2 (Ref. 10).For the Huntingdon DLE and CRSP Retrofit options, the same costs for the equivalent Peterborough Retrofit options is assumed as all works are undertaken within the compressor cab and no site surveys of Huntingdon were undertaken during the study.

Table 9-2: Huntingdon Summary +/-30% Cost Estimates

DESCRIPTION	Decommission Avon	DLE Retrofit	Counterfactual (Do Nothing)	CSRP Retrofit
Total Installed Cost P-50 Estimate (kGBP)				
+/-30% Cost Estimates	[redacted]	[redacted]	[redacted]	[redacted]

Notes:

1. Cost are total installed cost including procurement, off-site fabrication. onsite construction / installation, commissioning, contract in-directs. Logistics, National Grid costs etc. Refer to Reference 10 for full details of the scope of each option plus breakdown of costs.
2. Costs include, as appropriate, relief / asset health costs for options that require continued use of the Avon C unit. Asset health re-life scope and associated costs are based on recent National Grid 2022/23 estimates [Ref. 25].

10.0 PHASE 2 OPTIONS EXECUTION SCHEDULES

Key Reference Documents

203513C-002-PLG-0301 — Peterborough Compressor Station Level 1 Schedules (Phase 2) [Ref. 11]

10.1 General

Level 2 schedules for the Phase 2 options were developed to highlight any differences in overall project execution duration for the alternative options for use in the cost benefit analysis.

10.2 Basis for Schedules

The basis and the main assumptions used to develop the Level 2 schedules were as follows:

- The Peterborough Ofgem Re-Opener period is 31/01/23 to 31/07/23. At the conclusion of this Re-Opener period, an option will be selected for the Peterborough MCPD project.
- A second Ofgem Re-Opener period of 2 months is required to agree funding allowances, This period will be after Execute (i.e. EPC) tenders have been received.
- The project will be executed in the following project phases:
  - Pre-FEED;
  - FEED;
  - Detailed Design;
  - Construction;
- The Pre-FEED can start before option approval / selection, i.e. before Ofgem Re-Opener period closure, if it is required in order to achieve project completion before the MCPD target date of 2030.
- The following National Grid internal approvals / governance periods are required:
  - 2 months between pre-FEED and FEED (F3 Sanction). This can occur in parallel to the FEED ITT period.
  - 2 month governance cycle (F4 sanction) immediately before the second Ofgem re-opener to confirm remaining funding allowances. This sanction process commences post receipt of Execute bids.
  - 2 months governance cycle at the end of construction/commissioning (T6 Sanction).
- The tendering periods required plus durations of these project phases for the new build options will be longer than the retrofit options given the significantly greater scope.
- Pre-FEED ITT award activities are kicked off immediately following option selection being finalised, i.e. conclusion of Re-opener period.
- Activities that involve total shutdown of the compressor station can only occur during the period April – September. For the retrofit options, it is currently assumed that Unit A is also only taken offline for upgrade / refurbishment in this period too, to ensure that

it is available during winter months etc. It may not be necessary to limit the Unit A outage window, as Units B and C are still available to provide reliance during the winter periods.

- For both new build and retrofit options, the Avon units that are not MCPD compliant will need to be demolished. It is assumed that this demolition occurs after the MCPD project upgrades. Thus, the demolition activities are not on the MCPD project critical path and demolition can occur any time after start-up of the MCPD project facilities.
- On site construction activities not requiring a total shutdown of the compressor station can occur all year round, i.e. constructions and operations SIMOPS is allowed.
- The delivery time for the GT driven compressor package is 16 months (ex. Works) and this includes string test. The delivery time for the equipment required for the retrofit options will be significantly shorter. A duration of 6 months is assumed based on information provided by Reference 5 and previous project experience.
- Purchasing of equipment etc. will occur post FEED, i.e. no early investment. However, in order to reduce the overall procurement cycle for the new compression unit, it is assumed that the procurement specs / documents and compressor unit ITT technical bid evaluations will be performed during FEED. A period for vendor engagement will occur during FEED. Therefore, the purchase order can be placed soon after the Execute activities commence.
- For the retrofit options, the project execution activities for the MCPD facilities and 're-life' facilities can be done in parallel and managed by a single design and installation contractor.
- Adequate manpower is available to support the construction activities, i.e. there are no manpower restrictions. A 7-day working week / 12 hours a day is assumed for the preliminary schedules. This provides opportunity to increase site working hours if delays are experienced.
- Required permits and planning permissions are not on the critical path. It is assumed these activities will be performed in parallel to the engineering activities and will be managed such that they will not be on the critical path and thus will not impact the overall schedule. The environmental assessment and planning consents / approvals for the retrofit options are assumed to be of a shorter duration than the new build options.
- For the new build and SCR retrofit option, space outside the site fence is required for the temporary construction camp. It is assumed that the space used will be the same as currently used for the ERP3 Project construction camp. The schedule currently includes a period for construction camp land lease agreements. However, there is a potential opportunity to re-use the existing land purchased for the ERP3 project construction camp, if it is not sold, which would mean a lease agreement for land is not required by the MCPD project. It is assumed that the negotiations, if required, will commence at the start of FEED, such that the land will be available for the start of the construction activities.
- National Grid's T2 Cyber delivery strategy does not permit compressor engine overhauls and cab refurbishments to be conducted at the same time as control system replacements due to overlap of working areas.

10.3 Level 2 Schedules

Table 10-1 provides a summary of the estimated project completion dates. The schedules indicate that the project completion by 2030 can be achieved and that there is also some schedule float. The retrofit options have more float and thus less schedule risk.

Table 10-1: Overall Execution Durations

Option	Project Completion Date	Comments
New Compressor Unit Options		
A (New Build GT)	1Q2029	Note 1
Compressor Retrofit Options		
C (DLE)	4Q2027	Note 2
D (CSRP)	4Q2027	Note 3
E (SCR)	4Q2027	Note 4

Notes

1. Only a single total site shutdown is considered to be required for hook-up of the new compressor into the general site facilities, as significant pre-investment is already included in ancillaries, electrical, control and support systems including cable ducting for the new unit.
2. Two unit outages are required, one for the compressor overhaul and refurbishment activities and one for the DLE facilities installation and associated control system upgrades. A site shutdown will also be required to tie-in the compressor's new control systems to existing station control systems etc

   It is assumed DLE technology will be tested / proven and commercially available by Q3 2023, before the commencement of pre-FEED / FEED project stages. It should be noted that during the compressor control system replacement, no other compressor cab infrastructure or machinery train overhauls can take place at the same time, due to an overlap in working areas. This is in accordance with National Grid Cyber Delivery Strategy
3. Two unit outages are required, one for the compressor overhaul and refurbishment activities and one for the CSRP facilities installation and associated control system upgrades. A site shutdown will also be required to tie-in the compressor's new control systems to existing station control systems etc. It should be noted that during the compressor control system replacement, no other compressor cab infrastructure or machinery train overhauls can take place at the same time, due to an overlap in working areas. This is in accordance with National Grid Cyber Delivery Strategy.
4. Two unit outages are required, one for the compressor overhaul and refurbishment activities and one for the SCR facilities installation and associated control system upgrades. A site shutdown will also be required to tie-in the new compressor control systems to existing station control systems etc

   The project completion date is the same as Options C and D, even though this option requires on site civils works to be undertaken prior to the SCR facilities installation. This is because all options are reliant on the year April – September window for all refurbishment and retrofit activities including the total site shutdown plus. It should be noted that during the compressor control system replacement, no other compressor cab infrastructure or machinery train overhauls can take place at the same time, due to an overlap in working areas. This is in accordance with National Grid Cyber Delivery Strategy.

11.0 PHASE 2 OPTIONS RISK ASSESSMENT

Key Reference Documents

203513C-002-RT-0200/A Peterborough Risk Workshop Report [Ref. 15]

11.1 General

The Peterborough Compressor Station Risk Workshop was held on Thursday 7th July 2022 via Microsoft Teams. The risk assessment results serve as input to onwards mitigation discussions and wider project risk management activities to reduce or eliminate the potential project value erosion.

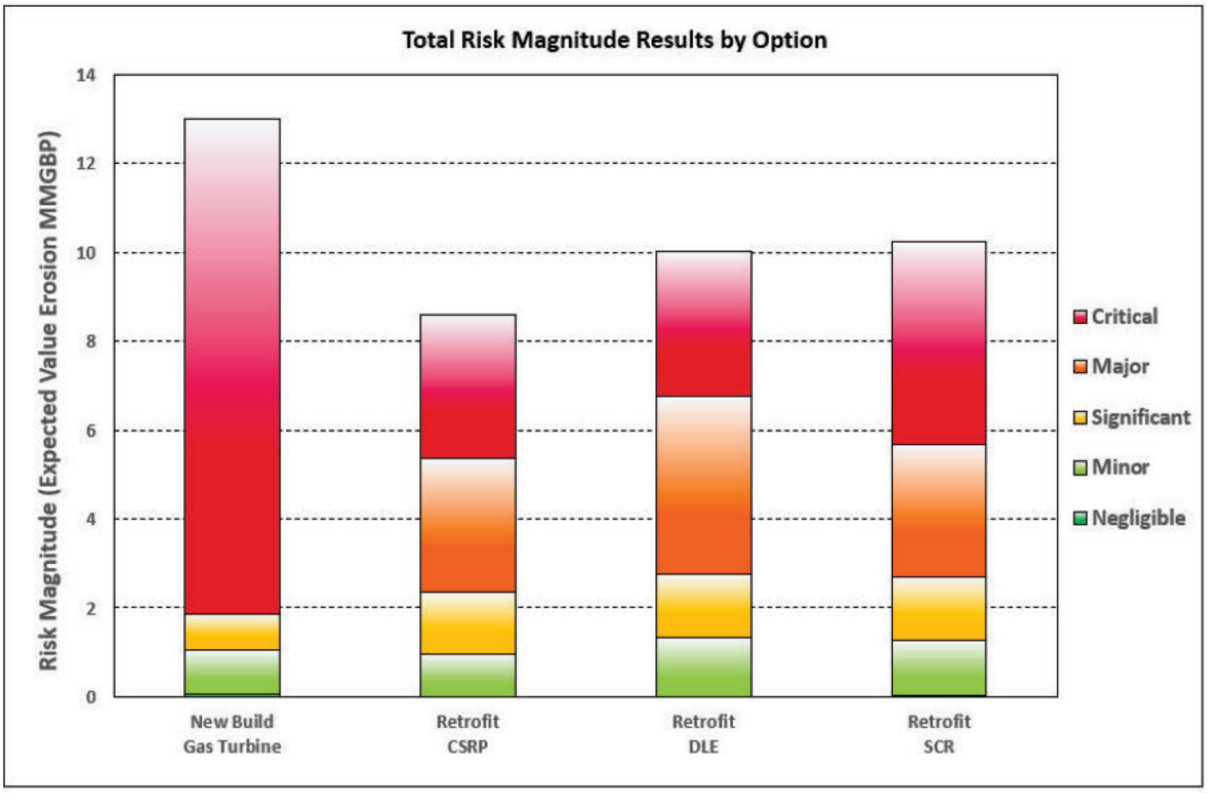
This section provides an overview of the results and outcome of the Risk Workshop, further detailed information can be found in [Ref. 15]. The purpose of the Workshop was to highlight differential risks between the options and thus allow the information to be used as part of selecting the preferred MCPD compliance option for the Peterborough Compressor Station.

11.2 Workshop Results

The technical options considered during the Risk Workshop are described in Section 1.2.

Figure 11-1 provides a summary of the total risk magnitude by option, as calculated from the sum of the individual risks identified in the risk register [Ref. 15]. These results should be used as an indicative comparison of the options only, as they are based on indicative risk impact ranges and probabilities.

Figure 11-1: Total Risk Magnitude and Risk Breakdown of the Options



From Figure 11-1 the new build option carries the highest risk magnitude. This is attributed to the risks concerning; planning permission, country specific and worldwide geopolitical issues affecting equipment and workforce and coordination and alignment with external stakeholders. For the Retrofit options, the Selective Catalytic Reduction (SCR) option carries the highest risk magnitude (although only marginally) due to the location of SCR facilities and potential equipment clash with ERP3 project installed draw pits. Note, if the SCR option is selected by the MCPD Project, the location of the SCR facilities needs to be confirmed following detailed site surveys including assessment of all existing underground pipework / channels etc. This is followed closely by the DLE Option which is considered a new technology for National Grid. Test bed Trials are currently ongoing, which may help to mitigate future operability concerns.

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

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

Coordination and Alignment with External Stakeholders – As part of the project phase gate milestones, coordination with external stakeholders is required (Ofgem etc.,). For the New Build Option, there may be a potential delay in gaining alignment on a preferred option and as a result, a schedule delay (initial engagement between Ofgem and National Grid indicate a strong preference from Ofgem for Retrofit Options).

Coordination and Alignment with Internal Stakeholders – As part of the project phase gate milestones, coordination with internal stakeholders is required. For the Retrofit Options, there may be a potential delay in gaining alignment on a preferred option and as a result, a schedule delay (currently the New Build Options are the preferred option for internal stakeholders).

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

Planning Applications – For the New Build Option and SCR Retrofit Option, planning permission is required. A critical risk has been identified regarding extension to schedule due to planning consent taking longer than anticipated. This was an issue experienced on the ERP3 Project.

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

Refurbishment Scope for Avon Unit – For the Retrofit Options, a major risk was identified around the Avon Unit refurbishment scope. As this is a conceptual phase project, no in-depth condition assessment surveys have been carried out for the existing Avon Unit A. Therefore, there is uncertainty in the 're-life' scope modifications currently identified and whether all areas of concern have been captured. There is potential for 're-life' component scope growth and as a result, CAPEX increase. This risk can be mitigated by undertaking detailed condition assessments and facilities surveys prior to project execution.

Re-Use of Existing Underground Production Piping – For the Retrofit Options, a major risk was identified around the condition of the existing underground production piping. As this is a conceptual phase project, no in-depth underground piping survey has been carried out.

Therefore, there is potential for more extensive damage/ lower integrity of pipework than currently expected (more of a concern for the Retrofit Options). There could be requirement to replace large sections of underground piping and as a result, CAPEX increase.

New Technology Reliability – For the DLE Retrofit Option, the technology being implemented is considered new for National Grid. As a result, there are potential unknown operability issues (e.g., wider system dynamic issues) which may arise. If these operability issues / teething troubles are discovered during the initial operating period, this may result in poor availability. However, test bed trials are currently ongoing which may help to mitigate / alleviate these concerns.

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

All other risks are classified as either **significant**, **minor** or **negligible** and are detailed in full (including identified opportunities) within the risk register provided in Reference 16.

11.3 Recommendations

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

[redacted]

12.0 CONCLUSIONS AND RECOMMENDATIONS

12.1 General

This section provides a summary of the main conclusions resulting from this phase, plus recommendations for future project phases.

12.2 Conclusions

The main conclusion resulting from this study are as follows:

- Installation of a new build Gas Turbine driven unit or the retrofitting of the Avon Unit A with SCR, DLE or CSRP to achieve MCPD compliance for the Peterborough station is technically feasible. All options can achieve the required process duty specifications (PDS) plus comply with National Grid's recommended site layout / spacing requirements.
- A new build Electrical VSD Compressor is not recommended for Peterborough due to:
    - High development costs and schedule risk particularly due to requirement for new UKPN incomer;
    - Introduction of procedures, components, spares, etc. unique from existing site. New GT driven units have recently been installed on site.
- Significant potential risks were identified for the new build and retrofit options:
    - Geopolitical issues affecting supply and cost of equipment and workforce for project execution.
    - The degree and scope of refurbishment required to the existing Avon Unit A for the 're-life' necessary for the retrofit options.
    - Uncertainty in the condition of existing underground piping servicing the Avon compressor units as no in-depth site surveys have been carried out. The integrity of the existing pipework needs to be further assessed.
    - DLE technology applied as a retrofit modification to an Avon is not currently proven in an operational setting. Limited factory testing has been conducted to date and field trials are planned on the NTS in 2023.
    - Potential schedule delay due to the planning application process based on recent experience from the ERP3 project.
    - CSRP has not received permitting / approval for use as a retrofit technology.

  These risks can be mitigated by planning and more detailed assessments during the next project phase. Refer to the recommendations below.

- The retrofit options offer project development cost, project execution schedule and environmental benefits (i.e. lower embodied carbon emissions and impact on site biodiversity). As noted above, there are no significant site safety (i.e. site layout) or PDS compliance concerns with any the options. However, new build units offer better operational flexibility and availability.

[redacted]

- All retrofit options have comparable project execution schedule and impact on site biodiversity. However, the SCR option has a higher project development cost and embodied carbon emissions than the DLE and CSRP options. As noted above, the DLE option carries potential risk due to it being considered to be a new technology, whereas the CSRP option offers less operational flexibility.

12.3 Recommendations

The main recommendations arising from this study are as follows:

Peterborough Process Duty Specifications:

- It has been determined that the DLE, SCR and CSRP retrofit options are able to achieve the required duty specifications but with mitigations required for certain onerous operating points. These mitigations involve either operating two units when operating point only calls for one unit operation or better balancing of flows between two duty units. The mitigations are feasible and National Grid operations need to confirm that they can be implemented.

Peterborough MCPD Project Scope:

- Detailed multi-discipline site surveys should be undertaken, and condition assessments of all existing facilities servicing the Avon compressor units, including underground pipework, cables and available space in cable trenches. This is in order to define in detail all modifications / upgrades necessary to be performed for 're-life' of the compressor station. However, based on the investigations and work already undertaken as part of the ERP3 Project, significant issues with the existing Avons' units underground pipework and cables is not expected.
- A detailed execution schedule for the MCPD project should be developed including detailed assessments of the asset health implementation scope in order to produce an optimised execution schedule which considers synergies between different work scopes and thus minimise site shutdown durations etc.

Peterborough MCPD Project Execution / Optimisation:

- At the beginning of the next phase, the concept phase risk register should be filtered to show just the identified potential risks for the selected MCPD compliance option. Then, all relevant risks identified as critical, major or significant should be subject to onwards risk management and development of risk action plans appropriate mitigations under future phases of the project.
- Depending upon the selected MCPD compliance option, detailed safety assessment / QRA studies should be undertaken to confirm that existing site fence extension is not required for the retrofit options.
- Potential opportunities to coordinate activities and sharing of workforce etc. with other MCPD projects should be investigated as this may offer potential development cost and execution schedule savings.
- Potential opportunities to coordinate activities and sharing of workforce etc. between the MCPD project and other Peterborough site projects should be investigated as this may offer potential development cost and execution schedule savings.

- The available network outage periods for construction/ commissioning activities (e.g., tie-ins) should be identified and agreed and factored into the project execution schedule. Opportunities should be considered for early installation of piping isolation valves at tie-in location etc. that will minimise durations for later required network outages.

<u>Fleet RAM Study:</u>

If a retrofit option is selected, the recommendations from [redacted] Fleet RAM Study [Ref. 20] should be considered and implemented in order to enhance the availability of the existing Avon B unit. As a minimum, the following upgrades are required as part of the Avon Unit B 're-life' modifications to ensure the requisite design life is achieved:

- Safety / Protection/ ESD Systems;
- Control Systems;
- Compressor Package Overhaul.
- Better understanding of the spare parts inventory and overall obsolescence issues.

<u>BAT Technologies:</u>

Current BAT technologies and other innovations (i.e. zero loss dry gas seals) should be explored at the next phase to ensure design is BAT compliant.

<u>DLE Retrofit Option:</u>

- A back-up retrofit option should be carried forward until test bed trials have been satisfactorily completed and it is confirmed that DLE technology does not carry significant new technology risk.

<u>SCR Retrofit Option:</u>

- A detailed review of the potential ammonia hazards should be performed in order to confirm location of the ammonia storage and offloading facilities plus identify changes to existing operating procedures that will be necessary.
- For the SCR option, the layout considered in this study is based on making use of available space to optimise proximity from buildings, vehicle access and installation schedule. The location of the SCR facilities needs to be confirmed following detailed site surveys including assessment of all existing underground pipework / channels etc.

<u>New Build Unit Option:</u>

- For the purposes of this study, the new unit design has been assumed to the same as the T130 units recently installed as part of the ERP3 project. If a new build unit is selected as the MCPD compliance option, then the compressor package design should be reviewed and optimised in terms of size / capacity of the unit, footprint and foundation requirements, structural support / access platform requirements, acoustic cladding attenuation requirements etc.
- There is a potential to decommission the old control room as the existing Avon units, which interface with the room, are demolished. Detailed assessments of this potential should be undertaken as there may be other existing systems / interfaces that would require relocation to the new control room in order to decommission the old control room.

Construction Camp Land Requirement

- For the new build and SCR retrofit option, space outside the site fence is required for the temporary construction camp. There is a potential opportunity to re-use the existing land purchased for the ERP3 project construction camp, if it is not sold, which would mean a lease agreement for land is not required by the MCPD project. Therefore, this opportunity should be investigated further.

13.0 REFERENCES

REFERENCES	
Ref 1	Peterborough Compressor Station Study Basis of Design, doc. no. 203513C-002-RT-0008-0002, Rev C.
Ref 2	Peterborough Compressor Station Site Visit Report, doc. no. 203513C-002-RT-0500, Rev B.
Ref 3	Cost Estimating Methodology, doc. no. 203513C-000-RT-0300, Rev B.
Ref 4	Peterborough Compressor Station Cost Estimates (Phase 1 +/-50%), doc. no. 203513C-002-RT-0300, Rev B.
Ref 5	Peterborough Compressor Station Level 1 Schedules (Phase 1), doc. no. 203513C-002-PLG-0300 Rev B.
Ref 6	Peterborough Compressor Station Layout Review Report (Phase 1), Rev. B, doc. no. 203513C-002-RT-0250 Rev B.
Ref 7	Peterborough Compressor Station Options Review Report (Phase 1), doc. no. 203513C-002-RT-0503 Rev B.
Ref 8	Peterborough Compressor Station Mechanical Equipment List (Phase 1), doc. no. 203513C-002-EL-026 Rev. B.
Ref 9	T/SP/G/37, Rev. 03/13, "Specification for Site Location and Layout Studies and Reviews", National Grid, dated June. 2013
Ref 10	Peterborough Compressor Station Cost Estimates (Phase 2 +/- 30%), doc. no. 203513C-002-RT-0301 Rev B.
Ref 11	Peterborough Compressor Station Level 2 Schedules (Phase 2), doc. no. 203513C-002-PLG-0301 Rev B.
Ref 12	Peterborough Carbon Interface Tool Summary Report (Phase 2), doc. no. 203513C-002-RT-6200-0002 Ref. B.
Ref 13	Peterborough Compressor Station BAT Input Sheet (Phase 2), doc. no. 203513C-002-CN-6200-0001 Ref. C.
Ref 14	Peterborough Compressor Station Biodiversity Net Gain Assessment, doc. no, 203513C-002-RT-6200-0001 Ref. B.
Ref 15	Peterborough Compressor Station Risk Workshop Report (Phase 2), doc. no. 203513C-002-RT-0200 Rev C.
Ref 16	Peterborough Compressor Station Process Description, doc. no. 203513C-002-RT-0008-0001 Ref B.
Ref 17	Peterborough Layout Drawings, doc. no. 203513C-002-DW-0051-0001 Ref B.
Ref 18	Peterborough Compressor Station Electrical Modifications Summary, doc. no. 203513C-002-RT-1600-0001 Rev B.
Ref 19	Peterborough Process Flow Diagrams, doc. no. 203513C-002-PFD-0010-0001 Rev B
Ref. 20	[redacted] NGGT Fleet RAM Study Report, Doc. no. 1429403, Rev 2 (14-03-2022)
Ref. 21	Directive (EU) 2015/2193 of the European Parliament and of the Council of 25 November 2015 on the limitation of emissions of certain pollutants into the air from medium combustion plants

Ref. 22	EPR Variation Notice (EPR/UP3038LG/V003) dated 02/11/2017.
Ref. 23	Avon DLE Technical Note, Document Number: PAC105119C-14-41-00-0000-NGG-0026 (Dated 19/01/2022)
Ref. 24	BAT Input Proforma Meeting Minutes, Dated 13/05/2022 (Received on 13/05/2022)
Ref. 25	PAC1051191-14-41-00-7220-NGG-0043, Rev. 01, Peterborough and Huntingdon MCPD Asset Health Requirements