Peterhead CCS Project

Doc Title: Basis of Design for the CCS Chain

Doc No. **PCCS-00-PT-AA-7704-00001**
Date of issue: **08/03/2016**
Revision: **K06**
DECC Ref No: **11.001**
Knowledge Cat: **KKD – Technical**

KEYWORDS
Goldeneye, CO_2, Carbon Capture and Storage. Basis of Design.

Produced by Shell U.K. Limited
ECCN: EAR 99 Deminimus

IMPORTANT NOTICE

Information provided further to UK CCS Commercialisation Programme (the **Competition**)

The information set out herein (the **Information**) has been prepared by Shell U.K. Limited and its sub-contractors (the **Consortium**) solely for the Department for Energy and Climate Change in connection with the Competition. The Information does not amount to advice on CCS technology or any CCS engineering, commercial, financial, regulatory, legal or other solutions on which any reliance should be placed. Accordingly, no member of the Consortium makes (and the UK Government does not make) any representation, warranty or undertaking, express or implied as to the accuracy, adequacy or completeness of any of the Information and no reliance may be placed on the Information. In so far as permitted by law, no member of the Consortium or any company in the same group as any member of the Consortium or their respective officers, employees or agents accepts (and the UK Government does not accept) any responsibility or liability of any kind, whether for negligence or any other reason, for any damage or loss arising from any use of or any reliance placed on the Information or any subsequent communication of the Information. Each person to whom the Information is made available must make their own independent assessment of the Information after making such investigation and taking professional technical, engineering, commercial, regulatory, financial, legal or other advice, as they deem necessary.

Table of Contents

Table of Figures

List of Tables

Executive Summary

The purpose of the document is to provide a high level technology and engineering scope description for the Peterhead Carbon Capture and Storage (CCS) project. A brief description of the parties involved and their respective roles in the project is provided to help give an understanding of the division of the plant for operational and maintenance activities.

An overall summary of the Peterhead CCS project, including locations of the main Carbon Capture and Storage (CCS) elements and a description of the existing facilities which will be re-used or modified for use in the Project, is contained within the document. Climatic and geotechnical conditions at the various locations are summarised to provide a basis of the design conditions.

An overview of the end-to-end process is included along with high level details of the interfaces and their parameters between the main process elements at the intended normal operating condition. These provide links to further information which can be found in the documents included in the reference list.

Table ES-1 below shows a brief overview of the main performance parameters of the Peterhead CCS project at the normal operating conditions of the plant. It was the Project's intention that these parameters would define the performance of the full PCCS chain and provide the basis of a Minimum Functional Specification for the Execute phase of the project.

Table ES-1: Summary of Plant Performance

Parameter	Units	Target Level	Notes
Gross electrical power	MWe	397.4	Total gross electrical power for PCCS is the sum of the GT13 gas turbine and ST20 steam turbine generator's rated output.
Net exported electrical power	MWe	383.5	Net PCCS exported power is the electrical power exported across the fiscal meter at the 275kV substation. This equates to the PCCS gross electrical power less the unitised PCCS auxiliary demand (supplied directly from the generating units).
Electrical Parasitic Load			
Power Plant Block 2	MWe	6	This is the electrical parasitic load attributable to the PCCS generating plant when in operation at rated output. This figure does not include demand directly supplied from the gas turbine or steam turbine units.
Carbon Capture Plant	MWe	16.5	Demand for design operating case.
Compression and Conditioning	MWe	18	Demand for design operating case.
Platform	MWe	0.1	Demand for design operating case.
Low pressure steam flow to Carbon Capture Plant	t/h	181	At design operating case.
Medium pressure steam flow to Carbon Capture Plant	t/h	4.8	At design operating case.

Parameter	Units	Target Level	Notes
Flue gas processed by Carbon Capture Plant	t/h	2,466	GT13 flue gas flow to Carbon Capture Plant at rated output.
Mass of CO_2 in flue gas processed	t/h	145.5	At design operating case.
Mass of CO_2 transported, $M_{CO2TRANS}$	t/h	128.3	CO_2 flow from compressor plant into the offshore transportation system.

The PCCS FEED study scope had a duration from March 2014 to December 2015 and consisted of two phases. Within the overall PCCS FEED study scope, an Engineering FEED study was undertaken by Shell and its engineering contractors between March 2014 and February 2015. Once the Engineering FEED study phase was completed, the project team focused on developing the EPC tendering arrangements and undertaking other activities in readiness for the Execution phase (Execution Preparation Phase) until the end of November 2015. A detailed package of engineering documents was produced during the Engineering FEED study which is included in the appendices of the Basic Design and Engineering Package (BDEP) – KKD 11.003 [1].

The technical concepts of the PCCS design were further developed in some areas after completion of the Engineering FEED deliverables at the end of February 2015 – for example as a result of feedback from the EPC tendering process for the Execute phase. The detailed Engineering FEED deliverables were not updated to reflect these concepts during the Execution Preparation Phase of FEED but those affected are identified in the index in the Basic Design and Engineering Package (BDEP) – KKD 11.003 [1].

As described in the Scope of Work for Execute Contracts – KKD 11.058 [2], after commencement of the Execute phase the intention was that the preferred EPC contractors would perform Detailed Design based on the PCCS technical design, as finalised at the end of the FEED, prior to commencing construction activities. Final technical deliverables which would have superseded the Engineering FEED study deliverables would have been produced at the conclusion of that Detailed Design exercise.

An overview of the entire PCCS FEED study work can be obtained in the FEED Summary Report - KKD 11.133 [3]. This document - the Basis of Design – KKD 11.001 - has been updated to reflect any design decisions taken up to December 2015 and reflects the Project's technical status at the end of the PCCS FEED.

Detailed technical information on the technical aspects of the PCCS FEED study phase outcomes can be found in the Basic Design and Engineering Package (BDEP) – KKD 11.003 [1], which expands on the technical information provided in the Basis for Design and includes technical design documentation such as Process Flow Diagrams (PFDs), Piping & Instrumentation Diagrams (P&IDs), heat and mass balance data and electrical single line diagrams as developed by the Engineering FEED study. Key decisions which were made during FEED, including decisions related to the technical scope of work, are summarised in the FEED Decision Register – KKD 11.020 [4].

Other aspects of the technical FEED study which are described in the suite of PCCS FEED Study Key Knowledge Deliverables include:

- The Surveillance, Metering, Allocation Strategy and Design Package – KKD 11.077 [5] which contains further information on the CfD and EU ETS metering;

- The Technology Maturation Plan – KKD 11.064 [6], which describes the development of identified key technology aspects which were identified, investigated and/or progressed during FEED;
- The Risk Management Plan and Risk Register – KKD 11.023 [7], which described the top project risks, overall risk profile and risk management plan at the end of the FEED study including technical risks; and
- The FEED Lessons Learned Report – KKD 11.019 [8], which describes the lessons learned process undertaken during FEED and presents key learnings identified including CCS specific technical learnings.

1. Introduction

An End-to-End CCS Chain Basis of Design document was developed during the pre-FEED phase of the Peterhead Carbon Capture and Storage (PCCS) project. This was based on the best available data at the time and summarised the project design data which was utilised by the FEED contractors at the commencement of the FEED study.

This document has been developed from the pre-FEED End-to-End CCS Chain Basis of Design. It defines indicative key project design data and criteria, and the process conditions at the principal interfaces between the various elements of the CCS chain. Consequently it provides potential developers with the basic design of a full-scale CCS system. This document includes changes to data that were identified as design requirements during FEED. It does not provide a detailed basis of design for individual plant or parts of the CCS chain.

After this introduction section, an overview of the PCCS project is provided in Section 2. Design criteria and site and engineering data applied in the developed FEED design are described in Sections 3 and 4 respectively. Sections 5 and 6 describe the significant parameters of the key process and utility streams on the PCCS project. Note that due to differing conventions between the power and oil and gas sectors, Process Flow Diagrams (PFDs) and Piping & Instrumentation Diagrams (P&IDs) produced for the power plant scope are equivalent in content to the Process Flow Schemes and Process and Utility Engineering Flow Schemes respectively for the CCCC and offshore scope elements.

The technical content presented in this document reflects a snapshot taken at the end of the overall PCCS FEED Phase. Some elements of the technical scope have been updated during the Execution Preparation Phase after the majority of the design deliverables were issued, so the latest information in this document is not always consistent with the design dossiers included in the Appendices of the Basic Design and Engineering Package – KKD 11.003 [1]. The design dossiers that are affected are annotated in their respective Appendix contents listing. The areas of continued design development in the Execution Preparation Phase will be addressed during Detailed Design in the Execute phase of the Project. The main areas in this category are as follows:

- Waste Water Treatment Plant simplification;
- Gas Turbine Upgrades;
- GT13 275kV Export Cable replacement;
- Oxygen Removal Specification <5ppm in CO_2;
- Revised CO_2 Tracer using Xenon isotopes; and
- Contract for Difference (CfD) and EU Emissions Trading Scheme (EU ETS) specific metering.

The waste water treatment plant design proposed at the end of FEED is described in Section 6.8 of the Basic Design and Engineering Package – KKD 11.003 [1]. Further information is also provided in the FEED Decision Register – KKD 11.020 [4].

The Engineering FEED was not based upon implementation of the gas turbine upgrades and therefore the technical information included in APPENDIX 2 of the Basic Design and Engineering Package – KKD 11.003 [1] does not reflect the position at the end of FEED. Further information can be found in the FEED Decision Register – KKD 11.020 [4]. Updates to the FEED technical documents to reflect this change will be undertaken during the Execute phase of the project. Engineering of the replacement of the GT13 275 kV export cable required to facilitate the GT upgrade will also be undertaken during the Execute phase.

Further information on the oxygen removal specification and revised CO_2 tracer can be found in the Technology Maturation Plan – KKD 11.064 [6]. Information on the CfD and EU ETS metering requirements can be found in the Surveillance, Metering, Allocation Strategy and Design Package – KKD 11.077 [5].

As well as the novel aspects of designing a First-of-a-Kind post-combustion capture CCS project for a gas-fired power plant, the design has also been influenced by local regulatory aspects, including EU ETS and the UK Government's Contract for Difference (CfD) mechanism which are still in the process of being matured. Further development in these regulatory requirements, or the interpretation thereof, may impact on the proposed design at the next phase.

2. Project Overview

2.1. Overall Project Description

The Peterhead CCS Project aims to capture around one million tonnes of CO_2 per annum, over a period of 15 years, from an existing Combined Cycle Gas Turbine (CCGT) located at SSE's Peterhead Power Station (PPS) in Aberdeenshire, Scotland. This would be the world's first commercial scale demonstration of CO_2 capture, transport and offshore geological storage from a (post combustion) gas-fired power station.

The Goldeneye gas-condensate production facility has already ceased production. Under the PCCS Project, the facility will be modified to allow the injection of dense phase CO_2 captured from GT-13 into the depleted Goldeneye reservoir.

The CO_2 will be captured from the flue gas produced by one of the gas turbines at Peterhead Power Station (GT-13) using amine-based technology provided by Cansolv Technologies Inc (Cansolv) (a wholly-owned subsidiary of Royal Dutch Shell). After capture the CO_2 will be routed to a compression facility, where it will be compressed to dense phase, cooled and conditioned for water and oxygen removal to meet suitable transportation and storage specifications. The resulting dense phase CO_2 stream will be transported directly offshore to the wellhead platform via a new offshore pipeline which will tie-in subsea to the existing Goldeneye pipeline.

Once at the Goldeneye platform, the CO_2 will be injected into the Goldeneye CO_2 Store (a depleted hydrocarbon gas reservoir), more than 2 km under the seabed of the North Sea. The project layout is depicted in Figure 2-3.

A summary of the full chain CCS process is described in the following sections.

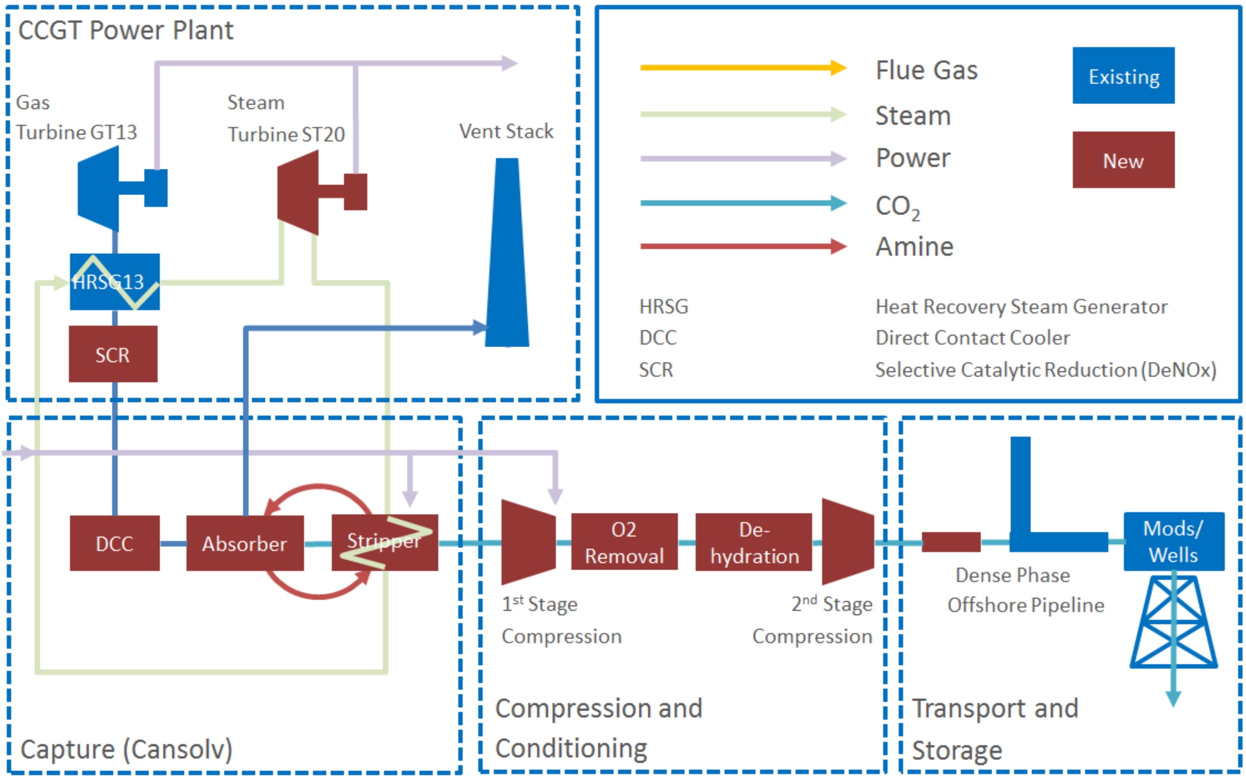

Figure 2-1: CCS Chain

2.1.1. Gas-Fired Power Plant

The existing Peterhead Power Station is owned and operated by SSE Generation Limited (SSE) and is a gas-fired Combined Cycle Gas Turbine (CCGT) Power Station. The station first began operating in 1982 and originally had two conventional steam-generating boilers, ('Unit 1' and 'Unit 2'), which fired natural gas or oil depending on the prevailing economic conditions. These boilers were coupled to two 660 MWe steam turbine generators. As a result of a major repowering project which took place in 2000, three Siemens (SGT5-4000F) gas turbines (GT) were installed, denoted GT11, GT12 and GT13, powering three new generators and raising steam through three new Heat Recovery Steam Generators (HRSG11, HRSG12 and HRSG13). The steam from all three HRSGs is routed to the original Unit 1 steam turbine (ST1). The three GTs and the common ST1 are together referred to as 'Block 1', which has a net capacity output of approximately 1180 MWe. The original boilers are no longer used. The 'Unit 1' boiler has been decommissioned and 'Unit 2' boiler and steam turbine unit have been mothballed and are not used.

The PCCS project will modify the present operational status of Peterhead Power Station. Flue gas from GT13 will be rerouted to the carbon capture plant instead of being directed to the existing 90 m repowering stack. A small slipstream of less than 1 % of the total GT13 flue gas will be emitted from GT13's flue, within the 90 m repowering stack. A Selective Catalytic Reduction (SCR) system will be fitted to existing HRSG13 to remove NOx in the GT13 flue gas (deNOx) before it is transferred to the carbon capture plant.

A new steam turbine generator, denoted ST20 with an output of approximately 135 MWe, will also be installed. ST20 is sized to operate in combined cycle with GT13 and will output 135 MWe when operated in unabated mode. Under PCCS operation, Low Pressure (LP) steam will be diverted from the turbine and supplied to the carbon capture plant process resulting in a reduced electrical output from the ST20 generator. The turbine will include suitable bypass provisions so that during start-up or in the event of a turbine trip, LP steam can continue to be supplied to the Carbon Capture Plant.

New auxiliary boilers will be installed within the power station as part of the PCCS project. The boilers will provide Medium Pressure (MP) steam to the entire site.

After implementation of the PCCS project, the existing CCGT arrangement will be redefined as follows:

- "Block 1" - comprising GT11, GT12 and ST1;
- "Block 2" - comprising GT13 and ST20; and
- Common plant equipment.

This is shown schematically in Figure 2-2 below.

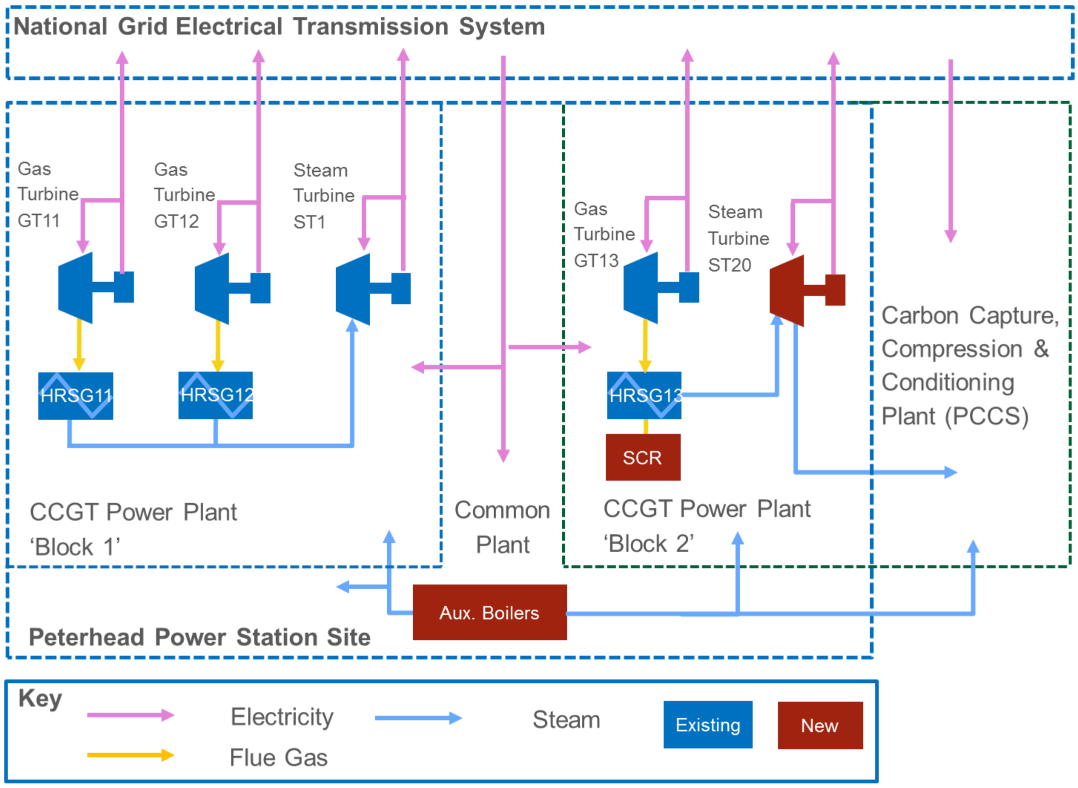

Figure 2-2: PCCS Configuration for Block 1, Block 2 and Common Plant

The Peterhead Power Station generating units export power onto the GB transmission system at 275kV at the Peterhead Substation. In mainland GB, access to the transmission system is governed by National Grid Electricity Transmission (NGET) who also act as the overall System Operator (SO). However, the local onshore transmission assets are owned and maintained by SSE Transmission, part of the SSE plc group of companies.

Although the existing and new generating units will be redefined as belonging to Block 1 or Block 2 under PCCS, there are a number of existing common plant systems which will support both Block 1 and Block 2 operations after implementation of the PCCS project. These common plant systems include:

- HRSG feedwater system;
- Auxiliary steam system;

- Main cooling water system;
- Towns water system ;
- De-mineralised water treatment plant;
- Station transformers, 4 off 132kV import connections;
- Station electrical distribution system;
- Fuel gas pressure reduction station;
- Firefighting water system.

Further details on the engineering FEED design can be found in APPENDIX 2 of the Basic Design and Engineering Package – KKD 11.003 [1]. The metering solution developed to satisfy CfD and EU ETS requirements was developed after completion of the technical FEED design and can be found in the Surveillance, Metering, Allocation Strategy and Design Package – KKD 11.077 [5].

2.1.2. CO_2 Carbon Capture Plant

The project will capture the CO_2 from the flue gas of GT13 that has been extracted from the existing installation, downstream of HRSG13. The carbon capture plant is designed on the basis of achieving a 90 % capture efficiency, considering the mass CO_2 leaving the capture plant for compression to the mass CO_2 in the stream from the capture plant's pre-treatment system. This will abate approximately 90 % of the CO_2 normally produced by the 400 MWe (CCGT) of output (pre CCS retrofit).

The carbon capture plant has a designed duty of approximately 1 Mt CO_2 per annum and is intended to capture some 15 Mt of CO_2 during the PCCS Project's design life of 15 years.

2.1.3. CO_2 Compression & Conditioning Plant

The CO_2 product delivered from the carbon capture plant to the compression and conditioning plant, co-located at the Peterhead Power Station, will be water saturated and will contain traces of oxygen. The produced CO_2 stream will be cooled and partly compressed before having oxygen removed via catalytic reactions with hydrogen. Water will be removed using molecular sieve technology. The conditioned CO_2 will then further be compressed to approximately 120 barg for export to the offshore transportation and storage system.

2.1.4. CO_2 Transportation

Following post-compression cooling, the resulting dense phase CO_2 stream will be transported directly offshore via a new short section of onshore pipeline which incorporates the pipeline landfall and a new offshore pipeline which will be tied in subsea to the existing Goldeneye pipeline. The chosen method for the pipeline landfall installation is Horizontal Directional Drilling (HDD). However, should the HDD technique encounter unexpected problems during execution, a conventional open cut technique would be adopted for the shore approach. The tie-in between the new pipeline and existing Goldeneye pipeline will be made via a flanged spool which can provide expandability in future.

The CO_2 will then be transported via the existing Goldeneye pipeline to the depleted Goldeneye hydrocarbon field for permanent storage.

2.1.5. CO_2 Storage

The CO_2 will be permanently stored in an underground store comprising the depleted Goldeneye gas field reservoir. The existing unattended production platform will require minimal modifications to be made suitable for the proposed CO_2 duty. The five existing wells, served by the Goldeneye platform, are suitable for conversion to CO_2 injection wells and will provide sufficient injectivity for CO_2 storage. In practice, three primary injection wells are proposed with one well used for monitoring purposes. The fifth well will be abandoned.

Studies performed both prior to and during FEED indicate that the depleted field store can hold up to 34 Mt CO_2 and is adequate for the PCCS Project's required storage capacity of 15 Mt CO_2 over the 15-year operation period.

2.1.6. Methanol Injection

Methane hydrates are ice-like compounds that occur worldwide in sea-floor sediments. In most offshore hydrocarbon extraction applications, hydrate formation is controlled by injection of a thermodynamic hydrate inhibitor. Methanol and mono-ethylene glycol (MEG) are common inhibitors. The existing MEG injection and storage facilities at Shell's compound within the St Fergus Terminal site, which were used for hydrate inhibition during Goldeneye hydrocarbon extraction operations, will be reused for PCCS operations. Methanol has been preferred to MEG for PCCS operations for the prevention of hydrate formation during well start-up to minimise reaction with the injected CO_2.

2.1.7. Full Chain Operations and Control Philosophy

Once operational, the PCCS Project will be operated and controlled from the dedicated PCCS Control Room which will be located within the PCCS boundary on the Peterhead Power Station site. Note that GT13, ST20 and the associated Block 2 of the power plant will be controlled from the Peterhead Power Station control room. PCCS control room will be remotely located from the existing Peterhead Power Station control room. The Goldeneye Platform will remain a Normally Unmanned Installation and will be operated from the PCCS Control Room under normal operating conditions, although the ability to perform local control operations on the platform will be retained. When required, methanol injection will be managed from the PCCS Control Room. However, methanol operations will be carried out by the existing Shell St Fergus Terminal control room under instruction from the PCCS Control Room. The Shell St Fergus Terminal control room operations will not be part of the PCCS project. This support will be provided under a third party agreement to the PCCS Project.

2.1.8. Full Chain CO_2 Venting Philosophy

There are two principle means for CO_2 to be released to atmosphere in the PCCS CO_2 system design:

- Via vent stacks; and
- Via Pressure Safety Valves (PSVs) and thermal relief.

Where the potential to be able to release large volumes of CO_2 is required, this is achieved onshore via vent stacks with the CO_2 first heated (via a KO drum or in the Onshore Gas-Gas Heat-Exchanger) to aid buoyancy and dispersion. Direct venting is proposed offshore via a new dedicated CO_2 vent.

For the onshore CO_2 system, PSVs release CO_2 into vent headers with CO_2 ultimately released to atmosphere via either the existing 170 m tall stack or the new vent stack local to the compression plant.

Therefore the primary PCCS CO_2 vent locations are:

- Onshore (Peterhead Power Station) – venting to the bottom of the absorber tower, where it is recycled in the absorption process. Some of this vented CO_2 may eventually be released to atmosphere via the existing 170 m tall stack;
- Onshore (Peterhead Power Station) - at the vent stack local to the compression plant;
- Offshore (Goldeneye platform) – at the existing vent stack structure, which will be retained and modified to be suitable for the required CO_2 duty; and
- Offshore (Goldeneye platform) – via below deck thermal relief valves.

The results of CO_2 dispersion modelling studies performed during FEED confirm that little or no slumping back to the ground is predicted to occur provided that there is some air movement. On completely still days there is the potential that the UK Health and Safety Executive's eight hour CO_2 exposure limit could be reach if mitigating action were not taken. Operational restrictions are therefore proposed to prevent venting of CO_2 on completely still days when the vented CO_2 could potentially slump to ground.

Since onshore CO_2 venting takes place via the existing 170 m tall stack or the new compression plant vent stack, the risk to persons (on or off site) is considered to be minimal and can be controlled under normal site operations. Additional mitigation measures include installation of CO_2 detection at the Peterhead Power Station site and use of personal CO_2 detectors for site staff once the carbon capture plant is operational. These measures will be reviewed further and finalised during Detailed Design.

Although GT13 is intended to be operated in abated mode with the flue gas CO_2 capture and stored, GT13 will continue to be able to operate in unabated mode should this be required e.g. in the event the capture plant is unavailable. In unabated mode, the GT13 flue gas will be emitted to atmosphere via the existing 90 m repowering stack as per present power station operations.

2.1.9. Waste Water Treatment Plant

Large quantities of surplus water will be generated in the Direct Contact Cooler where the water vapour in the gas turbine flue gas will be condensed. This water will contain traces of ammonia carried over from the SCR and the ammonia will have to be removed before the effluent can be discharged to sea. Bio-treatment has been selected as the preferred processing medium which converts the ammonia to nitrogen gas in a two-stage biological degradation process, The Waste Water Treatment Plant will be located adjacent to the compression and conditioning facilities and the treated effluent will be discharged via the existing power station discharge No. 4.

The possibility to treat the acid wash effluent containing quantities of amine was also investigated but the resultant water treatment plant design was highly complex, expensive, operator intensive and would have most likely have suffered from poor reliability. It was therefore decided at the end of the Execution Preparation phase to transport the acid wash effluent to a licensed offsite disposal facility for incineration. The Thermal Reclaimer Unit degraded amine bottom product will also be sent to the same location for disposal.

2.2. Location of the Project Infrastructure

The Peterhead Power Station is located on a coastal site less than 2 km south of the town of Peterhead. It is an operating CCGT power station. Peterhead Power Station is the only power station in this area and is used extensively by National Grid to balance their electrical grid system.

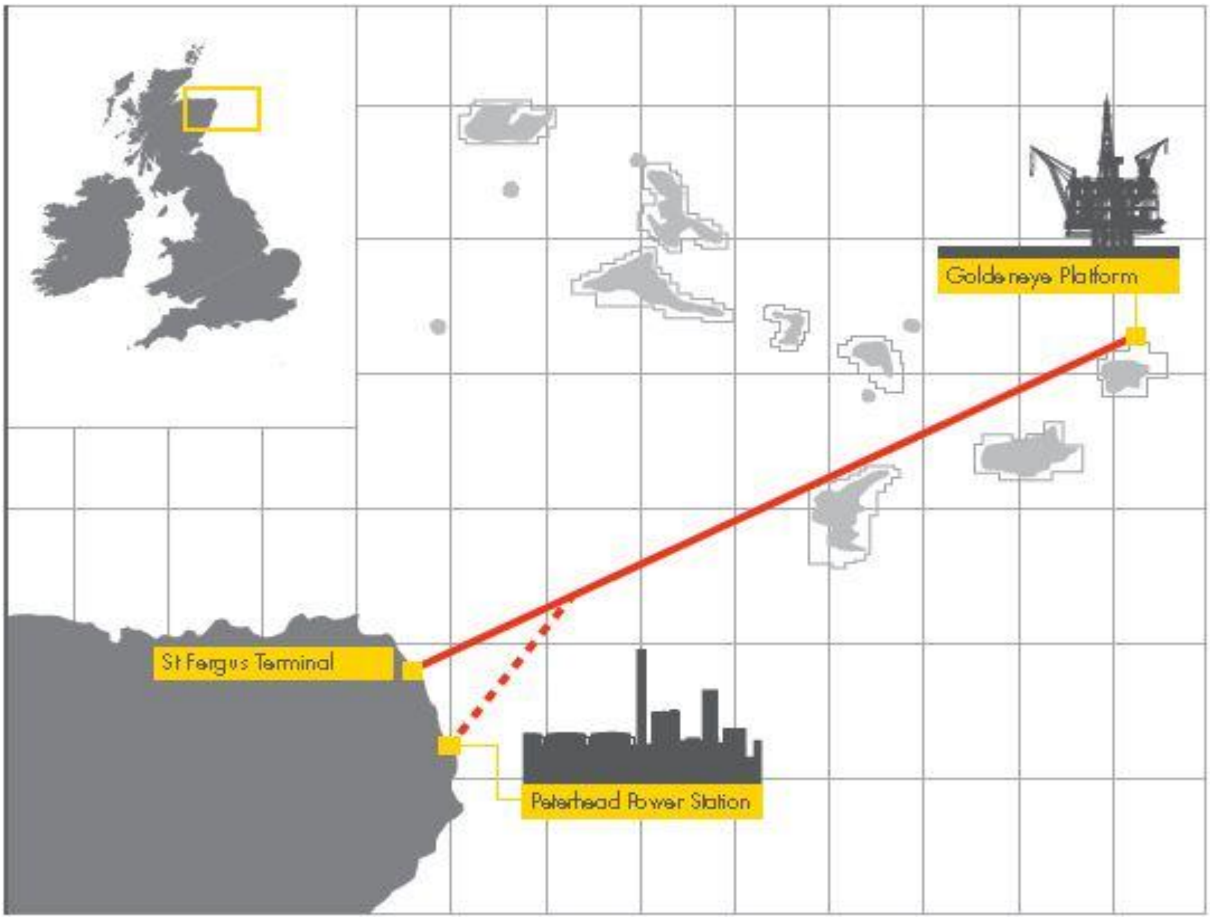

Figure 2-3: Location Map

The dried, deoxygenated CO_2 stream will be transported directly offshore via a new short section of onshore pipeline which incorporates the pipeline landfall and a new offshore pipeline which will be tied in subsea to the existing Goldeneye platform via the existing 20 inch (508 mm) Goldeneye pipeline. The existing pipeline was installed for dedicated gas field production from the Goldeneye field in 2004. The pipeline was used to carry natural gas to St Fergus from the Goldeneye field and its suitability for dense phase CO_2 transport was validated during FEED, subject to a pipeline integrity check through an intelligent pigging campaign to be conducted prior to start-up.

CO_2 storage will be in an underground store comprising the depleted Goldeneye gas field reservoir lying in the Outer Moray Firth area of the Central North Sea. This is located in the United Kingdom Continental Shelf (UKCS) Blocks 14/29a and 20/4b. The field commenced production in 2004 and the last gas well was shut-in in 2011. Shell is a part owner and the operator of the field. The injection site will be the Goldeneye offshore platform in the North Sea using existing wells which will be recompleted.

2.3. Parties Involved

Shell U.K. Limited (Shell) is currently the sole developer of the Peterhead CCS Project. Shell will be responsible for leading the project through the design, construct and operational phases for the entire Peterhead CCS chain from CO_2 capture to storage reservoir and will be accountable for the engineering, construction, operations, decommissioning and abandonment of the full end-to-end

CCS chain. Shell will deal with a number of sub-contractors to deliver the project, including SSE Generation Limited, the Power Station owner.

Shell U.K. Limited is part of the Royal Dutch Shell group of companies. SSE Generation Limited is the owner and operator of the existing Peterhead CCGT power station site and will be responsible for the power generation in the project and will provide the supply of the NOx-free CO_2 laden flue gas through a Shell owned Selective Catalytic Reduction (SCR) system, as well as the steam and other utilities required for the Carbon Capture, Compression and Conditioning plant.

For the project to proceed, the Department of Energy and Climate Change (DECC), specifically the Office of Carbon Capture and Storage (OCCS), need to act as a funding client for the Project, and provide a capital grant as well as a Contract for Difference (CfD) arrangement during the operational phase under the UK Government's Electricity Market Reform (EMR) policy.

The main parties involved during the subsequent Detailed Engineering, Procurement and Construction (EPC) phase, or Execute phase, will be Shell, SSE and the EPC Contractors selected to deliver specific elements of the CCS chain scope.

2.4. Outline of Existing Facilities

A number of highly suited existing assets are already in place and available for use by the PCCS Project for the purpose of CO_2 capture and storage. This provides significant efficiencies in respect of Project cost and schedule. The principal existing assets to be used in the Project are the Peterhead GT13 gas turbine and exhaust stack and the Goldeneye offshore pipeline, platform and wells. Re-use of these facilities will reduce the environmental impact of pipe-laying and offshore drilling operations.

The most significant existing assets that will be re-used by this project include:

- GT13 gas turbine, generator, generator transformer, and auxiliary and ancillary systems at Peterhead Power Station;
- Fuel gas and electrical connections to the Peterhead Power Station site;
- The 170 m tall stack at Peterhead;
- 80 km of the offshore Goldeneye pipeline and riser;
- The Goldeneye platform;
- The Goldeneye wells and subsurface knowledge bank; and
- The MEG (Monoethylene Glycol, hydrate inhibition) injection and storage facilities at St Fergus as well as the pipeline / riser to the Goldeneye platform.

2.4.1. Existing Power Station Equipment

The PCCS project will make use of the existing GT13 and HRSG13 equipment at Peterhead Power Station. This also includes the existing utilities for the GT13 train equipment including the gas supply; the main electrical system and also the existing 275 kV cable connection to the nearby National Grid Peterhead substation. The existing equipment was installed in 2000, lifetime assessments have or will be carried out on the equipment and based on the outcome of the assessment the equipment will be refurbished or replaced as necessary to achieve the Project design life of 15 years.

GT13 is a Siemens SGT-4000F, formerly known as V94.3A, F-Class turbine which when the life extension works are complete will be capable of 290 MW at site reference conditions of 8°C; 1013 mbar and 80% relative humidity when operating on outlet temperature control. HRSG13 is a standard triple pressure with reheat, natural circulation, and is of horizontal gas flow design. Mechanical ratings for High Pressure (HP) steam, Hot Reheat (HRH) steam and LP (Low Pressure) steam conditions are 165, 50 and 12 barg, and 545°C, 545°C, 265°C respectively. The cold reheat line is rated for 50 barg and 405°C.

The new steam turbine shall be located in the existing turbine house after the demolition of the existing Unit 2 steam turbine and will be designed as far as practicable to utilise the existing foundations. The existing water cooled condensers shall be re-used by the new ST20 and parts of the existing steam and water system shall be used for the water/steam cycle between HRSG13 and the new ST20 steam turbine. The existing sea water system shall be modified to provide cooling water to the new steam turbine and the carbon capture plant. The PCCS cooling water return will be routed to the existing PPS outfall structure.

The 170 m tall stack at the power station will be modified for use as the exhaust stack for the carbon capture plant which will release the 'cleaned' GT13 flue gas to atmosphere after removal of its CO_2 content.

Control of the GT13/HRSG13 train and the new ST20 steam turbine will be from the existing Peterhead Power Station control room.

The existing power plant utilities infrastructure will provide towns water; fire and demineralised water for use in the carbon capture plant - reducing the amount of infrastructure which requires to be constructed to support PCCS operations.

Figure 2-4: Peterhead Power Station

2.4.2. Existing Pipeline

The Goldeneye pipeline was installed in 2004 and operated until December 2010. The offshore pipeline and wells are currently owned by the Goldeneye Production Joint Venture established to produce gas from the field under the existing production licence. Production from the field has now ceased and the transfer of ownership of the assets to the Peterhead CCS Project Venture Organisation is being progressed. The existing pipelines are described in Table 2-1.

Table 2-1: Existing Pipeline

Pipelines	
Length & Diameter	Length: offshore 101 km, onshore 0.6 km (FLAGS route) Main pipeline : 20" (OD) MEG service line: 4" (NB)
Onshore Arrival Pressure	Initial : 86 bara Decline to : 25 bara (minimum)
Route & Crossings	Direct from Goldeneye platform to Shell-Esso terminal at St Fergus (parallel to and south of Miller / SAGE pipeline corridor) Five pipeline crossings

The pipeline was cleaned and made hydrocarbon-free in 2013. A minimal quantity of solid deposits was recovered by the cleaning operations but samples were taken and analysed for chemical content. Based upon the results of this analysis it was concluded that no detectable corrosion had taken place and the pipeline was in a satisfactory condition for re-use. It was left inhibited with biocide with a protection life of 7 years.

Previous study work done during the earlier Longannet CCS Project FEED study concluded that the existing 20-inch Goldeneye pipeline was suitable for the transportation of dense phase CO_2. This work was reviewed in the PCCS FEED study and no significant issues were identified. For further details of the pipeline please refer to Section 7.3 of the Basic Design and Engineering Package - KKD 11.003 [1].

2.4.3. Platform

2.4.3.1. General Description

The Goldeneye platform, shown in Figure 2-5, consists of a four-legged steel structure, connected to the seabed with two vertical steel piles at each corner, that supports a topsides deck structure with a helideck, pedestal crane and vent stack. The jacket and topsides were installed during 2003.

Figure 2-5: Goldeneye Platform

The topsides comprise two deck levels at elevations +22 m and +31.5 m with an intermediate mezzanine deck at elevation +27.15 m. The main plan dimensions of the decks are 31x16 m with the extra length cantilevered out to the west of the jacket, on the opposite side from the wellheads. This cantilever supports the helideck and contains the accommodation, control and equipment rooms.

The current operating weight of the topsides is approximately 1,680 tonnes but the design of the jacket structure allows for a topsides weight of up to 2,000 tonnes.

The jacket structure is a four-legged X-braced structure that was designed to be lift installed. The weight of the jacket is just under 2,500 tonnes.

The plan dimensions of the four-leg jacket vary from 19.7x16 m at elevation +11.9 m (w.r.t. LAT) to 35x35 m at elevation –119 m. Three of the jacket faces are battered with the fourth (east) face being vertical to allow the close approach of a jack-up drilling rig to access the wells. The faces of the jacket are X-braced with perimeter plan bracing only at the top and bottom levels.

2.4.3.2. Platform Orientation and Water Depth

The platform is orientated such that platform north is parallel to true north. The jacket faces are battered on three sides from the seabed at elevation –119 m w.r.t. LAT, to just below the deck at elevation +11.9 m w.r.t. LAT. From this point up the legs are vertical.

The water depth at the platform location is 119 m at LAT with a tolerance of 0.3 m. It was estimated that the seabed might subside up to 0.3 m during the life of the field due to reservoir depletion.

2.4.3.3. Existing Topsides Facilities

The platform is designed to operate as a 'Normally Unattended Installation' (NUI). It has accommodation for 12 personnel to facilitate periodic maintenance campaigns. Control of the existing platform is performed from Shell's St Fergus Control Room. The existing Goldeneye facilities comprise a number of process and utility systems.

The existing platform has 8 well slots although only 5 of these were used during the hydrocarbon production phase. During hydrocarbon operations, the wells were controlled from shore using a telemetry communications link. The existing Goldeneye Offshore Platform Design Parameters are summarised below.

Table 2-2: Summary of Existing Goldeneye Offshore Platform Design Parameters

Parameter	Value
Design Concept	Full Wellstream Tieback to shore, for onshore processing of the gas and condensate Normally unattended platform offshore for control of wells / chokes, manifolding, metering and water / oil detection
Design Life	20 years (to be extended under the PCCS Project)
Wells	5 jack-up drilled wells with sand exclusion, 3 producers, 2 producer / observation wells. All wells drilled prior to commissioning and start-up (minimum is 3 wells prior to start-up)
Offshore Facility	
Facility type	Normally Unattended Installation (NUI) Wellhead platform controlled from onshore (St Fergus) Short Stay Accommodation (provided for 12 Personnel On Board (POB) normally, with fold-down beds in five of the cabins to accommodate a maximum POB of 22) for overnight stays
Water Depth	119 m (LAT)
Offshore Process/ Equipment (Platform Topsides)	Manifold, Production separator Gas, hydrocarbon liquids and water metering Water and oil detection, sand detection Provision for possible future water treatment & sand collection
Manning Requirements	Six campaign maintenance visits per year of 6-8 days duration with a crew of 12 (planned and unplanned maintenance c. 6000 manhours per year); additional visits for ad-hoc work

2.4.4. Existing Reservoir

The offshore Goldeneye gas condensate field was produced between 2004 and 2011 via a pipeline to onshore facilities at St Fergus. DECC formally approved Cessation of Production in Q1 2011. The PCCS Project intends to re-use the Goldeneye subsea pipeline system and all the offshore facilities for the transport, injection and storage of CO_2. Modifications required to the offshore facilities include the topsides pipe work, new Christmas Trees, new completions and new vents.

It is planned to inject CO_2 into the storage site at a depth greater than 2516 m (8255 ft) below sea level into the high quality Captain Sandstone formation in the North Sea. The current reservoir pressure is estimated at 2716 psia (187 bara) (January 2015 at a datum of 8400 ft TVDss) based on permanent downhole gauge information. After the injection of 15 million tonnes of CO_2 the reservoir pressure will rise up to approximately 3760 psia (259 bara).

The platform has eight slots, five of which have been used during the production phase. The five production wells were suspended in 2012.

It is planned to place a heavy duty jack-up over the platform to re-complete the wells for CO_2 injection. Four of the five wells will be worked over (3 wells will be used for injection and 1 well for monitoring). The fifth well, currently envisaged to be GYA-05, is planned to be abandoned.

2.4.5. Existing Goldeneye Gas ProcessingFacilities at St Fergus

The St Fergus gas plant has facilities installed to process the hydrocarbon fluids from the Goldeneye, field, regenerate the MEG and export the hydrate and corrosion inhibitor to the platform via a 4" pipeline.

Table 2-3 provides a summary of the main Goldeneye facilities at St Fergus and their associated design parameters.

Table 2-3: Summary of Existing Onshore St Fergus Goldeneye Parameters

Parameter	Value
Standalone Reception / Process Facilities	Slugcatcher Surge Capacity 97 m^3 to 120 m^3 (variable weir height) Maximum condensate flowrate from slugcatcher: 200 am^3/hr Maximum aqueous flowrate from slugcatcher: 50 am^3/hr Gas Conditioning, drying using Molecular Sieve driers Water / MEG and Condensate separation Condensate stabilisation and flash gas recompression MEG recovery, regeneration and return Designed 35% above normal operating flow to process 5-day breakdown buffer in 14 days. Depletion Compressor (required from c. 2.2 years after start of production)
Utilities	Hot oil system 2x100% WHRUs on existing Frame 5 gas turbines Driving export sales gas compressors. Flare and vent (tie-in) Fuel gas Nitrogen Instrument air Electrical supply & distribution Drainage system
System Control	System (offshore and onshore) control from St Fergus control room; local offshore control facility for offshore visits

The St Fergus gas plant contains redundant facilities that were used to:

a) Process Goldeneye gas and condensate;
b) Supply MEG and corrosion inhibitor on a continuous basis to the Goldeneye Platform; and
c) Regenerate the MEG separated with mainly condensed water from the inlet separation system.

The PCCS project will re-use some of the equipment associated with the storage and export of the MEG and corrosion inhibitor for hydrocarbon production for the purpose of delivering methanol to the Goldeneye Platform under PCCS operations.

The main items of equipment that will be re-used for PCCS are as follows:

- Glycol Holding Tank (T-7703)
- Offshore Glycol Injection Pumps, (P-7704 A/B)
- Glycol Sump Vessel, (P-7704), and associated Glycol Sump Pump, (P-7706).

It was a baseline assumption in FEED that the Goldeneye hydrocarbon facilities will remain decommissioned but will not be removed unless required for PCCS. However, there is also the potential for the infrastructure to be modified and utilised for other projects. This requires further consideration in the PCCS Detailed Design phase.

2.5. Scope Overview

2.5.1. General

The scope breakdown for the Peterhead CCS Project between the two primary responsible parties, SSE and Shell, is shown in the figure below.

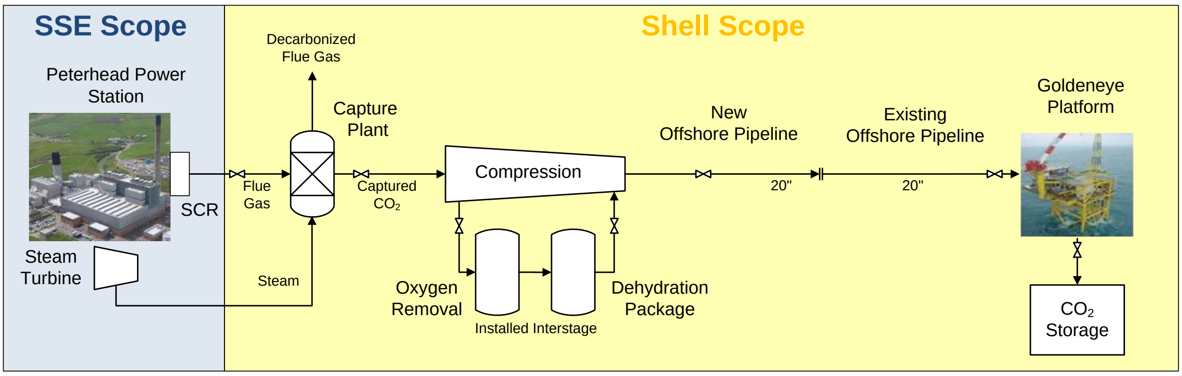

Figure 2-6: Scope Diagram between Key Responsible Parties

A list of the end-to-end Peterhead CCS chain links as considered during the FEED phase is provided below:

- Power Station (SSE's Generation Facilities);
- Carbon Capture, Compression and Conditioning (CCCC);
- Pipeline;
- Platform;
- Wells; and
- Reservoir.

2.5.2. Power Station

In the Execute project phase, the power plant scope of work shall segregate GT13/HRSG13 from the existing Block 1 steam system and provide steam for the new steam turbine, ST20, to form Block 2 of the power plant. Ducting shall be added to the exhaust gas path from HRSG13 to allow the gas to be drawn into the CCP. New Low Pressure (LP) steam supply lines and condensate return lines will take heat to and from the Carbon Capture Plant. A new auxiliary boiler system shall be installed, which will meet the CCP's MP steam demand as well as continuing to supply steam to the power plant's existing auxiliary steam consumers.

Existing site utilities such as cooling water, raw water and fire water will be modified to provide the necessary utility services to the CCP. Modification will also be required to the existing electrical network for utilisation with ST20 and the modified plant.

Demolition work will be carried out to remove redundant equipment from the power plant to provide space for the new CCCC plant.

2.5.3. Carbon Capture, Compression and Conditioning (CCCC)

The CCCC scope of work extends from the exhaust duct of the HRSG13 of the existing platform to the landfall connection onto the CO_2 export pipeline. The equipment in the area is split into three main process units:

- Pre-treatment (U-1000);
- Capture (U-2000); and
- Compression and Conditioning (U-3000).

It includes all the associated systems required for the above process.

In addition to the main CO_2 capture, compression and conditioning facilities there will be a Waste Water Treatment Plant to process the large quantities of surplus water generated by the capture process and make it suitable for discharge into the sea. Any process streams that are unsuitable for on-site processing will be transported by road tanker to a suitable licensed disposal site for further treatment.

A detailed description of the equipment to be provided can be found in Sections 5 and 6 of the Basic Design and Engineering Package - KKD 11.003 [1].

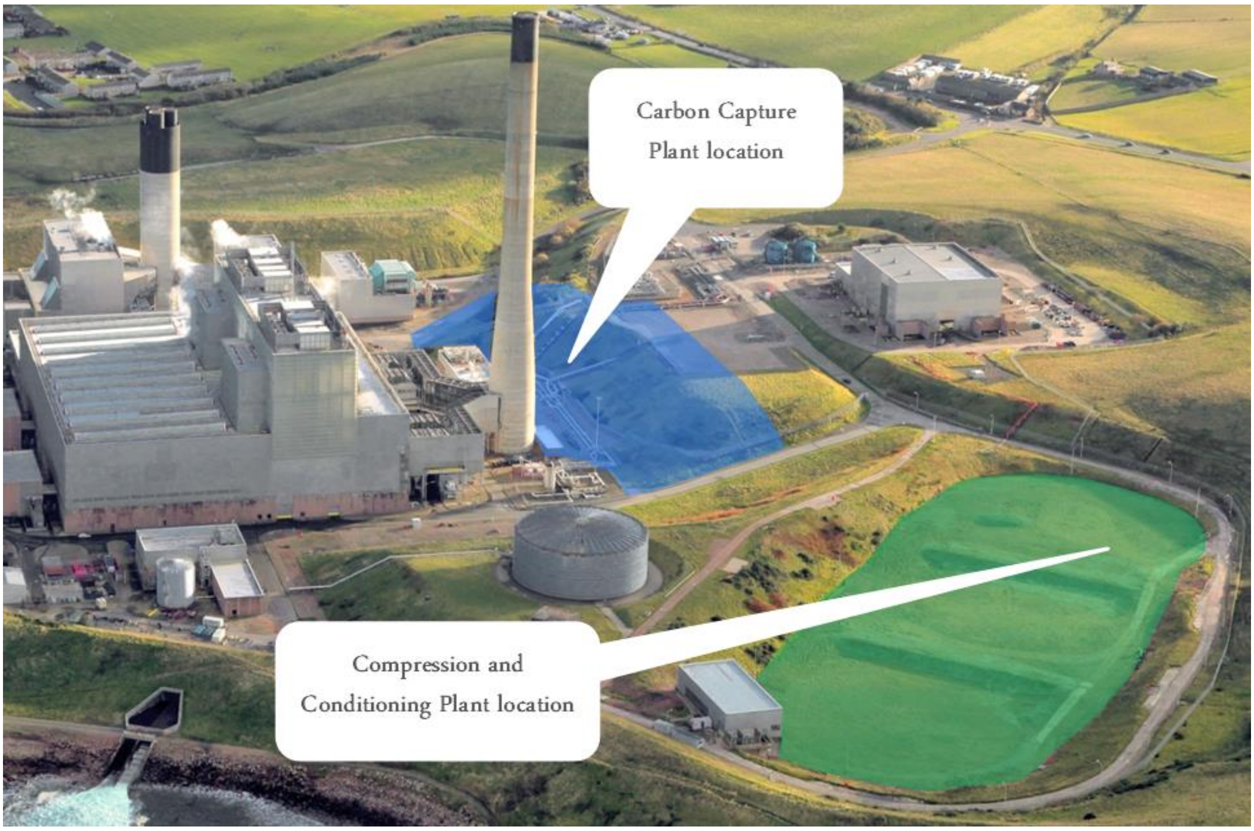

Figure 2-7: Carbon Capture, Compression and Conditioning Plant Location

2.5.4. Pipeline Systems

The subsea facilities shall comprise:

- New onshore pig launcher facility;
- 300m of onshore pipeline to HDD initiation point;
- 900 m HDD landfall tunnel;
- New 21.6 km 20 inch carbon steel CO_2 export pipeline from Peterhead Power Station to a subsea tie-in (approx. Kp19.6) to the existing 20" Goldeneye pipeline;
- New CO_2 export pipeline subsea flanged tie-in arrangement;
- New Sub-Sea Isolation Valve (SSIV) including the associated control facilities, umbilical and Topside Umbilical Termination Unit (TUTU);
- Subsea Isolation Valve (SSIV) tie-in spools;
- Existing platform riser and spools to the upstream weld of the riser Emergency Shutdown Valve (ESDV);
- Re-use of the existing 4-inch carbon steel MEG pipeline from St Fergus which has been confirmed suitable for conversion to methanol transportation.

2.5.5. Modification to the Offshore Facilities for PCCS

For PCCS, the operational life of the Goldeneye platform will be extended from 20 years to 35 years for the purpose of injecting CO_2 into the depleted reservoir for long-term storage. During the Execute phase a lifetime assessment will be carried out and based on the outcome of the assessment the facility will be refurbished as necessary to achieve the Project design life of 15 years. The platform is generally in good condition and no major works are anticipated to be required to achieve the lifetime extension.

A number of process and piping modifications are required to adapt the platform and pipeline for this change of use. The structural scope is limited to the offshore modifications to the Goldeneye platform in order to facilitate its change in operation from gas production to receiving and injecting CO_2 into the reservoir.

With the possible exception of strengthening the vent stack support structure, there are no major structural modifications required for this change in operation. The structural scope entails verifying the integrity of the structure for the extended design life in addition to supporting the modifications required by the other engineering disciplines, i.e., provision of access to the CO_2 filters, provision of equipment support trimmers and pipe supports. The estimated weight of structural steelwork additions is circa 23 tonnes.

After CO_2 injection is completed, the platform will be decommissioned. The wells will be plugged and sealed and topsides and jacket will be removed so that the reservoir can be left with the CO_2 stored. Reservoir performance will be monitored post decommissioning by periodic boat-borne surveys. These surveys will be undertaken for a period of time that will be agreed with the relevant Authority. For planning purposes it has been assumed that seabed and seismic surveys will be executed by Shell at cessation of injection and again after some four to five years at the end of decommissioning. An expenditure allowance has been included to cover two further seabed surveys in the period up to 30 years after cessation of injection. This activity has been included in the OPEX cost estimate for the Project's Execute phase as detailed in the Cost Estimate Report – KKD 11.043 [9].

2.5.6. Modification to the Goldeneye Module at St Fergus for PCCS

Methanol injection is required during start-up of each well for the following reasons:

1. To allow equalisation across the SSSV before opening (only when SSSV is closed);

2. To prevent hydrate formation within the injection tubing and reservoir during well start-up; and
3. To bullhead wells with high Closed-in Tubing Head Pressures (CITHPs) that can result when the well tubing is full of hydrocarbon gas.

For PCCS, methanol injection is required intermittently whereas the existing Goldeneye MEG facilities were required to operate continuously during hydrocarbon production.

To allow provision of methanol from St Fergus the following scope of supply is required:

- Each well start-up requires a volume of up to 6.5 m^3 of methanol before the initiation of dense phase CO_2 injection. Simultaneous injection of methanol with dense phase CO_2 is not required; and
- A flow rate of about 4 m^3/h to 5 m^3/h will be required. This will be provided by converting the existing Goldeneye glycol supply facilities at St Fergus to methanol storage and pumping. The new facilities will be once through (i.e. there is no return of methanol). The existing glycol regeneration facilities are not required for PCCS.

The St Fergus asset organisation will operate the storage and pumping facility. Methanol will be pumped on a call-off basis. The Peterhead CCS control room will contact the St Fergus control room when methanol injection is required. Remote monitoring of methanol pumping will be in place at the Peterhead CCS control room.

2.5.7. General/Common Facilities

Common facilities that are shared between the Project and other parties have only been considered at the Peterhead power station site. However, the CCS operating principle is to have a physically separate and independent operating structure whereby CCS operations and warehousing/workshops are monitored and controlled in separate control and workshop/store buildings remote from the equivalent existing PPS facilities.

Common facilities/support functions such as security gate house/access control, roads/car parking, and the likes are assumed to be shared with PPS operations, noting that SSE may also request for these to be independent to SSE operations.

The St Fergus methanol supply will be operated and maintained by the St Fergus Gas Terminal owners and there are no common facilities required at St Fergus.

2.5.8. Spare Parts and Special Tools

Spare parts identification and stock holding requirements will be decided following assessment of the final facility Reliability, Availability and Maintainability (RAM) model studies to be carried out during the Project's detailed design phase. RAM model data will be used to identify equipment contribution to availability, downtime, failure modes and to identify spare parts requirements including any long lead capital spares.

Spare parts will be categorised into three levels:

- Capital spares;
- Commissioning and start-up spares; and
- Two year's operating spares.

Spares identified as capital spares will be purchased with initial equipment purchase orders.

Accessibility and maintainability studies will be performed to optimise plant and equipment layouts and verified by 3D CAD modelling reviews.

Specialised tools required for equipment removal, strip down and maintenance will be identified and included in equipment purchase orders.

2.6. Interfaces

The main internal mechanical project interfaces are given in the figure below. The block flow diagram describes the various process systems and the physical boundaries between the contracting parties.

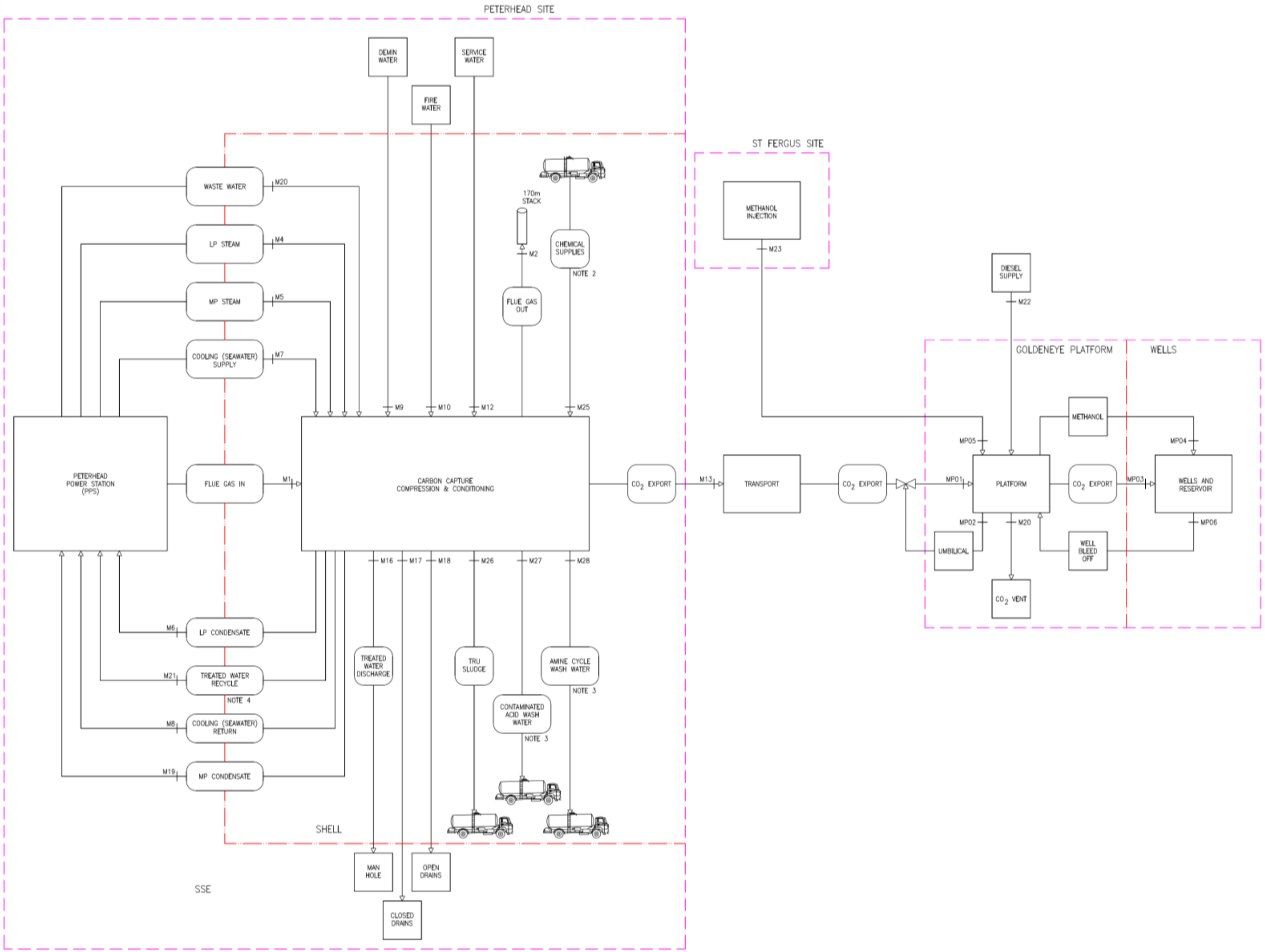

Figure 2-8: Block diagram of interfaces

2.6.1. Onshore Interface Points

The Carbon Capture Plant has interfaces with the following areas: -

- The new and existing power plant equipment (GT13 exhaust gas, ST20 and various utilities);
- Existing National Grid transmission system equipment (power supply to capture plant);
- CO_2 pipeline equipment (CO_2 export); and
- Goldeneye platform, St Fergus site and Shell data networks (telecoms and data for control and monitoring).

The power plant has existing interfaces with the following areas:

- National Grid Equipment (power export);
- Incoming gas supply pipeline from the National Grid National Transmissions System (NTS);
- Cooling water intake and outlet; and
- Waste water disposal.

Modifications will be required at each of these locations and will be required to be detailed further and controlled during the Execute phase.

Information on each interface (tie-in) can be found within the document Peterhead CCS (Onshore) Interface Schedule [10].

2.6.2. Offshore (Goldeneye Platform) Interface Points

The Goldeneye Platform has interfaces with the following areas:

- CO_2 pipeline;
- Methanol pipeline;
- The Subsea Isolation Valve (SSIV) manifold;
- The wells (CO_2 injection, methanol injection and monitoring & instrumentation); and
- Peterhead CCS, St Fergus site and Shell data network (telecoms and data for control and monitoring).

Due to the small number of key interfaces a summary of the locations key interfaces (tie-ins) has been identified in the list below:

Table 2-4: Main Offshore Interfaces

System	Medium	Location	Responsible party
CO_2 in	Gas	Tie-in to existing riser upstream of the new platform ESD valve (weld)	Offshore EPC
CO_2 out	Gas	Tie-in to the Well Christmas Trees downstream of the choke valves (flanged spool piece)	Offshore EPC
Methanol in	Liquid	Tie-in into existing 4-inch riser before new ESD valve (new ESD	Offshore EPC

System	Medium	Location	Responsible party
		valve onto existing flange)	
Methanol out	Liquid	Tie-in to the Well Christmas Trees downstream of the choke valves (flanged spool piece)	Offshore EPC
Umbilical to Sub Sea Isolation Valve manifold		Umbilical pull-in and connection to Topsides Umbilical Termination Unit (TUTU)	Pipeline & Subsea contractor to provide and install TUTU and to pull-in umbilical
Umbilical hydraulics to platform HPU	Liquid	Hydraulic connections TUTU – Platform HPU	Pipeline & Subsea contractor
Subsea SSIV instrumentation	Electric Signals	Tie-in of instrument cable from TUTU to platform ICSS	Offshore EPC
Communications	Comms signals	Goldeneye to Peterhead and other communications systems	Communications System Integrator
Integrated Control and Safety System		Goldeneye Control room to Peterhead CCS Control room	Honeywell as part of Offshore EPC scope

2.7. Oversizing

As detailed above, much of the Peterhead CCS infrastructure is already in existence. The principal CCS chain element which will be new and specifically designed to meet the Project duty is the carbon capture, compression and conditioning plant. The CCCC plant has been designed to match the anticipated CO_2 output from the existing GT13 unit. Although some margin has been included in the CCCC plant design (as detailed in later sections of this document), no provision for future additional capacity has been included in the design. There is space available on site to allow consideration of future expansion or access by other third parties seeking to store CO_2 which has been transported to the Peterhead site. Any such proposals would be considered under a separate future Project.

A feature of the existing system comprising the offshore pipeline transport pipeline, Goldeneye platform infrastructure, offshore wells and storage reservoir is that it is anticipated to be capable of storing more CO_2 than the 15 MT of CO_2 proposed by the PCCS Project and to be able to transport more than the designed maximum CO_2 flow rate of 137 T/h. Once the Goldeneye reservoir has been filled with CO_2, successful demonstration of the PCCS Project could then pave the way for other CCS projects and storage of CO_2 in the underlying Captain aquifer where much larger quantities of CO_2 could potentially be stored.

3. Design Criteria

3.1. Design Life

The design lifetime of the facilities required by the Project shall be 15 years from commencement of PCCS operations under the CfD.

3.2. Design Class

A design class workshop was conducted prior to commencing the FEED study with the objective of improving understanding, agreement and communication on the size, type and cost of the new plant for the Project. The main drive of the design class evaluation exercise was to "provide an optimum fit-for-purpose scope to meet the business needs". The design class workshop was carried out in accordance with Shell's internal project management processes which consider selection of one of three design classes to suit four key performance criteria. The most appropriate design class is selected for each performance criteria – i.e. different design classes can be applied to each performance criteria. Shell's standard guidance on the application of design class characteristics to individual project aspects is summarised in Table 3-1 below.

Table 3-1: Shell Standard Design Class Characteristics

	Class 1	Class 2	Class 3
Performance Categories	Will meet premises only at one set of design conditions; will not meet off-design cases	Selected process streams or systems will be upgraded to meet off-design cases	Will meet premises at all identified conditions, design and off-design cases
Capacity	-20% / +0%	-10% / +10%	0% / +20%
Expandability	None	Selected Streams	Considered
Capacity Utilisation	< 85%	85 to 95%	> 95%
Operability and Maintainability	No Turndown	Moderate Turndown	High Turndown

A high level summary of the selected design classes as applied to the PCCS pre-FEED design in the design class workshop is presented in Table 3-3 below:

Table 3-2: Summary of Design Class Workshop

	Class 1	Class 2	Class 3
Performance Categories	Will meet premises only at one set of design conditions; will not meet off-design cases	Selected process streams or systems will be upgraded to meet off-design cases	Will meet premises at all identified conditions, design and off-design cases
Capacity	Based on a blanket 5% overdesign included in current design, as per Design Basis. No more overdesign in facilities.		
Expandability	No expandability is proposed for the carbon capture plant design	Space is allocated for a 2nd CO_2 compressor	
Capacity Utilisation	CO_2 compressor and flue gas booster fan are not spared: a high reliability figure is required to meet target. Requires shutdown of equipment to repair		Carbon capture plant main rotating kit is spared. RAM to be used to justify holding other high Capital Expenditure (CAPEX) spared equipment
Operability and Maintainability		Planned shutdowns to follow SSE maintenance cycle. Sparing to be adjusted accordingly to meet availability target	Auto start available on wells

The design class process was not applied to the Offshore and Pipeline technical FEED scopes of work in view of the very limited amount of equipment involved.

3.3. Design Cases

Throughout FEED three design cases were considered for the development of the specifications of the full CCS chain. The cases were:

1. Design Load Max;
2. Normal operation; and
3. Turndown.

The 'Design Load Max' case corresponds to the maximum possible output from the power plant and CCCC plant during the most favourable ambient conditions.

The 'Normal operation' case corresponds to the output from the power plant and CCCC plant when operating at the reference ambient conditions at the Peterhead Site.

The 'Turndown' case corresponds to the operating scenario where the CO_2 output of the CO_2 compressor equates to the minimum injection flow rate for the wells. This is approximately equivalent to GT13 operating at 65 % output and the CO_2 export at 70 % of the normal operation case.

3.4. Design Margins

The following table shows the percentage design margin applied to the Design Load Max case for the major items of equipment in the Project. Note that the Design Case is based on the maximum possible output from the power plant and Capture and Compression Plant during the most favourable ambient conditions.

Table 3-3: Design Margins

Equipment	Design Margin %	Notes
Booster fans	0	On design gas throughput
DCC column	0	On gas throughput
DCC pump	20	On flowrate
DCC cooler	20	On surface area
Gas-Gas Exchanger	10	On flowrate and duty
CO_2 Absorber	5	On flue gas flowrate
Thermal Reclaimer Unit	50	On processing rate
CO_2 Compressor	0	On flowrate
LP Steam and Condensate systems to CCP	10	On flowrate
CCP closed loop cooling system	10	On flowrate
CCP heat exchangers	10	On surface areas
CCP Pumps	10 (min.)	On design flowrate
Demineralised Water supply from power plant to CCP	10	On peak flow rate

3.5. Availability

During FEED, a Reliability, Availability and Maintainability (RAM) study was undertaken to create an End-to-End reliability model for the PCCS project. The RAM model was used to quantify the overall reliability and availability of the project. The RAM model was also used to identify critical systems or components and events which caused significant plant downtime, determine where installation of redundancy would be most effective and present recommendations on how to achieve a target availability for the CCS chain of 80% or higher.

The results of the RAM modelling performed show the PCCS chain's designed availability to be approximately 85% based upon the end of FEED design. The highest impact on the full PCCS chain availability is as a result of the PPS station outages for gas turbine GT13 scheduled maintenance. The power plant outages provide an opportunity to align some of the necessary PCCS equipment maintenance with the power plant outages without impacting on the overall PCCS availability. The most significant source of downtime in the CCCC Plant design is attributed to the CO_2 compressor and booster fan, resulting from the lack of designed redundancy in this equipment. This decision was made as a result of the cost / benefit analysis performed during FEED.

3.6. Flexibility

The project has a secondary driver to demonstrate operating flexibility to support clean gas power with greater flexibility plus reliability than renewables.
Although full chain process modelling has been undertaken during FEED considering the transportation and injection of CO_2, due to the novelty and complexity of the overall CCS chain system, the extent to which the system can be operated flexibly can only be investigated accurately by determining all likely system interactions and constraints once operations have commenced.

3.7. Application of New Technology and Techniques

CCS individual technologies are largely proven and safe; the primary challenges relate to full chain and integration aspects. It is assumed that no significant new Research and Development (R&D) or technology development releases will be required during the Execute phase of the Peterhead CCS project. The novel aspects of the project that have been identified in the bid to DECC include the Power Station Tie-in, Capture, Compression and Conditioning, Onsite Effluent Water Treatment, Transport, Injection and Monitoring scope. For further details of the novel technologies considered on the project please refer to KKD 11.064 - Technology Maturation Plan [6].

In addition to new technology, the regulatory regime for CCS is still in development. Although much work was done in FEED to address likely regulatory requirements and compliance with EU ETS, CfD, etc., these requirements will continue to mature as the Project progresses and it is anticipated that further effort will be required during Detailed Design to satisfy these requirements which are still developing in terms of detail and the interpretation of how they should be applied to CCS projects in the UK.

4. Site and Engineering Data

All of the sites considered within the scope of the PCCS project have been in existence and have been operated by the principal project participants for many years. Therefore, significant meteorological and climactic data already exists for all of these sites. This information has been used to develop the data used in the PCCS FEED study and is summarised below.

4.1. Meteorological Data for the Peterhead Power Station Site

4.1.1. Air Temperature

Below are the design maximum and minimum temperatures for process and equipment at Peterhead Power Station site.

- Reference dry bulb: 8°C
- Minimum dry bulb: -5°C
- Maximum dry bulb: 30°C

The mean and extreme values for the daily minimum, daily mean and daily maximum air temperature per month and per annum are provided in the table below:

Table 4-1: Mean and extreme values for the air temperature per month and per annum (from years 2000 to 2012)

Air Temperature	January	February	March	April	May	June	July	August	September	October	November	December
Absolute Minimum (°C)	-3	-4	-4.3	0.2	1.5	4.2	8.2	6.7	3.9	1.1	-2	-5.8
Average Minimum (°C)	-0.6	-0.8	-0.4	2.5	4.2	7.2	9.8	9.5	6.9	4	0.9	-1.1
Mean (°C)	5.4	5.3	6.2	7.9	9.9	12.3	14.1	14.4	13.1	10.5	7.8	5.4
Average Maximum (°C)	11.4	12.1	14.9	15.1	17.8	20	21.3	21	19.8	16.3	14	11.3
Absolute Maximum (°C)	14.7	17	18	18.4	21.4	26	26.3	22.9	22.1	19.9	17.9	14.5

4.1.2. Barometric Pressure

Below are the design maximum and minimum barometric pressures for process and equipment.

- Reference: 1013.25 mbar
- Minimum: 960 mbar
- Maximum: 1045 mbar

The mean and extreme values for the daily minimum, daily mean and daily maximum barometric pressure per month and per annum are as provided below:

Table 4-2: Mean and extreme values for barometric pressure per month and per annum (from years 2000 to 2012)

Atmospheric Pressure	January	February	March	April	May	June	July	August	September	October	November	December
Absolute Minimum (Mbara)	957.8	966.6	966.9	977.1	985.7	990.2	987	988.3	977.6	962.7	957	956.2
Average Minimum (Mbara)	973.4	980.8	982.4	989.7	995.3	997.6	995	995.6	990.5	979.6	978.1	975.6
Mean (Mbara)	1008.2	1011.6	1011.7	1013	1014.6	1014.8	1012.6	1012.9	1013.3	1008.9	1006.1	1009.4
Average Maximum (Mbara)	1032.8	1035.5	1035.1	1030.6	1029.3	1029.1	1026.6	1025.9	1030.9	1029.5	1028.1	1034.6
Absolute Maximum (Mbara)	1040.6	1043.6	1041	1039.1	1034.4	1038.4	1037.8	1031	1040.4	1036.7	1040.1	1044.6

4.1.3. Relative Humidity

Below are the design maximum and minimum relative humidity for process and equipment.

- Reference: 60% at 8°C
- Minimum: 30%
- Maximum: 100%

In addition the environment at Peterhead should be considered highly saliferous.

The mean and extreme values for the daily minimum, daily mean and daily maximum relative humidity per month and per annum are as provided below:

Table 4-3: Mean and extreme values for atmospheric humidity per month and per annum (from years 2000 to 2012)

Atmospheric Humidity	January	February	March	April	May	June	July	August	September	October	November	December
Absolute Minimum (%)	46.8	49.3	35.3	30.3	32.4	38.1	38.9	36.4	40.1	48.1	48.8	36.3
Average Minimum (%)	55.6	54.3	45.3	42.2	45.3	47.2	48.2	47.4	45.2	51.6	57.1	55.3
Mean (%)	81	80.5	79.4	79.9	80.2	81.6	83.1	82.9	80.8	81.4	81.7	81.5
Average Maximum (%)	96.8	97.9	98.7	97.9	98.7	98.5	98.6	98.3	97.4	97.7	97.2	96.2
Absolute Maximum (%)	98.8	99.8	100.3	99.9	100	99.7	100	99.8	99.6	99.8	99.4	99.2

4.1.4. Rainfall

Below are the average annual rainfall and the max hourly rainfall.

- Average annual rainfall: 747.7 mm [1]
- Maximum hourly rainfall: 36 mm [2]

The mean values for the monthly and annual precipitations are as provided below:

Table 4-4: Values for the monthly and annual precipitations [3]

Month	Rainfall (mm)	Days of rainfall >= 1 mm (days)
Jan	65.2	13.2
Feb	54.4	12.9
Mar	55.6	11.8
Apr	58.4	12.4
May	49	11.3
Jun	48	8.3
Jul	62.9	10.9

[1] http://www.metoffice.gov.uk/public/weather/climate/peterhead#?tab=climateTables

[2] http://www.knaven-weather.co.uk/

[3] http://www.knaven-weather.co.uk/

Month	Rainfall (mm)	Days of rainfall >= 1 mm (days)
Aug	51.2	10.4
Sep	62.3	11.8
Oct	89.7	13.8
Nov	82.7	15.6
Dec	68.3	14.1
Annual	747.7	146.4

4.1.5. Wind Speed and Direction

Below are the average annual wind direction and speed (knots) distribution (%). [4]

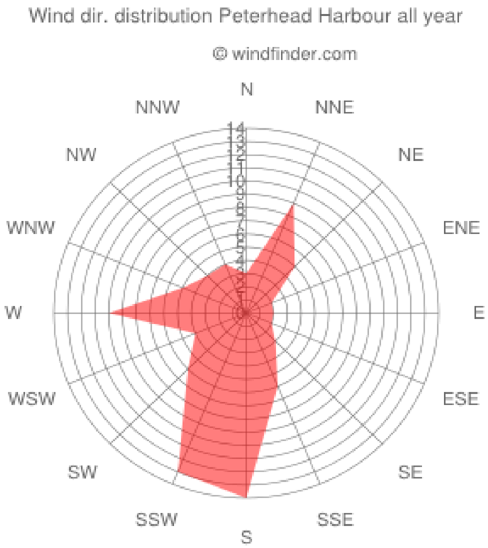

Figure 4-1: Average annual wind direction and speed (knots) distribution (%)

Table 4-5: Values for average monthly and annual wind speed

Month	Average Wind Speed (m/s)
Jan	6.7
Feb	6.7
Mar	6.2
Apr	4.6

[4] http://www.windfinder.com/windstats/windstatistic_peterhead.htm

Month	Average Wind Speed (m/s)
May	4.1
Jun	4.6
Jul	4.6
Aug	4.6
Sep	5.7
Oct	6.7
Nov	7.7
Dec	6.2
Annual	5.7

Further refer to BS EN 1991-1-1-4:2005 – Parts 1-4 General Actions, Wind Actions.

4.1.6. Snow Loading

The design ground snow loading at Peterhead is 0.6 kN/m^2. For further information refer to BS EN 1991-1-1-3:2003 – Parts 1-3 General Actions, Snow Loads.

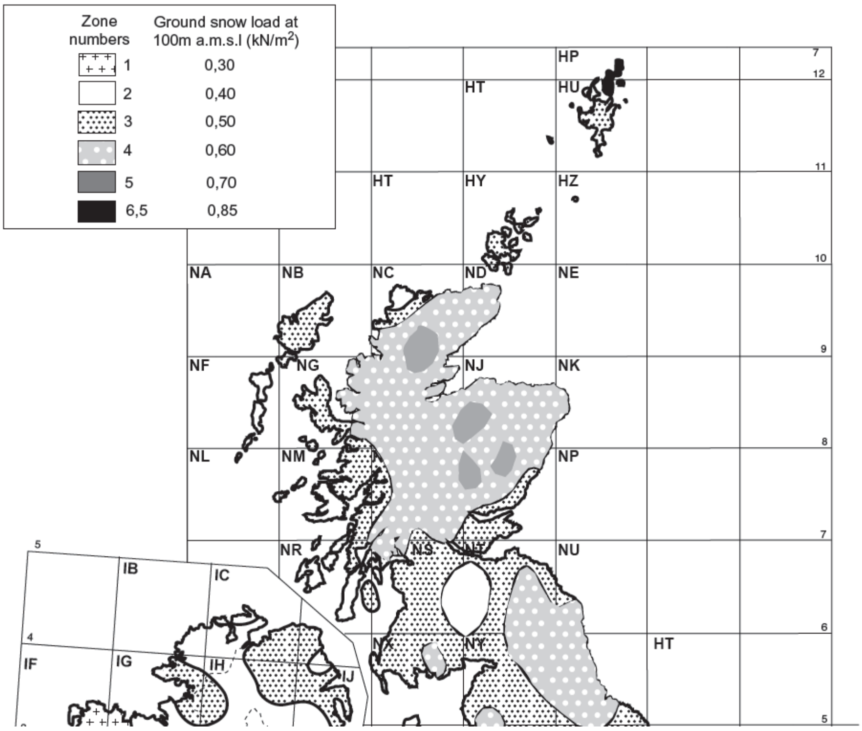

Figure 4-2: UK Snow Loadings

4.2. Pipeline Oceanographic Data

The one year and 100-year extreme values are provided Table 4-7 below.

Tidal levels are as follows:

Goldeneye platform location

MSL (Mean Sea Level) 1.26 m above LAT

MLWS (Mean Low Water Springs) 0.30 m above LAT

St Fergus beach

MSL 2.32 m above LAT

MLWS 0.50 m above LAT

Table 4-6: Sea Wind, Wave, Current and Level Data – 1 Year Extremes

1 Year Extremes	Winds			Waves				Currents				Levels
	V 1hr	V 1min	V 3sec	Hs	Tz	Hmax	Tmax	Surface	0.5d	0.1d	0.01d	Tide + Surge
	m/s	m/s	m/s	M	s	m	s	m/s	m/s	m/s	m/s	m
Goldeneye	27.5	33.5	38.0	9.5	9.8	17.7	12.5	0.75	0.75	0.59	0.43	2.8
Block 20/6	27.5	33.5	38.0	9.0	9.6	16.8	12.3	1.04	1.04	0.82	0.59	3.0
Block 19/13	26.8	32.7	37.1	8.7	9.5	16.3	12.2	1.40	1.40	1.10	0.80	3.7
Nearshore – Distance from shore (km)												
10	Winds are not considered as the pipeline is subsea.			7.6	8.9	14.1		1.45	1.45	1.14	0.83	4.0
9				7.5	8.9	14.0		1.50	1.50	1.18	0.86	4.0
8				7.7	9.3	14.3		1.55	1.55	1.22	0.89	4.1
7				8.1	9.3	15.1		1.60	1.60	1.26	0.92	4.2
6				7.5	8.9	14.0		1.65	1.65	1.30	0.95	4.3
5				7.4	9.3	13.8		1.70	1.70	1.34	0.98	4.4
4				7.8	9.3	14.5		1.75	1.75	1.38	1.01	4.5
3				7.4	8.9	13.8		1.80	1.80	1.42	1.03	4.6
2				7.5	8.8	14.0		1.80	1.80	1.42	1.03	4.6
1.5				7.5	8.7	14.0		1.80	1.80	1.42	1.03	4.6
1				7.1	8.4	12.8		1.80	1.80	1.42	1.03	4.6
0.5				4.1	4.1	7.4		1.80	1.80	1.42	1.03	4.6
0.25				1.1	7.1	2.0		1.80	1.80	1.42	1.03	4.6

Table 4-7: Sea Wind, Wave, Current and Level Data – 100 Year Extremes

100 Year Extremes	Winds			Waves				Currents				Levels
	V 1hr	V 1min	V 3sec	Hs	Tz	Hmax	Tmax	Surface	0.5d	0.1d	0.01d	Tide + Surge
	m/s	m/s	m/s	m	s	m	s	m/s	m/s	m/s	m/s	m
Goldeneye	35.0	43.8	50.3	13.3	11.7	24.6	15.0	0.89	0.89	0.70	0.51	3.1
Block 20/6	35.0	43.8	50.3	12.7	11.4	23.5	14.6	1.24	1.24	0.98	0.71	3.5
Block19/13	34.0	42.5	48.8	12.2	11.2	22.6	14.3	1.70	1.70	1.34	0.98	4.4
Nearshore – Distance from shore (km)												
10	Winds are not considered as the pipeline is subsea.			10.8	10.7	20.1		1.75	1.75	1.38	1.01	4.8
9				10.7	10.7	19.9		1.80	1.80	1.42	1.03	4.9
8				10.9	11.2	20.3		1.85	1.85	1.46	1.06	5.0
7				11.6	11.2	21.6		1.90	1.90	1.50	1.09	5.1
6				10.6	10.7	19.7		2.00	2.00	1.57	1.15	5.2
5				10.5	11.2	19.5		2.10	2.10	1.65	1.21	5.3
4				11.3	11.2	21.0		2.20	2.20	1.73	1.26	5.4
3				10.5	10.7	19.5		2.30	2.30	1.81	1.32	5.5
2				10.6	10.6	19.7		2.30	2.30	1.81	1.32	5.5
1.5				9.1	10.5	16.4		2.30	2.30	1.81	1.32	5.5
1				7.1	10.1	12.8		2.30	2.30	1.81	1.32	5.5
0.5				4.1	9.2	7.4		2.30	2.30	1.81	1.32	5.5
0.25				1.1	8.6	2.0		2.30	2.30	1.81	1.32	5.5

4.3. Meteorological Data at Goldeneye Platform

The meteorological data provided is to be used for the purposes of CO_2 dispersion calculations. No significant changes are proposed to the Goldeneye Platform infrastructure and the meteorological data used in the original design remains applicable to the PCCS project. The meteorological data at the Goldeneye Platform for PCCS which is presented below has primarily been used in CO_2 dispersion calculations.

4.3.1. Water Depth

Water depth at platform location = 119.0 m LAT.

4.3.2. Water Levels

Table 4-8 below details water levels relative to tidal height (LAT) at Goldeneye platform location.

Table 4-8: Water Levels at Goldeneye Platform

Level	Height (m)
HAT	2.48
MHWS	2.21
¾ Tide	1.79
MHWN	1.70
MSL	1.29
MLWN	0.88
MLWS	0.28
LAT	0.00

100-year positive surge levels (MSL) = 1.15 m

100-year negative surge levels (MSL) = -1.1 m

Crest elevation = 14.6 m

100-year extreme water level (crest + associated SWL) = 16.9 m

10,000-year extreme water level (crest + associated SWL) = 21.2 m

4.3.3. Sea Current Profile

Table 4-9 below gives the 100 year extreme total current speed.

Table 4-9: Currents at Goldeneye Platform

Depth	Speed of current (m/s)
1.00 d (surface)	0.89
0.75 d	0.89
0.50 d	0.89
0.30 d	0.82
0.10 d	0.70
0.05 d	0.64
0.01 d (near seabed)	0.51

4.3.4. Wave Data

100-year omni-directional extreme wave (all year)

100-year significant wave height, Hs = 13.3 m

100-year maximum wave height, Hmax = 24.6 m

4.3.5. Wind Data

100-year omni-directional extreme wind speed at 10 m above MSL (all year):

3 second gust = 50.3 m/s

1 minute mean = 43.8 m/s

1 hour mean = 35.0 m/s

4.3.6. Joint Probability Data for Design

100-year Hmax = 24.6 m

Associated mean wind speed = 38.5 m/s

Associated depth-mean current = 0.37 m/s

Associated surface current = 0.40 m/s

4.3.7. Marine Growth

Radial marine growth relative to LAT:

Above +1.5 m = 0 mm

At +1.5 m = 50 mm

At +0.0 m = 50 mm

At -40.0 m = 50 mm

Below -40.0 m = 0 mm

4.3.8. Snow and Ice

The designed extreme snow and ice accumulations for the Goldeneye platform are as follows:

Tubular Member below deck level

Wet snow, maximum thickness = 40 mm (density 500 kg/m^3)

Circumferential ice from freezing spray, max. thickness = 25 mm (density 900 kg/m^3)

Lattice Member above deck level

Wet snow, maximum thickness = 40 mm (density 500 kg/m^3)

Semi-circumferential ice from frozen snow, maximum thickness = 25 mm (density 900 kg/m^3)

Horizontal Surface

Wet snow, maximum thickness = 200 mm (density 100 kg/m^3)

4.3.9. Temperature Data

The 100-year minimum/maximum values are:

Air temperature = -8 /+25°C

4.4. Oceanographic Data

4.4.1. Water Levels for Offshore

The significant water depths along the specified pipeline route, reference to LAT, are as follows:

Goldeneye Platform	-119.5 m
Subsea tie-in	-80.0 m
Landfall	0.0 m

HDD exit point (landfall tie-in) -12.0 m

4.4.2. Sea Temperature

4.4.2.1. Peterhead Power Station

The yearly profile of the sea water inlet temperature to the Peterhead Power station is provided in the Table 4-10 below.

Table 4-10: Mean and extreme values for the seawater temperature per month and per annum (from years 2001 to 2012)

Sea Water Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Absolute Minimum (°C)	5.6	5.4	5.2	5.9	7.1	9.2	10.7	12.3	12.1	9.9	8.2	6
Average Minimum (°C)	6.3	5.9	6	6.8	8.2	9.9	11.7	12.9	13	11.2	9.2	7.2
Mean (°C)	6.9	6.3	6.4	7.5	9.1	10.9	12.5	13.4	13.4	12	10.3	8.2
Average Maximum (°C)	7.4	6.7	7	8.3	10.3	11.9	13.4	14.1	13.9	13	11.1	9.1
Absolute Maximum (°C)	8.2	7.3	8	9.1	11	12.9	14.4	14.9	14.6	14.2	11.7	9.8

4.4.2.2. Goldeneye Platform

The 100-year minimum/maximum values at Goldeneye Platform location are:

Sea surface temperature = 1.0/22.0°C

Sea bed temperature = 4.0/11.0°C

4.5. Geotechnical

4.5.1. Soil Description

4.5.1.1. Peterhead Power Station

The drift geology across the site is defined as glacial till, composed of a sequence of plastic clays and sands with inclusions of gravel and cobbles. The solid bedrock geology across the site is igneous granite associated with the Caledonian Orogeny.

Additional geotechnical investigation was completed at the start of FEED activities focusing on the precise plot of the new plant. The investigation was carried out by Fugro and included a total number of 19 boreholes. This investigation covered 3 areas:

- Area 1 - Carbon Capture Plant
- Area 2 - Compression & Conditioning Plant
- Area 3 - Chemical Storage & Control Building

Made Ground was encountered in all exploratory holes and is associated with the construction of the existing power station with thicker deposits of Made Ground over Area 3. The maximum depth of

Made Ground for Areas 1 and 2 is about 1.40 m. For Area 3 the deposit extended to depths of between 0.70 mbgl and 2.70 mbgl.

Generally firm, locally soft, sandy and sandy gravelly clay with laterally variable horizons of medium dense gravelly sand was encountered immediately underlying the Made Ground across Area 3 only and extended to depths of between 13.75 mOD and 10.61 mOD.

Immediately underlying the Made Ground in Areas 1 and 2, and immediately underlying the Glacial Till in Area 3, generally extremely weak becoming medium strong to strong with depth, granite was encountered and was proven to a maximum depth of 0.35 mOD.

The investigation report considered Made Ground unsuitable as a load bearing stratum due to its variable composition and strength. Should shallow foundations be considered, any Made Ground will need to be removed and replaced with well compacted engineered fill. This will affect mainly the foundations in Area 3 due to thick Made Ground stratum in this area.

The foundations for the new structures are likely to comprise traditional pad footings, which need to be extended so that they wholly bear weight within the underlying weak to medium strong granite encountered at site. For heavy structures it is likely that large bases will be sufficient and no piles will be required, although this will be dependent upon the height and weight of the structures considered.

On commencement of the project Execution phase, emphasis should be placed on identifying and verifying the areas of contamination known or expected to be present from historical site usage and identifying any further areas potentially at risk. This would typically be progressed via an initial desk-based assessment including a study of available records (and previous investigations etc.) to develop the Conceptual Site Model for the site; this would include a review of the drift and solid geology, and the influence of groundwater.

4.5.2. Earthquakes

This area is considered of low seismicity.

4.5.3. Seabed Terrain

The pipeline route has been surveyed in a 2014 data acquisition which included side scan sonar, single and multi-beam echo sounder, magnetometer and pole-mounted sub-bottom profiler. Benthic environmental surveys were carried out immediately following the geophysical data acquisition. The findings of the surveys are discussed in Section 8.2 of the Basic Design and Engineering Package – KKD 11.003 [1].

4.5.4. Near-Shore Geotechnical Report on HDD pilot hole

Geotechnical information on the near-shore HDD bore hole is summarised in Section 8.2 of the Basic Design and Engineering Package – KKD 11.003 [1].

4.5.5. Pipeline Survey Report

Work carried out to evaluate the suitability of the pipeline condition and materials for CO_2 use during a previous FEED study concluded that the existing 20-inch (508 mm) Goldeneye pipeline was suitable for the transportation of dense phase CO_2 with pre-conditions. No significant issues were identified in the present FEED study.

To confirm the pipeline wall thickness and identify any potential metal loss, an inspection pigging programme has been developed and is scheduled to be carried out following the completion of the onshore pig launcher. The pigging operation combines both UT and MFL technologies.

No significant issues were identified and further information can be found in Section 8.3.1 of the Basic Design and Engineering Package – KKD 11.003 [1].

5. Key Feed and Product Stream Specifications

5.1. Fuel Gas

The fuel gas supplied by the UK National Transmission System (NTS) to the existing Peterhead Power station has been monitored during the previous operation of the power plant and based on this experience the following composition of fuel gas has been used in the FEED specifications.

Table 5-1: Fuel Gas Composition

Constituent	mol %
Methane	87.45
Ethane	6.98
Propane	2.19
I-Butane	0.00
N-Butane	0.41
I-Pentane	0.00
N-Pentane	0.05
Neo-Pentane	0.00
I-Hexane	0.00
N-Hexane	0.02
Heptane	0.00
Octane	0.00
Nonane	0.00
Decane	0.00
Nitrogen	0.99
Carbon Dioxide	1.91
Hydrogen Sulphide	0.0037
Water	0.00
Total	**100.00**

5.2. Flue Gas to Capture Plant

The flue gas exiting the HRSG after the SCR has the following parameters:

Table 5-2: Flue Gas Parameters

Battery Limit Conditions Gas Inlet to Capture Plant Booster Fan	Units	Value Normal Operation Case	Value Turn down	Value Design Load Max
Gas Inlet Flowrate	kg/s	685	512	710
CO_2 Mass Flowrate	t/h	145.5	99.9	153.1
Operating Temperature	°C	100	100	100

Battery Limit Conditions Gas Inlet to Capture Plant Booster Fan	Units	Value Normal Operation Case	Value Turn down	Value Design Load Max
Operating Pressure	bara	1.013	1.013	1.040
Composition				
SO_2	ppmv dry	1.4	1.4	1
CO_2	vol %	3.82	3.51	3.88
H_2O	vol %	7.70	7.15	7.53
O_2	vol %	12.80	13.45	12.81
N_2	vol %	74.78	74.99	74.88
Ar	vol%	0.90	0.90	0.9
CO	ppmm	0	87	0
total NOx	ppmm	1	1	1
HCl	vol %	0	0	0
HF	vol %	0	0	0
NH_3	ppmm	5	5	5
Dust Load	mg/Nm^3	0	0	0

Notes:

1- **A 65% turndown is used for the CCS chain.**

2- **Design of pre-treatment unit shall be made for 5 ppmm ammonia but expected value is 2 ppmm.**

5.3. Export CO_2 to Pipeline

The table below describes the operating parameters of the CO_2 leaving the CO_2 compressor package. A brief description of the reasons for the design limits on the significant CO_2 specification parameters is also provided.

Table 5-3: Export CO_2 to Pipeline

CO_2 Product (to Pipeline)	Units	Value	Comment
Pressure at battery Limit to Pipeline	bara	121	
Temperature at discharge of aftercooler	°C	25	
Flow Rate	t/h	137	Design Load Max Case
CO_2 Specifications	Design Limit	Comments	

CO_2 Product (to Pipeline)		Units	Value	Comment
H_2O	≤ 50 ppmv			Required to avoid corrosion. Should be ≤50% of the minimum saturation concentration of water in CO_2 during expected operations in pipelines and other equipment vulnerable to degradation by carbonic acid corrosion
O_2	≤ 5 ppmv			Required to maintain maximum concentration of 10 ppbv in formation water required to avoid pitting corrosion of 13 Cr stainless steel.
Volatile components	≤ 0.6%			The composition of the CO_2 must be controlled to prevent operation in a region where running ductile fractures can occur. The PCCS operating philosophy is that the Goldeneye pipeline must not be operated in a region where a small crack could develop into a running ductile fracture.
H_2	≤ 0.5%			The composition of the CO_2 must be controlled to prevent operation in a region where running ductile fractures can occur.
Noxious components				Toxic contaminants must be controlled to a level that does not significantly affect the hazards posed by CO_2 releases. This covers substances injurious to health and the environment such as nitrogen and sulphur oxides, mercury, aldehydes, particulates and carcinogenic substances that pose a greater hazard than CO_2.
Corrosive components	General specification			The composition of CO_2 must not adversely affect the integrity of the storage site or the relevant transport infrastructure. This covers substances such as oxides of nitrogen and sulphur, hydrochloric acid, Hg etc.
Particulates	Max size <5 microns			Prevent blockage of reservoir. Particulate matter should not create undue handling and disposal hazards due to toxicity, radioactivity etc.

6. Major Utilities Specification

The following table gives the specification for the main utilities of the Capture and Compression Plant:

Table 6-1: Major Utilities Specification

Battery Limit Conditions	UNITS	Design Load Max Case	Note
Low Pressure Steam from ST20 extraction point			
▪ Pressure	bara	3.22	
▪ Temperature	°C	141	

Battery Limit Conditions	UNITS	Design Load Max Case	Note
▪ Mass Flow	kg/h	219,456	
Medium Pressure Steam from Auxiliary boilers			
▪ Pressure	bara	21.51	
▪ Temperature	°C	236.9	
▪ Mass Flow	kg/h	4,810.3	
LP Condensate return to ST20 water, steam cycle			
▪ Return Temperature	°C	40	
▪ Return Pressure	bara	6	
▪ Mass Flow	kg/h	216,798	20 kg/h loss
▪ Total Hardness (Ca + Mg)	ppm	as per supply	
▪ Conductivity (SSE acceptance limit) (Abs or delta wrt M4)	µS/cm	To be confirmed during detailed design	
▪ Total Dissolved Solids (TDS)	ppm	as per supply	
▪ Contaminants			
- Chloride	ppm	as per supply	
- Sulphate	ppm	as per supply	
- Sodium	ppm	as per supply	
- Iron	ppm	as per supply	
- Others (specify)		as per supply	
Cooling (Seawater) Supply after CW Booster Pumps			
▪ Delivery Pressure	bara	4.3	
▪ Temperature Min.	°C	5	
▪ Temperature Normal	°C	10	
▪ Temperature Max	°C	15	
▪ Mass Flow (max)	kg/h	20,328,325	
Cooling (Seawater) Return to Seawater Outfall			
▪ Return Pressure	bara	2.8	
▪ Temperature	°C	<27.5	
▪ Mass Flow	kg/h	20,328,325	Contains 120% margin for DCC

Battery Limit Conditions	UNITS	Design Load Max Case	Note
			coolers and Water Wash
Demineralised Water			
▪ Supply Temperature	°C	10	
▪ Supply Pressure	bara	-	Static head available at existing demineralised water system is estimated as 1.5 bara.
▪ Mass Flow	kg/h	54,000	Design value is used several times daily 20 minute each
▪ pH		7	
▪ Conductivity	µS/cm	<5	
▪ Hardness $CaCO_3$	mg/kg	<0.1	
▪ Contaminants			
- Chloride (Cl)	mg/kg	<0.1	
- Sulphate	ppb	To be confirmed during detailed design	
- Sodium	ppb	To be confirmed during detailed design	
- Silica (SiO_2)	mg/kg	<0.1	
Firewater			
▪ Temperature	°C	Ambient	
▪ Pressure	bara	To be confirmed during detailed design	
▪ Mass Flow	kg/h	260,000	
Service Water			
▪ Temperature	°C	10	
▪ Pressure	bara	5	
▪ Mass Flow	kg/h	25,471	
▪ Temperature	°C	Ambient	
▪ Pressure	bara	1	
▪ Mass Flow	kg/h		

Battery Limit Conditions	UNITS	Design Load Max Case	Note
Closed Drains			
▪ Temperature	°C	Ambient	
▪ Pressure	bara	1	
▪ Mass Flow	kg/h	To be confirmed during detailed design	
Open Drains (Stormwater) (Multiple connections)			
▪ Temperature	°C	Ambient	
▪ Pressure	bara	1	
▪ Mass Flow	kg/h	885,000	
MP Condensate			
▪ Temperature	°C	200	
▪ Pressure	bara	16	
▪ Mass Flow	kg/h	4,810.3	Design Case is based on MP Steam

7. References – Bibliography

[1] KKD 11.003 - Basic Design and Engineering Package.

[2] KKD 11.058 - Scope of Work for Execute Contracts.

[3] KKD 11.133 - FEED Summary Report.

[4] KKD 11.020 - FEED Decision Register.

[5] KKD 11.077 - Surveillance, Metering, Allocation Strategy and Design Package.

[6] KKD 11.064 - Technology Maturation Plan.

[7] KKD 11.023 - Risk Management Plan and Risk Register.

[8] KKD 11.019 - FEED Lessons Learned Report.

[9] KKD 11.043 - Cost Estimate Report.

[10] PCCS-00-TC-AA-6627-00001, Peterhead CCS (Onshore) Interface Schedule.

8. Glossary of Terms

Term	Definition
3D	3 Dimensional
Ar	Argon
BDEP	Basic Design and Engineering Package
Ca	Calcium
CAD	Computer Aided Design
CAPEX	Capital Expenditure
CCCC	Carbon Capture, Compression and Conditioning
CCGT	Combined Cycle Gas Turbine
CCP	Carbon Capture Plant
CCS	Carbon Capture and Storage
CfD	Contract For Difference
CITHP	High Closed-in Tubing Head Pressure
Cl	Chloride
CO	Carbon monoxide
CO_2	Carbon dioxide
DCC	Direct Contact Cooler
DECC	Department of Energy and Climate Change
EMR	Electricity Market Reform
EPC	Engineer, Procure and Construct
ESD	Emergency Shutdown
ESDV	Emergency Shutdown Valve
ETS	Emissions Trading Scheme
EU	European Union
EU ETS	European Union Emissions Trading System
FEED	Front End Engineering Design
GT	Gas Turbine
H_2	Hydrogen
H_2O	Water
HAT	Highest Astronomical Tide
HCl	Hydrogen chloride
HDD	Horizontal Directional Drilling
HF	Hydrogen fluoride
HP	High Pressure
HPU	Hydraulic Power Unit
HRH	Hot Reheat
HRSG	Heat Recovery Steam Generator
HSE	(UK) Health & Safety Executive
ICSS	Integrated Control and Safeguarding System
IPCS	Integrated Protection and Control System
KKD	Key Knowledge Deliverable
KO	Knock Out
LAT	Lowest Astronomical Tide
LP	Low Pressure

Term	Definition
mbgl	Metres below ground level
MEG	Monoethylene Glycol
MFL	Magnetic Flux Leakage
Mg	Magnesium
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
mOD	Metres (above) Ordnance Datum
MP	Medium Pressure
MSL	Mean Sea Level
N_2	Nitrogen
NB	Nominal Bore
NGET	National Grid Electricity Transmission
NH_3	Ammonia
NO	Nitric oxide
NOx	Nitrogen Oxides
NTS	National Transmission System
NUI	Normally Unmanned Installation
O_2	Oxygen
OBN	Ocean Bottom Nodes
OCCS	Office of Carbon Capture and Storage
OD	Office Domain
OD	Outer Diameter
OPEX	Operating Expenditure
P&ID	Piping and Instrumentation Diagram
PCCS	Peterhead Carbon Capture and Storage
PFD	Process Flow Diagrams
POB	Personnel On Board
ppmm	Parts per million by mass
ppmv	Parts per million by volume
PPS	Peterhead Power Station
PSV	Pressure Safety Valve
R&D	Research and Development
RAM	Risk Assessment Matrix
RAM	Reliability, Availability and Maintainability
SCR	Selective Catalytic Reduction
SiO_2	Silica
SO	Sulphur monoxide
SO	System Operator
SO_2	Sulphur dioxide
SSIV	Subsea Isolation Valve
SSSV	Subsurface Safety Valve
ST	Steam Turbine
SWL	Safe Working Load

Term	Definition
TDS	Total Dissolved Solids
THP	Tubing Head Pressure
TUTU	Topside Umbilical Termination Unit
UK	United Kingdom
UKCS	United Kingdom Continental Shelf

9. Glossary of Unit Conversions

Table 9-1: Unit Conversion Table

Function	Unit - Imperial to Metric conversion Factor
Length	1 Foot = 0.3048 metres 1 Inch = 25.4 millimetres
Pressure	1 Bara = 14.5psia