nationalgrid

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# FEED Feasibility Study Report

## 20485-EP-RPT-000-0001_Rev 0

[redacted]

**BACTON FOS FEED FEASIBILITY**

**NATIONAL GRID**

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**Document Approval**

| Rev | Date | Description | By | Checked | PM |
|---|---|---|---|---|---|
| 0 | 25/11/2021 | Issued for Implementation | [redacted] | | |
| | | | | | |
| | | | | | |

# 1. EXECUTIVE SUMMARY

## 1.1 Overview

The Bacton terminal, constructed in 1968, imports gas from southern North Sea gas fields and can import or export natural gas via interconnectors to the Netherlands and to Belgium. In the 2030's the plan is for the Interconnectors to provide the sole means of gas supply to Bacton, with the cessation of gas supply from the South North Sea.
Bacton is the second largest gas terminal in the Uk and occupies a vital role in providing energy to London and South East of England.

Due to the age of the site and its coastal location, National Grid Bacton has encountered issues of equipment integrity and equipment function at the site and has undertaken a significant program of asset replacement during the RIIO-T1 price control. In order to safeguard the site for future energy requirements in the UK this current project of Bacton Future Operating Scenarios (FOS) FEED Feasibility Study has been undertaken. The study has a focus to examine and develop credible options to concept level of detail and make an overall recommendation of a best option to present to Ofgem for detailing in the next phase of the project.

The study is developed against a variety of influencing factors that include the rapidly changing energy landscape in the UK. As part of the FOS, there will be an opportunity to rationalise the volume of assets, simplify Terminal Operation and reduce the operational expenditure required to maintain the terminal.

The study has developed several options to determine the most effective long-term option for Bacton and these are recorded in this main study report and the appendices. Option development has occurred in two phases of work; an initial development of long list ideas and following an evaluation held with NG in July, a short list has been agreed for concept definition work in phase 2.

This process of short listing also included direction from NG after their receipt of OFGEM reopener guidance issued for the project 17/07/2021. The short list of options are as follows:

| Core methane option | Core methane option variant | Applicable time period reflecting site maximum gas flows |
|---|---|---|
| **1**<br>Make do and mend | | **1.1**<br>2021-2035 (site capacity up to 160 mscmd)<br>**1.2**<br>2035-2050 (site capacity up to 120 mscmd) |
| **2**<br>Major rationalisation & reduce inventory | | 2035-2050<br>(site capacity up to 120mscmd) |
| **3**<br>New build (above ground, modular build, minimal reuse of assets) | **3.1**<br>Fits within existing site | |
| | **3.2**<br>Requires site extension / offsite development | |

**Table 1-1 : Study Short List Options**

## 1.2 Phase 1 Long List Work

The study developed over the initial phase 1 of work 26 ideas for the future operations of Bacton up to 2050 utilising a variety of routes involving terminal reconfiguration to radical reuses of hydrogen or onsite electrical production.

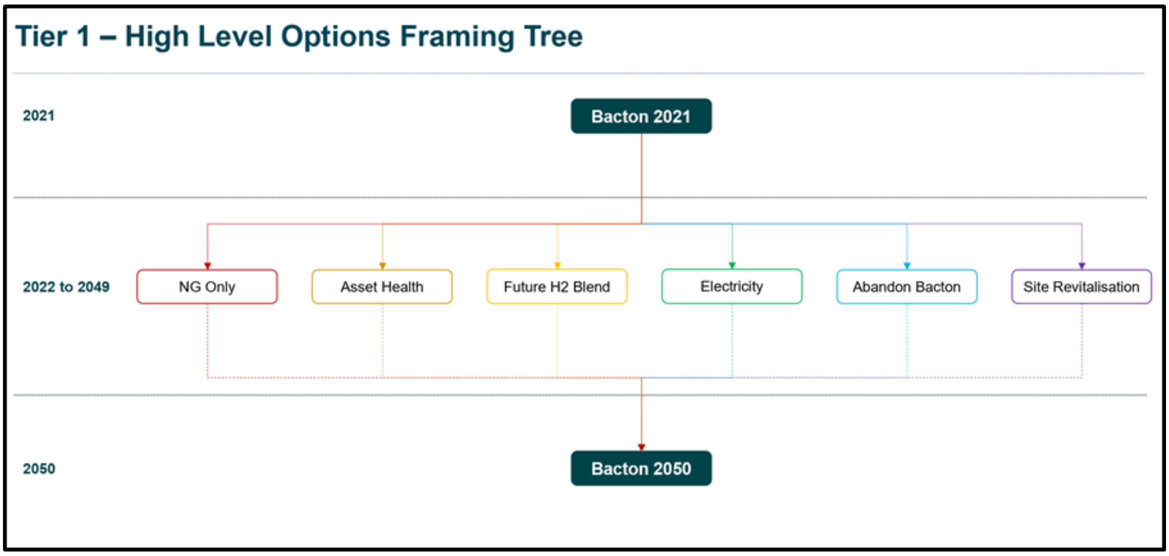



**Figure 1-1: Hydrogen Long list – Options Framing Tree**

The assessment of the long list and a focus on future use of Bacton as a methane terminal led to the reduction of the long list to just five ideas that respond most directly to this role, involving continued maintenance work, brownfield redevelopment or new build either on site or offsite (greenfield) development.

## 1.3 Phase 2 Short List Work

The five short listed options have been subjected to intensive development involving the use of the 3D BIM model and conceptual engineering has defined each option sufficiently to develop a +/-30% cost estimate. Further, detailed considerations of environmental and sustainability issues have been undertaken so that at the short list evaluation workshop a rigorous evaluation of the options could be completed by a joint NG/Consultant team using the following criteria:

- Allows for hydrogen compatible design
- CAPEX
- Constructability Risk (less SIMOPS)
- Greenfield development – planning conditions
- Opex should be reduced
- Permits reuse of existing assets
- Reduces current gas inventory (COMAH)
- Terminal operations simplified
- Minimal environmental impacts
- Above ground piping is minimal

The multi-criteria technique used allowed these criteira to be weighted and for the options to be scored by the evaluation team. Out of this work the **Option 1 Make do and Mend** was identified as the option best responding to the criteria.

| | CRITERIA | | Allows for hydrogen compatible design | CAPEX | Constructability Risk (less SIMOPS) | Greenfield development – planning conditions | Opex should be reduced | Reuse of existing assets | Reduces current gas inventory (COMAH) | Terminal operations simplified | minimal environmental impacts | Above ground piping is minimal | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weighted Criteria | 0.021 | 0.191 | 0.170 | 0.149 | 0.085 | 0.085 | 0.011 | 0.053 | 0.149 | 0.085 | |
| | OPTION TITLE | | | | | | | | | | | | |
| 1.1 | 2021-2035 (site capacity up to 160 mscmd) | weighted score | 0.03 | 1.61 | 1.23 | 1.37 | 0.39 | 0.70 | 0.02 | 0.11 | 0.97 | 0.65 | 7.07 |
| | | raw score | 1.27 | 8.40 | 7.20 | 9.20 | 4.53 | 8.27 | 1.73 | 2.07 | 6.53 | 7.60 | |
| 1.2 | 2035-2050 (site capacity up to 120 mscmd) | weighted score | 0.03 | 1.57 | 1.20 | 1.37 | 0.42 | 0.66 | 0.03 | 0.14 | 0.89 | 0.65 | 6.96 |
| | | raw score | 1.40 | 8.20 | 7.07 | 9.20 | 4.93 | 7.80 | 2.40 | 2.60 | 6.00 | 7.60 | |
| 2 | Major rationalisation & reduce inventory | weighted score | 0.08 | 1.02 | 0.85 | 1.34 | 0.52 | 0.55 | 0.07 | 0.30 | 0.84 | 0.50 | 6.08 |
| | | raw score | 3.64 | 5.33 | 5.00 | 9.00 | 6.07 | 6.47 | 6.40 | 5.67 | 5.67 | 5.93 | |
| 3.1 | New build (above ground, modular build, minimal reuse of assets) | weighted score | 0.15 | 0.61 | 0.78 | 1.26 | 0.52 | 0.28 | 0.06 | 0.35 | 0.72 | 0.32 | 5.07 |
| | Fits within existing site | raw score | 7.27 | 3.20 | 4.60 | 8.47 | 6.13 | 3.27 | 5.87 | 6.67 | 4.87 | 3.73 | |
| 3.2 | New build (above ground, modular build, minimal reuse of assets) | weighted score | 0.16 | 0.52 | 1.00 | 0.36 | 0.55 | 0.25 | 0.06 | 0.36 | 0.42 | 0.30 | 3.97 |
| | Requires site extension / offsite development | raw score | 7.47 | 2.73 | 5.87 | 2.40 | 6.47 | 2.93 | 6.00 | 6.73 | 2.80 | 3.47 | |

**Figure 1-2: Short list evaluation workshop – summary of results**

Parallel work by environmental and sustainability and also CBA analysis using the outputs from the cost estimation work have also endorsed Option 1 as the best suited option

# 2. INTRODUCTION

## 2.1 Bacton Terminal

Bacton Terminal was constructed in 1970 and brings in flows from southern North Sea gas fields, as well as hosting interconnectors to the Netherlands and Belgium. Due to the age of the site and its coastal location, National Grid Gas (NGG) has encountered issues operating the equipment at the site and has undertaken a significant program of asset replacement during the RIIO-T1 price control. In order to safeguard the site for future energy requirements in the UK NGG has established this project to examine and develop credible options to an adequate level of detail to present to Ofgem with recommendations for further design development.
Bacton terminal located on the Norfolk coast is strategically important to the UK National Gas Transmission Network. It is a key dynamic swing node for a large subset of the UK customer base at an interdependent part of the network. It bridges GB with the EU and controls flows into the South East ensuring security of supply for London.

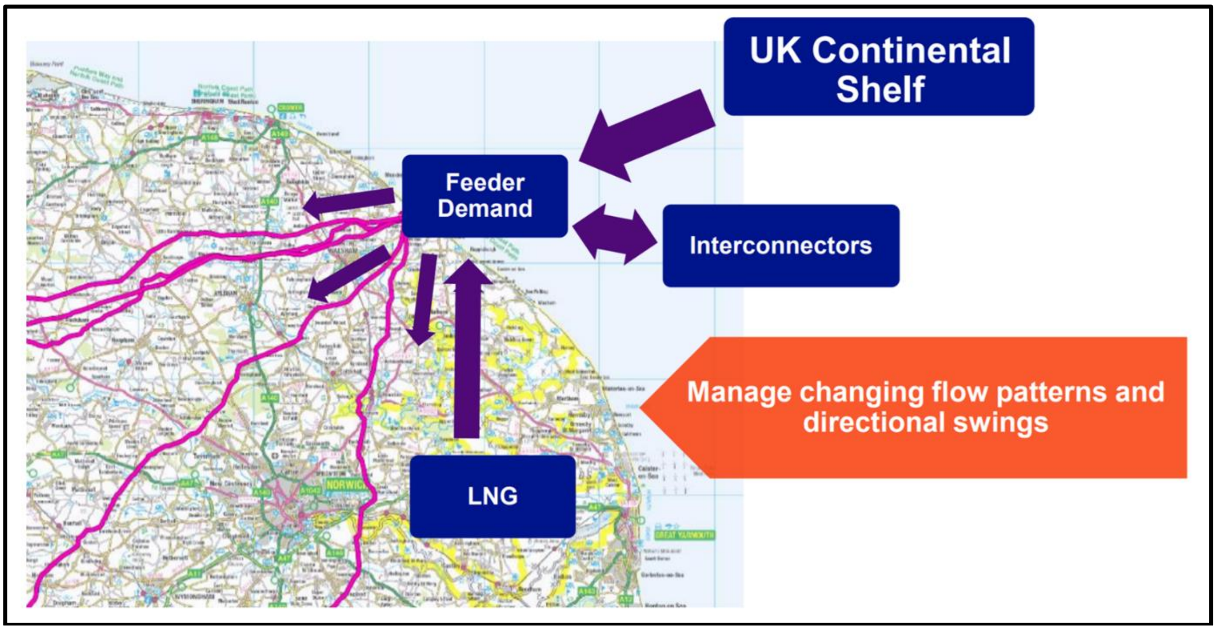



**Figure 2-1: Study Short List Options**

The Future Energy Scenario forecast data together with Reopener Guidance issued by OFGEM July 2021 during the course of the study, indicates a clear need for Bacton Terminal for the foreseeable future and a continuing role to act as a methane terminal.

[redacted]

**Figure 2-2: Study Short List Options Bacton Terminal as NTS nodal point**

The Project subject of this report is called the Bacton Terminal Future Operating Scenarios (FOS) FEED Feasibility Study and has been developed to generate options in the form of various responses that offer to safeguard Bacton future operations up to 2050. The backdrop to this work is a rapidly changing energy landscape in the UK and the Study needs a methodical examination of ideas prior to proceeding through an objective selection process to identify the best value option for Bacton Terminal.

As part of the Bacton Terminal Future Operating Strategy (FOS), there are opportunities to rationalise the volume of assets, simplify Terminal Operation and reduce the operational expenditure required to maintain the terminal. There are several additional factors such as the reduction of the site COMAH classification, or to ensure that the operation of Bacton terminal comes in line with the 2050 Net Zero Carbon Emissions strategy.
Note that the IUK facility within the NG fenceline is excluded from the scope. Integrity management and forward strategy for this is the responsibility of IUK, although regular consultations occur between IUK and NG. Additionally, the interconnecting import pipelines outside of the fenceline from the Perenco, Shell and ENI facilities are not considered, nor the NTS feeders outside the site fenceline.

## 2.2 Site History

Bacton Gas Terminal is a complex of six gas terminals within four sites located on the North Sea coast of North Norfolk in the United Kingdom. The sites are near Paston and between Bacton and Mundesley; the nearest town is North Walsham.
The Bacton complex which covers an area of about 180 acres (73 ha) opened during 1968. It has a frontage of 1 km (3200 feet) along the cliff top. It was initially built by Shell-Esso, Phillips Petroleum-Arpet Group, Amoco-Gas Council. Planning permission had been given on 16 June 1967 by Anthony Greenwood, Baron Greenwood of Rossendale. The Leman field began

production on 13 August 1968 (joint Shell-Esso and joint Amoco-Gas Council), the Hewett field (Phillips Petroleum-Arpet Group) began operations in July 1969 and the Indefatigable field (joint Shell-Esso and joint Amoco-Gas Council) began production in October 1971. Construction of the £5 million Phillips-Arpet plant began in April 1968. Gas from the Shell-Esso part of the Leman field was delivered to Bacton via a 34-mile-long pipeline. A 36-inch diameter 140-mile-long pipeline (Number 2 feeder main) costing £17 million was built by Italsider from Bacton to the National Transmission System near Rugby. When initially completed in 1968 the terminal had a total gas throughput capacity of 3,955 million cubic feet (112 million cubic metres) per day at standard conditions.

## 2.3 Terminals at Bacton Area

The Bacton complex consists of six gas terminals:

1) Shell
2) Eni (now abandoned)
3) Perenco
4) National Grid - feeding the National Transmission System (NTS)
5) Interconnector UK (within the National Grid site)
6) BBL (Bacton-Balgzand line) (within the Shell site)

Three of the terminals (Eni, Perenco and Shell) receive gas from Southern North Sea (SNS) and some Central North Sea (CNS) offshore gas fields. Initial gas processing, such as removal of free water, takes place on the offshore gas installations. At the terminals gas and condensate are received in slugcatchers (to separate gas and hydrocarbon liquids and condensed water), the gas is compressed if necessary, dehydrated using triethylene glycol, and chilled to achieve a specified hydrocarbon dewpoint. Sour gas (sulphurous) had previously been removed at the Eni site by amine gas treating, now decommissioned. Hydrocarbon condensate is stabilized and piped by the British Pipeline Agency along the route of the former North Walsham to Mundesley railway line to the North Walsham rail terminal and thence by rail to an oil refinery at Harwich Essex. Treated gas from the three terminals flows to the National Grid terminal located immediately to the south of the reception terminals. Two of the terminals (Interconnector and BBL) receive gas from, or deliver gas to, the gas networks of continental Europe. Manifolds within the National Grid terminal blend the gas and distribute it to the National Transmission System at around 1000 psig (69 bar).

The offshore reception terminals were originally run by Royal Dutch Shell-Esso, Phillips Petroleum-Arpet Group and Amoco-Gas Council. Amoco and BP announced they had merged in 1998 to form BP Amoco, the merged organisation changed its name to BP in 2001. Perenco took over the BP operations in September 2003. Tullow had begun operations in 2003 taking over the Phillips Petroleum terminal operations, ENI took over the Tullow Oil operations in December 2008.

### 2.3.1 Shell terminal

The Shell terminal, the most easterly of the three, receives gas and condensate from two offshore pipelines. These are a 55.7 km long 30-inch pipeline from the Leman 49/26AP offshore installation and a 73 km 24-inch pipeline from the Clipper PT installation. A mothballed 30-inch pipeline formally delivered gas from the Leman 49/26BT installation to Bacton. The terminal also receives gas from the 474 kilometres (295 mi) long 34-inch SEAL Pipeline, which transports gas from the Shearwater and Elgin-Franklin gas fields in the Central North Sea. The SEAL Pipeline is the longest on the UK Continental Shelf. The Shell plant has a gas treatment capacity of 900 million cu ft (25 million m3) per day at standard conditions and a condensate stabilization capacity of 8,000 barrels per day (1,270 m3/day). The gas hydrocarbon dewpoint is achieved by propane refrigeration. Truck loading facilities for condensate were originally provided.[2] It employs 46 people and began operations in 1968. The BBL Pipeline terminal became operational in December 2006 and is located within the Shell terminal. The BBL terminal is operated, but not owned, by Shell.

### 2.3.2 Eni terminal

The most westerly of the terminals is owned by Eni of Italy. It receives gas from two 30-inch pipelines from the Hewett field (27.7 km and 32.8 km long) and a 62 km long 20-inch pipeline from Lancelot 48/17A offshore installation (LAPS complex). A decommissioned 24-inch pipeline formerly delivered gas from the Thames 49/28A offshore installation. Gas and liquid from each pipeline are received and processed separately.[3] After gas and condensate are separated in vessel-type slugcatchers and filter-separators each gas stream is fiscally metered (for tax purposes). The two Hewett field gas streams are combined and increased in pressure through an eductor. The gas stream was formerly treated with amine to remove sulphur compounds, this facility was decommissioned in 2000 when production from the sour Hewett Upper Bunter reservoir was shut in. The gas is comingled with the LAPS gas then compressed. It was formerly dehydrated using triethylene glycol and underwent hydrocarbon dew point reduction by chilling with propane. Finally, it was fiscally metered (for sales) and transferred to the Bacton NTS plant. Formerly the terminal had pentane storage tanks and a truck loading facility.[2] The terminal has two GE 11MW Frame 3 and one GE 3.7MW Frame 1 gas turbines, connected to three centrifugal compressors. In 2011 the Eni Terminal was split by segregating the reception and some of the compression facilities from the dehydration and dewpoint control plant, the latter was decommissioned. Now after compression the gas is sent to the Perenco site for dehydration and dewpoint control. The separated condensate is also sent to the Perenco site. During late 2013/2014 the redundant processing facilities were removed and now the majority of the Eni site is unused.

### 2.3.3 Perenco terminal

This terminal, located between the Shell terminal and the Eni terminal, processes gas from pipelines from the Leman, Indefatigable and Trent & Tyne fields. These include two 30 inches (760 mm) pipelines from the Leman 49/27AP and Leman 49/27B offshore installations (61.82 km and 64.9 km respectively) and 24 inches (610 mm) pipeline from the Trent 43/24 offshore installation. The processing plant comprises two parallel trains (A1 plant and A2 plant) each with an initial processing capacity of 1,000 million cu ft (28 million m3) per day at standard conditions and a condensate stabilization capacity of 600 m3/day, stabilized condensate is stored in gasoline storage tanks[2] prior being piped to the North Walsham rail terminal. Gas from the 'Leman' pipe-type slugcatcher is normally routed to dewpoint control plant streams 1, 2 and 3; gas from the 'Inde' pipe-type slugcatcher is routed to dewpoint control plant streams 4 & 5. Gas from the Tyne and Trent pipe-type slugcatcher can be routed to either dew point control plant. There is also a cross-connection to and from the Shell terminal.
The ENI terminal was integrated into the Perenco Terminal in 2011, thereby diverting the Hewett, LAPS and at one time Thames gas and condensate from the slug catchers and compression in the Eni terminal to the Perenco terminal upstream of the dehydration and dew point control plant.

### 2.3.4 National Grid terminal

Connections from the offshore reception terminals comprise two 30-inch lines from the Eni terminal (now disused), two 30-inch lines from the Perenco terminal, four 24-inch lines from the Shell terminal and a 36-inch line from the BBL pipeline. Gas from the Perenco and Shell terminals is filtered, measured through orifice plates and the flow regulated by volume into a manifold system.[2] Facilities for heating the gas by pressurised hot water are provided should this be necessary if the pressure of the incoming gas has to be reduced appreciably. There are four 36-inch manifolds within the National Grid terminal, plus one spare, which can receive flow from any of the incoming lines, thus blending the gas.[2] A 24-inch by-pass ringmain around the site perimeter enables the terminal to be completely by-passed in an emergency. The blended gases are odorised (1 kg odorant for 60,000 m3 of gas)[4] and the flow rate is measured and distributed then to the National Transmission System via five outgoing feeders:

- Feeder No 2 to Brisley, Peterborough and Rugby, 36-inch
- Feeder No 3 to Roudham Heath, Cambridge and Hitchin, 36-inch
- Feeder No 4 to Great Ryburgh, King's Lynn and Alrewas, 36-inch
- Feeder No 5 to Yelverton, Diss, Chelmsford and Horndon-on-the-Hill, 36-inch
- Feeder No 27 to King's Lynn, 36-inch

From the National Grid terminal gas can also be sent to, or received from, Zeebrugge, Belgium via the Interconnector, received from the Netherlands via the 36-inch Balgzand Bacton Line BBL

Pipeline. Gas is also distributed to the local area via a low-pressure gas distribution system and sent via a 12-inch high pressure pipeline to Great Yarmouth power station

#### 2.3.5 Interconnector UK terminal

##### 2.3.5.1 Compressor station

The Interconnector terminal is located within the National Grid terminal. It can import gas from, or export gas to, Zeebrugge, Belgium via a 235 km pipeline operating at up to 147 bars. There is a 30-inch direct access line from the SEAL pipeline. It works via four GE LM2500 gas turbines and a Thermodyn centrifugal compressor in its compressor station, which was built by Kværner John Brown (now called Aker Solutions). The Interconnector was commissioned in 1998.

##### 2.3.5.2 BBL terminal

The BBL (Bacton–Balgzand line) terminal is located within the Shell terminal, it receives gas from the compressor station in Anna Paulowna in the Netherlands. The Bacton reception plant is owned by BBL Company and the plant is operated by Shell.[5] Gas arrives at Bacton at approximately seabed temperature and a pressure of up to 135 bar, but which varies depending on the amount of line pack. Bacton's role is to reduce the pressure for entry to the National Transmission System. As such, significant Joule–Thomson cooling may occur prior to gas injection into the NTS. Therefore, four identical parallel streams are installed at Bacton, each equipped with a direct-fired water bath heater on a slipstream and designed to operate as three duty and one standby at maximum flow conditions, in order to control the delivery temperature and pressure of the gas. The BBL Pipeline is 235 km long and was commissioned in December 2006.

### 2.4 Document Purpose

#### 2.4.1 Purpose

The purpose of this document is as follows:

- To summarise the work and outputs from the study and present the conclusions and recommendations identified for Bacton Terminal to 2050
- To identify key risks and assumptions
- Provide FEED Conceptual design scope
- To append all the supporting documentation and drawings which support the study report summary, conclusions and recommendations

# 3. REFERENCES

## 3.1 Precedence

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

> In the event of any conflict or inconsistency between the documents making up the contract, they shall take precedence as stated below (in descending order of priority):
>
> (i) this form of agreement;
>
> (ii) the Contract Data - Part one;
>
> (iii) the *conditions of contract* (including the *additional conditions of contract*);
>
> (iv) the Scope and any documents referred to in the Scope;
>
> (v) the Contract Data - Part two; and
>
> (vi) any other document forming part of the contract.

## 3.2 Statutory Regulations

The Control of Major Accident Hazards (COMAH) Regulations

## 3.3 National Grid Design Guides

See Project Execution Plan

## 3.4 Project Documentation

| | |
|---|---|
| PAC3721-14-58-00-1211-NGG-0041 | PROJECT SPECIFIC SCOPE Bacton FOS FEED Feasibility |
| PAC3721-14-58-00-1211-NGG-0002 | GENERIC SCOPE Bacton FOS FEED Feasibility |

## 3.5 Applicable Codes and Standards

Design and performance shall be in accordance with the latest applicable editions of international Codes and Standards listed in the project document 20485-EN-LST-000-0002 Codes, Standards and Technical Specifications.

# 4. DEFINITIONS

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

Throughout this document the following terminology is used:

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

# 5. ABBREVIATIONS

| | |
|---|---|
| AACE | American Association of Cost Engineers |
| API | American Petroleum Institute |
| ASME | American Society of Mechanical Engineers |
| BBL | Balgzand Bacton Line |
| BGC | British Gas Corporation |
| BIM | Building Information Model |
| BNG | Biodiversity Net Gain |
| BS | British Standard |
| CAPEX | Capital Expenditure |
| CBA | Cost Benefit Analysis |
| CDM | Construction Design Management |
| COMAH | Control of Major Accident Hazards |
| CP | Cathodic Protection |
| E&P | Engineering & Procurement |
| EJP | Engineering Justification Paper |
| FEED | Front End Engineering Design |
| FOS | Future Operating Strategy |
| FPSA | Formal Process Safety Assessment |
| GP | Global Practice |
| I&C | Instrumentation and Control |
| ITP | Inspection & Testing Plan |
| iUK | Interconnector UK |
| MCDM | Multi Criteria Decision Making |
| Mscm/d | Thousand Standard Meter Cubed per Day |
| NDT | Non-Destructive Testing |
| NG | National Grid |
| NGGT | National Grid Gas Transmission |
| O&M | Operational and Maintenance |
| OFGEM | XX |
| OPEX | Operational Expenditure |
| | |

| | |
|---|---|
| PPE | Personal Protective Equipment |
| PSSR | Pressure Systems Safety Regulations |
| RIOO | Revenue = Incentives + Innovation + Outputs |
| SDRL | SUPPLIER Data Requirements List |
| SEAL | Shearwater Elgin Area Line |
| SNS | Southern North Sea |
| SOW | Scope of Works |
| WSE | Written Scheme of Examination |

# 6. STUDY BACKGROUND

## 6.1 Basis

The basis and scope of the study was defined by NGG in the key scope documents issued as part of the ITT and listed below

- PAC3721-14-58-00-1211-NGG-0041 PROJECT SPECIFIC SCOPE Bacton FOS FEED Feasibility
- PAC3721-14-58-00-1211-NGG-0002 GENERIC SCOPE Bacton FOS FEED Feasibility

## 6.2 Requirements

In summary the NGG requirements as defined in the two scope of work documents are as follows The overriding objective is the review of potential solutions to secure the long-term operation of Bacton Terminal.

- The purpose of the service is to consider the best value option to redevelop the terminal for its current and future gas flows and use, the Client wishes to consider all options.
- Identify options to secure future operations that respond to one or more of the following parameters as well as any other developed relevant criteria
    - Rationalise volume of assets
    - Simplify terminal operation
    - Reduce OPEX
    - Bacton future operations conform to 2050 net zero carbon emissions strategy
    - Brownfield/greenfield site location (including planning requirements)
    - Local/remote control of future Terminal Assets
    - Consideration of potential future customer operating requirements
    - Consideration of electrical feeder connection or substation requirements
    - Decommissioning / Demolition / Re-use of existing assets
    - Reduction in site gas inventory (reduced COMAH classification)
    - Provision to allow internal inspection of pipework
    - Hydrogen compatible plant design
    - Physical options to facilitate gas blending to facilitate non-GSMR gas in line with project Neptune
    - Carbon neutral construction
    - Interconnector and BBL ramp rate option for 40mcmd/min.
    - Cost Benefit Analysis for segregation of the Cadent MOC with independent access
- Robust option selection supported by qualitative and quantitative data
- Delivery costs and programme (+/-30% accuracy)
- Detailed justification of the preferred option
- Identification of key risks and assumptions

## 6.3 Consultant Methodology

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

Phase 1 of the study was focussed on the production of an Options Longlist and was fundamental to all further work. The level of analysis of options in phase 1 was necessarily of a coarser definition than the phase 2 conceptual engineering work, but of sufficient detail to allow a reasoned choice between the options. 61
At the Phase 1 evaluation workshop, a short list of options was produced and during Phase 2 these options were examined in detail. A final short list evaluation workshop was then conducted to identify an overall recommended option. Final work has assembled all the work undertaken within the project and outputs from this will be inserted into the EJP document prepared by National Grid.

| | |
|---|---|
| **Phase 0:** Project Management | **CTR 1:** Project Management |
| | **CTR 2:** Design Management |
| | **CTR 3:** CDM Management |
| | **CTR 4:** Data & Site Reconnaissance |
| **Phase 1:** Options Longlist | **CTR 5:** Options Longlist |
| | **CTR 6:** Preliminary Study Engineering |
| | **CTR 7:** Environmental & Sustainability |
| | **CTR 8:** Cost Estimation |
| | **CTR 9:** Evaluate and Shortlist of Options |
| **Phase 2:** Options Shortlist | **CTR 10:** Study Engineering / 3D Model |
| | **CTR 11:** Environmental & Sustainability |
| | **CTR 12:** Programme (+/-30%) |
| | **CTR 13:** Cost Estimation (+/-30%) |
| | **CTR 14:** Ofgem Cost Benefit Analysis |
| | **CTR 15:** Design Reviews / Process Safety / Stakeholder Engagement |
| | **CTR 16:** Final Option Selection |
| | **CTR 17:** FEED Study Report |
| | **CTR 18:** Engineering Justification Paper Input & Support |

**Figure 6-1: CTR/Task Breakdown**

## 6.4 Key Study Elements

### 6.4.1 Data

Data was provided by National Grid to Consultant. The NG 3D model in native Autocad 3D files along with laser scan cloud data were given to the consultant for update for the project scope. Other specific site data has been provided by NG in the form of site records of asset conditions, soils, environmental and other data. The Consultant conducted a site visit on 04/08/2021 where the site was inspected with interviews and discussions with site operatives and managers.

### 6.4.2 Phase 0: Project Management

This phase of work comprises tasks and activities concerned with the correct setting up of the project and thereafter maintaining its orderly management until project close.

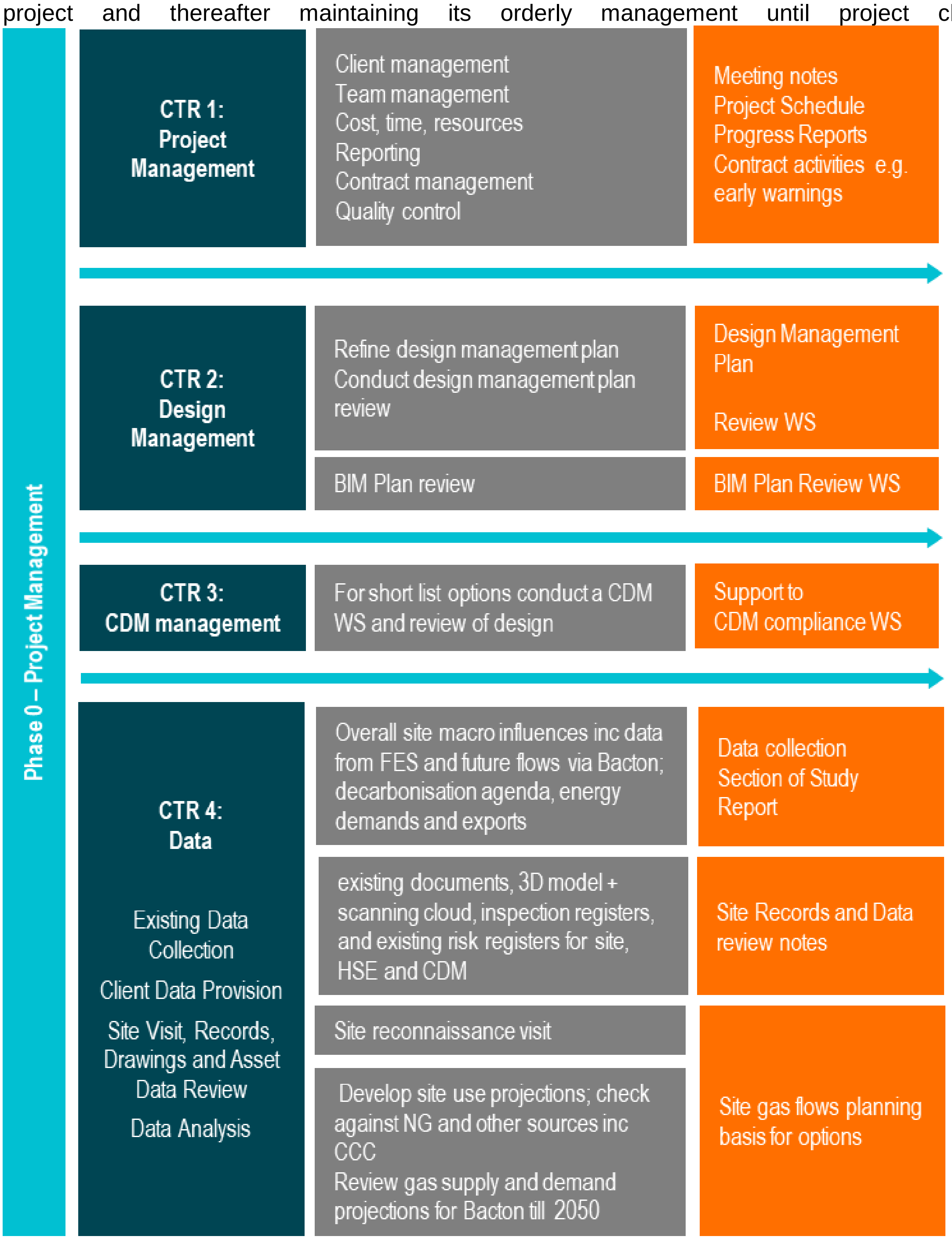



**Figure 6-2: Phase 0 Process**

Consultantheld a kick-off meeting with National Grid on 07/05/2021 where the draft schedule and planned meetings were reviewed to achieve alignment. Modifications to the schedule were agreed to allow the issue of the final project schedule following the meeting.

The following activities occurred at the kick-off meeting:

Joint review with National Grid of key project management elements including

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

Following award of contract, the project Design Management Plan (DMP) was submitted to National Grid for review and acceptance.

The DMP objectives, structure and requirements were briefed and made available to the Designer and Principal Designer Teams. The DMP uses evidence-based measures to ensure key design personnel, down to discipline leads, demonstrate understanding of the commitments, processes, and responsibilities contained within the Design Management Plan.

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

All the required engineering and design management activities, as detailed in the National Grid Project Specific and Generic Scope, Stakeholder and Design Activity Schedule and Schedule of Required Deliverables, will be integrated within the DMP. This will include the National Grid Formal Process Safety Assessment in accordance with T/PM/HAZ/9 and the Environmental & Sustainability Challenge & Review in accordance with T/PM/ENV/20

Outputs from the DMP included

- Procedure for the records and management of a technical risk register.
- Design Change Control procedure
- Procedure for Technical Queries and Deviation register
- Declaration of all Software Applications and Software Tools to be used during and for the delivery of FEED Feasibility
- The DMP is supplemented by other procedures (e.g. Project Execution Plan, Project Quality Plan, Quality Procedure etc
- CDM Management

Consultant undertook the duties of the Designer and Principal Designer in accordance with the requirements of the Construction Design and Management (CDM) Regulations 2015 and with National Grid specific requirements in accordance with NGUK/Con/BP156G – CDM Management. Consultant was responsible for the final design which complies with legislation, planning permission conditions and National Grid's specific requirements

The deliverables related to CDM regulations were:

- Pre-Construction Information Pack for the next phase of the project
- Project CDM Risk Register

Data is important to the development of credible options for the site in terms of what constraints are existing, the location, capacity and condition of all key piping and equipment together with the future shape and requirements for the site. It is known that as an existing site there are many records and survey data and as the study duration is limited it is anticipated that as much existing data as possible will be adopted for this work. As well as physical data on the existing installations data from any existing databases of component carbon from suppliers etc and existing assumptions on process and fugitive emissions was obtained.

The following activities were undertaken:

- Obtain existing site data – taken from various third-party sources in public domain
- Carbon database development and other data related to environmental, social, sustainability considerations
- Site data from National Grid

Site visit – following reviews of data provided the site visit was focused on the examination of key areas of operation at site, identification of hazards and risks (as part of the CDM regulations), understanding of modes of operation and flows particularly in relation to stakeholders at site, review of other areas of land adjacent to site such as possible green and brownfield sites and their locations/constraints relative to Bacton.

Discussions with key site and operational staff were useful to understand current issues, assets condition and how future development may need to respond to challenges

Analysis of the data logged was undertaken at formal internal reviews and meetings where key items can be tagged and copied to ensure the important elements are captured.
Data methods involved specific and general searches for data along with data requests to the National Grid team; site visits to record in person the layout and location of key plant and equipment and interviews with key persons at site.

The data collected was used initially to frame the boundary of idea development for options to address Bacton FOS and a summary site planning sheet was prepared as a key output for use in the initial long list idea development workshop.

## 6.5 Phase 1: Options Longlist

The purpose of phase 1 work was to generate a complete list of responses to the project objectives in the form of option ideas and then to reduce this list with some limited engineering definition, costing, and environmental assessment will be carried out consistent with the activity duration. This fed into a phase 1 final task where at a formal evaluation meeting the draft evaluation using formal multi-criteria techniques was reviewed and following meeting a finalised short list set of options produced as the main output from this phase of work. The short list options were the starting point for the next series of tasks under phase 2.

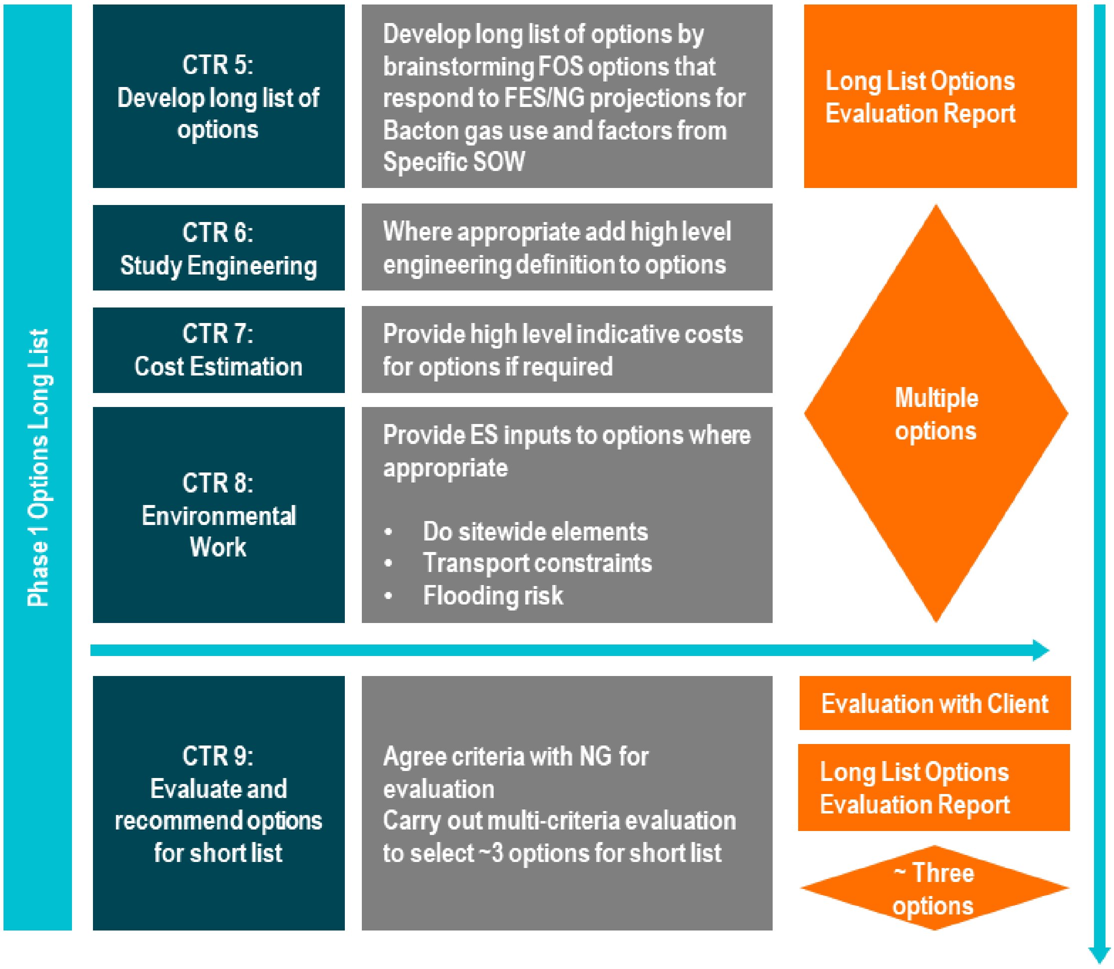



**Figure 6-3: Phase 1 Process**

The purpose of this task was to develop an initial long list of options that offer possible solutions to the project objectives of identifying future operational site responses to the prevailing constraints and so maintain Bacton working efficiently up to 2050.

This task was undertaken using key team members to spend time in reviewing a list of constraints for the options from consideration of macro factors including decarbonisation, field life, imports/exports of gas, security of supply, GDP and other items alongside micro issues such as site conditions of key piping and equipment, capacities, control systems, local planning issues, available space etc. A key input to the development of options was data collected in task 4 from various sources. The deliverables from this task were the Long List Options Report

Environmental issues for the long list options were assessed on a case by case basis. Where options are similar any key environmental aspects that distinguish between the options will attract more focus. Some key elements likely to be examined may include environmental impacts on the site, social issues including local effects, resilience, carbon emissions and other sustainability impacts, transportation issues etc. We will also seek to engage with stakeholders to investigate issues such as their policies on carbon and stated commitments in respect of this and other sustainability items. Following the requirements of PAS 2080, estimates of carbon impact for the options at this stage are consistent with the level of detail available on the key dependent variables for the options at this stage.

Environmental and sustainability data for each long list option (unless discounted already) were established using techniques to provide source data for scoring each option correctly relative one to another for use as one of the evaluation data inputs for Phase 1. The task work was recorded in the phase 1 evaluation report.

## 6.6 Phase 2: Options Shortlist

The objective of this phase of work was to examine in greater detail the short list options identified out of the phase 1 work. The BIM / 3D model was used to assess the implications of each short-listed option against criteria to be used in the further evaluation at the end of phase 2 to make a final preferred choice of option. The criteria chosen used parameters from NG and other items proposed by the joint client/consultant team

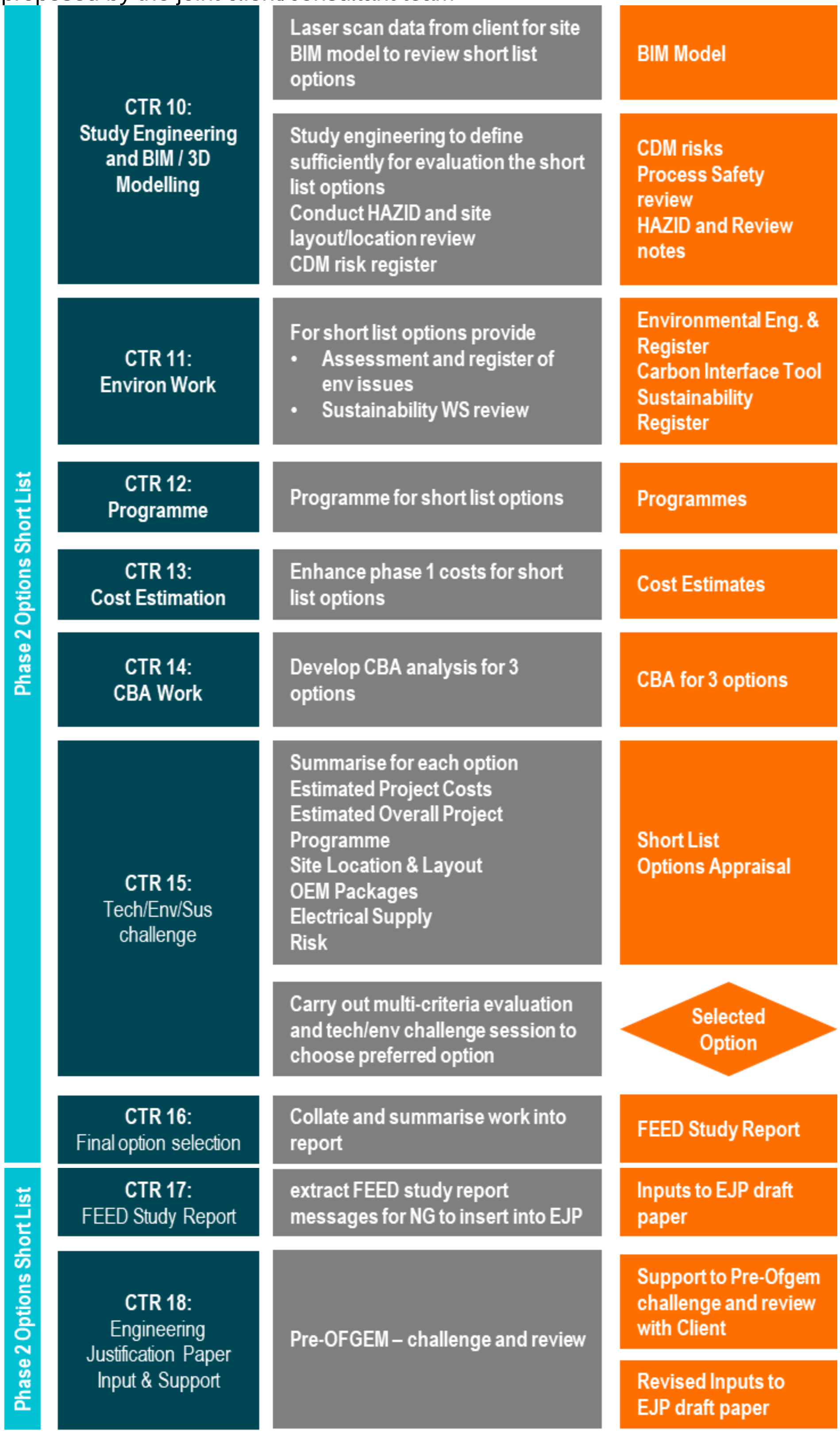



**Figure 6-4: Phase 2 Process**

## 6.7 Phase 2 Study Engineering / BIM & 3D model

The main output from the phase 1 work was a short list of formally evaluated options which were deemed most suitable against the criteria used for the selection. The focus of phase 2 engineering was to add considerable engineering details to the short list options and thereby form the basis for the inputs to the FEED study report and EJP as well as the other engineering reviews and workshops.

A key means of examining the details and implications of options on the site was the use of the BIM/3D model and a key activity within the task will be to develop this model into a fully functioning means of assessing each of the short list options.

## 6.8 Environmental & Sustainability

General
The short list options were assessed against environmental, social and sustainability criteria appropriate to the nature of the short list options and the criteria stated in the specific scope of work. As for phase 1 environmental work but at a deeper level of analysis, environmental issues etc were used as a means of teasing out differences and nuances between options with a view to finding the best option from an environmental and sustainability viewpoint. This fed into the overall phase 2 evaluation as one of the key elements in the final evaluation.

## 6.9 Programme

The option project schedule from FEED feasibility to Operational handover, was revised to align with the final Option recommendation acceptance for entering FEED Conceptual, through Detailed Design, Construction and Commissioning to operational handover.

Post-completion of the study when entering the FEED Conceptual phase of the project further refinement of the schedule occured as the design developed, vendor data received and incorporated into design allowing system / sub-system breakdown refining schedule, construction sequencing, pre-commissioning and commissioning system sequencing entering Detailed Design to Construction, Commissioning and Operation handover.

## 6.10 Cost Estimation

The short list options were assessed for their potential costs with the finally selected option subjected to a detailed cost estimate as per the specification to achieve +/-30% cost accuracy. A bottom up estimation approach to this task was used for each short list option in order to have visibility of the cost data elements within the overall estimate and additionally to ensure the required accuracy and transparency of the cost build-up. This facilitated the parallel carbon calculations, which are based on common component and process data.

Cost data inputs are crucial in order to demonstrate robustness in the final cost achieved and for it to resist any scrutiny by National Grid or OFGEM.

## 6.11 Ofgem Cost Benefit Analysis

### 6.11.1 General

The short list options have been subjected to CBA following the prescribed format for evaluation using the excel spreadsheet specified by Ofgem. This has pre-set lists of benefits etc and so circumscribes the limits of the analysis. The CBA work for each of the short list options informs the final evaluation work.

## 6.12 Design Reviews / Process Safety / Stakeholder Engagement

### 6.12.1 General

In the scope of work there are several specified challenges and reviews listed. These were carried out in various phases and toward the end of the engineering works.
The following reviews have been conducted with NG representatives during the study for the short list options:

- Design Opportunities (G19/Innovations, BAT) at 10.09.2021
- Design Review at 22.09.2021 and 12.10.2021
- HAZID1 at 30.09.2021 and 01.10.2021
- Site Location and Layout Review at 01.10.2021, 15.10.2021 and 18.10.2021
- Sustainability review at 12.10.2021
- CDM Compliance at 14.10.2021
- Final Option Selection at 20.10.2021
- Geoenvironmental / Geotechnical planning at 22.10.2021
- Cost and Risk review at 26.10.2021 and 01.11.2021
- HAZID and layout review actions closeout at 02.11.2021
- CDM follow up review at 04.11.2021
- Valves replacement review at 04.11.2021
- Costs follow up review at 09.11.2021

The objective of this phase of work was to conduct a final evaluation of the short list following the further work on engineering definition, costs and programme to select a preferred option. This should be the best candidate to meet the evaluation criteria as judged by the team and will follow the evaluation format using MCDM as at the end of the phase 1 work. . The nature of the short list options will determine to some degree the criteria to apply as it is critical that they distinguish clearly between options that may carry several common elements.

The evaluation methodology followed for the final option selection out of the short-listed options is the same as used at the end of phase 1. The criteria reflect the inputs from further work under phase 2 and the nature of the short list options.

The MCDM methodology ensures that the range of criteria are systematically reviewed in order to weight them in an agreed manner prior to each option being scored against the criteria.
The culmination of the study is preparation of the overall study report which capture the study activities and conclusions with appendices of deliverables and source data. We propose to issue a draft index of the report ahead of any substantial work to provide early opportunity for review and feedback by National Grid. We are aware that the composition of the report must in turn support the direct inputs to the EJP and hence we will work with National Grid to ensure that the two documents can 'speak' to each other without any need for additional text or explanation.

## 6.13 FEED Study Report

The indicative index to the FEED Study Report is provided by National Grid in the original ITT. The other key determinant of the contents of the FEED Report are the inputs to the EJP, as it will be important for the EJP elements to be able to be lifted out of the FEED Study Report. The overall preparation of the EJP will be by National Grid team.

## 6.14 Site description and current issues

### 6.14.1 Current Situation

Our assessment of the current condition of the site is based upon data and reports received from NG and the outputs from the site visit conducted 04/08/2021.

- NG Asset Health summary statement
- Bacton summary of work completed in schemes
- Consultant Summaries

Our assessment of equipment and other elements of the site is recorded in the following documents

- 20485-AI-RPT-100-0001 Existing Equipment Condition Assessments
- 20485-AI-RPT-100-0002 Drawing, Record and Report Condition Assessment Survey
- 20485-AI-RPT-100-0003_Work Statement Report

Current operations follow the site Operations Manual and maintenance follows practices and procedures initiated when National Grid was part of the nationalised industry the BGC.

The site must ensure compliance with the Regulations PSSR, PSR and COMAH. These regulations all require that the Operator maintains the pressure equipment and pipelines in a safe working condition and that the risks are understood and assessed so that they may be managed and mitigated effectively. The PSSR is the driving piece of legislation about maintaining the pressure containing systems in a safe condition. The requirements on the Operator are very specific. This specifically requires that all pressure containing systems, equipment and pressure safety devices have WSEs in place, with defined inspection frequencies. PSSR requires that the WSE is overseen by an experienced Competent Person who has the necessary knowledge and experience to be able to review the WSE, assess the results and refine the WSEs as required to ensure they remain in a safe condition. The Competent Person role can be undertaken by an organisation.
An effective WSE ensures that any signs of deterioration are identified and can be remedied before it becomes un-acceptable.

### 6.14.2 Future Situation

The current Bacton site and facilities are now beyond their design life. Extending operations to 2035 / 2050 will require work to the existing facilities. The make do and mend option is feasible and can be implemented in phases with the reduction in gas supplies to the terminal. There is opportunity to reduce O&M costs in line with the significant drop in gas supplies due in the mid 2030’s. Opportunities ahead of this date are limited.

The electrical I&C assessments upgrades are quite extensive. A lot of equipment will soon be obsolescent and require replacement. The status of the ESD and FGS systems should also be considered. The electrical assessments revealed failings in the existing equipment with signs of deterioration. Up-grades and replacements are necessary.

There is no automatic shutdown and venting system on the National Grid system/pipe work within the site boundary apart from the over pressure protection of incoming pipe work from the Delivery Facility Operator. Compliance with COMAH regulations is required. It is presumed a waiver or agreement with the regulators is in place. An assessment of any steps needed to ensure regulatory compliance is recommended for current future operations

The CP assessment showed that the existing system is operating at its limits and may not be protecting the buried pipework effectively. There is also evidence of stray currents which must be investigated and addressed as this is affecting the levels of protection to the buried pipework. The CP assessment identified that extensive up-grades will be necessary to the existing system if the buried pipework is to be protected adequately.

The site availability and reliability are dependent upon the integrity and operability of the valves. A number of these have functionality problems i.e. internal leakage, stem seals leakage, stuck in position. The layout of the site offers flexibility in operations and isolations. A limited number of valves are recommended for intervention and repair.

The mechanical integrity of the above ground pipework appears to be good and has been recently re-coated. The condition of the below ground pipework coating appears to be reasonably good for a facility as old as this. The CP surveys reported circa 20 DCVG defects in 2019, most of which were not sufficiently large to warrant excavation. Verbal evidence of recent pipe excavations indicated the coating was good. There was no evidence seen however of any pipe wall inspections to verify the internal and external condition of the pipe. Pipe wall inspections would provide assurance on the actual integrity of the pipe.

There have been failings in the integrity management in the past. The recent Asset Health Project has actively resolved several of the issues. While NG have WSEs for the pressure systems and good documented maintenance procedures these can only be effective if any identified failings or degradation are closed out.

## 6.15 Constraints

### 6.15.1 Single Point Failure

The most significant constraint on the development of options for the study has been a requirement not to introduce any single point of failure through the adoption of an option. For short list options this has been investigated via FPSA and other NG procedural reviews and recorded in the outputs from each workshop.

### 6.15.2 Terminal Capacity

Other key constraints relate to ensuring the capacity of the terminal meets the requirements for maximum flow. This has been discussed in detail with NG during the study and advice on the subject has been utilised. In summary the situation used in the study is as follows:
Since the Climate Change Committee is the statutory body for establishing binding Carbon Budgets, and its 6$^{th}$ Carbon Budget has appeared more recently than the scenarios and projections generated by NGG, a clarification was asked of NG concerning what impact the latest Carbon Budget will have on NGG's projections – and specifically on Bacton throughput projections.

The response was as follows:

The Carbon Budgets established by the Climate Change Committee sets out the national projections for the UK. For Bacton Terminal's projection the latest projections can be found in the figure below which shows the forecast flows at peak demands both for UK continental shelf (UKCS) and Interconnector (BBL+IUK) for peak conditions.
Using this information, it was agreed with NG that for the study planning purposes, a date of 2035 would be adopted to use as the date of SNS gas flows to Bacton ceasing and this date has been used in some of the option definitions.
Current Bacton Terminal capacity is up to a maximum of 160mscmd approximately comprising gas from the South North Sea (as delivered by Shell and Perenco) and gas from the Interconnectors which comes from Europe.

Gas from the SNS is declining and will cease sometime in the 2030's based on current predictions.

The change point for gas supply to Bacton is assumed to occur around 2035 noting that the date for the assumed significant reduction in SNS carries much uncertainty. The current date is derived from information shared by NG outlining their 2020 predictions for gas supplies to the terminal up to 2050. This data shows SNS gas rapidly declining in the 2030's and 2035 is an agreed date for this study when the limited SNS gas is taken to be zero at Bacton Terminal.

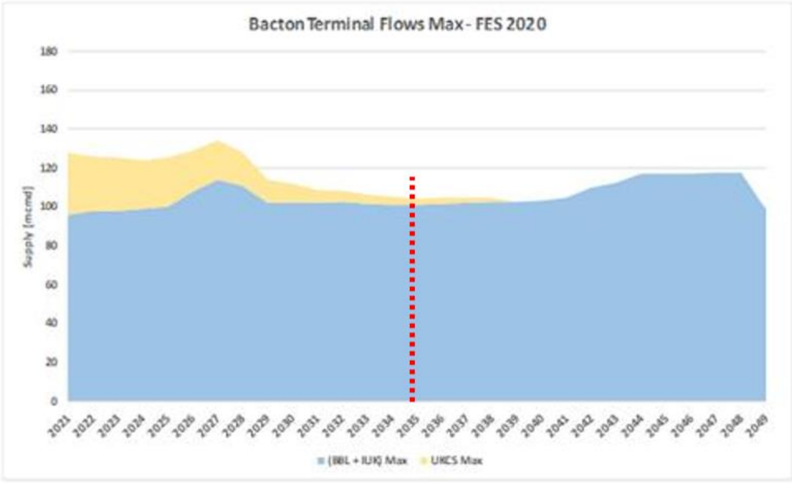



*Figure 1.0 shows the Bacton forecast flows at peak demands both for UK Continental shelf (UKCS) and Interconnector (BBL+IUK) for peak conditions with FES 2020 and FES 2018 forecasts*

**Figure 6-5 : Bacton – Future Gas Supplies (from NG)**

It is clear that Bacton Terminal will continue to experience high flows and remain as a critical entry point into the UK Gas Transmission system. Bacton terminal will need to maintain the capability of delivering 100-120 mcmd until 2050. It is worth noting that National Grid anticipate incoming supply from UKCS will taper to zero by 2038, however supply from the interconnectors are estimated to steadily increase. As the UK moves to decarbonisation and considers the possible use of hydrogen and other energy products, the context for this study considering the future shape of Bacton is a site

- that continues to be based on use of methane at levels to 2050 of around 75% of 2020 volumes,
- but based entirely on interconnector imports of gas from the continent

Based on this guidance the flow regime has been agreed as follows:

- 160 mscmd (max) 2021-2035
- 120 mscmd (max) 2035-2050

### 6.15.3 NG dialogue with System Operators

NGG has provided some information on the contractual arrangements at Bacton, and the balance of the impacts on future capacity requirements of

- the existing contractual arrangements,
- how the contractual arrangements will evolve in the light of decarbonisation, and
- revised post-Brexit security of supply requirements.

NGG advice is as follows:

- There are currently no changes to the existing contractual agreements at Bacton with the other terminal operators. The future energy scenarios provide a projection of the mix of supply flowing through Bacton which may influence the contractual agreements in the future.
- It is not possible to state how the contractual agreements may change in the light of decarbonisation. There are ideas under consideration to re-purpose Bacton for Hydrogen in the future. The primary objective of the study is to identify how the terminal can continue operations as a Gas Terminal accommodating for the flows set out in the Future Energy Scenario and should not preclude the option for hydrogen in the future.

- The FES projects that flows from both interconnectors significant in the next 30 years. It is likely that this will remain the case post-Brexit.

The System Operator's key requirements for Bacton Terminal include:

- To have potential asset solution enabling NGG requirement meet its Entry and Exit commitments at Bacton, with Obligated Entry capacity at Bacton terminal ~ 164 mcm/d (Future Energy Scenario(FES) forecast range is in between 138-107mcmd) and Obligated Exit capacity at Bacton ~60 mcm/d(FES forecast range is in between 70-40 mcmd) with minimal risk.
- Having the ability to meet the NTS South East Exit commitments (both assured pressures and pressure cover commitments) at the South East of the network along with maintaining the operational flexibility of the network. It is noted that this is currently provided by Bacton's ability to maximise feeder 3 and 5 pressures/flows.
- Having the terminal asset ability to manage the changing flows patterns and within day swings at Bacton terminal both coming in and going out of the National Transmission System, including Bacton IUK and BBL reverse flow requirements, along with the ability to meet the current ramp rate requirements as indicated in Bacton IUK contractual agreement.
- There is a requirement for process separation of individual suppliers as each has different processing capability to prevent unwanted process interactions such as back flows, issues of liquids coming into our network and potentially going out into key demand points like IUK.
- Bacton offtake and Great Yarmouth need to continue with their individual connections at Bacton terminal with an Exit capability [redacted] (based on the obligated baseline and the expectation of the site flow beyond 2040).
- Consideration given to the efficiency of Network Operations – the ability to efficiently transport gas via feeder 3 and 5 from Bacton terminal to the Southern part of the network - as this is a more operationally cost-effective route in comparison to routing it via Kings Lynn, Peterborough, Huntingdon and Cambridge.

To the extent that the option idea, study scope and battery limits permit, the above issues have been included in the study as constraints or influencing factors in the development of long list ideas and the definition of short list ideas.

# 7. PHASE 1 WORK

## 7.1 Overview

The development and definition of options that respond to the study objectives and constraints is the key focus of the project. As outlined in the project specific scope of work and methodology above, a wide ranging consideration of ideas in the phase 1 work was critical to demonstrate a response to the project specific scope of work to generate various responses to safeguard Bacton future operations against a backdrop of rapidly changing energy landscape in the UK.

The  requirements of the service included a need to identify ideas that secure future operations of Bacton Gas Terminal and then to carry out robust option selection supported by qualitative and quantitative data. The methodology and approach for both the long and short list workshops conformed to these requirements

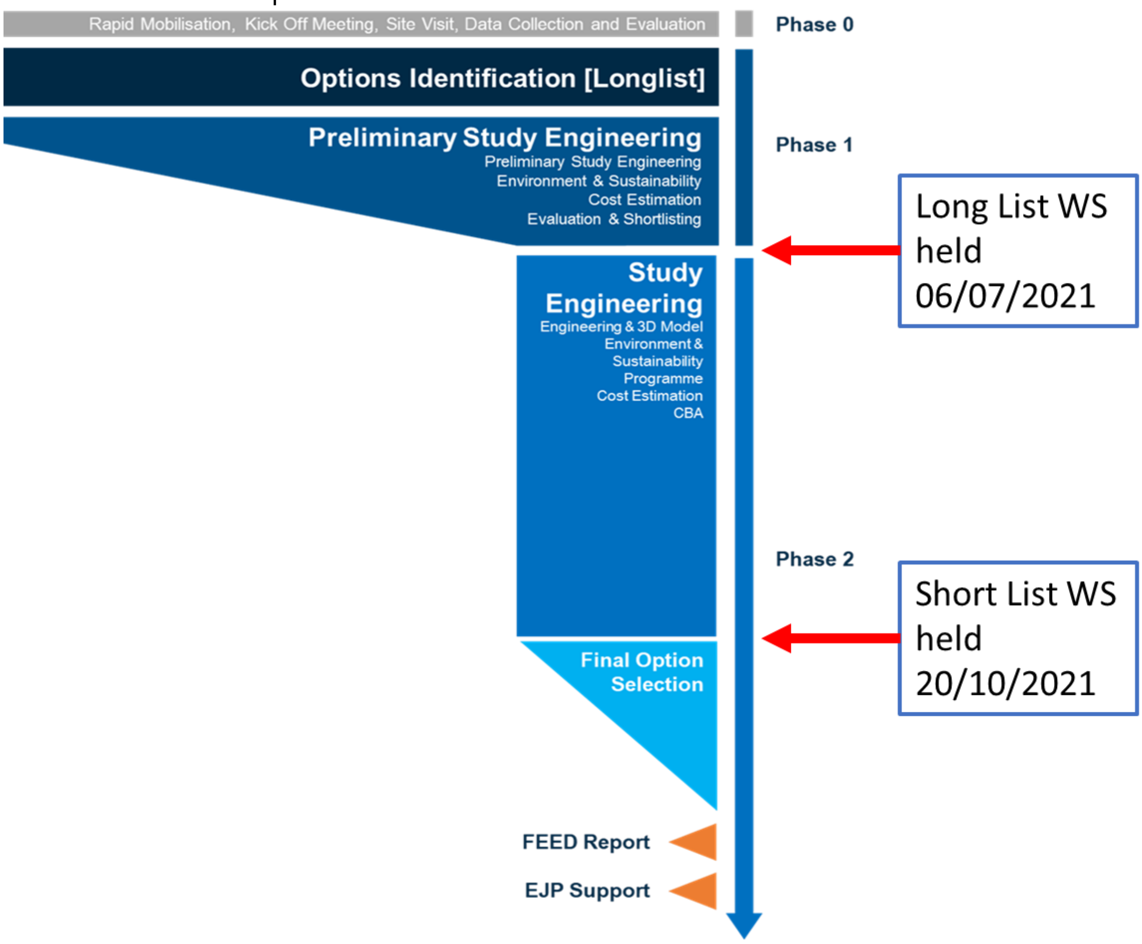



**Figure 7-1: Overall study methodology**

The long listing developed 26 ideas in outline and the identified five ideas for the short list which were then developed in considerable detail. The detailed information on these ideas is provided in the appendices and summarised in the next sections.

## 7.2 Long List

Phase 1 of the study was to develop responses to the project objectives. This work proceeded with the team developing ideas individually and as teams with periodic meetings to review progress, critique and improve ideas. The ideas were developed in May-June and a review workshop with the client held 06/07/2021.
In line with the NG study guidance the parameters framing the option development were to develop ideas that responded to one or more of the following:

- Rationalise volume of assets

- Simplify terminal operation
- Reduce OPEX
- Bacton future operations conform to 2050 net zero carbon emissions strategy
- Brownfield/greenfield site location (including planning requirements)
- Local/remote control of future Terminal Assets
- Consideration of potential future customer operating requirements
- Consideration of electrical feeder connection or substation requirements
- Decommissioning / Demolition / Re-use of existing assets
- Reduction in site gas inventory (reduced COMAH classification)
- Provision to allow internal inspection of pipework
- Hydrogen compatible plant design
- Physical options to facilitate gas blending to facilitate non-GSMR gas in line with project Neptune
- Carbon neutral construction
- Interconnector and BBL ramp rate option for 40mcmd/min.
- Cost Benefit Analysis for segregation of the Cadent MOC with independent access

## 7.3 Long List Options Workshop 06/07/2021

Out of the phase 1 work, 26 ideas were developed in the period up to the Long List Workshop held 06/07/2021. The full record of these ideas is provided in the appendices and a summary presented below.

A diverse mixed team from the Consultant and NG attended remotely for the workshop. The list of attendees is given in Appendix xx which provides a record of the workshop and outcomes. The intervention designed for the workshop to deliver the evaluation of the long list ideas is illustrated in the next figure.

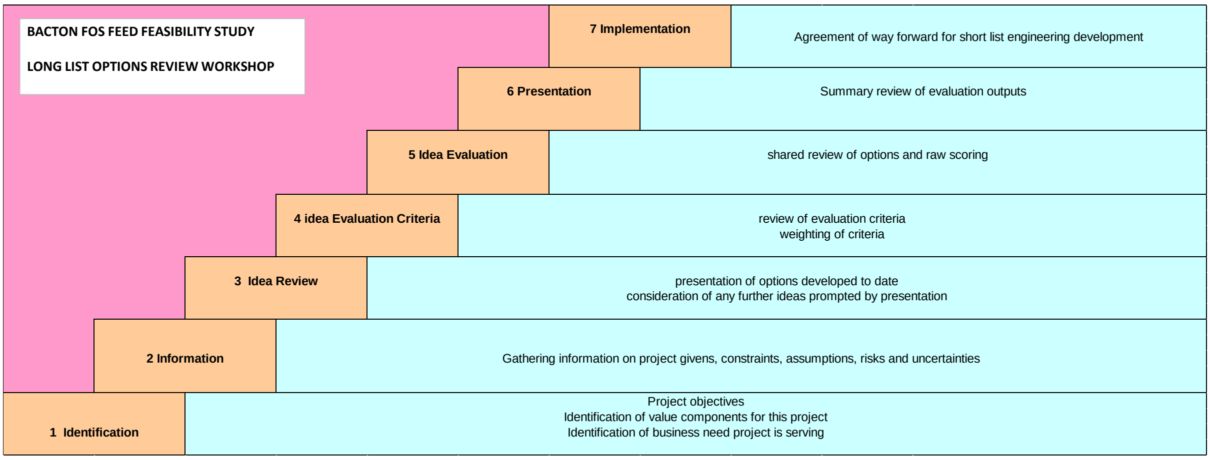



**Figure 7-2: Workshop Workplan**

### 7.3.1 Identification Phase

#### 7.3.1.1 Project Uncertainty

As part of the framing for the workshop, the subject of uncertainty was discussed, and a collective view taken on where this project sits with respect to external and internal uncertainties. The agreed view was that this project currently has a higher degree of external uncertainty compared to internal and is shown in the figure in green.

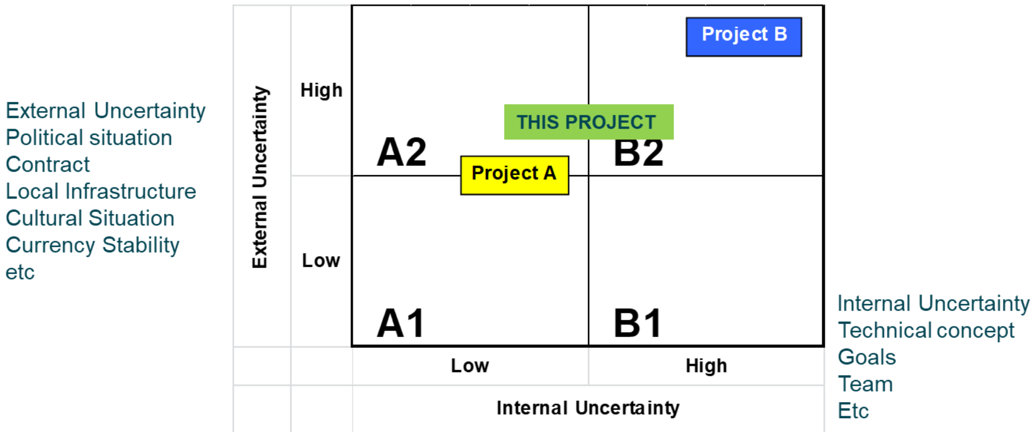



**Figure 7-3: Assessment of project uncertainty**

#### 7.3.1.2 Key Success Factors

Key Success Factors for the Bacton FOS project were discussed in the workshop and the following is the agreed list.

- **Spend exact amount budgeted from OFGEM**
- **Option shouldn't constrain terminal in any way or introduce a single point failure**
- **The investment should produce no regrets**
- **Reducing gas inventory within terminal**
- **Assets reduced whilst meeting functionality; ensuring reliability**
- **Asset health – appropriate intervention program; right level of maintenance and limited defects; acceptable level of risk with assets;**
- **Full life extension study? To confirm future investments and life of assets; success measured by assets in good condition, low level of defects**
- **Hitting forecast OPEX budgets by 2050 and acceptable level of defects**
- **Optimising existing assets – achieving good functionality for spend**
- **In 15 year's time, little or no regret actions due to lack of foresight e.g. space or flexibility**

**Figure 7-4: Key Success Factors for Bacton FOS at Long List Workshop**

#### 7.3.1.3 Risks and Constraints

Risks have been considered as follows:

- Long list ideas have had risk considered as part of the initial idea assessment and evaluation, noting that during phase 1 ideas were developed only to a high-level concept and this also applies to the consideration of risk. Risk was one of several factors influencing their rejection or retention at the phase 1 workshop.

Some of the issues constraining option ideas included consideration of the following:

- Terminal Current Condition - Age related asset health and obsolescence issues

- Future Supplies and Demands - Changing supply and demand patterns and the vital role Bacton plays currently for energy supplies to the south east and London
- Brownfield Terminal - Working terminal and construction related issues
- New Build Terminal – issues concerning consents and planning permission

### 7.3.2 Information Phase

As part of the information phase, presentations on key environmental and sustainability issues affecting option development were given.

#### 7.3.2.1 Environmental

Environmental criteria have been developed based on Environmental Characteristics as defined under the EIA Regulations 2017 and mainly based on environmental constraints. The aim is not to overlap with other criteria, e.g. Socio-Economic / Economic Case and Environmental / Sustainability.
Assessment will be split into three categories:

- Planning;
- Ecology/Biodiversity (given importance biodiversity not just to NG GRI reporting but also the key receptor that could be affected by this development);
- Other Environmental Impacts.

Criteria are risk based – the risk of a significant development cost or risk to programme. The following figures show main environmental designations affecting Bacton Site.

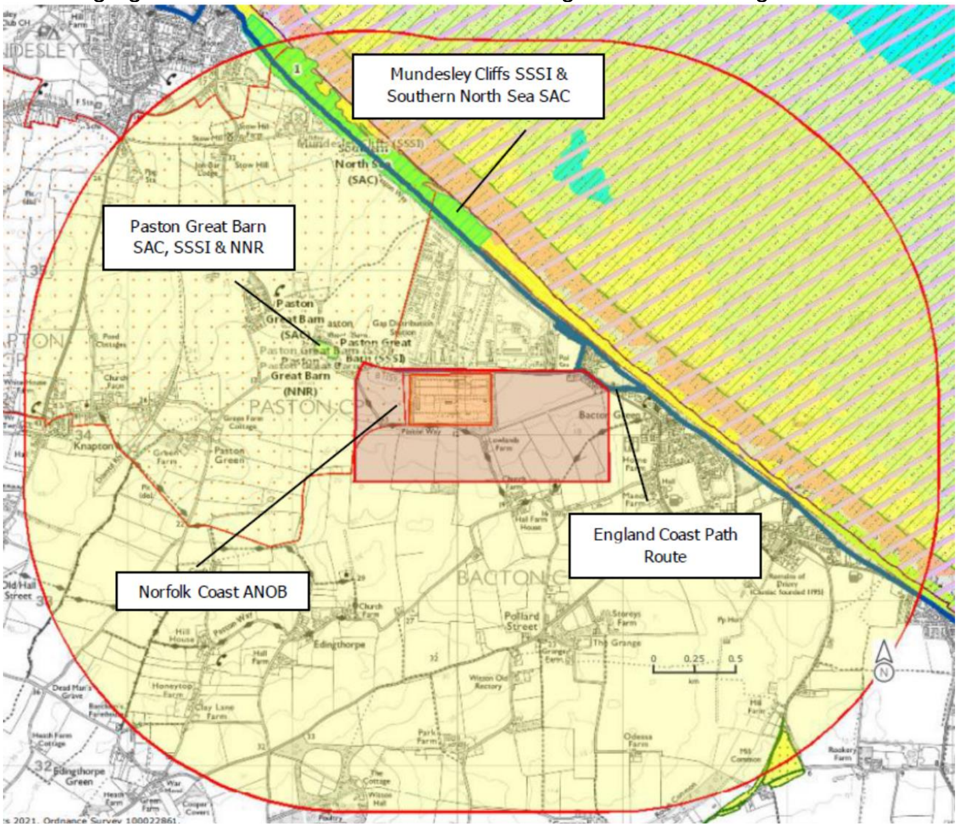



**Figure 7-5: Environmental constraints – designations within 2km buffer**

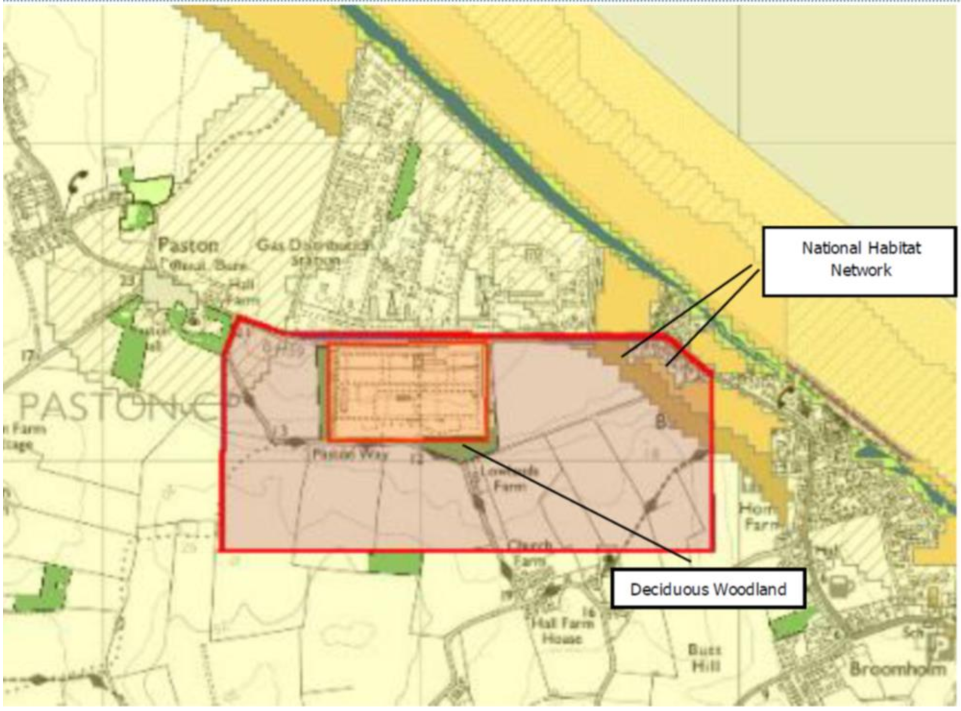



**Figure 7-6: Environmental Constraints – Key Habitats**

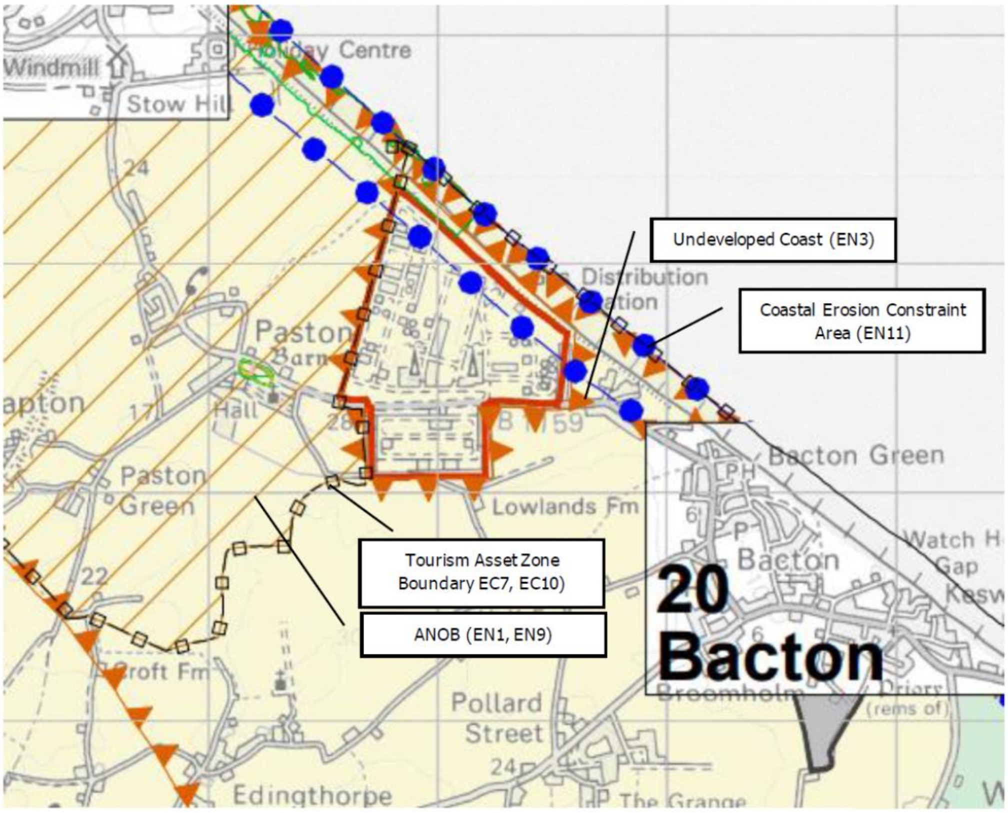



**Figure 7-7: Environmental Constraints – Local Plan**

Environmental impacts will depend on:

- Where any new development is located:
    - existing site
    - Brownfield site (north of Paston Road)

    - Greenfield development

- The size and scale of any new development:
    - Likely emissions (air, noise, waste)
    - Traffic movements required

Some impacts are contradictory to others, e.g. major works causing a significant environmental impact will also generate the most jobs in construction and operation.
The key environmental parameters are as follows:

| Location Based | Impact based |
|---|---|
| **Planning** | **Biodiversity** |
| Agriculture | Air Quality |
| Coastal Erosion | Noise |
| Cultural Heritage | Transportation |
| Landscape and Visual | Waste |
| Land Use (Contamination) | Construction Impacts |

| Antithetical Impacts | |
|---|---|
| Socio-Economics | Land Use (Contamination) |

**Figure 7-8: Key Environmental Parameters**

Some impacts are contradictory to others, e.g. major works causing a significant environmental impact will also generate the most jobs in construction and operation. Each criterion has a background to it, founded on environmental legal requirements.
Green indicates where there is no impact or should the option result in a potential small impact. Orange are small increases to costs/programme or minor risk; red is issues of major cost/programme or risk. Planning has been separated into 2 categories:

- Under the control of NG;
- Required to be delivered by a third party but causes a significant risk to NG if that planning permission is not granted.

| | | | |
|---|---|---|---|
| Planning | 1 (best) | Proposal requires no new construction works, or includes decommissioning works only | |
| | 2 | Development within parameters of existing planning consent (no planning application/permitted development) | |
| | 3 | Development within existing site, outside existing planning parameters (Town and Country Planning Act 1990 Application)<br>• Non-EIA Development<br>Development on brownfield site (T&CPA)<br>• Non-EIA Development | |
| | 4 | Minor extension onto greenfield site (T&CPA)<br>• Non-EIA Development | |
| | 5 | Development **within** existing site, outside existing planning parameters (Town and Country Planning Act 1990 Application)<br>• EIA Development<br>Development on brownfield site (T&CPA)<br>• EIA Development | |
| | 6 | Minor extension onto greenfield site (T&CPA)<br>• EIA Development | |
| | 7 (worst) | Major works on greenfield or brownfield site – Nationally Significant Infrastructure Project (Planning Act 2008)<br>• EIA Required | |

**Figure 7-9: Environmental Impacts**

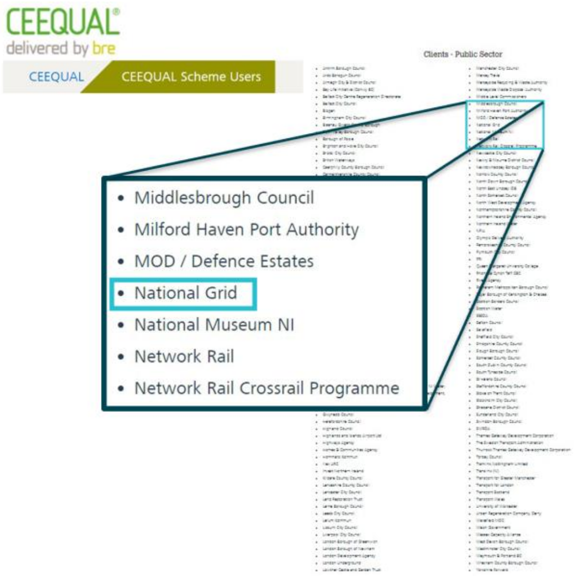
| [redacted] | Option Title | Planning Risk (National Grid) | Planning Risk (Third Party) | RANKING | Ecology / Biodiversity | RANKING | Agriculture | Air Quality | Coastal Erosion | Cultural Heritage | Landscape and Visual | Land Use (Contamination) | Noise | Transportation | Waste | Construction Impacts | Socio-Economics | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bacton Blue H2 Production | | | =3 | | =2 | | | | | | | | | | | | 5 |
| 2 | Make do and Mend | | | =1 | | =1 | | | | | | | | | | | | 1 |
| 3 | "Minor Reconfigure and reduce" inventory | | | =2 | | =1 | | | | | | | | | | | | 2 |
| 4 | Major Reconfigure and reduce" inventory | | | =1 | | =2 | | | | | | | | | | | | 2 |
| 5 | Nominate H2 blend feeders | | | | | | | | | | | | | | | | | |
| 6 | Import H2 or Blends | | | | | | | | | | | | | | | | | |
| 7 | Relocate IUK facilities | | | =6 | | =2 | | | | | | | | | | | | 3 |
| 8 | New Site | | | =4 | | =3 | | | | | | | | | | | | 10 |
| 9 | Electricity Generation | | | =5 | | =2 | | | | | | | | | | | | 4 |
| 10 | Bacton Green H2 Production | | | =5 | | =3 | | | | | | | | | | | | 6 |
| 11 | Offshore (Gas Platform) Green H2 Production | | | =5 | | =3 | | | | | | | | | | | | 7 |
| 12 | Offshore (Wind Sub-Station / Dedicated Platform) Green H2 Production | | | =5 | | =3 | | | | | | | | | | | | 7 |
| 13 | Marine Import of H2 | | | =5 | | =3 | | | | | | | | | | | | 8 |
| 14 | Local Green H2 Production & Blending | | | =5 | | =3 | | | | | | | | | | | | 8 |
| 15 | H2 Import from other UK Cluster, Route via Bacton to SE Feeders | | | =1 | | =2 | | | | | | | | | | | | 2 |
| 16 | Reduce Bacton and Locate H2 to Another Site (SE / London) | | | =1 | | =2 | | | | | | | | | | | | 1 |
| 17 | Gas Monetisation_option 1 | | | =5 | | =3 | | | | | | | | | | | | 9 |
| 18 | Gas Monetisation_option 2 | | | =5 | | =3 | | | | | | | | | | | | 9 |
| 19 | Gas Monetisation_option 3 | | | =5 | | =3 | | | | | | | | | | | | 9 |
| 20 | Make do and Mend - AI Review | | | =1 | | =1 | | | | | | | | | | | | 1 |

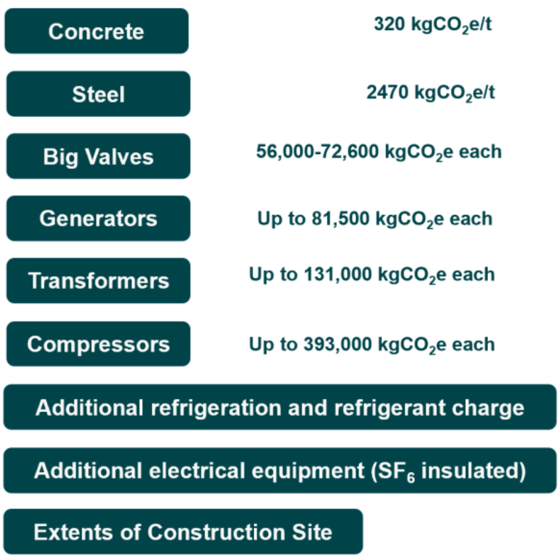
**Figure 7-10: Long List Assessment of Options against Environmental factors**

### 7.3.2.2 Sustainability

Bacton FOS forms part of wider long-term sustainability strategy for National Grid (Economic, Environmental, Social) and the UK (Energy Security and Decarbonisation). Site Sustainability is not a differentiator at this stage but starts the conversation. Tools for logging CapCarbon and more sustainable choices relate to Short-Listing resolution, not Long-Listing granularity.

Included at this stage to produce paper trail of consideration of sustainability issues from the earliest stages, should some form of certification for the works (e.g. CEEQUAL) be desirable later.



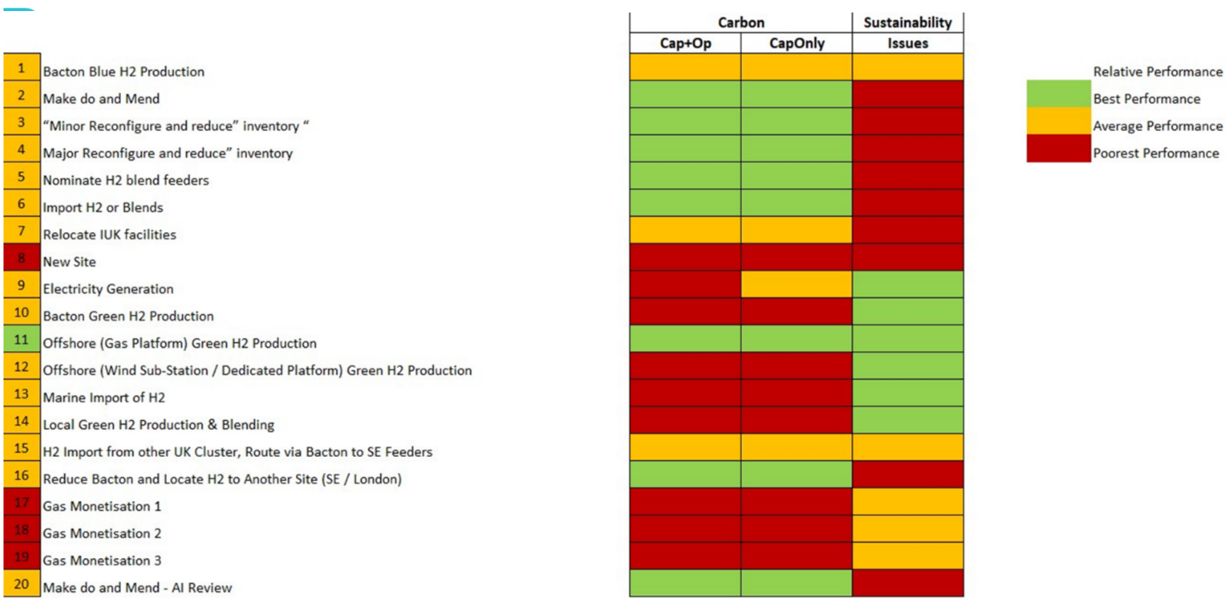




**Figure 7-11: Long List Sustainability Issues for Long List Options**

### 7.4 Idea Review

The foregoing combined with the constraints applied by the consideration of engineering issues shaped the development of the long list options. These were developed by individuals and small groups in response to the stated project parameters.

#### 7.4.1 Bacton Terminal - Existing Situation

The overall layout and configuration of Bacton Terminal is illustrated in the next figure

[redacted]

**Figure 7-12: Illustration of Bacton Terminal Key Elements**

Inlets to the site currently are from Shell and Perenco, bringing gas from the South North Sea. Positioned in the middle of the site, gas is received from the EU via the Interconnectors. From the mid 2030's as SNS gas ceases, interconnector gas will be the only remaining gas supply to the site up to 2050. The feeders on the south of the site connect Bacton into the UK NTS and supply London and a large part of the south-east network.

Our assessment of the current condition of the site is based upon data and reports received from NG and the outputs from the site visit conducted 04/08/2021.

- NG Asset Health summary statement
- Bacton summary of work completed in schemes
- Consultant Summaries

Our assessment of equipment and other elements of the site is recorded in the following documents

- 20485-AI-RPT-100-0001 Existing Equipment Condition Assessments
- 20485-AI-RPT-100-0002 Drawing, Record and Report Condition Assessment Survey
- Work Statement Reports by discipline (These are provided in the Appendices).

Current operations follow the site Operations Manual and maintenance follows practices and procedures initiated when National Grid was part of the nationalised industry the British Gas Corporation (BGC).

The site must ensure compliance with the Regulations PSSR, PSR and COMAH. These regulations all require that the Operator maintains the pressure equipment and pipelines in a safe working condition and that the risks are understood and assessed so that they may be managed and mitigated effectively. The PSSR is the driving piece of legislation about maintaining the pressure containing systems in a safe condition. The requirements on the Operator are very specific. This specifically requires that all pressure containing systems, equipment and pressure safety devices have Written Schemes of Examination (WSEs) in place, with defined inspection frequencies. PSSR requires that the WSE is overseen by an experienced Competent Person who has the necessary knowledge and experience to be able to review the WSE, assess the results and refine the WSEs as required to ensure they remain in a safe condition. The Competent Person role can be undertaken by an organisation. An effective WSE ensures that any signs of deterioration are identified and can be remedied before it becomes un-acceptable.

### 7.4.2 Long List Ideas

The broad families of ideas were grouped into three tiers of options developed in increasing detail. The top-level tier 1 is illustrated in the following figure which shows the main transitional routes considered for Bacton on its journey from 2021 to 2050.

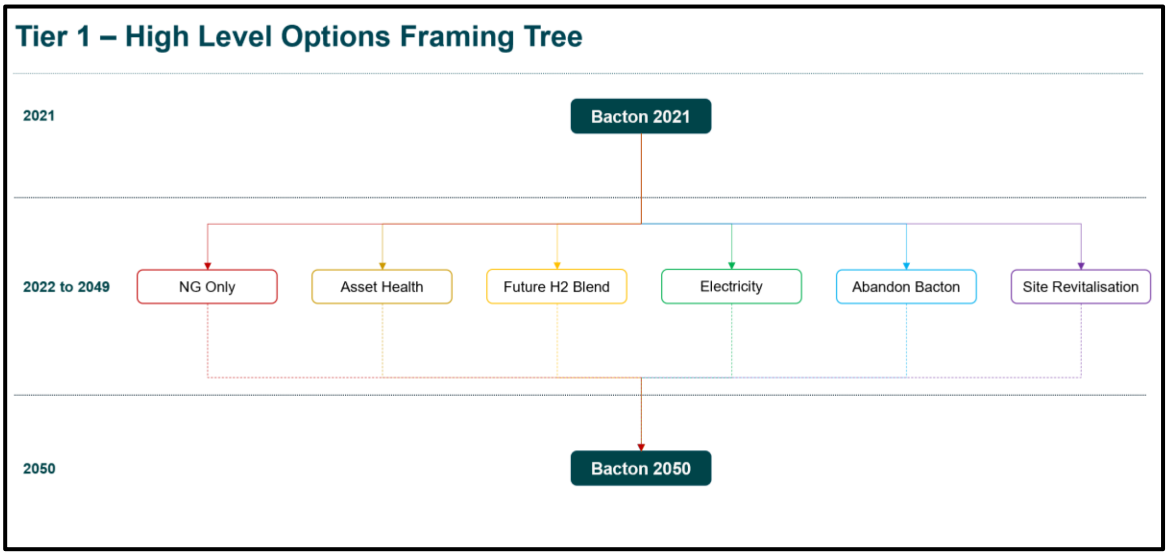



**Figure 7-13: Long List Options Framing Tree**

Options were developed that responded to the study input parameters set by NG, took account of the FES scenarios and other external influences and from this devised several appropriate responses, and grouped by the above themes, noting that many options cut across multiple themes.

Each option was developed in outline by the originator(s) and a summary pack made which lists the following items for each option :

- General information
- Description
    - Existing arrangements
    - Revised scheme
- High level advantages and disadvantages
- Justification
- Risks and opportunities
- Programme
- Cost Impact
- Proposal sketches

The packs as presented for the workshop are provided in Appendix A and a summary of the 26 option ideas is given in the table below

| [redacted] | Option No. | Option Title | High Level Summary | Option Family Trees |
|---|---|---|---|---|
| 1 | 3.3.A | Bacton Blue H2 Production | Ensuring asset health for NatGas until 2030+, installation of SMR / ATR unit with CCS in 2030, export of H2:NG blend thereafter up to 2050.<br>Use blue H2 for business case to unlock 2 Tcf of stranded gas reserves within the SNS.<br>Beyond 2050, replacement of blue H2 units and CCS with green H2 units as switch to 100% H2 export is made and NatGas supply ceases. | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only |
| 2 | DA/GB1 | Make do and Mend | Investigate maintenance and integrity records.<br>Develop integrity and repair strategy. Repair in situ.<br>Use pipework for H2 /and blends as is. Review in future for onset of hydrogen blend, for material suitability. Remove redundant pipework | Asset Health<br>Future H2 Blend<br>Natural Gas Only |
| 3 | DA/GB2 | Minor Reconfigure and reduce inventory | Investigate maintenance and integrity records.Review flow mixing, duplication filter meter and bypass requirements into future and remove assets not required as a COMAH reduction, leaving others as is. Construction done in situ, using hot tap and bypass arrangements Review in 2028 for onset of hydrogen blend, for material suitability. | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation |
| 4 | DA/GB3 | Major Reconfigure and reduce inventory | Review site flow mixing, duplication and bypass requirements into future. Calculate operating parameters for H2 (size, pressure, flow) Remove Perenco filter and divert to inlet of Shell incoming stream. Reconfigure site by putting all outgoing pipelines on a single mixing loop, supplied by incoming pipelines on a single manifold leaving BBL, Feeders 3,5,&27 as is, and moving 2&4. Reserve space for H2 generating facilities on site or include option for hydrogen injection, on new pipework. New pipework to be constructed in situ/ pre-constructed/or be built on gantries above existing, and tied in. Purchase new materials | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation |
| 5 | DA/GB 1A<br>DA/GB 2A<br>DA/GB 3A | Nominate H2 blend feeders | As per1, 2 and 3 but in future demarcate Bacton for supply of methane and blends to specific feeders, by valve isolation. H2 blend to London and methane to remainder to feeders 2,4,27, to alternative H2 generating site inland. Alternatively, keep producing methane for all feeders (except local supply) to new H2 production and blending | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation |
| 6 | DA/GB 1B<br>DA/GB 2B<br>DA/GB 3B | Import H2 or Blends | As per LL ideas DA/GB 1,2, & 3 plus but avoids the need for H2 generation entirely | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation |
| 7 | DA/GB 4 | Relocate IUK facilities | Any other idea combined with Remove IUK site, pipelines and associated pipework to redundant Phillips area across Paston road | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation |
| 8 | DA/GB5 | New Site | Build new site, specifically designed for purpose on adjacent site, or somewhere else. | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation<br>Abandon Bacton |
| 9 | DA/GB6 | Electricity Generation | Supply only 3&5 feeders for security of supply to south east and maybe 1 to midlands (2or4) Convert part site to electricity generation Either H2 or Blend or Methane only | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Electricity |
| 10 | 3.3.B | Bacton Green H2 Production | Ensuring asset health for NatGas until 2039, installation of electrolyser unit in 2030 to 2035, export of H2:NG blend thereafter up to 2050.<br>Transition to 100% H2 export by 2050 or before.<br>Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only. | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |
| 11 | 3.3.C.1 | Offshore (Gas Platform) Green H2 Production | Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only.<br>Re-purposing of redundant offshore platform and pipeline to green H2 production facility and import to Bacton.<br>Power cable from shore or from offshore wind sub-station nearby.<br>Installation of desalination facility on platform or re-use of existing small bore pipeline (i.e. methanol) to supply water for electrolysers.<br>Blend H2:NG up to 2045, thereafter 100% H2. | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |
| 12 | 3.3.C.2 | Offshore (Wind Sub-Station / Dedicated Platform) Green H2 Production | Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only.<br>Additional use of existing offshore wind sub-station or a new-build offshore wind sub-station (with H2 capacity) or dedicated platform near wind farm.<br>New export pipeline to shore or tie-in to existing pipeline (could use pipeline as line pack to store H2 in over supply events).<br>Installation of desalination facility on platform or re-use of existing small bore pipeline (i.e. methanol) to supply water for electrolysers (would require tie-in subsea or new build from onshore). | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |
| 13 | 3.3.D | Marine Import of H2 | Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only.<br>Installation of fixed offshore jetty platform (1 to 5 km of the coast from Bacton). Run new insulated pipeline from fixed jetty to shore.<br>Import of liquid H2 into terminal, store, and re-gas when required.<br>Blend H2:NG up to 2045, thereafter 100% H2. | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |

| [redacted] | Option No. | Option Title | High Level Summary | Option Family Trees |
|---|---|---|---|---|
| 14 | 3.3.E | Local Green H2 Production & Blending | Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only.<br>Undertake asset health works to ensure asset is still fit for purpose and safe for natural gas until 2039.<br>Build H2 electrolyser facilities local to point of utilisation by 2030 to 2035. Blend NatGas supply with produced hydrogen with switch to 100% H2 by 2045. | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |
| 15 | 3.3.F | H2 Import from other UK Cluster, Route via Bacton to SE Feeders | Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only.<br>Undertake asset health works to ensure asset is still fit for purpose and safe for natural gas until 2039.<br>Route new pipeline or re-use of existing feeder to supply H2 (i.e. ZCH, NZT, Acorn, HyNet) to Bacton by 2035.<br>Blend H2 with NatGas initially at Bacton, transition to 100% H2 by | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |
| 16 | 3.3.G | Reduce Bacton and Locate H2 to Another Site (SE / London) | Continue to produce gas into Bacton until SNS CoP in 2039, thereafter adjust site to Interconnector gas landing point only until 2050.<br>Undertake asset health works to ensure asset is still fit for purpose and safe for natural gas until 2050.<br>Build new H2 facility closer to London / SE, expand on existing facility (i.e. Isle of Grain), or create additional capacity at another H2 cluster such as Southampton or ZCH. | Asset Health<br>Site Revitalisation<br>Future H2 Blend<br>Natural Gas Only<br>Abandon Bacton |
| 17 | X.X.1 | Gas Monetisation_option 1: Separation of feed gas into C2- (for NTS export) and C3+ to recover NGL / LPG | Based on feed gas compositional analysis, segregate rich gas and lean gas stream at feeder entry points to NG site; employ a turbo-expander or mechanical refrigeration based NGL recovery technology (multiple licensed technologies available) to separate C2- and C3+ streams. C2- stream is re-compressed to required outlet presssure and C3+ can be exported as NGLs for further NGL fractionation at gas treatment / refining plants or export as LPG (based on feed gas quality). The NGL plant is assumed to be located at the abandoned ENI site (plot space TBC) or over the adjacent site (subject to availability).<br>Number of NGL recovery trains of will be a function of rich gas quality and the projected demand for NG between 2025 - 2050, which is assumed to drop to adopt to the Balance Net Zero Pathway scenario generated by Climate Change Committee post 2030. | BNZP adoption<br>Gas Monetisation<br>Greenfield development |
| 18 | X.X.2 | Gas Monetisation_option 2: Separation of feed gas into C1 (for NTS export) and C2+ to produce petrochemical derivatives (Subject to rich gas quality check) | Based on feed gas compositional analysis, employ gas separation by mechanical refrigeration technology (multiple licensed technologies available) to separate methane and C2+ streams. Methane is is re-compressed to required outlet presssure for NTS export and C2+ stream is sent to an onsite gas Steam Cracker to produce petrochemical derivatives e.g. Ethylene and Propylene for export via sea route. The Steam Cracker plant assumed to be located at the abandoned ENI site (plot space TBC) or developed over the adjacent site (subject to availability). Hydrogen and C5+ are byproducts of the Steam Cracker plant, which may be used for local power generation or blended into the methane for NTS export.<br>The number of steam cracker furrnaces will be a function of gradually higher availability of natural gas due to adoption of Balance Net Zero | BNZP adoption<br>Gas Monetisation<br>Greenfield development |
| 19 | X.X.3 | Gas Monetisation_option 3: Adoption of BNZP scenario post 2025 to produce Hydrogen through Syngas route for NG blending and clean power generation onsite | Hydrogen production through Syngas route (Reforming of methane to convert natural gas into synthesis gas, via catalytic processes based on dry reforming of methane (DRM), steam reforming of methane (SRM), partial oxidation of methane (POM) or tri-reforming of methane (TRM) technologies) as the projected demand for NG drops to adopt to the Balance Net Zero Pathway scenario generated by Climate Change Committee post 2030.<br>Hydrogen produced is used for blending into NG for NTS export and for local clean power generation. The Syngas plant and gas turbine(s) assumed to be located at the abandoned ENI site (plot space TBC) or over the adjacent site (subject to availability). | BNZP adoption<br>Gas Monetisation<br>Greenfield development |
| 20 | DA/GB1 + MB (AI) input | Make do and Mend - AI Review | Site maintenance is to "MAINT6" this should be reviewed to ensure this remains the most cost-effective maintenance strategy. There is now a significant history of site condition, faults and degradation rates. Costs for maintenance should be targeted to maximise value.<br>Inspection is carried out to a Written Scheme of Examination as required by the Pressure Systems Safety Regulations. The PSSR require regular Audits and the scope and frequency of the WSOE inspections should be subject to critical audit and update if justified. The audit, as for maintenance activities, should take account of pressure component condition, faults found and records of degradation. Records of repairs and replacements would form an input to the process.<br>Components / procedures to review include: Pipelines (OLI1 and OLI4); Heat Exchangers (e.g. ES/14/01); Ball Valves (ES/96/29.1); Filters (ES/94/15.1 and ES/94/15.2); pigtraps, pipework etc. | Asset Health<br>Future H2 Blend<br>Natural Gas Only |

| [redacted] | Option No. | Option Title | High Level Summary | Option Family Trees |
|---|---|---|---|---|
| 21 | - | Integrated Remote Terminal Site Operations & Control | To integrate and remotely operate all terminals standalone systems into a common control room with dedicated control centre HMI for each terminal management . The envisaged remote control shall be integrated with the field through :<br>RTU/SCADA<br>Or through IOT ( Utilizing latest smart instrumentation capability and advanced connectivity options.<br>The integrated remote terminal control room shall deploy advanced software and hardware configurations and set up to allow for stream lined individual operability of each terminal independently inline with the existing operations philosophy of each terminal.<br><br>Note : The option can be extended to include all remaining 5 terminals | Site Revitalisation |
| 22 | - | Integrated & Automated ESD System and Functional Safety Management | To automate all terminal individual ESD systems and/or automate and integrate all ESD requirements and philosophies into one Integrated ESD system for all 5 terminals managed from a centralized control room.<br>EC61508/11 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES). Is established to address functional safety issued pertaining Electrical/Electronic/Programmable Electronic Safety-related Systems .<br>The reliance on human intervention to achieve safety requirements in the facility not only invalidates the intent of the governing standard but also introduces further layers of risk that impact in the overall SIL rating of the safety function.<br>Part of the functional safety life cycle is for owner to have a comprehensive functional management system in place . This entails (documentation , assessments , testing ..etc. ) The automated & integrated ESD system shall be developed with functional safety management in place. | Site Revitalisation |
| 23 | - | (Advanced Process Control ( Predictive Control Algorithms ) | To implement advance process control on top of the basic process control layer. The advanced process control layer shall reside in the proposed Bacton integrated terminal control systems . The proposed Advanced Process Control (APC) provides higher level of computational capability resulting in optimization of the entire terminal process.<br>Note : The option can be extended to include all remaining 5 terminals | Site Revitalisation |
| 24 | - | (Integrated Asset Management System (AMS) | To equip the facilities with an Assets Management System (AMS) . This option can be implemented in any of the below scenario.<br>As an individual system for each terminal<br>As an integrated system for all 5 terminals<br>Introducing and asset management system enables the client to monitor the overall asset life cycle , proactively identify and manage risks , manage assets , reduce maintenance costs ..etc | Site Revitalisation |
| 25 | - | Capitalizing on Internet of Things (IOT) | Capitalize on the evolving trend of IOT and smart instrumentation at site . Adopting IOT can be incorporated in many forms :<br>-Smart algorithms Improving diagnostics and maintenance .<br>-Robots , drones & Wearables<br>-Data crunching & remote trouble shooting<br>-Smart Connectivity<br>-Cyber Secuirty | Site Revitalisation |
| 26 | - | Integrated Fire & Gas System | Perform a 3D FGS mapping model for entire site and establish the existing detector coverage and existing gaps for improvement.<br>Adopt an Integrated FGS concept by integrating fire detectors, fire alarm panels, fire suppression systems, gas detectors, sounders, beacons and other fire safety systems into1 common integrated system<br>. | Site Revitalisation |

**Table 7-1 : Long List Options**

## 7.5 Evaluation Phase

The planned evaluation involved a two-stage process as follows:

1) First cut to remove *prima facie* unacceptable and unsuitable ideas
2) Second cut formal evaluation using multiple criteria

In the event the first cut review led by NG removed most of the ideas to leave the following short list:

| [redacted] | Option No. | Option Title | High Level Summary | Option Family Trees | Option Lead | Option Team Members | ISBL Ranking | keep/no ke | Post WS definitional Requirements |
|---|---|---|---|---|---|---|---|---|---|
| 4 | DA/GB3 | Major Reconfigure and reduce inventory | Review site flow mixing, duplication and bypass requirements into future. Calculate operating parameters for H2 (size, pressure, flow) Remove Perenco filter and divert to inlet of Shell incoming stream. Reconfigure site by putting all outgoing pipelines on a single mixing loop, supplied by incoming pipelines on a single manifold leaving BBL, Feeders 3,5,&27 as is, and moving 2&4. Reserve space for H2 generating facilities on site or include option for hydrogen injection, on new pipework. New pipework to be constructed in situ/ pre-constructed/or be built on gantries above existing, and tied in. Purchase new materials for future hydrogen blend | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation | David Abbs | Graham Brooks<br>Steve Osmond | 1 - Confined to NGG Bacton Limits | keep | thorough assessement of minimum required assets for routing and mixing gas: incude asset integrity of option 20 as part of this analysis; include other areas of redundant plant eg boiler houses, odourant tank etc which may free up land in addtion to ENI site; land could be useful to this option for if land is required; consider reconfig or new control building; consider venting options for any freed up land |
| 5 | DA/GB 1A<br>DA/GB 2A<br>DA/GB 3A | Nominate H2 blend feeders | As per1, 2 and 3 but in future demarcate Bacton for supply of methane and blends to specific feeders, by valve isolation. H2 blend to London and methane to remainder to feeders 2,4,27, to alternative H2 generating site inland. Alternatively, keep producing methane for all feeders (except local supply) to new H2 production and blending facilities elsewhere. | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation | David Abbs | Graham Brooks<br>Steve Osmond | 1 - Confined to NGG Bacton Limits | keep | engineer what is needed for H2 facility and cost of same as e/o on option 4 |
| 8 | DA/GB5 | New Site | Build new site, specifically designed for purpose on adjacent site, or somewhere else. | Asset Health<br>Future H2 Blend<br>Natural Gas Only<br>Site Revitalisation<br>Abandon Bacton | David Abbs | Graham Brooks<br>Steve Osmond | 3 - Primarily Focussed on OSBL Aspects | keep | optmised new site suitable for 100-120mcmd; methane only site; check for plot size, cost / benefits of H2 flexibility; size of incomers from shell and perenco for 2030 flows; either no venting or flaring or minimum |
| 8A | | brownfield development | within current boundary on NG land, either Bacton site or ENI site; ELD mxiing of gases; compare against existing pipelines etc | | | | | | brownfield has e.g. 75% new assets integrated with e.g. 25% existing assets; will it still fit? |
| 20 | DA/GB1 + MB (AI) input | Make do and Mend - AI Review | Site maintenance is to "MAINT6" this should be reviewed to ensure this remains the most cost-effective maintenance strategy. There is now a significant history of site condition, faults and degradation rates. Costs for maintenance should be targeted to maximise value.<br>Inspection is carried out to a Written Scheme of Examination as required by the Pressure Systems Safety Regulations. The PSSR require regular Audits and the scope and frequency of the WSOE inspections should be subject to critical audit and update if justified. The audit, as for maintenance activities, should take account of pressure component condition, faults found and records of degradation. Records of repairs and replacements would form an input to the process.<br>Components / procedures to review include: Pipelines (OLI1 and OLI4); Heat Exchangers (e.g. ES/14/01); Ball Valves (ES/96/29.1); Filters (ES/94/15.1 and ES/94/15.2); pigtraps, pipework etc. | Asset Health<br>Future H2 Blend<br>Natural Gas Only | Mike Brown | Steve Osmond<br>Graham Brooks<br>David Abbs | 1 - Confined to NGG Bacton Limits | keep | option 4 to include aspects of this option; control rooms are old; are rooms ok for continued future use; roads too; external fence; internal sites demarcation; getting car park outside |
| 21 | - | Integrated Remote Terminal Site Operations & Control | To integrate and remotely operate all terminals standalone systems into a common control room with dedicated control centre HMI for each terminal management . The envisaged remote control shall be integrated with the field through :<br>RTU/SCADA<br>Or through IOT ( Utilizing latest smart instrumentation capability and advanced connectivity options.<br>The integrated remote terminal control room shall deploy advanced software and hardware configurations and set up to allow for stream lined individual operability of each terminal independently inline with the existing operations philosophy of each terminal.<br>Note : The option can be extended to include all remaining 5 terminals | Site Revitalisation | Amir Konda | Steve Osmond | 1 - Confined to NGG Bacton Limits | keep | |
| 22 | - | Integrated & Automated ESD System and Functional Safety Management | To automate all terminal individual ESD systems and/or automate and integrate all ESD requirements and philosophies into one Integrated ESD system for all 5 terminals managed from a centralized control room.<br>EC61508/11 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES). Is established to address functional safety issued pertaining Electrical/Electronic/Programmable Electronic Safety-related Systems . The reliance on human intervention to achieve safety requirements in the facility not only invalidates the intent of the governing standard but also introduces further layers of risk that impact in the overall SIL rating of the safety function.<br>Part of the functional safety life cycle is for owner to have a comprehensive functional management system in place . This entails (documentation , assessments , testing ..etc. )<br>The automated & integrated ESD system shall be developed with functional safety management in place.<br>Note : The option can be extended to include all remaining 5 terminals | Site Revitalisation | Amir Konda | Steve Osmond | 1 - Confined to NGG Bacton Limits | keep | |
| 23 | - | (Advanced Process Control ( Predictive Control Algorithms ) | To implement advance process control on top of the basic process control layer. The advanced process control layer shall reside in the proposed Bacton integrated terminal control systems . The proposed Advanced Process Control (APC) provides higher level of computational capability resulting in optimization of the entire terminal process.<br>Note : The option can be extended to include all remaining 5 terminals | Site Revitalisation | Amir Konda | Steve Osmond | 1 - Confined to NGG Bacton Limits | keep | |
| 24 | - | (Integrated Asset Management System (AMS) | To equip the facilities with an Assets Management System (AMS) . This option can be implemented in any of the below scenario.<br>As an individual system for each terminal<br>As an integrated system for all 5 terminals<br>Introducing and asset management system enables the client to monitor the overall asset life cycle , proactively identify and manage risks , manage assets , reduce maintenance costs ..etc | Site Revitalisation | Amir Konda | Steve Osmond | 1 - Confined to NGG Bacton Limits | keep | |

**Table 7-2 : Long List Options – Post Evaluation**

The Long List Phase 1 outputs focus were on

- the role of Bacton Terminal continuing as a methane terminal
- defining a least cost option

- ideas that kept within the existing site boundary
- ideas that dealt with current and future foreseeable problems
- some additional ideas arising from the creative process that promised functional and efficiency improvements to the site by new instrumentation and control architecture

### 7.6 Post Workshop Definition

The workshop outputs arising from the outlines prepared for the Long List needed several meetings and discussions with NG to define with more precision the details of each idea prior to phase 2 work commencing. This occurred in the period 06/07/2021 – 05/08/2021.

The final definitional scope of work is given in Appendix A and the summary table of the short list options shown below.

| Core methane option | Core methane option variant | Applicable time period reflecting site maximum gas flows |
|---|---|---|
| **1**<br>Make do and mend | | **1.1**<br>2021-2035 (site capacity up to 160 mscmd)<br>**1.2**<br>2035-2050 (site capacity up to 120 mscmd) |
| **2**<br>Major rationalisation & reduce inventory | | 2035-2050<br>(site capacity up to 120mscmd) |
| **3**<br>New build (above ground, modular build, minimal reuse of assets) | **3.1**<br>Fits within existing site | |
| | **3.2**<br>Requires site extension / offsite development | |

**Table 7-3 : Study Short List Options**

In this table it should be noted that Option 1.1 covering the period 2021-2035 is common to all options.

The consideration of instrumentation and control improvements were agreed as applicable to any of the options.

The short list was finalised 05/08/2021 with NG and this enabled the Phase 2 work to commence which was focussed on defining each of the options to an engineering level whereby the environmental, sustainability, costs and cost benefits for each would be clearly discerned to a level commensurate with the specifications and sufficient to enable the short list evaluation to be conducted.

# 8. PHASE 2 WORK

## 8.1 Overview

The agreement of the final scope for the short list options on 05/08/2021, enabled the main engineering with associated activities for environment, sustainability, cost estimation and CBA work to begin. The definitional work for conceptual engineering permitted the assessment of key environmental and sustainability issues for each option to be investigated. The quantification of the FEED feasibility design in terms of material quantities, excavation estimates etc allowed the cost estimate work to progress. In parallel, indicative quotations for some of the key long lead items of equipment were sought from suppliers. Cost estimates and calculations for carbon were then used within the CBA analysis. For the latter it should be noted that the format was prescribed by OFGEM and issued as part of the ITT for this study project.

The short list options are commented upon under the following headings concerning the work carried out in Phase 2:

- Engineering
- Cost Estimation
- Environmental
- Sustainability
- CBA

## 8.2 Option 1 – Make Do and Mend

### 8.2.1 General

This option is considered over two-time frames in line with the consideration of gas supplies to Bacton site:

- Option 1.1 (2021-2035) – site maximum capacity 160mscmd
- Option 1.2 (2035-2050) – site maximum capacity 120mscmd

The change in capacity in line with gas flows permits significant rationalisation of existing site assets.

In summary Option 1 is focussed on continuing current operational and maintenance work for the site as existing procedures and taking advantage of the reduced flows from 2035 to reduce the number of assets that need maintenance. There is a need within the option to make several investments in the site to replace items such as defective valves, instrument and control systems and electrical works. Some investments such as I&C also need a further replacement within the second phase of the option in period 2035-2050 on account of the natural 10-15-year life for such systems.

### 8.2.2 Engineering

Option 1 is specified by NG as the 'Base Case' option against which the other options listed above are evaluated. By inspection it is the option that causes the least disturbance to the current site configuration and its rationale is 'business as usual' in the sense of continuing existing terminal practices, except where with the change in gas supply or other circumstances, there is a corresponding reduction in site infrastructure extent and thereby associated requirements for O&M personnel.

All integrity data for gas systems carries uncertainties on account of the difficulties particularly at terminals of carrying out inspections of all key elements due to factors such as operational need for continuous operation, difficulties of reaching some remote parts of the system, time periods between inspections and other factors. It is also noted that the existence of a WSE does not mean that it is carried out unless there is evidence of this in some format. The assumed benefits of procedures often need ideally a form of supporting evidence to give confidence that the benefits of the procedure are accruing. Bacton Terminal is the oldest such terminal in the UK and with Option 1 it is planned to operate safely for another near 30 years, there needs to be an awareness of the potential longer-term risks arising from the approximately 80-year terminal life by 2050. The quantification of such risks is outside of the scope of this study but where based on experience we have views, and these are recorded.

The engineering work for Option 1 included an assessment and commentary on existing O&M practices and procedures and from this propose future regimes that meet operational safety needs and demonstrate efficient use of resources for the two main flow conditions of 2021-2035 (160mscmd) and 2035-2050 (120mscmd).

Option 1 has been developed in the study through a combination of data collection, site visit including interviews with operational staff, data interpretation and derivation of viewpoints on the existing procedures and the possible future requirements for O&M maintenance.

Note that the IUK facility within the NG fence line is excluded from the scope. Integrity management and forward strategy for this is the responsibility of IUK, although regular consultations occur between IUK and NG. Additionally, the interconnecting import pipelines outside of the fence line from the Perenco, Shell and ENI facilities are not considered, nor the NTS feeders outside the site fence line. The main engineering work for this option involved the following activities:

- Existing equipment assessed
- Performed site visits, interviews, reviewed documentation / records
- Defined what maintenance and replacements need to be done on existing assets to maintain safe efficient operations of the site (and allow the slow decline of SNS gas to occur)
- Consideration of defects and risks and how to reduce them with the minimum intervention / brownfield development
- Re-used as many assets as necessary
- Solutions proposed with the objective to ensure continuing operations, with the minimum rationalization of assets while keeping costs at minimum and keeping operational flexibility without compromising safety, operability and maintainability
- The solutions have been reviewed in the design opportunities workshop (10.09.21), design review workshop (22.09.21), HAZID (30.09.21), CDM compliance (14.10.21) and valves replacement review (04.11.21)

In the work we have considered the current condition of Bacton and then considering asset integrity issues, what the future situation of Bacton may require in terms of 'make do and mend' operational expenditure to safeguard its safe operation.

The PDF with the assessment of the sealing status of the valves is included in Appendix D.

#### 8.2.2.1 Current Situation

Our assessment of the current condition of the site is based upon data and reports received from NG and the outputs from the site visit conducted 04/08/2021.

- NG Asset Health summary statement
- Bacton summary of work completed in schemes
- Consultant Summaries

Our assessment of equipment and other elements of the site is recorded in the following documents

- 20485-AI-RPT-100-0001 Existing Equipment Condition Assessments
- 20485-AI-RPT-100-0002 Drawing, Record and Report Condition Assessment Survey
- 20485-AI-RPT-100-0003_Work Statement Report (These are provided in the Appendices).

Current operations follow the site Operations Manual and maintenance follows practices and procedures initiated when National Grid was part of the nationalised industry the British Gas Corporation (BGC).

The site must ensure compliance with the Regulations PSSR, PSR and COMAH. These regulations all require that the Operator maintains the pressure equipment and pipelines in a safe working condition and that the risks are understood and assessed so that they may be managed and mitigated effectively. The PSSR is the driving piece of legislation about maintaining the pressure containing systems in a safe condition. The requirements on the Operator are very specific. This specifically requires that all pressure containing systems, equipment and pressure safety devices have WSEs in place, with defined inspection frequencies. PSSR requires that the WSE is overseen by an experienced Competent Person who has the necessary knowledge and experience to be able to review the WSE, assess the results and refine the WSEs as required to ensure they remain in a safe condition. The Competent Person role can be undertaken by an organisation. An effective WSE ensures that any signs of deterioration are identified and can be remedied before it becomes un-acceptable.

8.2.2.2 Future Situation

The current Bacton site and facilities are now beyond their design life. Extending operations to 2035 / 2050 will require work to the existing facilities. The make do and mend option is feasible and can be implemented in phases with the reduction in gas supplies to the terminal. There is opportunity to reduce O&M costs in line with the significant drop in gas supplies due in the mid 2030's. Opportunities ahead of this date are limited.

The electrical I&C assessments upgrades are quite extensive. A lot of equipment will soon be obsolescent and require replacement. The status of the ESD and FGS systems should also be considered. The electrical assessments revealed failings in the existing equipment with signs of deterioration. Up-grades and replacements are necessary.

There is no automatic shutdown and venting system on the National Grid system/pipe work within the site boundary apart from the over pressure protection of incoming pipe work from the Delivery Facility Operator. Compliance with COMAH regulations is required. It is presumed a waiver or agreement with the regulators is in place. An assessment of any steps needed to ensure regulatory compliance is recommended for current future operations

The CP assessment showed that the existing system is operating at its limits and may not be protecting the buried pipework effectively. There is also evidence of stray currents which must be investigated and addressed as this is affecting the levels of protection to the buried pipework. The CP assessment identified that extensive up-grades will be necessary to the existing system if the buried pipework is to be protected adequately.

The site availability and reliability are dependent upon the integrity and operability of the valves. A number of these have functionality problems i.e. internal leakage, stem seals leakage, stuck in position. The layout of the site offers flexibility in operations and isolations. A limited number of valves are recommended for intervention and repair.

The mechanical integrity of the above ground pipework appears to be good and has been recently re-coated. The condition of the below ground pipework coating appears to be reasonably good for a facility as old as this. The CP surveys reported circa 20 DCVG defects in 2019, most of which were not sufficiently large to warrant excavation. Verbal evidence of recent pipe excavations indicated the coating was good. There was no evidence seen however of any pipe wall inspections to verify the internal and external condition of the pipe. Pipe wall inspections would provide assurance on the actual integrity of the pipe.
There have been failings in the integrity management in the past. The recent Asset Health Project has actively resolved several of the issues. While NG have WSEs for the pressure systems and good documented maintenance procedures these can only be effective if any identified failings or degradation are closed out.

A more detailed life extension assessment should be performed to ensure that all the risks and failure modes have been fully identified and investigated. This is consistent with best industry practice and may add further work to that identified in the Appendices to this report. Also, audits of the current asset integrity management systems should be carried out in order to confirm that the stated procedures and processes are being carried out in practice with documented records and evidence. Dependent upon the outcomes of the audit, further actions may be necessary.

The implications of proposed work for other Bacton operators should be discussed and assessed at an early stage in order to understand any further issues they wish to raise concerning proposed works and to form a view on timescales, which may need discussions in order to align programmes.

#### 8.2.2.3 Conclusions

The assessment and interpretation of data and records from the site combined with meetings with site operational staff have converged to formulate the following conclusions:

- Mechanical integrity –
  - Pipework/ trap/ heat exchanger integrity is acceptable and should be monitored/ maintained by rigorous compliance with the WSEs, necessary follow-up and repairs and appropriate fabric maintenance.
  - Valves – Ongoing challenges about availability/ condition. These affect operational flexibility. Repair/ replacement will be necessary which with NG inputs have been identified as 26 in number.
  - Pipelines – Reports from ILI inspections showed no significant defects (export lines). Pipeline/ road crossings – minimal data available and this should be investigated further due to their criticality to operations
  - CP – Current system is operating at its limits. Replacement/ up-grade is required. In-adequate CP risks degradation of integrity of buried pipework.
- Electrical/ Instrument and Control – Equipment/ systems at end of design life. Obsolescence is a growing problem. Up-grades are required.
- Up to 2035
  - More detailed Life Extension Assessment is recommended.
  - Maintain compliance with all regulatory requirements – PSSR, PSR, COMAH & HSWA
  - Ongoing dialogue with third parties (IUK, BBL, authorities)
  - A rigorous program of Integrity Management program and Risk Assessments be maintained for timely identification & repair of defects.
  - Time dependent risks to include fatigue, coating degradation, corrosion.
  - Electrical system up-grades are required (lighting/ cabling/ etc)
  - Control and instrumentation up-grades required

- Up to 2050
  - As above for operational plant and pipelines.
  - Shutdown of non-operational plant and facilities.
  - Reduced plant offers potential opportunity for reduced manning levels for operations.
  - Decommissioning of non-operational plant may begin. SIMOPs/ Control of Work practices required to ensure a continued safe site.

Option 1 is a credible option to maintain operations up to 2035 and potentially to 2050. The Appendix D contains the conceptual engineering work carried out defining the investments needed together with its cost and sequencing.

### 8.2.3 Cost Estimation

A key part of the FEED scope of work for all options is the production of a CAPEX estimate with an accuracy of +/- 30% to support a Cost Benefit Assessment (CBA). For Option 1, Make Do and Mend, the CAPEX expenditure primarily focusses on replacement of defective equipment (i.e., valves), site works, and replacement of obsolete components / upgrades.

Cost estimates have used a factored methodology with additional input from vendor supplied information and industry norms, where appropriate. The components of the cost estimate incorporate the following:

- Cost of key materials;

- Market factors; and,

- Contingency.

Note that inflation has not been accounted for within the cost estimate. Appendix B contains the full cost estimate report and in this section is a summary of the main costs estimated for both CAPEX and OPEX is given.

The CAPEX estimate value is summarised below, with values presented in £thousands (£k). Two periods are analysed, 2021 to 2035 incorporating UKCS SNS production and both interconnectors supply, and 2036 to 2050 incorporating both interconnectors supply only.

| | 2021 - 35 | 2036 - 50 |
|---|---|---|
| Area | £k | £k |
| Engineering | [redacted] | [redacted] |
| Procurement | [redacted] | [redacted] |
| Freight and Misc | [redacted] | [redacted] |
| Construction | [redacted] | [redacted] |
| Owners Costs | [redacted] | [redacted] |
| Decommissioning | [redacted] | [redacted] |
| Total | [redacted] | [redacted] |

**Table 8-1 : CAPEX Estimate Summary**

For further breakdown of the estimate CAPEX values and other items such as the expenditure S-curve refer to the Option 1 cost report. The basis of the cost estimate elements is summarised below.

- **Piping**- Option 1.1 includes for 26 valves, 7 above ground and 19 below ground. As detailed in the material MTO below.

- Option 1.2 includes for the removal of 18 No valves and sealing the piping with end caps as detailed in the material MTO below.

- **Electrical**- Option 1.1 includes for LV distribution, lighting. As detailed in the material
- MTO below.

- **C&I**- Option 1.1- includes for the instruments for flow, pressure and temperature switches, analysers, MR doors, OMMNI capitaliser and a CCTV system. As detailed in the material MTO below.

- For Option 1.2 this includes for the instruments for flow, pressure and temperature switches, analysers, and OMMNI capitaliser and a distributed control system. As detailed in the material MTO below.

- **Cathodic protection**- Includes for anodes, transformer rectifier, test points, reference cells and cables. As detailed in the material MTO below. Allowance is also being made for excavations.

- **Exchangers and Filters**- Provisional sum of [redacted] has been allocated for future replacement.

- **Painting, wind & water line protection**- Option 1.1 includes for an allowance for painting and WWL based on values provided by NG. It has been assumed that 30% of the cost will be required to maintain facility until 2035.

- Option 1.2 allows for maintaining paint, wind and water line protection and allowance has been set at [redacted] to maintain the facility from 2036 to 2050.

- **Roads**- Option 1.1 allows for remedial repair of roads and allowance has been set at
- [redacted] to maintain the facility up to 2035.

- Option 1.2 allows for remedial repair of roads and allowance has been set at [redacted] to maintain the facility from 2036 to 2050.

- **Buildings**- Option 1.1 allows for remedial repair of buildings and allowance has been set at [redacted] to maintain the facility up to 2035.

- Option 1.2 allows for remedial repair of buildings and allowance has been set at [redacted] to maintain the facility from 2036 to 2050.

- **Removal of Compound –** A base allowance of [redacted] as instructed by NG has been included for the removal of the contractor's compound.

- **Road Crossing Investigations –** A base allowance of [redacted] instructed by NG has been included within the estimate.

- **Decommissioning**- This assumes that the facility will be returned to greenfield state after
- 2050 when the facility ceases production. It has been assumed that [redacted] would be the value to clear and reinstate. This does not consider any sales from scrap.

8.2.4 Environmental

Option 1 results in no new construction of plant, and only ongoing maintenance of existing plant. This includes pipework, values and pumps, as well as electrical systems, control and instrumentation. The layout of the site is shown in the figure below. The incoming pipes from ENI are already not in use, and the incomers from Perenco and Shell will be shut down in 2035, but it is assumed that no decommissioning will start till 2050.

[redacted]

**Figure 8-1: Bacton Site Layout and Structures (NG, 2020c)**

Operational impacts are outlined below.

| **Environmental Topic** | **Potential Impact – Option 1** |
|---|---|
| **Ecology and Biodiversity** | No change to existing biodiversity for the site and its surroundings, however BNG 10% proposed to meet NG Policy (NG, 2019a) (see Section 9) |

| Environmental Topic | Potential Impact – Option 1 |
|---|---|
| **Air Quality** | Potential small, and probably unmeasurable improvement due to reduction in fugitive emissions. However, potential for larger leaks in the futures due to older equipment failures. |
| **Noise** | No change to existing noise emissions from the site. Small reduction in noise expected through reduced operations after 2035. |
| **Transportation** | No change to existing traffic movements associated with the site. Small reduction in traffic levels from site staff commutes expected through reduced operations after 2035. |
| **Waste and raw materials** | Likely to be a small, but immeasurable increase in waste and raw materials due to failures of older equipment. |
| **Agriculture** | No impact to local farmland. |
| **Flood Risk, Hydrology and Drainage** | No change to existing drainage on the site. No earth movements that would affect hydrology and flood risk. |
| **Coastal Erosion** | N/A |
| **Archaeology and Cultural Heritage** | No new buildings or construction on the site that would affect cultural heritage assets. |
| **Landscape and Visual** | No new above ground buildings or earthworks that would affect existing landscape character or open up views for visual impacts. |
| **Contaminated Land** | No contamination on existing site, and no earthworks that would create contamination sources. |
| **Community** | No impact on local community facilities. |
| **Socioeconomics** | N/A |

**Table 8-2: Potential Environmental Impacts of Option 1**

8.2.4.1 BNG Considerations for Short List Option Appraisal

Option 1 is not strictly required as it is a continuation of the existing programme of works but enhanced to ensure repairs are undertaken quickly. However, should NG wish to show BNG, then a calculation has been undertaken, based on the total area of the grassland found on the periphery of the site (i.e. non-operational land).
This total area is 1.3 ha, and to create 10% net gain, an area of 0.06ha of this land could be dedicated to a species rich grassland.

## 8.3 Option 2 – Major Rationalisation and Reduce Inventory

### 8.3.1 General

Option 2 is only applicable from 2035 following the cessation of SNS gas flows and thereby the abandonment of Shell and Perenco assets and uses the opportunity to simplify the site with some major investments in simplified piping and valve arrangements including a new ring main concept to permit operational flexibility.

### 8.3.2 Engineering

The conceptual engineering work consisted of the following main activities

- Review of all existing above ground and below ground assets in light of rationalisation opportunities presented by the gas flow reduction by 25%. Items identified that can be abandoned, removed or re-routed together with opportunity to install new above ground pipeline routes to present new gas flow improvements across the site.
- Operational flexibility ensured without compromising safety, operability and maintainability
- Re-use of as many assets as necessary
- Areas of land identified that can be freed up as a result of rationalising assets
- Constructability and operations considered, e.g. prefabrication of pipework offsite, and installation whilst existing plant is operational

- C&I design for new installations as per modern standards of control and automation. Optional module upgrades for enhanced safety, integrity, automations and remote operation
- Minimum separation distances as per standard T/SP/G/37 The design has been reviewed in the design opportunities workshop (10.09.21), design review workshop (22.09.21), HAZID (30.09.21 & 01.10.21) and site location review workshop (01.10.21 & 15.10.21)

### 8.3.3 Cost Estimation

The CAPEX estimate value is summarised in the Option 2 Cost Estimate report, with values presented in £thousands (£k). Two periods are analysed, 2021 to 2035 incorporating UKCS SNS production and both interconnectors supply, and 2036 to 2050 incorporating both interconnectors supply only.

| Area | 2021 - 35<br>£k | 2036 - 50<br>£k |
|---|---|---|
| Engineering | [redacted] | |
| Procurement | | |
| Freight and Misc | | |
| Construction | | |
| Owners Costs | | |
| Decommissioning pre 2050 | | |
| Decommissioning after 2050 | | |
| Total | | |

**Table 8-3: CAPEX Estimate Summary**

For further breakdown of the estimate CAPEX values and other items such as the expenditure S-curve refer to the Option 2 cost report. The basis of the cost estimate elements is summarised below.

- **Piping**- Option 2 includes for linepipe, tees, end caps, bends and valves.. Bids have been provided for piping and valves.
- **C&I**- Option 2 includes for the instruments for flow meters, flow transmitters, distribution systems, pressure and temperature switches, analysers, OMMNI flow totaliser controller and a distributed control system.. Within this option there are further options that have been excluded but may be considered at a later date.
- **Cathodic protection**- Includes for anodes, transformer rectifier, test points, reference cells and cables. As detailed in the material MTO below. Allowance is also being made for excavations.
- **Painting, wind & water line protection**- Option 2 includes for an allowance for painting and WWL based on values provided by NG. It has been assumed that 30% of the cost will be required to maintain facility until 2050.
- **Decommissioning**- NG provided an estimate circa [redacted]. This was assessed with the engineers and was calculated to be circa 4% of the total decommissioning scope of the facility. Based on this 4% it was assessed that to remove the full plant under brownfield conditions would be [redacted]. It has been assessed that removal for decommissioning for the Shell and Perenco area would represent 40% to be completed under option 2 giving a total of [redacted]. The remainder of the work would be completed after 2050. This does not consider any scrap credit.

### 8.3.4 Environmental

Option 2 envisages the construction of a new above ground ring-main by 2035 and decommissioning of a lot of existing underground pipework in the north of the site, alongside upgrades to C&I and lighting. The proposed layout is shown in the plot plan below, where new pipelines are shown in green.

[redacted]

**Figure 8-2: Option 2 Plot Plan**

This would result in construction impacts, such as noise from vehicles and plant, dust generation, traffic on the existing road network, and risk of contaminated water run-off. However, these impacts could be reduced as far as practical through good construction practices. New raw materials would be used (although assets would be reused as far as practical) and construction waste would be generated, including excavated soils, which would have to be disposed of off-site where reuse onsite is not practical. Existing underground pipework may be recycled as scrap metal. Overall there would be a negative construction impact.

Operational impacts are outlined below.

| Environmental Topic | Potential Impact – Option 2 |
|---|---|
| **Ecology and Biodiversity** | Loss of amenity grassland in the north of the site, however 10% BNG proposed to meet NG Policy (see Section 9). Removal of lighting from the perimeter fence and improved lighting may reduce light disturbance to animals, including bats. Overall likely to be a positive impact on biodiversity. |
| **Air Quality** | Potential small, but probably unmeasurable improvement due to reduction in fugitive emissions. Less risk of larger leaks in the future as older equipment is replaced. Overall positive impact. |
| **Noise** | Small reduction in noise expected through shutdown of high-pressure pipelines after 2035, and fewer vehicle trips required due to newer equipment. Overall positive impact expected. |
| **Transportation** | Small reduction in traffic levels from site staff commutes and mobile plant expected through reduced operations and maintenance after 2035. |
| **Waste and Raw Materials** | Likely to be a small reduction in waste and raw materials due to failures of older equipment, as so overall positive impact expected. |

| Environmental Topic | Potential Impact – Option 2 |
|---|---|
| **Agriculture** | No impact to local farmland. |
| **Flood Risk and Hydrology** | No overall change to existing drainage on the site as no significant change to hardstanding areas, and therefore no change to flood risk and hydrology. |
| **Coastal Erosion** | N/A |
| **Archaeology and Cultural Heritage** | No new buildings or works on the site that would affect cultural heritage assets. |
| **Landscape and Visual** | No new above ground buildings or earthworks that would affect existing landscape character or open up views for visual impacts. |
| **Contaminated Land** | No contamination on existing site, and earthworks would not create contamination sources. |
| **Community** | No impact on local community facilities. |
| **Socioeconomics** | N/A |

**Table 8-4: Potential Environmental Impacts of Option 2**

#### 8.3.4.1 BNG Considerations for Short List Option Appraisal

For Option 2, it has been assumed that a large area to the north of the site will be dug up to remove existing plant and to install new. It is assumed that the area of amenity grassland lost would be 0.79 ha. This can be compensated by the creation of 0.26 ha of neutral grassland habitat.

## 8.4 Option 3 – New Build (brownfield / greenfield)

### 8.4.1 General

Option 3 is based on a new build terminal designed appropriately for the prevailing gas supplies and demands of the period 2035-2050 at Bacton, when all gas supply is coming from the interconnector supplies. Option 3.1 positions the new terminal within the existing boundary of Bacton fenceline, whilst Option 3.2 would be outside of the fenceline on new land currently being farmed to the south west of the existing site (and partly used as a construction camp in the recent past).

### 8.4.2 Engineering

The engineering concept for Option 3.1 Brownfield is as follows:

- Proposed design for new arrangement to be fitted within existing boundaries of Bacton using any freed-up land from rationalisation due to diminished flows and other actions such as removing redundant assets.
- Operational flexibility ensured without compromising safety, operability and maintainability
- Minimal reuse of existing assets
- Use of above ground modular builds
- Tie-ins to existing feeder pipelines, IUK and BBL systems
- Constructability and operations considered, e.g. prefabrication and testing of pipework and other equipment offsite, and installation whilst existing plant is operational
- C&I design for new installations as per modern standards of control and automation. Optional module upgrades for enhanced safety, integrity, automations and remote operation
- Minimum separation distances as per standard T/SP/G/37
- The design has been reviewed in the design opportunities workshop (10.09.21), design review workshop (22.09.21 & 12.10.21), HAZID (30.09.21 & 01.10.21) and site location review workshop (01.10.21 & 15.10.21)

The concept for Option 3.2 Greenfield is as follows:

- Proposed design for new arrangement outside of the existing site, in a greenfield compact area south-west of the perimeter fence.

- Operational flexibility ensured without compromising safety, operability and maintainability
- Minimal reuse of existing assets
- Use of above ground modular builds
- Tie-ins to existing feeder pipelines, IUK and BBL systems
- Constructability and operations considered, e.g. prefabrication and testing of pipework and other equipment offsite, and installation whilst existing plant is operational
- C&I design for new installations as per modern standards of control and automation. Optional module upgrades for enhanced safety, integrity, automations and remote operation
- Minimum separation distances as per standard T/SP/G/37
- The design has been reviewed in the design opportunities workshop (10.09.21), design review workshop (22.09.21 & 12.10.21), HAZID (30.09.21 & 01.10.21) and site location review workshop (01.10.21 & 15.10.21)

### 8.4.3 Cost Estimation

The CAPEX estimate value is summarised in the Option 3 Cost Estimate report in the Appendix, with values presented in £thousands (£k). Two periods are analysed, 2021 to 2035 incorporating UKCS SNS production and both interconnectors supply, and 2036 to 2050 incorporating both interconnectors supply only.

| Area | Option 3.1 | Option 3.2 |
|---|---|---|
| | £k | £k |
| Engineering | [redacted] | |
| Procurement | | |
| Freight and Misc | | |
| Construction | | |
| Owners Costs | | |
| Decommissioning- Existing Facility (Pre 2050) | | |
| Decommissioning- Existing Facility (Post 2050) | | |
| Decommissioning- Future Facility (Post 2050 | | |
| Total | | |

**Table 8-5: CAPEX Estimate Summary**

For further breakdown of the estimate CAPEX values and other items such as the expenditure S-curve refer to the Option 3 cost report. The basis of the cost estimate elements is summarised below.

- **Piping**- Option 3.1 and 3.2 includes for line pipe, tees, end caps, bends, pig traps, filters upstream of metering skid and valves. As detailed in the material MTO below. Bids have been provided for piping and valves.

- **C&I**- Option 3.2 and 3.2 includes for the instruments for flow meters, flow transmitters, distribution systems, pressure and temperature switches, analysers, OMMNI flow

- totaliser controller and a distributed control system. As detailed in the material MTO

- Within these options there are further for C&I materials options that have been excluded but may be considered at a later date. They have also been itemised in the MTO below.

- **Electrical**- Option 3.1 and 3.2 Includes distribution boards, cables, earthing conductors, lighting poles, kiosks.

- **Civils**- Option 3.1 this includes for geotechnical membrane, foundations, pipe rack, pipe supports, paved pathways, trenching for underground pipework, asphalt for roads, concrete hard standing pavement at pig trap.

- Option 3.2 this includes for geotechnical membrane, foundations, pipe rack, pipe supports, paved pathways, trenching for underground pipework, asphalt for roads, concrete hard standing pavement at pig trap, grading and clearance, security fencing and gates.

- **Land** - Within Option 3.2 an allowance for the use for the new facility including obtaining permission has been included within NG costs.

- **Cathodic protection**- Option 3.1 and 3.2 Includes for anodes, transformer rectifier, test points, reference cells and cables. As detailed in the material MTO below. Allowance is also being made for excavations.

- **Painting, wind & water line protection**- Option 3.1 includes for an allowance for painting and WWL based on values provided by NG. It has been assumed that 30% of the cost will be required to maintain facility until 2050. For Option 3.2 an additional 10% has been added.

- **Decommissioning**- NG provided an estimate circa [redacted]. This was assessed with the engineers and was calculated to be circa 4% of the total decommissioning scope of the facility. Based on this 4% it was assessed that to remove the full plant under brownfield conditions would be [redacted]. It has been assessed that removal for decommissioning for the Shell and Perenco area would represent 40% to be completed under option 3.1 and 3.2 giving a total of [redacted]. The remainder of the work would be completed after 2050. This does not consider any scrap credit.

- For decommissioning of the new facility we have allowed 30% of the new facility cost

### 8.4.4 Environmental

#### 8.4.4.1 Option 3.1

Option 3.1 is similar to Option 2 but envisages a more comprehensive replacement of equipment through the construction of new above ground pipework in the north of the site. The works would include upgrades to C&I and lighting. The plan for Option 3.1 is shown in the figure below.

[redacted]

**Figure 8-3: Option 3.1 Plot Plan**

This would result in the same construction impacts as Option 2, namely noise from vehicles and plant, dust generation, traffic on the existing road network, and risk of contaminated water run-off. The works would be more extensive than Option 2 and be constructed over a longer length of time. However, again these impacts could be reduced as far as practical through good construction practices. Raw materials use would be greater than Option 2 (although assets would be reused as far as practical) and a greater degree of construction waste would be generated, including excavated soils, which would have to be disposed of off-site where reuse onsite is not practical. Existing underground pipework may be recycled as scrap metal. Overall there would be a negative construction impact.

Operational impacts are outlined below and are similar to Option 2. The benefits of Option 3.1 over Option 2 are likely to be greater, but overall impacts are starting from a low base.

| Environmental Topic | Potential Impact – Option 3.1 |
|---|---|
| **Ecology and Biodiversity** | Loss of amenity grassland in the north of the site, however 10% BNG proposed to meet NG Policy (see Section 9). Removal of lighting from the perimeter fence and improved lighting may reduce light disturbance to animals, including bats. Overall likely to be a positive impact on biodiversity. |
| **Air Quality** | Potential small, but probably unmeasurable improvement due to reduction in fugitive emissions. Less risk of larger leaks in the future as older equipment is replaced. Overall positive impact. |
| **Noise** | Small reduction in noise expected through shutdown of high-pressure pipelines after 2035, and fewer vehicle trips required due to newer equipment. Overall positive impact expected. |
| **Transportation** | Small reduction in traffic levels from site staff commutes and mobile plant expected through reduced operations and maintenance after 2035. |
| **Waste and Raw Materials** | Likely to be a small reduction in waste and raw materials due to failures of older equipment, as so overall positive impact expected. |

| Environmental Topic | Potential Impact – Option 3.1 |
|---|---|
| **Agriculture** | No impact to local farmland. |
| **Flood Risk and Hydrology** | No overall change to existing drainage on the site as no significant change to hardstanding areas, and therefore no change to flood risk and hydrology. |
| **Coastal Erosion** | N/A |
| **Archaeology and Cultural Heritage** | No new buildings or works on the site that would affect cultural heritage assets. |
| **Landscape and Visual** | No new above ground buildings or earthworks that would affect existing landscape character or open up views for visual impacts. |
| **Contaminated Land** | No contamination on existing site, and earthworks would not create contamination sources. |
| **Community** | No impact on local community facilities. |
| **Socioeconomics** | N/A |

**Table 8-6: Potential Environmental Impacts of Option 3.1**

8.4.4.2 Option 3.2

Option 3.2 is a proposed design for new arrangement outside of the existing site, in a greenfield compact area south-west of the perimeter fence. The location of the site and layout is shown in Figure 7-16 below. Most pipework will be above ground, except for the crossing of Hall Farm Road, where pipework and electrical cables will be culverted under the road and the drainage ditch.

[redacted]

At this stage, mitigation measures such as the need for Sustainable Urban Drainage Systems (SUDS) to mitigate water run-off from hard surfaces have not been calculated into the plot size. Comments on BNG are covered in Section 9 of the environmental report in Appendix XX.

The works would result in a significant construction project over a longer timescale than the previous works. All raw materials for the site are likely to be new, with limited opportunity for reuse. Excavated soils could be reused for landscaping and screening purposes, but otherwise the works would give rise to significant construction waste. Construction traffic would be using a single lane road, with disruption to the existing use of that road, including as part of the Paston Way and other long-distance pedestrian and cycle routes.

The noise and lighting from a construction site could also cause disturbance to the protected bats of Paston Barn NNR. Water run-off and pollution can be controlled by good construction practices, but overall the construction works would have a negative impact due to its greenfield status. The new site would need to be removed in 2050 and the land returned to greenfield.

| Environmental Topic | Potential Impact – Option 3.2 |
|---|---|
| **Ecology and Biodiversity** | Loss of cropland, which has limited biodiversity, but will be enhanced by BNG of 10%. Potential risk of disturbance to wildlife including bats of Paston Barn NNR through noise and permanent lighting. Mitigation could comprise of a tree/shrub belt to the west of the site, and tree/shrub planting the east of the site. However, risk that mitigation is not enough to reduce negative impact on wildlife, including protected species. |
| **Air Quality** | Slight improvements to air quality (hydrocarbons) due to new equipment leading to positive impact. |
| **Noise** | Slight improvements to noise on main site post 2035, due to shutdown of high-pressure pipes, but increased noise due to maintenance activities and traffic on new site. Overall a negative impact is expected. |
| **Transportation** | Road access is currently through a single land road with passing places which may require upgrading, due to risk of potential accidents. Potential conflict with users of the Paston Way and farm access. Likely significant impacts and Traffic Management Plan would be required. |
| **Waste and Raw Materials** | Maintenance raw material use and waste likely to improve post 2035 due to new equipment, however, all needs to be removed in 2050. |
| **Agriculture** | Significant impact as the site is on Grade I agricultural land. Approximately 1.99 ha will be lost, excluding BNG and SUDS mitigation. |
| **Flood Risk and Hydrology** | Requirement for future design of water run-off from the site, and SUDS are likely to be required. The ditch on the south of the site is in a flood risk area, so design of the site would need to mitigate any impact. Potentially a significant impact without mitigation. |
| **Coastal Erosion** | N/A |
| **Cultural Heritage** | Direct views to nearby listed buildings are potentially significant and likely to require mitigation through screen planting. |
| **Landscape and Visual** | Landscape and Visual mitigation provided by proposed planting, but still industrial development in a greenfield, rural location, so overall a negative impact. |
| **Contaminated Land** | The land is greenfield, and unlikely to be contaminated. The works however introduce potential for new contamination of the land, which would require to be controlled, with all materials removed at decommissioning. |
| **Community** | Potential negative impact on community through expansion of industrial development creating objections and disruption to community walking routes. |
| **Socioeconomics** | N/A |

**Table 8-7: Potential Environmental Impacts of Option 3.2**

8.4.4.3 BNG Considerations for Short List Option Appraisal

For Option 3.1, it has been assumed that, as with Option 2, a large area to the north of the site will be dug up to remove existing plant and to install new. Therefore 0.79 ha are lost, and 0.26 ha of species rich grassland would compensate.

For option 3.2, the works involve construction on a greenfield site, that is currently used for cereal crops. It is assumed the existing Murphy's temporary construction compound will be returned to greenfield in 2025, before the construction of Option 3.2 would begin.

The area of the new site would be 1.99 ha. In order to assume that habitat planting could be undertaken to the west of the site to provide screening, it has been estimated that an additional 0.5 ha of cereal cropland would be lost. For a 0.5 ha woodland belt, the category "Other woodland; broadleaved" has been chosen, with an aim to achieve Moderate condition. However, this would not be enough to fully obtain 10% BNG, and so a further offsite habitat creation of 0.6 ha of neutral grassland would be proposed on the existing NG Bacton Site.

This blend of woodland screening, with 0.5 ha being considered a minimum area to be viable, combined with off-site planting on the existing BNG site would minimise the additional land take and land purchase costs required to fulfil BNG for this option.

## 8.5 Sustainability

In the context of this project, sustainability picks up where environmental impact assessment leaves off:

- Going above and beyond the requirements of the current regulations; and
- Covering specific areas of environmental, social and economic sustainability not included in a standard environmental appraisal or impact assessment.

There were a number of requirements identified in the project scope – generic and specific – relating to sustainability. These are summarised below.

Additionally, a number of organisational aspirations were identified in the Client's corporate literature, to which this project aims to respond.

### 8.5.1 Project Requirements

The Project Specific Scope Service (PSSS) Objectives sees *an opportunity* in this project for the operation of Bacton terminal comes in line with the 2050 Net Zero Carbon Emissions strategy.

Design Options are required to consider as a minimum:

Decommissioning / Demolition / Re-use of existing assets

Hydrogen compatible plant design

*Carbon neutral* construction and future terminal operation[1]

FEED Feasibility Report is additionally required to identify Feasibility Design Options which meet Net Zero[2] Carbon Design & Construction.

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

Apply the PAS2080 standard to Cap Carbon[3]

Provide a baseline

Maximise reductions

Achieve Biodiversity Net Gain (BNG) of +10%

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

[2] Net Zero Emissions covers Scope 1, 2 and 3, with a further requirement to reduce emissions in line with science-based targets for achieving stabilisation of warming of 1.5°C above datum.

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

Adopt Best Availability Technologies (BATs) and Innovations where possible.

Log measures taken

### 8.5.2 Scope of Sustainability

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

Carbon

Materials - Waste Minimisation in line with good practice principles of the waste hierarchy

Biodiversity - Biodiversity Net Gain (BNG)

Neighbour/Environment/Public Nuisance

- Noise
- Light pollution
- Litter
- Dust

- Water Management
    - Mitigation of Flood Risk
    - Mitigation of pollution to Waterbodies including containment of concrete and other cement-based products from washout to natural watercourses and interception of drainage from refuelling areas.
- Contaminated land

### 8.5.3 Other National Grid Corporate Commitments

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

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

**Figure 1: Material issues for GRI reporting purposes**

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

**Figure 8-5: Global Reporting Initiative issues in NG Responsible Business report**

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

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

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

**Figure 8-6: SDGs in the Responsible Business report**

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

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

Under **Air Quality the** following are KPIs

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

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

| |
|---|
| Electric: Average Customer Bill (Low Income Customers Excluded)- affordability |
| Gas: Average Customer Bill (Low Income Customers Excluded)- affordability |

| |
|---|
| Electric: Average Low Income (only) Customer Bill- affordability |
| Gas: Average Low Income (only) Customer Bill- affordability |
| Contribution of National Grid's UK's transmission costs to consumer bills - affordability |

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

Therefore, a review of the scheme proposals against the CEEQUAL scheme is included in Section 6.5 and Appendix B to enable the Client to articulate CEEQUAL aspirations through the design and procurement stages, ensuring that the scheme remains CEEQUAL-ready.

#### 8.5.4 Carbon

The Scheme will be refurbished and decommissioned by 2050. This means that all emissions associated with the scheme and its future operation happen on or before the 2050 target to contain emissions to within 1.5ºC above 1990.

Capital carbon is currently considered to be a good proxy for resource efficiency[4].

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

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

*Scope of Carbon Emissions on the Project*

The Client has set an ambitious target to achieve net zero construction on all major construction projects by 2025/26 in accordance with PAS2080. This aims to reduce the emissions to air during the whole life cycle of the project. Principles of PAS2080 are to be applied to maximise the % reduction in carbon, between baseline and delivered design, contributing to the attainment of Net Zero construction emissions on major schemes by 2025/26.

A project carbon baseline shall be provided. This carbon footprint shall be updated quarterly during design and delivery. A final carbon footprint shall be provided for the delivered design

Measures to reduce carbon should be recorded in the Sustainability Register and the CIT tool or in another suitable form as approved by the Client

All stages of the project that have a carbon impact should be taken into consideration – including the embodied carbon of the asset as well as the energy used to construct it.

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

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

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

- Pipes
- Flanges
- Elbows
- Reducers
- Equal Tees
- Insulation Joints
- Compressors
- Pig Traps

[4] HM Treasury (2013) Infrastructure Review

- Diesel Generators
- Transformers
- Valves
- Actuators
- Cables
- Demolition
- Earthworks
- Equipment Foundations
- Roads & Hardstandings
- Fences
- Buildings and Foundations – limited to Steel-clad building w/foundation – standard design, bricks, steel cladding, doors.
- Trenches & Ducts
- Services – water, pipework, tank, firefighting, generator bund
- Other (basic material)
- Additional Items not listed

The PAS 2080 Stages are explained in the next section.

*PAS 2080 Essentials*

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

*A Capital Carbon –*

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

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

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

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

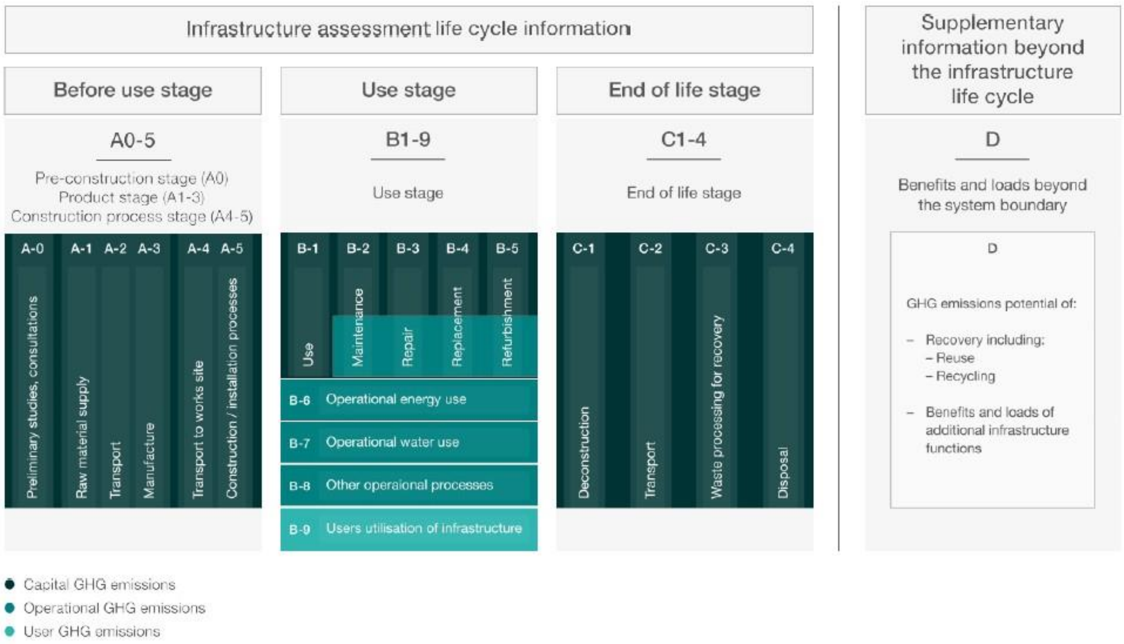



**Figure 8-7: PAS2080 Stages**

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

The most recent addition to this section is *User Carbon.* This is the increase or saving in carbon that is enabled by this infrastructure – for instance railways enable a saving in user carbon on personal vehicle emissions. Likewise, Bacton inevitably has – over the course of its lifetime – enabled a transition from coal or oil-fired power generation to cleaner natural gas. It is potentially still on that journey.

It is recommended that a study specifically for Bacton is carried out to estimate the carbon already saved over Bacton's lifetime to date. This carbon is deducted from the Whole Life Carbon.

The opportunity to gain further *User Carbon* savings would accelerate if a decision to transport hydrogen through the terminal were taken. Bacton has the potential to leverage vast carbon savings through the transition to hydrogen of the south-east of England.

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

*Environmental Product Declarations (EPD)*

The information on embedded carbon of a product is standardised in the EPD format. Production of EPDs, bearing the environmental impact per unit of a product across all of the stages of the life cycle, is increasing among manufacturers, with many of the household name suppliers having approximately 30% of their product ranges independently certified.

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

*PAS 2080 Process*

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

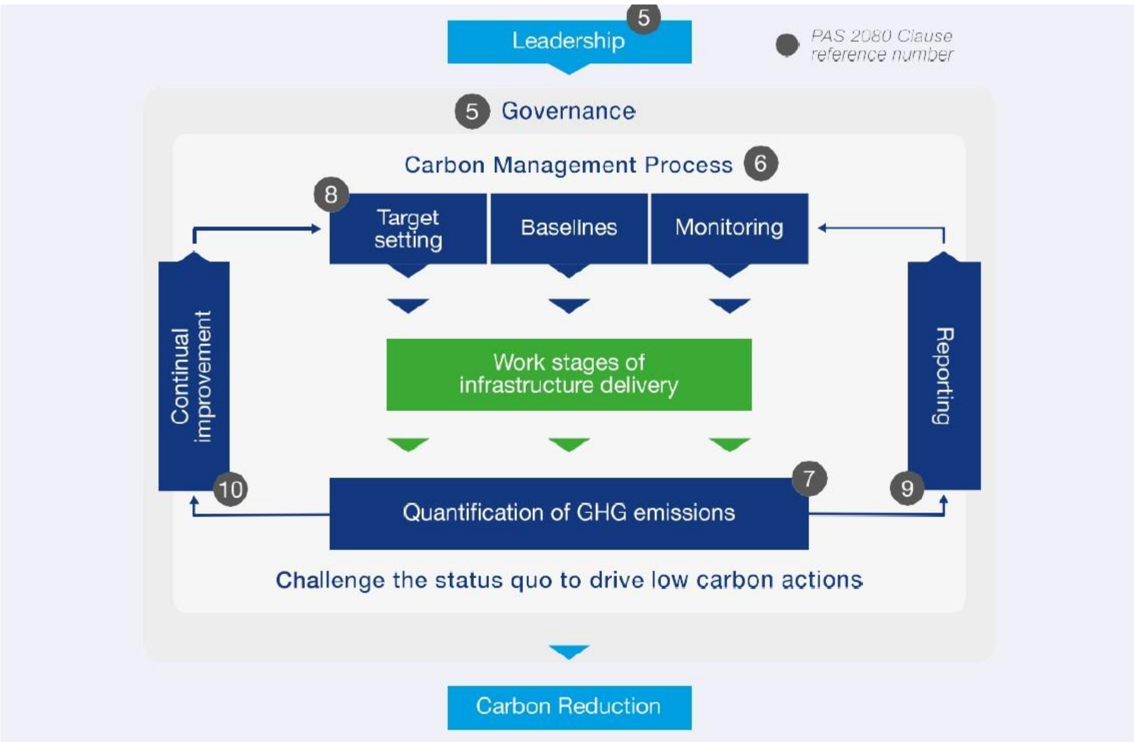



**Figure 8-8: PAS2080 Process**

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

1) The greatest gains, biggest and quickest wins are achievable in the early stages, following the Getting to Net Zero Hierarchy:
   a) Build nothing
   b) Build less
   c) Build Clever
   d) Build Efficiently
2) However, the data for many components and stages are at their lowest accuracy because the details on which carbon data relies is simply not available. Equipment, materials and quantities are not specified in such a level of detail at the early stages to allow the embodied emissions to be calculated from scratch, where a product does not already carry an Environmental Product Declaration.

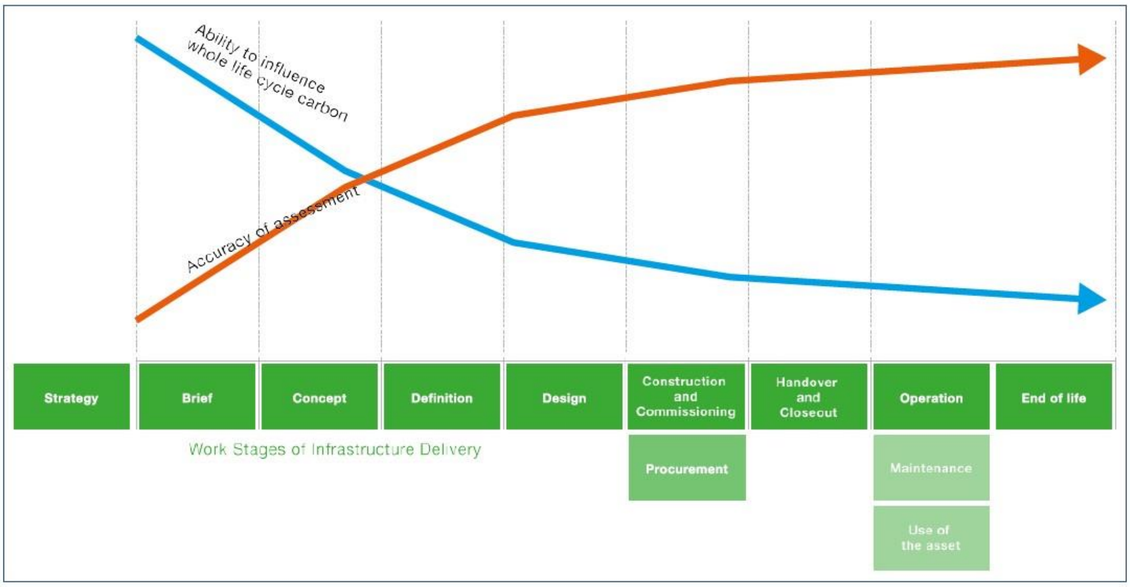



**Figure 8-9: PAS2080 Workstages**

*Key Features & Concepts of PAS2080 applicable to this project*

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

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

In this instance the physical boundary is taken as the maximum site boundary (Existing + Option 3.2). Emissions considered here related to activities taking place within this boundary only.

That said, there is currently no mechanism at this scale for considering the contribution of a green field.

The boundary in time is taken as 2025-2050, as this is the period of equivalence.

All options are functionally identical over this period. They deliver the same quantity of product and are all fully decommissioned by the 2050s, returning to greenfield. Different options phase this return to greenfield, meaning that they are not functionally similar at any point before this, as they are in various states of decommissioning.

**Functional Units** – The functional unit is a terminal with delivery capability of Mcm/day to 2035, reducing to 120 Mcm/day from 2035 with the cessation of supply from the UKCS; returning to greenfield from 2050.

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

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

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

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

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

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

**Baselines –** PAS 2080 advocates developing a baseline and seeking to improve on it within the same design stage. However, in practice, by the time a dataset has been assembled, that is sufficiently robust and accurate to base design decisions with financial implications, the time to exert significant influence over the design would well have passed. The drive to automate WLC assessment is a necessary step to enable design decisions to be made based on carbon.

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

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

For the purposes of this project we consider that the preferred option represents the baseline, but it should be noted from the data map below that a significant amount of data (material, stage emissions) are not included at this stage due to the lack of information on their specification, quantities (current and proposed), installation processes, in-use emissions and decommissioning. This could exceed 20% of emissions, but even this estimate is hard to make.

**Improvement** – The feasibility study itself is an exercise in improvement in relation to costs and – since GHG emissions carry costs – also emissions. Within the cycle itself a number of small improvements have also been made, nonetheless, there remains much scope for improvement in the FEED stage through the detailed design, specification and consideration of O&M. A number of ideas have been presented in the Sustainability Register in the Appendix for which the FEED stage may permit the time to explore further.

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

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

**Target-setting** – In view of the data availability and accuracy possible at this stage, some benchmarks are desirable for different aspects of the project (mechanical, civil, construction etc). Targets emerging from the FEED stage can almost certainly result in targets to apply at tender for the construction phase of the project. However, emissions are likely to increase between optioneering and FEED stages owing to the material not explicitly accounted for at feasibility. Small valves 10-15mm bore, for instance are not included, although they are numerous.

**Works Avoided –** In the context of optioneering projects, there are two ways to view works avoided. Works avoided at any particular stage can be viewed as works deferred to 2050, which remains within the system boundary. Within this context, works to rationalise the asset inventory that add inventory in the intermediate stages, could be considered to be avoided if not selected.

**Methodology** – Due to the site being returned to greenfield at 2050, and the PAS2080 requirement for equivalence of boundary and functional unit, the methodology adopted at this stage was the development of as complete an inventory of materials on site and chart the changes to 2050, rather than simply adding and subtracting material at each phase. Starting the boundary at 2025 means that new material is placed in the A1-3 class, rather than considered as replacements on an asset that is more than halfway through its life, since the history of replacements is not known.

*Project Inventory and Data Availability*

A rough map of the data availability at this stage is shown below. Notable gaps at this stage are small items included in bulks in the cost plan. Detail was not sufficient to build materials profiles from scratch or extrapolate from products with EPDs.

Some cabling is included where these data were available in the cost plan. This was to show the relative size of these items in carbon terms. However, it was noted that decommissioning of cable trenches had a particularly high unit emissions rate, introducing something of a distortion on a number that already carried large uncertainty.

Energy consumption of construction methods in relation to pipework is a significant gap, particularly in view of the complete decommissioning of the site by 2050. Stages A4 and C1 have artificially low emissions as a result.

Equipment tying into Great Yarmouth Power Station and Interconnector UK are also excluded. For the most part the modifications to existing pipework to tie-in the new arrangements are small by comparison with the works proposed.

**Table 8-8: Illustration of data availability and suitability for carbon assessment at the feasibility stage for the PAS2080 Stages**

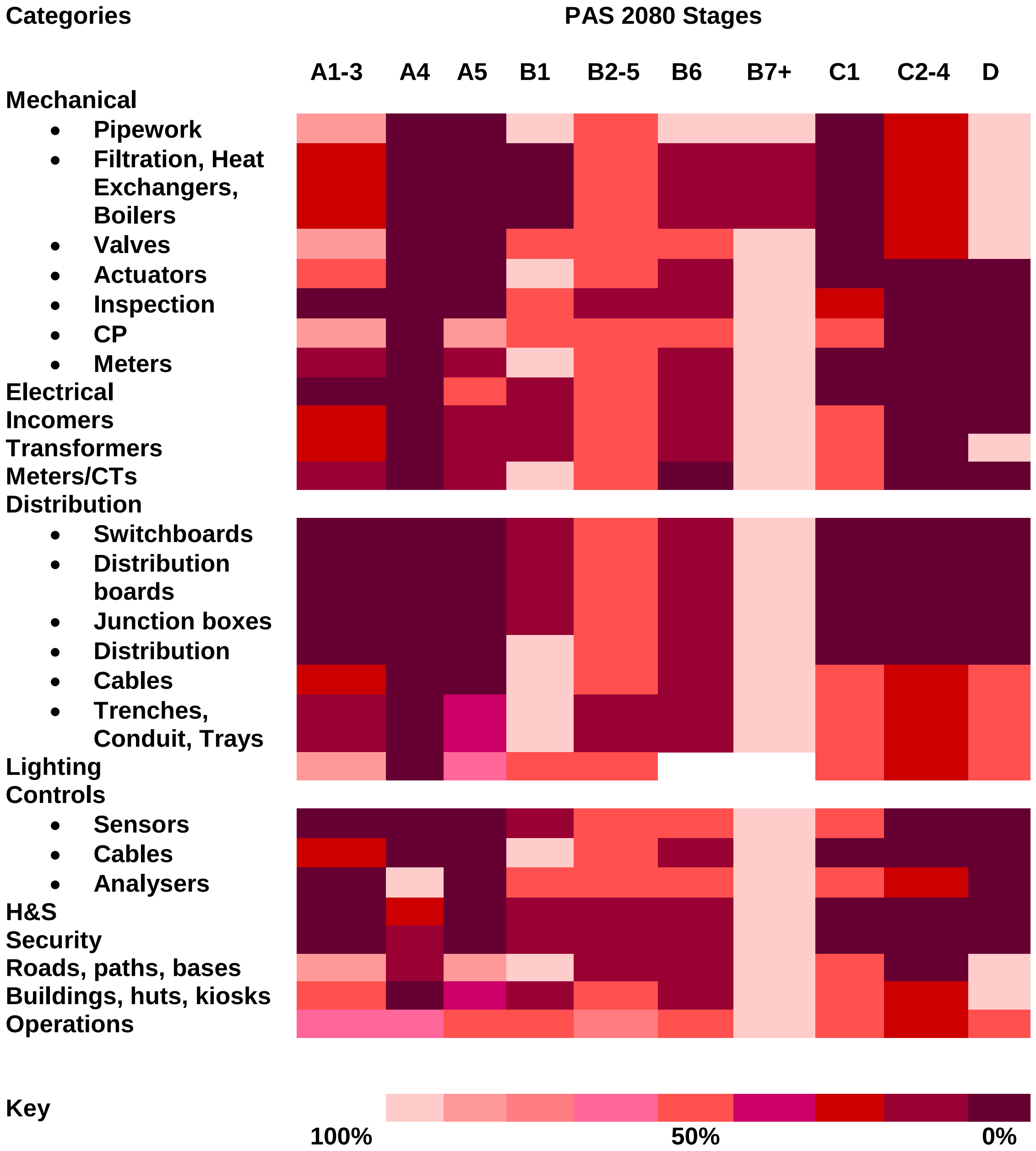



**Figure 8-10: Key Assumptions and Rules of Thumb**

### 8.5.4.1 A0 Design

This feasibility study has coincided with a global pandemic, when staff and client team are largely working from home and travelling very little. All meetings have been at least partially virtual, except for those connected with site visits. Most meetings and design team communication has been virtual. The carbon associated with this study has been usually low and may set a precedent for projects to come. Estimates and the data used are presented in Appendix B.

### 8.5.4.2 A1-3 Materials

Most of the data for modules A1-3 derives from the CIT itself. Sources of additional data are referenced in the spreadsheets, which is available on request.

The aspiration was to include 96% of material. The cost plan itself is +/-30%. It is expected that the material captured here lies within this margin of the cost plan.

Significant exclusions for which sufficiently representative data could not be found include:

Electrical equipment

Controls & Instrumentation

Cathodic Protection

Meters

This was in part because few product EPDs have been produced for this equipment; those that have been produced have are not sufficiently generic to permit extrapolation. The fall-back position is to estimate emissions from the materials composition of the equipment, which is not known in detail at this stage. We may know, for instance, that switchboards may need to be replaced, but the detail of the components is not specified at this stage.

Based on the scant information available, it is estimated that exclusions account for not more than 20% of mass.

#### 8.5.4.3 A4 Construction Site Transport.

Again, due to the level of detail at this stage, emissions due to site transport cannot be estimated accurately.

For buildings, the Institute of Structural Engineers suggests a rule of thumb for early stage calculations, which is 10% of structural carbon.[5]

#### 8.5.4.4 A5 Construction Site Carbon

Three sources are considered here:

General Site Operations, for which the Institute of Structural Engineers offers two possible benchmarks. These are for buildings structures. The relevance of them to infrastructure is not known. However, some equivalence is to be expected:

% of Project Whole Life Carbon (Stages A-C) – 1%

% of Project Cost[6] – 700 kg$CO_2$e per £100k superstructure

Specific site processes such as excavation, which can be accounted for.

Fugitive emissions – venting isolated sections prior to working on them to make safe.

Here fugitive emissions have been considered outside of the normal A5 processes.

The volume of methane in the pipework has been estimated and release attributed to the stage at which those pipework sections are proposed to be worked on in the options. It is assumed that this is vented in its entirety from the isolation valves downstream, unless a way is found to recover this, as proposed as a project in the Sustainability Register.

Valve removal is assumed to include 2m of associated pipework. This is likely to be the absolute minimum.

#### 8.5.4.5 B1+ In-Use Emissions

Two classes of information are accounted for here.

B1 Operational Emissions on Site

B6 Operational Energy use (Grid Electricity)

Data available for both is not complete, therefore the emissions are indicative only.

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[5] Orr JJ and Gibbons OP (2020) How to calculate embodied carbon, Institute of Structural Engineers, 2020.

[6] RICS 2017 Whole life carbon assessment for the built environment, November 2017

B1 Emissions on site

No details were available in relation to boiler and generator emissions or refrigerant leaks.

The latest fugitive emissions assessment was supplied[7].

Site staff confirmed that this was reasonably constant over time, as maintenance endeavoured to keep up with failures of seals on the valves.

The present level of emissions is assumed to be proportional to the valve inventory. (See Appendix for details of the calculation.) This is therefore adjusted proportionately for changes in the number of valves in the different options.

For instance, when the Shell and Perenco areas cease operations in the 2035, it is assumed this level of emissions will drop significantly.

Use of the boiler and diesel generator will increase $CO_2$ emissions, so the values calculated here can be considered to be a minimum.

#### *8.5.4.6* B6 Operational Energy use (Grid Electricity)

Limited electrical meter data was made available at the start of the project. It is not known equipment is included in this. It has been assumed that this covers lighting, actuation and cathodic protection. The consumption has been split across these end uses, using reasonable assumptions. This means that when these inventories change as a result of changes to these options, the electricity drawn from the grid changes proportionately.

For lighting, it is both the reduction in lighting columns, but also the introduction of LED lighting.

For cathodic protection, it is adjusted based on the pipework length.

For actuators, this is based on the inventory of actuators on site with some assumptions about how often these move.

#### 8.5.4.7 C1-C4 End of Life Benchmarks

Some data has been provided in the CIT for some of the relevant processes, but this is by no means comprehensive.

Significantly missing is data from pipework deconstruction and removal. This is an area in which a lot of energy can be used or saved. Also, there is significantly potential for improving recovery and reuse through the cutting technique and indeed the flanging of joints. That said, flanges themselves are a significant source of embodied carbon.

#### 8.5.4.8 C1 Demolition

Where provided in the CIT (trench removal, excavation etc) these values have been used here for C1 Demolition. No other suitable benchmarks could be found for this type of site. These estimates are very conservative.

#### 8.5.4.9 C2-C4 Removal, Processing and Disposal

Benchmarks from the Institute of Structural Engineers guidance has been used here of 0.018 $kgCO_2e/kg$ waste. This is based on the typical fractions of material recycled in the UK at the moment[8].

Disposal figures have been provided in the CIT and this was calculated. The figures for these are significantly lower than for the IStructE benchmarks, so these have been used here.

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[7] Bacton Leaks 2020.pdf
(Summary of Leaks identified During Fugitive Emissions Survey Using the Bacharach Hi-Flow (w/c 19th October 2020 – supplied by the Client)

[8] DEFRA/GSS UK Statistics on Waste, 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002246/UK_stats_on_waste_statistical_notice_July2021_accessible_FINAL.pdf

8.5.4.10 D Re-use

While not currently part of the PAS2080 process, this is due to be added and is likely to be a component by the time the proposed works start on site. There is a large potential for "recovery" of carbon here through offsetting the production of new material.

Weights of the components have been estimated approximately and linked to the fraction of recycling as per the previous section.

*Results*

A summary of the estimated emissions across all PAS2080 Stages is shown in the Table and Figures below.

The CIT Tool is provided in the Appendix J

As can be seen from the below, the life cycle is dominated by operational fugitive emissions, with embodied emissions contributing significantly less.

Option 1 (the preferred option) has the lowest carbon emissions inventory across all options for the full period of 2025-2050.

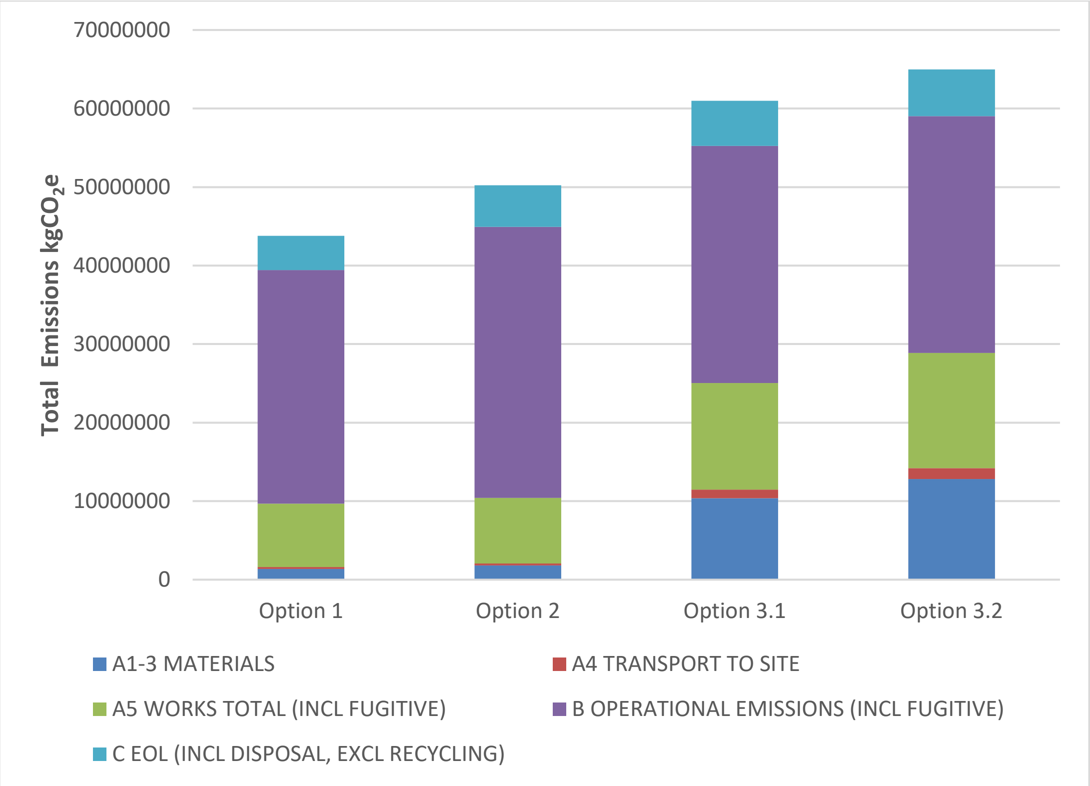


**Figure 8-11: Breakdown of emissions (kgCO2e) for each option across the PAS 2080 inventory**

| | | Option 1 | | | Option 2 | | Option 3.1 | | Option 3.2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **kilograms** | **2025** | **2035** | **2050** | **2035** | **2050** | **2035** | **2050** | **2035** | **2050** | |
| **A0** | Design | | | | | | | | | | **Source** |
| **A1-3** | Materials | 942025 | 437873 | 0 | 883716 | 0 | 9236958 | 0 | 11889459 | 0 | *CIT* |
| **A4** | Transport | 94203 | 43787 | 93195 | 88372 | 64161 | 923696 | 88422 | 1188946 | 90166 | *IStructE* |
| **A5** | Works - Excavation | 0 | 0 | 1252822 | 515740 | 737082 | 534545 | 740774 | 532246 | 754271 | *IStructE /CIT* |
| **A5** | Works - Vent $CH_4$ | 1465 | 594 | 270165 | 186810 | 95743 | 349740 | 140151 | 367238 | 165761 | *See calculations* |
| **A5** | Works - Vent CO2e | 36636 | 14857 | 6754116 | 4670253 | 2393577 | 8743489 | 3503781 | 9180948 | 4144026 | *See calculations* |
| **B1** | Operational Fugitive $CH_4$ | 96580 | 965800 | 117615 | 965800 | 309616 | 965800 | 137607 | 965800 | 137607 | *See calculations* |
| **B1** | Operational Fugitive $CH_4$ - $CO_2$e | 2414500 | 24145000 | 2940375 | 24145000 | 7740415 | 24145000 | 3440184 | 24145000 | 3440184 | *See calculations* |
| **B6** | Operational $CO_2$e - Grid Electricity | 14967 | 149674 | 72090 | 149674 | 33833 | 149674 | 22620 | 149674 | 20933 | *See calculations* |
| **B9** | User Carbon | | | | | | | | | | *Not considered* |
| **C1** | Demolition | 114 | 2 | 931951 | 774168 | 641614 | 775363 | 884218 | 748353 | 901655 | *CIT* |
| **C2-4** | End of Life | 1592 | 85 | 3431448 | 1889693 | 2001003 | 1940100 | 2141476 | 1911357 | 2366589 | *IStructE* |
| **C4** | Disposal | 28 | 10 | 273657 | 121464 | 164670 | 129551 | 171071 | 123951 | 198807 | CIT |
| **D** | Re-Use/Recycling | -43605 | 0 | -34362873 | -27309098 | -19296349 | -28383772 | -22766624 | -27734672 | -35940695 | *IStructE* |

**Table 8-9: Estimated emissions of CO2 and CH4 for all Options and all PAS 2080 Stages**

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Operational emissions are estimated to fall with the reduction in inventory but remain higher than any capital carbon studied.

Indeed, fugitive emissions on the construction site, from venting to atmosphere prior to carrying out works, show that these emissions are of a similar order of magnitude to the capital carbon, adding imperative to address this if capital carbon is to be addressed.

The assumption made here is for the maximum venting during decommissioning of pipework – all methane in the pipework to be worked on is vented. In practice this is unlikely, but it shows the comparative impact if this did happen.

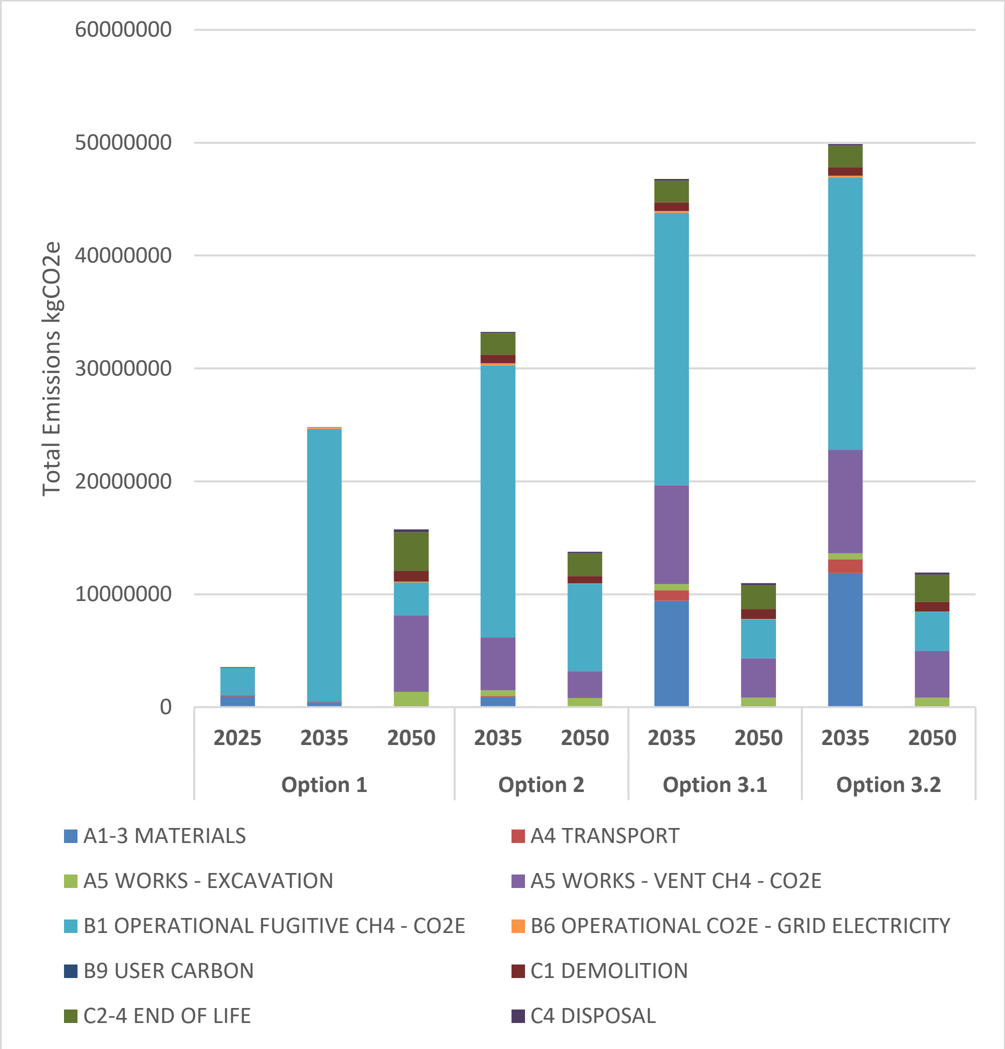



**Figure 8-12: Breakdown of emissions (CO2e) for each option across the PAS 2080 inventory by phase**

Removing operational and works emissions from the totals, the relative carbon embedded in the material and associated with its disposal can be seen. Our assumptions are that steel will be recycled at 95%. In spite of this, emissions associated with removal remain significant.

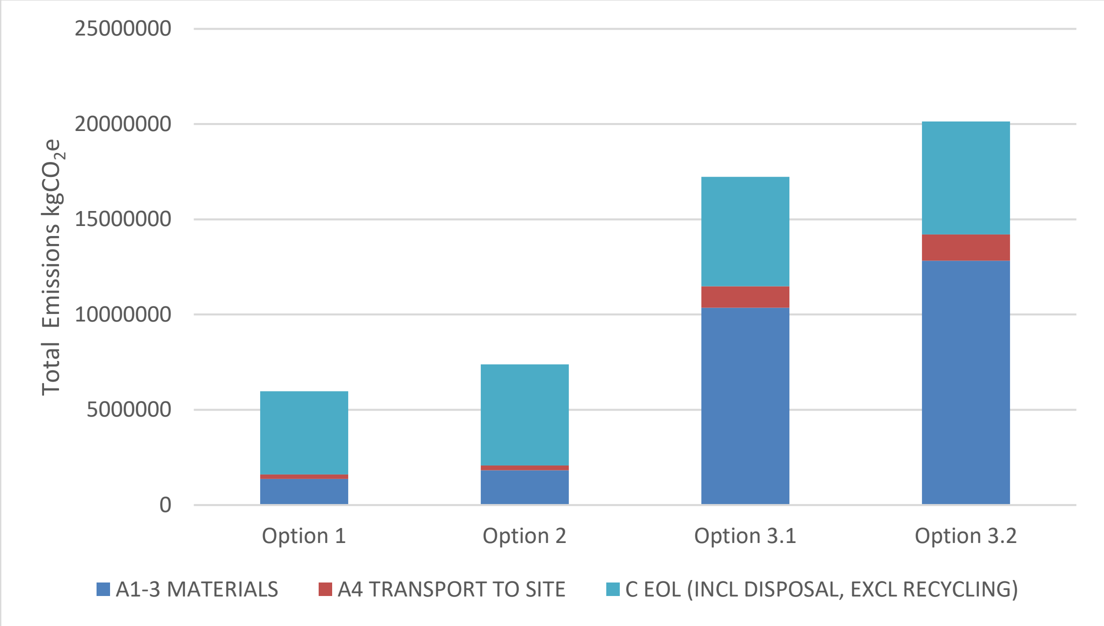



**Figure 8-13: Estimated material carbon, its transport and removal (methane excluded)**

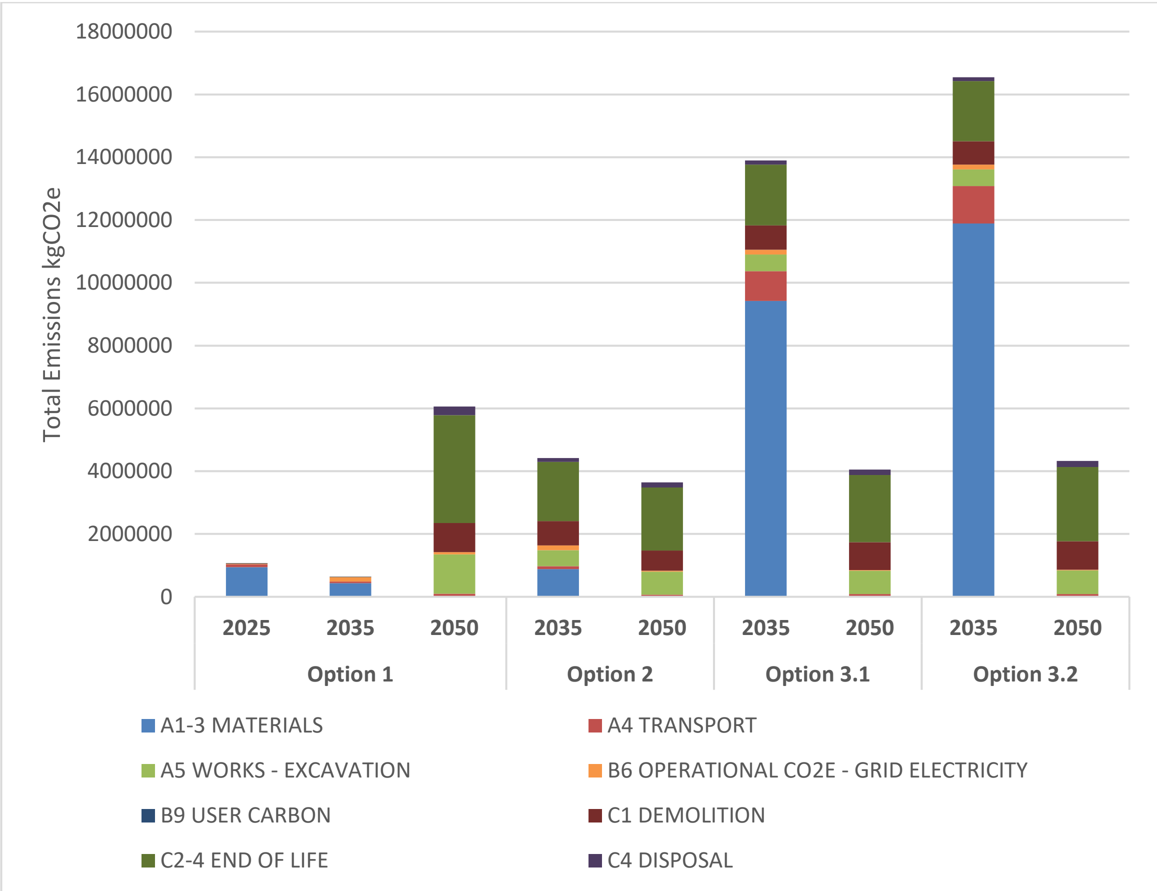



**Figure 8-14: Estimated breakdown of carbon across the phases, excluding methane**

*Where is all the material carbon going?*

Carbon associated with new materials and installation (shown on the right of this diagram) is dominated by pipework and valves – new and replacements.

Carbon associated with removals – shown on the left of the graph (for illustrative purposes only – this is not negative carbon – it is added to installation carbon) is dominated by new fill.

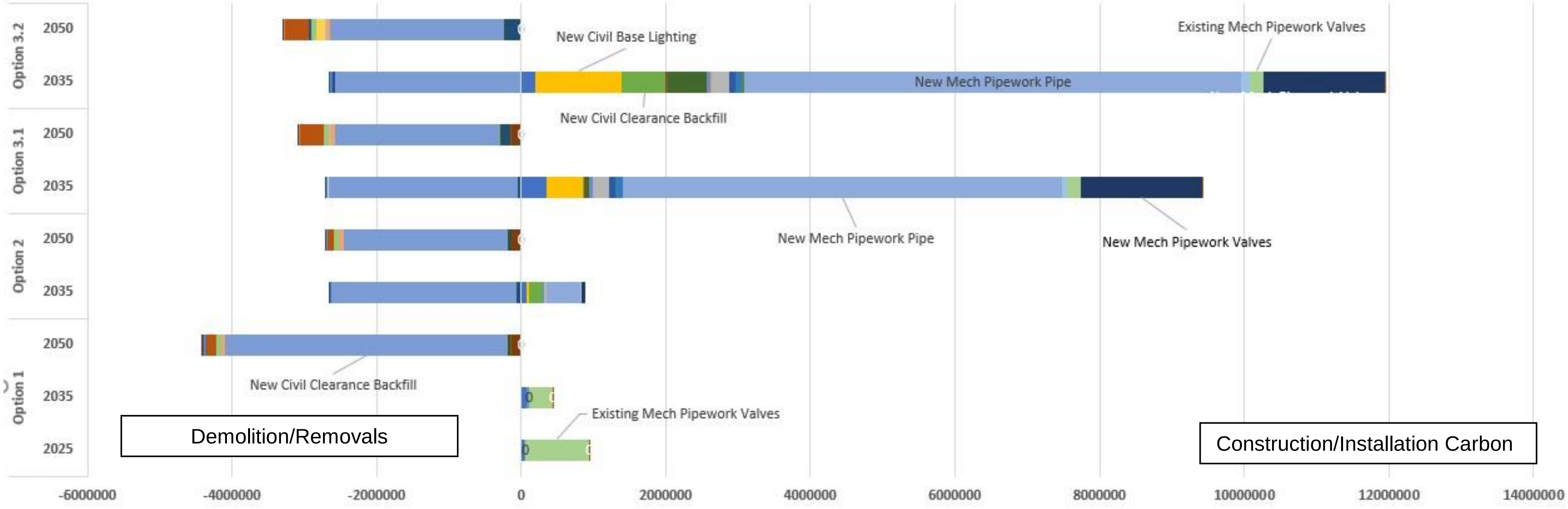



**Figure 8-15: Estimated breakdown of carbon across the materials, excluding methane**

*Comparison of Full Inventory with the CIT*

The carbon resulting from materials data logged in the CIT is summarised in the table below for each option.

| | *$kgCO_2e$* | Option 1 | Option 2 | Option 3.1 | Option 3.2 |
|---|---|---|---|---|---|
| CIT | *Option 1.1 (pre-2035)* | *886456* | *886456* | *886456* | *886456* |
| | *Options at 2035* | *2363271* | *3057737* | *11796143* | *15296998* |
| | *Totals* | *3249727* | *3944193* | *12682599* | *16183454* |

**Table 8-10: CIT results for the Options for the period 2025-2050**

The equivalent information is shown below for the whole inventory, noting that the whole inventory itself has a number of omissions.

| *kg CO2e* | | **Option 1** | **Option 2** | **Option 3.1** | **Option 3.2** |
|---|---|---|---|---|---|
| | | **2025-2050** | **2025-2050** | **2025-2050** | **2025-2050** |
| A1-3 | Materials | 1379899 | 1825741 | 12191088 | 12831484 |
| A4 | Transport | 231079 | 246682 | 1371533 | 1373261 |
| A5 | Works - excavation | 1252823 | 1252823 | 2528142 | 1286518 |
| A5 | Works - vent ch4 - co2e | 6812885 | 7100466 | 19391648 | 13361611 |
| B1 | Operational fugitive ch4 - co2e | 29499875 | 34299916 | 64299600 | 29999685 |
| B6 | Operational co2e - grid electricity | 236732 | 198475 | 385737 | 185575 |
| C1 | Demolition | 931009 | 1414836 | 3073471 | 1649063 |
| C2-4 | End of life | 3433543 | 3892211 | 7975303 | 4279460 |
| C4 | Disposal | 273695 | 286161 | 586811 | 322785 |
| | **Sub-total** | **44051539** | **50517311** | **111803334** | **65289441** |
| D Re-use/recycling (deducted at time of reuse) | | *-34406478* | *-46649052* | *-97843052* | *-63718972* |
| | **Total** | **9645061** | **3868259** | **13960282** | **1570469** |

**Table 8-11: Full Inventory results for the Options for the period 2025-2050**

Comparing the CIT to these calculations, it can be seen that the inventories are identical for Stages A1-3 (materials), Stage A5 excavation, and Stage C1 demolition. Departures relate to the items not included in the CIT and approximated as described above. Overall, the CIT inventory represents 7-25% of the emissions captured by the wider inventory. This is clearly heavily skewed by the methane emissions.

| **CIT Totals vs Full Inventory Totals** | **Option 1** | **Option 2** | **Option 3.1** | **Option 4.1** |
|---|---|---|---|---|
| CIT / Full (A1-3+A5+C1) | 1 | 1 | 1 | 1 |
| CIT / Full (A1-3+A5+C1+C4) | 0.85 | 0.83 | 0.69 | 1.01 |
| **CIT as % of Full Inventory (excl D)** | 7.42 | 7.85 | 20.80 | 24.91 |

**Table 8-12: Comparison of CIT scope and Full Inventory scope**

*GHG Savings made*

One of the main savings made has been the selection of the lowest carbon option – Option 1 – to 2050.

With this, removal of perimeter lighting has resulted in some energy savings in addition to reducing light nuisance for neighbours and local ecology.

Pipe supports have also been reduced in number. The relative proportions of the materials of these may be considered when the time comes.

Please refer to the Sustainability Register where further areas for savings are suggested.

### 8.5.5 Sustainability

#### 8.5.5.1 Sustainability Register

The Sustainability Register supplied to the project was populated with initiatives explored, incorporated or recommended to be explored for the next stage. The register is shown in Appendix B.

#### 8.5.5.2 Projects

Some projects were identified to be explored further in the next stage. These focussed on ways to promote newly liberated land to pursue a sustainable development agenda. These included:

Green infrastructure to increase the biodiversity on site and retain more water

Small scale local PV cover to provide local power to lighting, instrument huts, actuators or EV charging points for staff or site vehicles

Exploration of the generation of biogas on site from co-digestion of local farm waste and macroalgae, for injection to the gas grid at Bacton. A community outreach project to the farming and coastal communities that could be managed on behalf of NG by a biogas developer.

#### 8.5.5.3 CEEQUAL Overview

CEEQUAL has been widely adopted as a way of quantifying the sustainability performance of infrastructure projects in the UK. It was developed by the Institute of Civil Engineers and sold to BRE Ltd. to join their family of BREEAM Assessment products. It has been adopted as a requirement by a large number of public and private sector clients including, National Grid[9]. The scope of CEEQUAL is provided at the end of this doc.

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

A brief assessment has been made of the current situation in Appendix B. Most credits appear possible at this stage. Stages were action is needed have been marked. This is mainly agreement of terms, development of policy documents for the project and inclusion of requirements in tender and contract documents.

## 8.6 CBA

### 8.6.1 Overview

A report on the CBA work and outputs including native file for CBA is provided in Appendix C with the cost estimates which were a primary source of input data together with emissions taken from Appendix J Environment and Sustainability.

Ofgem's CBA template is tightly structured and highly prescriptive. It applies long-established economic concepts and techniques and modifies the application to assess the types of projects considered and implemented by regulated gas transmission network firms. It is not a "black box"; the embedded calculations are entirely transparent. It is simply that no discretion is

[9] https://www.ceequal.com/all-users/

allowed in performing the calculations. Once the input data requirements are satisfied, the embedded calculations will generate the required outputs.

The completed workbook, setting out the evaluation of the options with various sensitivities, is appended to this report. As a result, it is considered unnecessary to present a detailed description of the workbook since it is largely self-explanatory and will be familiar to those with knowledge and experience in these matters. In addition, it is expected that the report will a have small, mainly specialised audience made up of those on the Client side with knowledge and responsibilities in this area and with responsibility to progress the Reopener Process to a successful conclusion.

Instead the focus is on how the workbook inputs were assembled from the data and analysis already conducted and on the key outputs.

### 8.6.2 Data requirements

The principal data requirements of Ofgem's CBA Template are:

- Outputs;
- Investment;
- NG Pass Through Costs;
- Avoided TO Costs;
- Societal benefits; and
- A Risk Register for the selected option.

Option 1 – "Make do and Mend" has been chosen as the Baseline Option in Ofgem's CBA Template. All the other options and sensitivities are assessed in relation to this option.

### 8.6.3 Investment Type

The CBA Template identifies nineteen different types of investment:

i) Load Related – Entry;
ii) Load Related – Exit;
iii) Load Related - Network Capability;
iv) Load Related – Offtakes;
v) Load Related - Other Costs;
vi) Non-Load Related - Emissions Reduction;
vii) Non-Load Related - Asset Health (condition driven);
viii) Non-Load Related - Cyber Security;
ix) Non-Load Related - Physical Security;
x) Non-Load Related – Decommissioning;
xi) Non-Load Related - Other Costs;
xii) Opex;
xiii) Business Support;
xiv) Closely associated Indirects;
xv) Operational Activities - Planned Inspection & Maintenance;
xvi) Operational Activities - Fault Repairs;
xvii) Operational Activities - Property Management;
xviii) Non-Operational - Non-Operational Capex;
xix) System Operator Capex;

The options considered include elements of a number of these investment types, but the focus of the investment that will be incurred is on **Load Related – Entry** and this type of investment has been selected. Other types of investment, for example, in relation to Opex and Decommissioning are treated as both supportive of this objective and integrated in the analysis.

### 8.6.4 Outputs

Since all the options are designed and structured to meet NGGT's statutory, contractual, commercial and societal obligations, it is not possible to identify and quantify any variations in output between pairs of options or among the options.

### 8.6.5 Investment

The investment covers all the direct economic costs incurred and the inputs are derived in their entirety from the cost estimates and the reports prepared. These cost estimates were prepared for the following categories of expenditure:

- Total Material Expenditure;
  - Material
  - Freight;
- Engineering;
  - Engineering Design
  - 3rd Party Support
- Construction Expenditure;
- Construction Labour
  - Temporary Works
  - Indirect Construction Expenditure
  - Miscellaneous
  - Commissioning
- Client Costs; and
- Decommissioning.

For the principal cost categories, the phasing of investment expenditure has been applied on a monthly basis for the years when investment is concentrated. This occurs for all options in the early years of both Phase 1 and Phase 2 and towards the end of Phase for Options 3.1 and 3.2. In contrast, the CBA template specifies fifty-two (52) investment expenditure types. For this project the following expenditure types were identified as relevant:

- 08 - CIVIL ASSETS (ACCESS)
- 09 - CIVIL ASSETS (BUILDINGS/ENCLOSURES)
- 12 - CIVIL ASSETS (PIPE SUPPORTS)
- 15 - CATHODIC PROTECTION
- 16 - ELECTRICAL (INCUDING STANDBY GENERATORS)
- 18 - FILTER / SCRUBBERS
- 29 - NETWORK CONTROL AND INSTRUMENTATION
- 44 - NON-RETURN VALVES
- 45 - REMOTE ISOLATION VALVES
- Other
- Opex and
- Decommissioning

The cost estimates generated by category have been modified to comply with this classification. Great care has been taken to ensure that the classification in terms of totals, over time on an annual basis and among categories of cost is accurate and consistent.
The expenditure under “Other” is for Painting/Weather and Waterline (WWL) Protection. It includes some limited expenditure reconfiguring the site and built facilities in advance of the longer-term decommissioning requirement. Expenditure on decommissioning is specified separately.

### 8.6.6 NG Pass Through Costs

It is understood that all costs incurred by NGGT in providing services at Bacton are recovered via the current and continuing contractual arrangements with service users at the site. Therefore, it is assumed that there no specified pass through costs to be considered. And, to the extent that there might be some, it is assumed in addition that these would be passed through on the same basis, and for the same amount, under all options.

### 8.6.7 Avoided TO Costs

Again, it is assumed that if avoided TO costs arise, they will be broadly similar for all options. However, it is possible that, with the reconfiguration of the site and site operations under Options 3.1 and 3.2, some TO costs might be avoided that might not be avoided under Options 1 and 2. At this stage, it is difficult to quantify these. This is primarily a matter for the relevant staff of NGGT with knowledge and competence in this area and might be worth investigating in the next stage of the Reopener Process.

#### 8.6.8 Societal Benefits

This section requires the entry of any figures relevant to the reduction in emissions/losses/leakage and the provision of details on the reduced probability of Fatality and Non-Fatal injury.

8.6.8.1 Emissions

Specifically, the focus is on:

- NOx Emissions
- CO2 Emissions
- Other GHG emissions (CO2e) - Methane

Typically, when the CBA template is being applied, the Baseline Option is a “do nothing” scenario. As explained above, a “do nothing” option is not an option and, as a result, Option 1 has been chosen as the Baseline Option. Therefore, the costs of emissions are included for each option and reductions (or increases) in emissions are expressed as variations of the NPVs Options 2, 3.1 and 3.2 relative to Option 1.

8.6.8.2 Health and Safety

The requirements in this section relate to estimates of the reduced probability of fatality, non-fatal injury and any other detrimental impacts to health and well-being.

#### 8.6.9 Risk Register

The CBA Template guidance specifies that the risk register should be filled in only for the option that has been selected. It requires that details should be provided for all risk(s) affecting the following areas:

(i) Delivery Timeframe;
(ii) Distinct Variance in original Forecast Cost; and
(iii) Criteria which may result in the Scheme being cancelled.

The guidance further specifies that each row in the risk register should be treated as a single risk entry. There is an expectation that relevant information will be provided on the:

- Risk Description;
- Impact;
- Likelihood; and
- Mitigation/Controls.

There is also an expectation that any relevant commentary is included as supporting evidence.

#### 8.6.10 Satisfying the data input requirements

In line with the discussion in the previous section, the focus in this section is on:

- Investment;
- Societal Benefits; and
- The Risk Register.

#### 8.6.11 Investment

The CBA investment expenditures by option and by year are presented in the following tables. These data are then presented graphically by option. The graphical representation highlights variations in the profiles of investment expenditure.

| | Total | 2023 | 2024 | 2025 | 2026 | 2027 to 2031 | 2032 | 2036 | 2037 | 2038 | 2039 to 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2053 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08 - CIVIL ASSETS (ACCESS) | [redacted] | | | | | | | | | | | | | | | | |
| 09 - CIVIL ASSETS (BUILDINGS/ENCLOSURES) | | | | | | | | | | | | | | | | | |
| 15 - CATHODIC PROTECTION | | | | | | | | | | | | | | | | | |
| 16 - ELECTRICAL (INCUDING STANDBY GENERATORS) | | | | | | | | | | | | | | | | | |
| 18 - FILTER / SCRUBBERS | | | | | | | | | | | | | | | | | |
| 29 - NETWORK CONTROL AND INSTRUMENTATION | | | | | | | | | | | | | | | | | |
| 44 - NON-RETURN VALVES | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | |
| Opex | | | | | | | | | | | | | | | | | |
| Decommissioning | | | | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | | |

**Table 8-13**: **Bacton Option 1 – CBA Classified Investment Expenditures**

| | Total | 2023 | 2024 | 2025 | 2026 | 2027 to 2030 | 2031 | 2032 | 2036 | 2037 | 2038 | 2039 | 2040 to 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2053 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08 - CIVIL ASSETS (ACCESS) | [redacted] | | | | | | | | | | | | | | | | | | |
| 09 - CIVIL ASSETS (BUILDINGS/ENCLOSURES) | [redacted] | | | | | | | | | | | | | | | | | | |
| 12 - CIVIL ASSETS (PIPE SUPPORTS) | [redacted] | | | | | | | | | | | | | | | | | | |
| 15 - CATHODIC PROTECTION | [redacted] | | | | | | | | | | | | | | | | | | |
| 16 - ELECTRICAL (INCUDING STANDBY GENERATORS) | [redacted] | | | | | | | | | | | | | | | | | | |
| 18 - FILTER / SCRUBBERS | [redacted] | | | | | | | | | | | | | | | | | | |
| 29 - NETWORK CONTROL AND INSTRUMENTATION | [redacted] | | | | | | | | | | | | | | | | | | |
| 44 - NON-RETURN VALVES | [redacted] | | | | | | | | | | | | | | | | | | |
| 45 - REMOTE ISOLATION VALVES | [redacted] | | | | | | | | | | | | | | | | | | |
| Other | [redacted] | | | | | | | | | | | | | | | | | | |
| Opex | [redacted] | | | | | | | | | | | | | | | | | | |
| Decommissioning | [redacted] | | | | | | | | | | | | | | | | | | |
| Total | [redacted] | | | | | | | | | | | | | | | | | | |

**Table 8-14: Bacton Option 2 – CBA Classified Investment Expenditures**

| | Total | 2023 | 2024 | 2025 | 2026 | 2027 to 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | 2038 | 2039 | 2040 to 2047 | 2048 | 2049 | 2050 | 2051 | 2052 | 2053 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08 - CIVIL ASSETS (ACCESS) | [redacted] | | | | | | | | | | | | | | | | | | | | |
| 09 - CIVIL ASSETS (BUILDINGS/ENCLOSURES) | | | | | | | | | | | | | | | | | | | | | |
| 15 - CATHODIC PROTECTION | | | | | | | | | | | | | | | | | | | | | |
| 16 - ELECTRICAL | | | | | | | | | | | | | | | | | | | | | |
| 18 - FILTER / SCRUBBERS | | | | | | | | | | | | | | | | | | | | | |
| 29 - NETWORK CONTROL AND INSTRUMENTATION | | | | | | | | | | | | | | | | | | | | | |
| 44 - NON-RETURN VALVES | | | | | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | | | | |
| Decommissioning | | | | | | | | | | | | | | | | | | | | | |
| Opex | | | | | | | | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | | | | | | |

**Table 8-15: Bacton Option 3.1 – CBA Classified Investment Expenditures**

| | Total | Years as per previous table |
|---|---|---|
| 08 - CIVIL ASSETS (ACCESS) | [redacted] | |
| 09 - CIVIL ASSETS (BUILDINGS/ENCLOSURES) | | |
| 15 - CATHODIC PROTECTION | | |
| 16 - ELECTRICAL | | |
| 18 - FILTER / SCRUBBERS | | |
| 29 - NETWORK CONTROL AND INSTRUMENTATION | | |
| 44 - NON-RETURN VALVES | | |
| Other | | |
| Decommissioning | | |
| Opex | | |
| Total | | |

**Table 8-16: Bacton Option 1 – CBA Classified Investment Expenditures**

### 8.6.12 Option 1

[redacted]

**Figure 8-16: Option 1: Profile of Investment Expenditures**

For Option 1, there is an initial tranche of expenditure over the first four years to maintain asset health and the functional capability of the facilities. The next tranche of investment occurs after 2035 and is focused on maintaining the condition and functionality of the Interconnector related facilities. It also includes some limited reconfiguration of the facilities and the sealing and making safe of redundant facilities in advance of the eventual total site decommissioning after 2050.

### 8.6.13 Option 2

[redacted]

**Figure 8-17: Option 2: Profile of Investment Expenditures**

For Option 2, the initial tranche of expenditure matches that for Option. However, from 2035 the facilities redundant at that stage are decommissioned and there is some limited expenditure on reconfiguring the site. The remaining facilities are decommissioned after 2050.

### 8.6.14 Option 3.1

[redacted]

**Figure 8-18: Option 3.2: Profile of Investment Expenditures**

Again Option 3.1 mirrors the initial tranche of expenditure with Options 1 and 2. However, there is considerable expenditure prior to 2035 to reconfigure the site which is followed by decommissioning of the redundant facilities after 2035. The remaining facilities are decommissioned after 2050.

8.6.15 **Option 3.2**

[redacted]

**Figure 8-19: Option 3.2: Profile of Investment Expenditures**

Option 3.2 is very similar to Option 3.2. The principal difference is the acquisition of an adjoining greenfield site to locate some of the reconfigured site facilities. This slightly increases the expenditure on decommissioning the remaining facilities after 2050.

8.6.16 **Overview of Options**

The following chart presents the investment expenditure profiles for each of the options over the project evaluation period.

[redacted]

**Figure 8-20: Bacton – Expenditure Profile by Option**

Up to the early 2030s the expenditure for all options is the same and it is the same for Options 1 and up to 2035. However, from the early 2030s the expenditures for Options 3.1 and 3.2 increase significantly in response to the reconfiguration of the existing site and, in the case of Option 3.2, the development and incorporation of the adjoining 'greenfield' site.

In the years immediately after 2035, all options present increases in expenditure primarily related to the decommissioning of the site facilities no longer being used. This expenditure is least for Option 1 as it related to sealing off and making safe the unused facilities. A higher, but almost identical, expenditure is incurred for pre-2050 decommissioning under Option 3.1 and 3.2. Option 2 incurs the highest pre-2050 decommissioning expenditure as it is being performed while full operations are being maintained for the IUK and BBL Interconnectors and considerable reconfiguring of the site is being affected. In contrast, the site reconfiguration expenditures for Options 3.1 and 3.2 take place prior to 2035 and, as a result, their pre-2050 decommissioning expenditures are lower.

However, when it comes to post-2050 decommissioning expenditures, Option 1, unsurprisingly, incurs the highest expenditure, while the other options incur broadly the same level of expenditure.

## 8.7 Societal Benefits

The estimates of $CO_2$ and Methane emissions have been derived from the Environmental & Sustainability Report (20485-EV-RPT-000-0002).

## 8.8 Risk Register

Consultant has compiled a risk register for each option. In parallel, NGGT compiled a risk register and applied an Expected Monetary Value tool to quantify the expected cost impact of the relevant risks. These risk registers are appended to the main study report.

Not surprisingly, the risks are broadly similar across all options and their impacts vary in relation to the extent of the activities being performed.

This table presents a summary of the results generated by NGGT's EMV analysis.

| Option 1 | P-20 | P-50 | P-80 | EMV |
|---|---|---|---|---|
| Contractor | [redacted] | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |
| | | | | |
| Option 2 | | | | |
| Contractor | | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |
| | | | | |
| Option 3.1 | | | | |
| Contractor | | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |
| | | | | |
| Option 3.2 | | | | |
| Contractor | | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |

Source: NGGT

**Figure 8-21: Bacton – Summary of EMV Risk Analysis**

It is important to note that the cost estimates have been generated to an accuracy of +/-30%. This range is well in excess of these EMV estimates.

### 8.8.1 Outputs

Once the inputs have been entered appropriately the CBA Template automatically generates a Summary Tab.

ofgem Making a positive difference for energy consumers

| Option No. | Desc. Of Option | Preferred Option | Total Forecast Expenditure (£m) | Spend Area *(RRP Table Reference)* | Total NPV | Delta *(Option to baseline)* | NPVs based on Payback periods (£m)<br>10 Years | 20 Years | 30 Years | 45 Years |
|---|---|---|---|---|---|---|---|---|---|---|
| Baseline | Mend & Make Do | [redacted] | | | | | | | | |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | Option 2 | | | | | | | | | |
| 6 | Option 3.1 | | | | | | | | | |
| 7 | Option 3.2 | | | | | | | | | |
| 8 | 2 - Enhanced C& | | | | | | | | | |
| 9 | 3.1 - Enhanced C | | | | | | | | | |
| 10 | 3.2 - Enhanced I | | | | | | | | | |

**Figure 8-22: Bacton – Summary of CBA Results**

Four rows have been left blank to provide scope to consider relevant sensitivities. At an earlier stage in the study the impact of advancing to 2032 or delaying to 2038 the termination of North Sea South Basin supplies, but the impact was not material. Therefore, this sensitivity has been dropped. The only sensitivity considered is the impact of additional expenditure for Options 2, 3.1 and 3.2 on enhanced Control & Instrumentation.

This analysis confirms the conclusion formed during the Short List Evaluation Workshop that Option 1 is the optimal solution among those considered.

The CBA excel sheet is provided as a native file separately to this report.

# 9. FPSA and Technical Risk Register

## 9.1 General

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

- HAZID1 Report Doc. No 20485-HS-RPT-000-0001
- Site Location and Layout Review Report Doc. No 20485-EN-RPT-000-0009
- Design Process Safety Report Doc. No 20485-EN-RPT-000-0003
- CDM Risk Register Doc. No 20485-PM-REG-000-0004
- Technical Risk Register Doc. No 20485-PM-REG-000-0003

## 9.2 HAZID1

The scope of the HAZID1 study was to identify potential hazards arising from the design, siting and operation of the plant. The HAZID1 study was carried out in accordance with the National Grid standard T/SP/HAZ/8 as a structured assessment technique using guidewords.
All of the Action record sheets were issued to both National Grid and Consultant for each company to further issue these internally to the responsible engineer. Each responsible engineer is then required to provide a suitable method by which each of their action(s) can be closed.
A further meeting was held on 02/11/2021 with all parties to table and agree the action responses for all options and what is documented in the record sheets has been agreed. The meeting was in accordance with section 5.7 'Study Follow-Up/Close-Out' of the HAZID standard T/SP/HAZ/8. All actions / worksheets have been agreed and signed by the HAZID Chairperson.
The status of the raised actions is:

| Option | Actions | Fully Closed | Transferred to recommendations and the Technical Risk Register | Transferred to Environmental Risk Register | Transferred to Project Risk Register |
|---|---|---|---|---|---|
| 1 | 6 | 3 | 2 | 1 | 1 |
| 2 | 7 | 3 | 4 | - | - |
| 3.1 | 14 | 7 | 5 | 2 | 2 |
| 3.2 | 11 | 2 | 8 | 2 | 1 |

## 9.3 Site Location & Layout Review

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

All of the Action record sheets were issued to both National Grid and Consultant for each company to further issue these internally to the responsible engineer. Each responsible engineer is then required to provide a suitable method by which each of their action(s) can be closed.
A further meeting was held on 02/11/2021 with all parties to table and agree the action responses for all options and what is documented in the record sheets has been agreed. All actions / worksheets have been agreed and signed by the Site Location & Layout Review Chairperson.
The current status of the raised actions is:

| Option | Actions | Fully Closed |
|---|---|---|
| **2** | 3 | 3 |
| **3.1** | 3 | 3 |
| **3.2** | 3 | 3 |

### 9.4 CDM Risk Register

The CDM risk register for the project has been developed and continually updated throughout the project. No residual actions from the design FPSA studies have been transferred to the CDM risk registers. The status of the register has been shared and all open entries will be managed through to the construction phase of the project.

### 9.5 Technical Risk Register

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

Following project completion, any residual open actions will be handed over to National Grid Operations. The status of the register has been shared and all open entries will be managed in the next design phase.

The risks that have been identified are listed below (for more details, see the document 20485-PM-REG-000-0003:

| Ref No. | Hazard and Location | Design Action |
|---|---|---|
| 1 | PIPEWORKS FLEXIBILITY & STRESS<br>Options: 2 / 3.1 / 3.2<br>Risk of stresses being above the allowable code limits | Post Option selection all pipework should be subjected to a full stress analysis taking account of change in process and environmental conditions. |
| 2 | PiPEWORKS MATERIALS & WALL THICKNESS<br>Options 2 / 3.1 / 3.2<br>Risk of stresses being above the allowable code limits | The selection of standards, codes and calculation methods will be validated at the next FEED stage |
| 3 | UPDATE OF DRAWINGS<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Having carried out a drawing consistency review for supplied ELDs and Terminal Layout for Options 3.1 / 3.2, several inconsistencies are observed when comparing pipe connections shown on the ELDs and those on the layout drawings. It is strongly recommended that all drawings are reviewed and updated as soon as possible such that they reflect the as-built status of the Bacton terminal. Given the importance of the site and its COMAH Tier 1 rating, up-to-date records are vital for continued management of asset health |
| 4 | CONDITION OF ASSETS<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Equipment, Valves and pipework – Use updated inspection & maintenance records<br>It is strongly recommended that maintenance records are reviewed, updated and verified in light of the updated information during the meeting of 04.11.21. |
| 5 | UPDATE OF 3D MODEL<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Update the 3D model to represent the "As Built" status especially in the connections to IUK in the feeders 2 -4 area |

| | | |
|---|---|---|
| 6 | UPDATE OF DRAWINGS WHICH HAVE BEEN PRODUCED FROM THE EXISTING SITE 3D MODEL<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Having carried out a drawing consistency review for supplied ELDs and Terminal Layout for Options 3.1 / 3.2, several inconsistencies are observed when comparing pipe connections shown on the ELDs and those on the layout drawings that have been produced from the existing Site 3D Model. It is strongly recommended that the existing site 3D model and all drawings produced by it are reviewed and updated as soon as possible such that they reflect the as-built status of the Bacton terminal. Given the importance of the site and its COMAH Tier 1 rating, up-to-date records are vital for continued management of asset health |
| 7 | ROAD CROSSINGS (Perenco & Shell Feeders)<br>Option 1<br>Risk of pipework failure | The condition of the pipework from Perenco and Shell in the road crossings is unknown and it is not easy to be investigated currently. Actions cannot be recommended based on the original drawings.<br>The recommendations are to carry out Inspections to investigate the condition |
| 8 | VALVES TO BE REPLACED<br>Option 1<br>Risk of not meeting emissions requirements | It is strongly recommended that the list of valves is further reviewed in the next design phase and in the light of upcoming changes to environmental policies related to methane emissions. The recent commitments made at COP26 to cut methane emissions by 30% by 2030 are likely to require the list of valves to be reviewed and updated. |
| 9 | VALVES TO BE REPLACED<br>Option 1<br>Risk of not meeting emissions requirements | Valves that are known to pass quantities of methane rich gas to the atmosphere (e.g. due to stem seal failures) uncontrollably over extended periods of time should be considered for immediate replacement under existing maintenance strategy and budgets.<br>Valves that pass methane rich gas to atmosphere due to a failure to seal correctly should be considered unfit for purpose and replaced under current maintenance strategy and budgets. |
| | **RECOMMENDATIONS / RISKS BASED ON THE FPSA STUDIES** | |

| | | |
|---|---|---|
| 10 | ELECTRICAL IGNITION SOURCES<br>Option 1 action 2<br>Risk of potential ignition sources from old electrical distribution boards | Certain electrical distribution boards have been identified that need removal or updating to reduce possible ignition sources or to reduce hazards of shocks as shown below (for details see Documents 20485-AI-RPT-100-0003_Rev 0 (Option 1 report) & 20485-EL-LST-200-0001 SLD):<br>- Switchboard C (This is a single supply from old A LV board (A23)<br>- Switchboard D (This is a single supply from old A LV board (A27)<br>- Switchboard E (This is a single supply from old A LV board (A24)<br>- Switchboard F (This switchboard is in two sections a single supply from old A LV board (A28) & a supply from B board.<br>- Switchboard G (This switchboard is in two sections a single supply from old A LV board (A3) & a supply from B board.<br>- Switchboard L (This has 2 supplies from old A LV board (A25 &A26)<br>- Switchboard M (This has 1 supply from old A LV board (A5)<br>- Switchboard N (redundant & currently isolated)<br>- Switchboard P (incorporate lighting scheme into new "B" board)<br>- DB Q1 & Q2<br>- DB R / DB S / DB T / DB V & DB Z (new combined DB with Z) / DB W (3P+N instead of single phase)<br>- Switchboard B (Feeds H, J, & K – resupply from T1 & T2 extension. Any retained plant loads will be supplied by new distribution centres.<br>- B1 (retained loads to be rationalised in new DB) / - B2 & DBB2 (retained loads to be rationalised in new DB – mostly lighting and small power) / DB2 (retained loads to be rationalised in new DB)<br>- B6 & DB3 (retained loads to be rationalised in new DB) / B4 (retained loads to be rationalised – mostly lighting and small power)<br>- DB/B/27 (Replicate retained sub-circuits in new distribution centre to be located in feeder 3&5 south east area)<br>- Switchboards that are not needed for Options 1.2 and 2 (e.g. New Kiosk in Middle-West of Site / New Kiosk in Middle-East of Site / DB H / DB J / DB K) |
| 11 | Suppliers Overpressure protection systems do not meet the required SIL rating.<br>Option 1 action 3<br>Risk related with reliance on a suppliers HIPPS | NG to carry out a separate project ahead of the possible adoption of this option to decide whether to upgrade the NG HIPPS to the required SIL level or rely on the suppliers HIPPS. |
| 12 | Air Pollution<br>Option 1 action 5<br>Environmental risk associated with manual venting | NG Environmental Team to discuss on the necessity to develop a Policy Statement on venting and to develop a future project to capture all emissions to atmosphere to record and inform the regulator |
| 13 | Explosion / Impact on Interconnector UK HV Transformer House and the RUK Boiler House for the new part of the ring main<br>Option 2 action 3 | Further Fire & Gas 3D mapping is recommended to be carried out in the next phase to ensure there is suitable and sufficient F&G detection in these areas. A 3D Fire and Gas Mapping would allow for placement of fire and gas detectors within the model and the determination of the effectiveness of each detector based on the coverage area targets. |

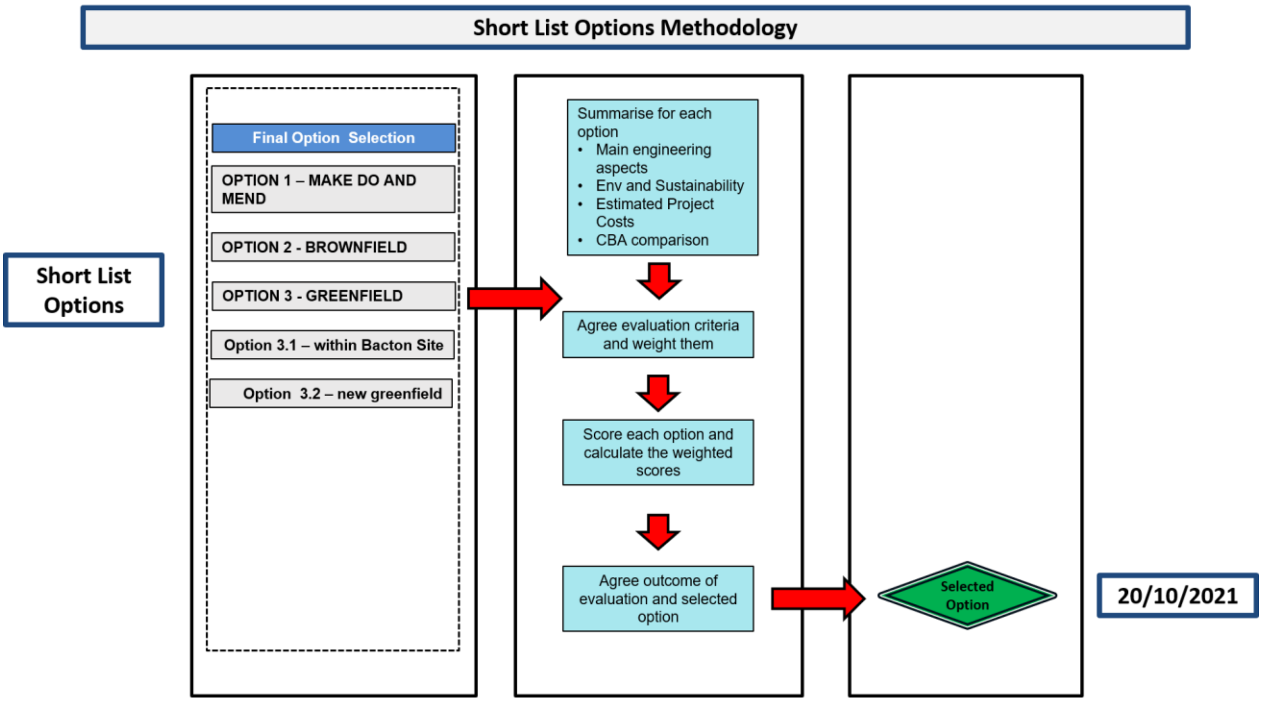
| | | |
|---|---|---|
| 14 | Remote possibility of missiles being the result of compressor failures in the Interconnector UK compressor system, also from the BBL incomer Option 2 action 4/ Option 3.1 action 7 | It is recommended that these 2 areas are committed to further study work to resolve this event scenario. |
| 15 | Fatigue - During any blowdown scenarios there would be a JT effect cooling the pipework leading to embrittlement and failure. Option 2 action 5 | The installation of a blowdown system is recommended for consideration to allow safe removal of inventory in the event of external fire etc. This should include evaluation of the requirement for either elevated or ground flare. As part of blowdown study, minimum metal temperatures to be confirmed. |
| 16 | The ring main could be subjected to overpressure from either the RUK or BBL incomers Option 2 action 6 (item 2) | It is recommended that an overpressure protection and flow / pressure control study is carried out during the next phase (where a process simulation model will be available) |
| 17 | Possible rapid phase transition during maintenance or emergency blowdown of the process Option 3.1 action 6 / Option 3.2 action 3 | The installation of a blowdown system is recommended for consideration to allow safe removal of inventory in the event of external fire etc. This should include evaluation of the requirement for either elevated or ground flare. As part of blowdown study, minimum metal temperatures to be confirmed. |
| 18 | The system could be subjected to over-pressure from either the RUK or BBL incomers. Option 3.1 action 9 & 10 / 3.2 action 5 | NG to review their policy with respect to over-pressure protection on third party feeds and determine the acceptability of reliance on third-party measures (HIPPS |
| 19 | The system could be subjected to over-pressure from either the RUK or BBL incomers. Option 3.1 action 11 / 3.2 action 6 | It is recommended that an over-pressure protection study is carried out during the next phase of the project. |
| 20 | During maintenance operations some gas is vented to atmosphere (e.g. venting of the Pig Traps, venting of pipework to make it safe to work). Currently there is no requirement for NG to inform the regulator of these releases Option 3.1 action 12 & 13/ 3.2 action 7 & 9 Environmental risk associated with manual venting | NG Environmental Team to discuss on the necessity to develop a Policy Statement on venting and to develop a future project to capture all emissions to atmosphere to record and inform the regulator |
| 21 | During maintenance operations some gas is vented to atmosphere (e.g. venting of the Pig Traps, venting of pipework to make it safe to work). Currently there is no requirement for NG to inform the regulator of these releases Option 3.1 action 12 & 13 / 3.2 action 7 & 9 | A review is recommended of how manual venting can be minimised during routine maintenance activities |

| | | |
|---|---|---|
| | Environmental risk associated with manual venting | |
| 22 | Third parties could gain access to the new site if unmanned<br>Option 3.2 action 4 | Ensure the site is secure either as a Stand Alone AGI or connected to the main site with the main site security fencing extended around the new site. The recommendation is to investigate compliance to the National Grid ISS (Integrated Security System) in the next design phase |
| 23 | Occupational Health<br>Option 3.2 action 8 | The investigation of the Sanitation requirements for this new site is recommended and whether the provision of clean drinking water and treatment and disposal of human excreta and sewage is required |
| 24 | Escape routes<br>Option 3.2 action 11 | include in the FEED SOW the development of the normal and emergency escape routes for this new area and how they tie-in to the existing system along with the location of new muster points if required, will be included in the FEED SOW |
| 25 | There Is only one flow control valve tying into feeder 3 and 5 manifolds<br>Option 1<br>Risk of a potential Single Point of Failure. | To be investigated further in the next design phase |
| 26 | Supply to Cadent offtake<br>Option 2 | Need to consider the Feeder 5 supply to Cadent offtake and optimise the design |
| 27 | Bi-directional metering options for IUK and BBL interconnectors<br>Options 3.1 & 3.2 | Bi-directional metering options for IUK and BBL interconnectors to be investigated further for Option 3 |
| 28 | Phased approach to construction<br>Option 3.1 | Option 3.1 is proposed to undertake a phased approach to construction. The design has minimised overlaps with existing plant where possible however this could not be eliminated. Construction to be phased West to East starting in the redundant ENI area. A similar approach was followed during the IUK construction. Due to time constraints and non-availability of records, recommendations cannot be done at this stage. However, records and lessons learned from IUK to be captured in the next design phase. |

# 10. SHORT LIST EVALUATION WORKSHOP

## 10.1 Introduction

The review and evaluation of the short list options was carried out in a joint NG/Consultant workshop on the 20/10/2021 with face to face and remote attendance. In total 23 persons were invited, and the majority were able to take part for most of the workshop and contribute to the outcomes. The methodology involved a two part approach of (1) presentation summary of each option against the key areas of engineering, environment, sustainability, cost and CBA to enable the workshop team to align on a common understanding of each option and (2) agreement of a list of agreed criteria and use within a formal multi-criteria decision making evaluation of the short list options.




## 10.2 Short List Options Presentation

In the presentation of key aspects of each option against themes of engineering, environment, sustainability, cost and CBA the issues summarised in section 8 for each option were shared with the workshop team in order to establish a common understanding of key issues ahead of proceeding to a formal evaluation. A copy of this presentation is given in Appendix A.

## 10.3 Evaluation Criteria

### 10.3.1 Initial List

Evaluation criteria had been developed for use with the Long List evaluation. For the short list the same initial list was used and reviewed by the workshop team for any amendments and changes in the light of the knowledge gained from the Phase 2 study work. The initial criteria were as follows:

| | EVALUATION PHASE |
|---|---|
| | Criteria |
| 1 | Allows for 2050 terminal IC flows of 100-120mcmd |

| | |
|---|---|
| 2 | Allows for gas blending with hydrogen |
| 3 | Allows for hydrogen compatible design |
| 4 | Allows internal inspection of pipework |
| 5 | Allows segregation of Cadent assets |
| 6 | Assets volume reduced |
| 7 | Brownfield development – reduced planning |
| 8 | CAPEX |
| 9 | Carbon neutral construction |
| 10 | Constructability |
| 11 | Electrical feeder requirements within existing envelope |
| 12 | Future operations align with net zero |
| 13 | Greenfield development – planning conditions |
| 14 | Opex should be reduced |
| 15 | Option is not complex (schedule not excessive) |
| 16 | Option not likely to lead to obsolescence |
| 17 | Permits future customer operating requirements |
| 18 | Permits reuse of existing assets |
| 19 | Reduces current gas inventory |
| 20 | Reliability |
| 21 | Terminal control systems - improvement |
| 22 | Terminal operations simplified |

**Table 10-1: Full List of Criteria**

### 10.3.2 Final List of Criteria

From this list some items were removed where they were of limited use in differentiating between options and some new criteria were added. The following was agreed for use in the short list evaluation.

| | EVALUATION PHASE |
|---|---|
| | Criteria |
| 1 | Allows for hydrogen compatible design |
| 2 | CAPEX |
| 3 | Constructability Risk (less SIMOPS) |
| 4 | Greenfield development – planning conditions |
| 5 | Opex should be reduced |
| 6 | Permits reuse of existing assets |
| 7 | Reduces current gas inventory (COMAH) |
| 8 | Terminal operations simplified |
| 9 | Minimal environmental impacts |
| 10 | Above ground piping is minimal |

**Table 10-2: Final List of Criteria**

### 10.3.3 Weighting of Criteria

The workshop team was facilitated to weight the list of criteria using a pairwise comparison technique. The list of criteria was assessed in pairs to quantify their relative importance against each other. The results of this work resulted in the following weights (noting that 'G' was allocated a mark of 1 although it did not 'score' any marks in the exercise, the team agreed it was useful to include it with a nominal weight.

**EVALUATION CRITERIA TO BE USED**

| | EVALUATION PHASE | DETERMINING WEIGHTS FOR EVALUATION | |
|---|---|---|---|
| | Criteria | Raw Score | Assigned Weights |
| A | Allows for hydrogen compatible design | 2 | 2.13% |
| B | CAPEX | 18 | 19.15% |
| C | Constructability Risk (less SIMOPS) | 16 | 17.02% |
| D | Greenfield development – planning conditions | 14 | 14.89% |
| E | Opex should be reduced | 8 | 8.51% |
| F | Reuse of existing assets | 8 | 8.51% |
| G | Reduces current gas inventory (COMAH) | 1 | 1.06% |
| H | Terminal operations simplified | 5 | 5.32% |
| J | minimal environmental impacts | 14 | 14.89% |
| K | Above ground piping is minimal | 8 | 8.51% |
| | | | 0.000 |
| | TOTAL | 94 | 1.000 |

**EVALUATION MATRIX**

| A | B | C | D | E | F | G | H | J | K | L | M | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | **B3** | **C2** | **D2** | **E3** | **F3** | A2 | H2 | J3 | K2 | | | 1 | 22% |
| B | | **B2** | **B3** | **B1** | **B1** | B3 | B2 | B1 | B2 | | | 1 | 15% |
| C | | | **D1** | **C3** | **C3** | C3 | C2 | C2 | C1 | | | 1 | 15% |
| D | | | | **E3** | **D3** | D3 | D2 | D1 | D2 | | | 1 | 14% |
| E | | | | | **F1** | E1 | E1 | J2 | K1 | | | 1 | 6% |
| F | | | | | | F2 | F1 | J3 | F1 | | | 1 | 7% |
| G | | | | | | | H3 | J3 | K2 | | | 1 | 8% |
| H | | | | | | | | J3 | K2 | | | 1 | 5% |
| J | | | | | | | | | K1 | | | 1 | 1% |
| K | | | | | | | | | | | | 1 | |
| L | | | | | | | | | | | | 1 | |
| M | | | | | | | | | | | | 1 | |
| **total** | | | | | | | | | | | | **12** | |

1 slight preference
2 medium preference
3 strong preference

**Figure 10-1: Criteria Weighting**

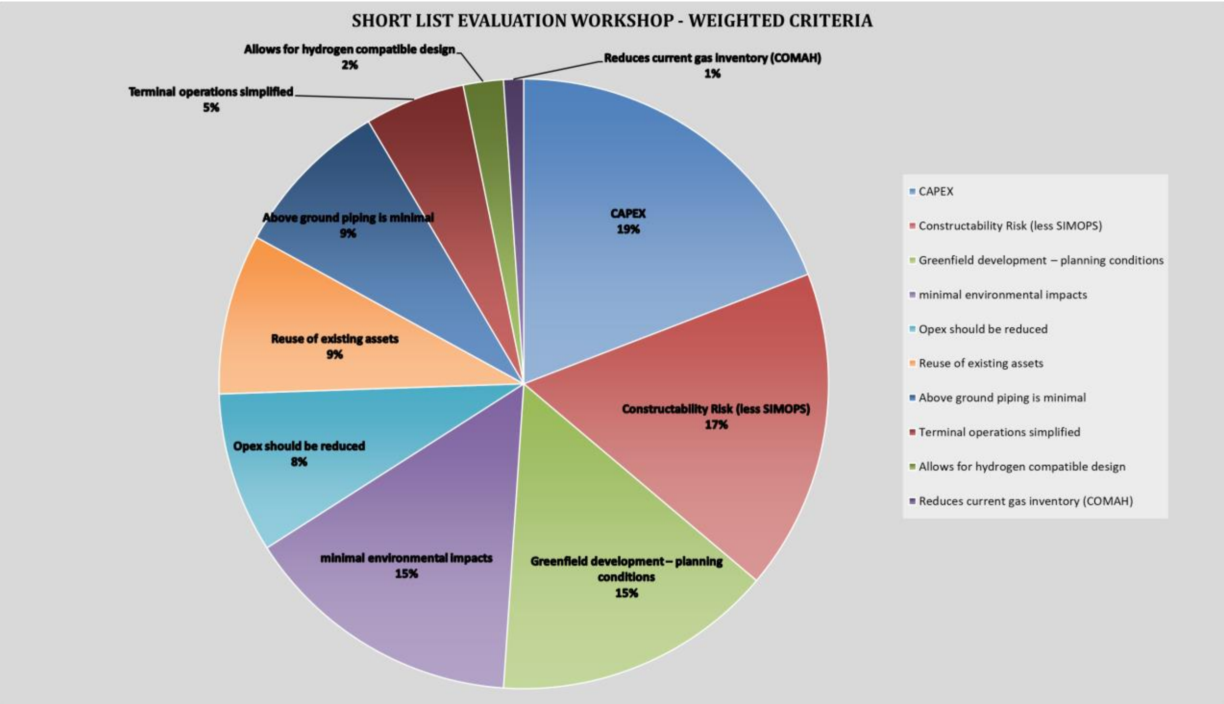



**Figure 10-2: Criteria Weighting Illustration**

## 10.4 Evaluation

The formal evaluation then proceeded to assess each option against the criteria and for each team member, an allocation of a raw score per option per criteria was obtained and summed. This provided each team member with a chance to score each option against their perception of how well or badly it performed against the criteria using a 1-10 scale. All scores were submitted on voting slips and summed to give an average raw score.

The raw scores provided by each team member were then summed and averaged to give an overall average score per option as shown in the table below.

| | OPTION TITLE | | | | |
|---|---|---|---|---|---|
| | 1.1 | 1.2 | 2 | 3.1 | 3.2 |
| | 2021-2035 (site capacity up to 160 mscmd) | 2035-2050 (site capacity up to 120 mscmd) | Major rationalisation & reduce inventory | New build (above ground, modular build, minimal reuse of assets) | New build (above ground, modular build, minimal reuse of assets) |
| | | | | Fits within existing site | Requires site extension / offsite development |
| **Criteria** | AVERAGE OF TEAM SCORES USING 1-10 SCALE | | | | |
| Allows for hydrogen compatible design | 1.27 | 1.40 | 3.64 | 7.27 | 7.47 |
| CAPEX | 8.40 | 8.20 | 5.33 | 3.20 | 2.73 |
| Constructability Risk (less SIMOPS) | 7.20 | 7.07 | 5.00 | 4.60 | 5.87 |
| Greenfield development – planning conditions | 9.20 | 9.20 | 9.00 | 8.47 | 2.40 |
| Opex should be reduced | 4.53 | 4.93 | 6.07 | 6.13 | 6.47 |
| Reuse of existing assets | 8.27 | 7.80 | 6.47 | 3.27 | 2.93 |
| Reduces current gas inventory (COMAH) | 1.73 | 2.40 | 6.40 | 5.87 | 6.00 |
| Terminal operations simplified | 2.07 | 2.60 | 5.67 | 6.67 | 6.73 |
| minimal environmental impacts | 6.53 | 6.00 | 5.67 | 4.87 | 2.80 |
| Above ground piping is minimal | 7.60 | 7.60 | 5.93 | 3.73 | 3.47 |

**Figure 10-3: Raw Scores for Options by Team**

The raw scores as above were entered the overall multi-criteria evaluation sheet and multiplied by the weighted criteria to give overall weighted scores per option as follows:

| | CRITERIA | | Allows for hydrogen compatible design | CAPEX | Constructability Risk (less SIMOPS) | Greenfield development – planning conditions | Opex should be reduced | Reuse of existing assets | Reduces current gas inventory (COMAH) | Terminal operations simplified | minimal environmental impacts | Above ground piping is minimal | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weighted Criteria | 0.021 | 0.191 | 0.170 | 0.149 | 0.085 | 0.085 | 0.011 | 0.053 | 0.149 | 0.085 | |
| | OPTION TITLE | | | | | | | | | | | | |
| 1.1 | 2021-2035 (site capacity up to 160 mscmd) | weighted score | 0.03 | 1.61 | 1.23 | 1.37 | 0.39 | 0.70 | 0.02 | 0.11 | 0.97 | 0.65 | 7.07 |
| | | raw score | 1.27 | 8.40 | 7.20 | 9.20 | 4.53 | 8.27 | 1.73 | 2.07 | 6.53 | 7.60 | |
| 1.2 | 2035-2050 (site capacity up to 120 mscmd) | weighted score | 0.03 | 1.57 | 1.20 | 1.37 | 0.42 | 0.66 | 0.03 | 0.14 | 0.89 | 0.65 | 6.96 |
| | | raw score | 1.40 | 8.20 | 7.07 | 9.20 | 4.93 | 7.80 | 2.40 | 2.60 | 6.00 | 7.60 | |
| 2 | Major rationalisation & reduce inventory | weighted score | 0.08 | 1.02 | 0.85 | 1.34 | 0.52 | 0.55 | 0.07 | 0.30 | 0.84 | 0.50 | 6.08 |
| | | raw score | 3.64 | 5.33 | 5.00 | 9.00 | 6.07 | 6.47 | 6.40 | 5.67 | 5.67 | 5.93 | |
| 3.1 | New build (above ground, modular build, minimal reuse of assets) Fits within existing site | weighted score | 0.15 | 0.61 | 0.78 | 1.26 | 0.52 | 0.28 | 0.06 | 0.35 | 0.72 | 0.32 | 5.07 |
| | | raw score | 7.27 | 3.20 | 4.60 | 8.47 | 6.13 | 3.27 | 5.87 | 6.67 | 4.87 | 3.73 | |
| 3.2 | New build (above ground, modular build, minimal reuse of assets) Requires site extension / offsite development | weighted score | 0.16 | 0.52 | 1.00 | 0.36 | 0.55 | 0.25 | 0.06 | 0.36 | 0.42 | 0.30 | 3.97 |
| | | raw score | 7.47 | 2.73 | 5.87 | 2.40 | 6.47 | 2.93 | 6.00 | 6.73 | 2.80 | 3.47 | |

**Figure 10-4: Final Evaluation Matrix for Options**

The conclusion from this evaluation is that Option 1 (both 1.1 and 1.2), represent the option judged to respond to the criteria.

## 10.5 Environmental Conclusions for Short List Appraisal

The environmental presentation for the Short List Workshop is included in the main environmental report appendix.

Section 10.3 outlines the key evaluation criteria used in the Evaluation workshop. "Minimising Environmental Impact" was one of the key criteria chosen and was weighted significantly in the scoring process. Together with the other evaluation criteria, Option 1 was chosen to take forward to the next stage.

# 11. PROJECT RISKS

## 11.1 Context

Risks have been considered by NG and Consultant throughout the study and at specific joint risk workshops. The context of all risk assessments is for a project at conceptual study stage prior to FEED and authorisation from OFGEM.

## 11.2 Consultant Risks

Following the identification of Option 1 at the Short List Workshop, a high-level assessment of risks for the option was carried out. The results of this internal workshop are shown below. The outputs were shared with NG and items not duplicated were added to the NG risk register.

| OPTION 1<br>Asset/Area/Activity | Risk Description | Risk Modifier/Cause | Impact Description | CAPEX | OPEX | Maintenance Budget | Schedule | Operations | Constructability | Overall Project | Severirty | Probability | Risk | Mitigation Steps |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT | SCOPE CREEP | LEGISLATION CHANGE, PUBLIC SCRUTINY | DESIGN REVISED, ADDITIONAL EQUIPMENT | x | x | x | x | x |  | x | Medium | High | *High* | Project management, press releases, social media presence |
| PROJECT | PERSONNEL RESOURCING | SHORTFALL QUALIFIED PERSONNEL | POTENTIAL DELAY | x |  |  | x | x |  | x | Medium | Medium | *Medium* | Planning, scheduling, management |
| ASSET | EQUIPMENT LIFE | LOWER THAN EXPECTED | ADDITIONAL NEW (REPLACEMENT) EQUIPMENT | x |  | x | x | x | x | x | High | Low | *Medium* | Equipment Maintenance, Records Audits |
| ASSET | SYSTEM INCOMPATIBILITY | SOFTWARE UPGRADES (C&I) | IMPLEMENTATION DELAY, SYSTEM INTEGRATION | x |  |  | x | x |  | x | High | Low | *Medium* | Proper Functional Design Specification Development, Planning, Scheduling, management |
| ASSET | ACCURATE RECORDS | SUPERSEDED DOCUMENTATION | REVISED EQUIPMENT, IMPLEMENTATION DELAY, ASSET HEALTH, SAFETY OF OPERATIONS | x | x | x | x | x | x | x | High | Medium | *High* | Records in a centralised data base, Accurate As Built documents, Audits |
| FINANCIAL | FUNDING / FID | NOT APPROVED | PROJECT INTERRUPTION, POSSIBLE FID DELAY |  |  |  |  |  |  | x | High | Medium | *High* | Development of strong business case |
| FINANCIAL | INFLATION | INCREASE | COST INCREASE ALL AREAS | x | x |  |  |  |  | x | Medium | Medium | *Medium* | Financial Planning, Loan Structuring, Debt Management |
| CONSTRUCTABILITY | VALVE SUPPLY / FABRICATION | MATERIAL AVAILABILITY, SUPPLY CHAIN | POTENTIAL DELAY | x |  |  | x |  |  | x | Medium | Medium | *Medium* | Planning |
| OPERATIONS | SIMOPS | CLASH | PROJECT INTERRUPTION, POSSIBLE DELAY | x | x |  | x | x | x | x | Medium | Medium | *Medium* | Planning, Scheduling, Management |

**Figure 11-1: Consultant Risk register for Option 1**

## 11.3 NG Risks

Site specific operational and technical risks have been identified by National Grid in the document "PAC3721-14-99-00-1211-NGG-0128_Bacton_ORAM" (28.07.21). In a joint risk workshop with [redacted] NG used Consultant risks together with their own assessment to compile a risk register with risk impact costs for each option and this was used in a Monte Carlo risk package to generate profiles for costs of risks. A draft summary of the outputs for the currently identified list of risks is provided below:

| Option 1 | P-20 | P-50 | P-80 | EMV |
|---|---|---|---|---|
| Contractor | [redacted] | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |
| | | | | |
| Option 2 | | | | |
| Contractor | | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |
| | | | | |
| Option 3 | | | | |
| Contractor | | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |
| | | | | |
| Option 3.2 | | | | |
| Contractor | | | | |
| Project | | | | |
| | | | | |
| **Total** | | | | |

**Figure 11-2: NG Risk Assessment of Potential Costs**

# 12. CONCLUSIONS AND RECOMMENDATIONS

## 12.1 Conclusions

The conclusions of this study are as follows:

- A variety of possible responses to the future energy scenarios for Bacton together with the influencing parameters specified by NG have been developed covering traditional reconfigurations through to radical changes for Bacton's role and function
- At a long list evaluation of these 26 ideas held in July 2021, NG taking note of Re-opener Specific Guidance issued by Ofgem Mid July 2021 which confirmed that Bacton should remain centrally a methane terminal, reduced the long list to three main options for the short list of which the new terminal option had two variants and option 1 had two time frames, making five options overall
- The short listed five options have been subjected to conceptual engineering, various layout and safety reviews held jointly with NG, assessment of environmental and sustainability issues, cost estimation of the options and an overall CBA comparison
- At the formal evaluation of the five short list options, the option identified as most appropriately responding to the evaluation criteria is Option 1 'make do and mend', which envisages a continuing regime of operational maintenance (with valve replacements etc) on the site from 2023-2035 (Option 1.1 time period) and thereafter on a reduced infrastructure on account of the cessation of SNS gas also permitting rationalisation of assets and manpower, with consequent cost savings, this being identified as Option 1.2 (2035-2050).
- Option 1.1 to 2035 is required as a precursor to any of the other options considered due to other options being dependent upon the rationalisation possible at or around 2035 from the end of SNS gas for the site, as well as some other factors such as lead times for option 3.2 to acquire new land.
- Option 1 represents the least cost estimate of the five considered and in Option 1.1 also enables a further review of the site and responses to future requirements in the period leading up to 2035 and is therefore a robust option permitting future flexibility to take account of continuing changes to the UK energy regime and other macroscopic factors.

## 12.2 Recommendations

The recommendations of this study are included in the Technical Risk Register Doc. No 20485-PM-REG-000-0003 and they are shown in the list below:

| Ref No. | Hazard and Location | Design Action |
|---|---|---|
| 1 | PIPEWORKS FLEXIBILITY & STRESS<br>Options: 2 / 3.1 / 3.2<br>Risk of stresses being above the allowable code limits | Post Option selection all pipework should be subjected to a full stress analysis taking account of change in process and environmental conditions. |
| 2 | PiPEWORKS MATERIALS & WALL THICKNESS<br>Options 2 / 3.1 / 3.2<br>Risk of stresses being above the allowable code limits | The selection of standards, codes and calculation methods will be validated at the next FEED stage |

| | | |
|---|---|---|
| 3 | UPDATE OF DRAWINGS<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Having carried out a drawing consistency review for supplied ELDs and Terminal Layout for Options 3.1 / 3.2, several inconsistencies are observed when comparing pipe connections shown on the ELDs and those on the layout drawings. It is strongly recommended that all drawings are reviewed and updated as soon as possible such that they reflect the as-built status of the Bacton terminal. Given the importance of the site and its COMAH Tier 1 rating, up-to-date records are vital for continued management of asset health |
| 4 | CONDITION OF ASSETS<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Equipment, Valves and pipework – Use updated inspection & maintenance records<br>It is strongly recommended that maintenance records are reviewed, updated and verified in light of the updated information during the meeting of 04.11.21. |
| 5 | UPDATE OF 3D MODEL<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Update the 3D model to represent the “As Built” status especially in the connections to IUK in the feeders 2 -4 area |
| 6 | UPDATE OF DRAWINGS WHICH HAVE BEEN PRODUCED FROM THE EXISTING SITE 3D MODEL<br>Options 1 / 2 / 3.1 / 3.2<br>Risk of having not updated records | Having carried out a drawing consistency review for supplied ELDs and Terminal Layout for Options 3.1 / 3.2, several inconsistencies are observed when comparing pipe connections shown on the ELDs and those on the layout drawings that have been produced from the existing Site 3D Model. It is strongly recommended that the existing site 3D model and all drawings produced by it are reviewed and updated as soon as possible such that they reflect the as-built status of the Bacton terminal. Given the importance of the site and its COMAH Tier 1 rating, up-to-date records are vital for continued management of asset health |
| 7 | ROAD CROSSINGS<br>(Perenco & Shell Feeders)<br>Option 1<br>Risk of pipework failure | The condition of the pipework from Perenco and Shell in the road crossings is unknown and it is not easy to be investigated currently. Actions cannot be recommended based on the original drawings.<br>The recommendations are to carry out Inspections to investigate the condition |
| 8 | VALVES TO BE REPLACED<br>Option 1<br>Risk of not meeting emissions requirements | It is strongly recommended that the list of valves is further reviewed in the next design phase and in the light of upcoming changes to environmental policies related to methane emissions. The recent commitments made at COP26 to cut methane emissions by 30% by 2030 are likely to require the list of valves to be reviewed and updated. |
| 9 | VALVES TO BE REPLACED<br>Option 1<br>Risk of not meeting emissions requirements | Valves that are known to pass quantities of methane rich gas to the atmosphere (e.g. due to stem seal failures) uncontrollably over extended periods of time should be considered for immediate replacement under existing maintenance strategy and budgets. Valves that pass methane rich gas to atmosphere due to a failure to seal correctly should be considered unfit for purpose and replaced under current maintenance strategy and budgets. |

| | **RECOMMENDATIONS BASED ON THE FPSA STUDIES** | |
|---|---|---|
| 10 | ELECTRICAL IGNITION SOURCES<br>Option 1 action 2<br>Risk of potential ignition sources from old electrical distribution boards | Certain electrical distribution boards have been identified that need removal or updating to reduce possible ignition sources or to reduce hazards of shocks as shown below (for details see Documents 20485-AI-RPT-100-0003_Rev 0 (Option 1 report) & 20485-EL-LST-200-0001 SLD):<br>- Switchboard C (This is a single supply from old A LV board (A23)<br>- Switchboard D (This is a single supply from old A LV board (A27)<br>- Switchboard E (This is a single supply from old A LV board (A24)<br>- Switchboard F (This switchboard is in two sections a single supply from old A LV board (A28) & a supply from B board.<br>- Switchboard G (This switchboard is in two sections a single supply from old A LV board (A3) & a supply from B board.<br>- Switchboard L (This has 2 supplies from old A LV board (A25 &A26)<br>- Switchboard M (This has 1 supply from old A LV board (A5)<br>- Switchboard N (redundant & currently isolated)<br>- Switchboard P (incorporate lighting scheme into new "B" board)<br>- DB Q1 & Q2<br>- DB R / DB S / DB T / DB V & DB Z (new combined DB with Z) / DB W (3P+N instead of single phase)<br>- Switchboard B (Feeds H, J, & K – resupply from T1 & T2 extension. Any retained plant loads will be supplied by new distribution centres.<br>- B1 (retained loads to be rationalised in new DB) / - B2 & DBB2 (retained loads to be rationalised in new DB – mostly lighting and small power) / DB2 (retained loads to be rationalised in new DB)<br>- B6 & DB3 (retained loads to be rationalised in new DB) / B4 (retained loads to be rationalised – mostly lighting and small power)<br>- DB/B/27 (Replicate retained sub-circuits in new distribution centre to be located in feeder 3&5 south east area)<br>- Switchboards that are not needed for Options 1.2 and 2 (e.g. New Kiosk in Middle-West of Site / New Kiosk in Middle-East of Site / DB H / DB J / DB K) |
| 11 | Suppliers Overpressure protection systems do not meet the required SIL rating.<br>Option 1 action 3<br>Risk related with reliance on a suppliers HIPPS | NG to carry out a separate project ahead of the possible adoption of this option to decide whether to upgrade the NG HIPPS to the required SIL level or rely on the suppliers HIPPS. |
| 12 | Air Pollution<br>Option 1 action 5<br>Environmental risk associated with manual venting | NG Environmental Team to discuss on the necessity to develop a Policy Statement on venting and to develop a future project to capture all emissions to atmosphere to record and inform the regulator |
| 13 | Explosion / Impact on Interconnector UK HV Transformer House and the RUK Boiler House for the | Further Fire & Gas 3D mapping is recommended to be carried out in the next phase to ensure there is suitable and sufficient F&G detection in these areas. A 3D Fire and Gas Mapping would allow for placement of fire and gas detectors within the model and the determination of the |

| | | |
|---|---|---|
| | new part of the ring main Option 2 action 3 | effectiveness of each detector based on the coverage area targets. |
| 14 | Remote possibility of missiles being the result of compressor failures in the Interconnector UK compressor system, also from the BBL incomer Option 2 action 4/ Option 3.1 action 7 | It is recommended that these 2 areas are committed to further study work to resolve this event scenario. |
| 15 | Fatigue - During any blowdown scenarios there would be a JT effect cooling the pipework leading to embrittlement and failure. Option 2 action 5 | The installation of a blowdown system is recommended for consideration to allow safe removal of inventory in the event of external fire etc. This should include evaluation of the requirement for either elevated or ground flare. As part of blowdown study, minimum metal temperatures to be confirmed. |
| 16 | The ring main could be subjected to overpressure from either the RUK or BBL incomers Option 2 action 6 (item 2) | It is recommended that an overpressure protection and flow / pressure control study is carried out during the next phase (where a process simulation model will be available) |
| 17 | Possible rapid phase transition during maintenance or emergency blowdown of the process Option 3.1 action 6 / Option 3.2 action 3 | The installation of a blowdown system is recommended for consideration to allow safe removal of inventory in the event of external fire etc. This should include evaluation of the requirement for either elevated or ground flare. As part of blowdown study, minimum metal temperatures to be confirmed. |
| 18 | The system could be subjected to over-pressure from either the RUK or BBL incomers. Option 3.1 action 9 & 10 / 3.2 action 5 | NG to review their policy with respect to over-pressure protection on third party feeds and determine the acceptability of reliance on third-party measures (HIPPS |
| 19 | The system could be subjected to over-pressure from either the RUK or BBL incomers. Option 3.1 action 11 / 3.2 action 6 | It is recommended that an over-pressure protection study is carried out during the next phase of the project. |
| 20 | During maintenance operations some gas is vented to atmosphere (e.g. venting of the Pig Traps, venting of pipework to make it safe to work). Currently there is no requirement for NG to inform the regulator of these releases Option 3.1 action 12 & 13/ 3.2 action 7 & 9Environmental risk associated with manual venting | NG Environmental Team to discuss on the necessity to develop a Policy Statement on venting and to develop a future project to capture all emissions to atmosphere to record and inform the regulator |

| | | |
|---|---|---|
| 21 | During maintenance operations some gas is vented to atmosphere (e.g. venting of the Pig Traps, venting of pipework to make it safe to work).<br>Currently there is no requirement for NG to inform the regulator of these releases<br>Option 3.1 action 12 & 13 / 3.2 action 7 & 9<br>Environmental risk associated with manual venting | A review is recommended of how manual venting can be minimised during routine maintenance activities |
| 22 | Third parties could gain access to the new site if unmanned<br>Option 3.2 action 4 | Ensure the site is secure either as a Stand Alone AGI or connected to the main site with the main site security fencing extended around the new site. The recommendation is to investigate compliance to the National Grid ISS (Integrated Security System) in the next design phase |
| 23 | Occupational Health<br>Option 3.2 action 8 | The investigation of the Sanitation requirements for this new site is recommended and whether the provision of clean drinking water and treatment and disposal of human excreta and sewage is required |
| 24 | Escape routes<br>Option 3.2 action 11 | include in the FEED SOW the development of the normal and emergency escape routes for this new area and how they tie-in to the existing system along with the location of new muster points if required, will be included in the FEED SOW |
| 25 | There Is only one flow control valve tying into feeder 3 and 5 manifolds<br>Option 1<br>Risk of a potential Single Point of Failure. | To be investigated further in the next design phase |
| 26 | Supply to Cadent offtake<br>Option 2 | Need to consider the Feeder 5 supply to Cadent offtake and optimise the design |
| 27 | Bi-directional metering options for IUK and BBL interconnectors<br>Options 3.1 & 3.2 | Bi-directional metering options for IUK and BBL interconnectors to be investigated further for Option 3 |
| 28 | Phased approach to construction<br>Option 3.1 | Option 3.1 is proposed to undertake a phased approach to construction. The design has minimised overlaps with existing plant where possible however this could not be eliminated. Construction to be phased West to East starting in the redundant ENI area. A similar approach was followed during the IUK construction. Due to time constraints and non-availability of records, recommendations cannot be done at this stage. However, records and lessons leanrned from IUK to be captured in the next design phase. |
| | **OTHER RECOMMENDATIONS** | |
| 29 | Lightning strike protection<br>Options: 1 / 2 / 3.1 / 3.2 | A study of the onsite lightning strike protection, such as equipotential bonding and earthing of metallic structures, should be carried out. |
| 30 | Earthing Continuation<br>Options 1.2 / 2 | Buried earthing mesh should not be disturbed and must be kept as it is. Only above ground connections to be removed (earthing pig tails) |

| | | |
|---|---|---|
| 31 | Operating Conditions<br>Options: 2 / 3.1 / 3.2 | A study to be carried out to determine if heating is required to ensure the process gas does not operate in the JT phase. If heating is required, then consideration should be given to using either domestic gas or electric powered heater |
| 32 | Noise levels<br>Options 2 / 3.1 / 3.2 | Noise study to be carried out for pipework & design pipework as per industry standards for fluids velocity |
| 33 | New site arrangement<br>Option 3.2 | The arrangement/location of the new development site raises questions as to whether it will be considered a stand-alone AGI therefore requiring its own COMAH Report or will it be combined with the existing Bacton site. To be investigated in the next design phase in case the option is selected |
| 34 | New site arrangement<br>Option 3.2 | There has been no visibility of a Geotech Report covering the location of the new development site. A study should be carried out in the next phase to confirm there are no hazards from high water table levels, flooding of the local ditch, water run-off onto adjacent land. |
| 35 | Surveys & condition assessments<br>Options 1 / 2 / 3.1 / 3.2 | Necessary Surveys & condition assessments to be undertaken prior to the start of the next design phase, including among others: earthing condition, soil resistivity measurements and buried services survey |
| 36 | Surveys & condition assessments<br>Options 1 / 2 / 3.1 / 3.2 | Gap analysis of geotech report (Harrison site investigation) to be performed & and more targeted surveys to be requested. Buried services surveys to be requested too. |
| 37 | Fire Fighting Network<br>Options 2 / 3.1 / 3.2 | Fire Fighting to cover all areas for options 2, 3.1 and 3.2 |
| 38 | Site Process Simulation Model<br>Options 1 / 2 / 3.1 / 3.2 | There is no process simulation model that would allow the study of operating scenarios and conditions and would be used to generate Heat & Material balance tables. The creation of such a model is recommended for the current and the future operating scenarios |
| 39 | Optimisation of Site 3D Model | The existing 3D Model is not an 'intelligent' 3D model, e.g. the pipework is designed as solid parts without attributes, the civil items and information is inserted twice or three items in the same area and the structure is not proper to allow further expansion and use for other projects. It is recommended to use fit for purpose 3D modelling packages with intelligent attributes and structure and to avoid presentation of generic solids. |
| 40 | Vent gases<br>Options 1 / 2 / 3.1 / 3.2 | Additional/new isolation valves to be considered in the next design phase to allow system volumes and therefore volume of methane rich gas needing to be vented for maintenance to be reduced. |
| 41 | Vent gases<br>Options 1 / 2 / 3.1 / 3.2 | Provision to be considered in the next design phase for capturing and disposing of all vent gases during maintenance activities. |

| | | |
|---|---|---|
| 42 | Isolations<br>Option 1.2 | In a similar way to how ENI incomers have been handled , to provide positive isolation and prevent ingress of methane rich hydrocarbon gas into the abandoned Shell and Perenco incomers, we recommend that positive, mechanical isolation is provided by cutting and capping pipework at the following locations:<br>Perenco:<br>• Remove valves A1/3X, A1/3 & A1/1<br>• Cap between Ring Main and A1/3X<br>• Cap piping downstream of A1/1<br>• Remove valves A2/3X, A2/3 & A2/1<br>• Cap between Ring Main and A2/3X<br>• Cap piping downstream of A2/1<br>• Cut and cap manifold downstream of F5/7<br>• Cut and cap pipe (in direction of flow) between:<br>F2/9 & F2/12, F3/9 & F3/1, F4/9 & F4/12, F5/9 & F5/12<br>Shell:<br>• Remove valves S1/1, S1/3 & S1/3X<br>• Cap between Ring Main and S1/3X<br>• Cap piping downstream of S1/1<br>• Remove valves S2/1, S2/3 & S2/3X<br>• Cap between Ring Main and S2/3X<br>• Cap piping downstream of S2/1<br>• Remove valves S3/1, S3/3 & S3/3X<br>• Cap between Ring Main and S3/3X<br>• Cap piping downstream of S3/1<br>• Remove valves S4/1, S4/3 & S4/3X<br>• Cap between Ring Main and S4/3X<br>• Cap piping downstream of S4/1<br>• Cut and cap pipe (opposite to direction of flow) upstream of F2/18, F3/18, F4/18 & F5/18<br>• Cut and cap pipe (opposite to direction of flow) upstream of F2/13, F3/13, F4/13 & F5/13 |

# APPENDICES

# Appendix A: Long List and Short List Workshops

# Appendix B: Cost Estimates and CBA

# Appendix C: Option Schedules

# Appendix D: Design Packages

# Appendix E: Design Reviews and Internal Stakeholder Management

# Appendix F: Formal Process Safety Assessment

# Appendix G: CDM PCI and Risk Register

# Appendix H: Project and Technical Risk Registers

# Appendix J: Environment and Sustainability

# Appendix K: MDR

# Appendix L: FEED SOW