Peterhead CCS Project

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Executive Summary

The Project

The Peterhead Carbon Capture Storage (CCS) project involves capturing CO_2 from the gas-fired power station situated at Peterhead, transportation via an onshore/offshore (subsea) pipeline and storage in a depleted hydrocarbon reservoir in the Central North Sea. The Company has identified the Goldeneye field as the depleted hydrocarbon reservoir for storing CO_2.

CO_2 will be captured and processed from the post combustion gases produced by a gas turbine (GT-13) unit located at SSE (SSE Generation Limited) Peterhead Power Station (PPS). Transportation of CO_2 will be through an existing multiphase pipeline.

The Company's contribution to the project includes:

- Extraction and transportation of waste gases from GT-13 stack;
- Extraction, treatment and compression of CO_2 from the waste gas stream;
- CO_2 transportation from CCS Plant to the Goldeneye offshore platform;
- CO_2 injection into Goldeneye reservoir; and
- Reservoir surveillance to ensure containment of the CO_2.

The project lies within the Company UK (Northern Systems & Plants) Assets.

Operation & Maintenance Philosophy

This Operation & Maintenance (O&M) Philosophy is intended to give an overview of operations concepts, to describe the operational requirements to be applied to the design, and to document the philosophy for operating the new facilities. The Operations Philosophy is a key document in the Company's Operations Readiness (OR) process.

Highlights of this O&M Philosophy are:

- Coarse availability modelling has been applied to the CCS Chain and predicts the Project will deliver a production availability level of circa [1]86%. Contractual availability is set at 80%;
- Design philosophy specifies that an 'n+1' (redundancy/back-up) approach will be used for selected auxiliary equipment. Main process vessels, inlet booster fans and export compressor are not spared and appropriate measures need to be included in design to facilitate quick equipment isolations and equipment accessibility to facilitate maintenance interventions during any equipment downtime/shutdown;
- The Operations Philosophy requires provision of a "minimally manned facility" approach. Plant complexity is similar if not less than a processing plant such as St Fergus. A mechanical equivalency factor (MEF) analysis has been carried out, and as a result indicative personnel numbers based on Company benchmarking and experience operating similar processes at St. Fergus has identified that an operating team of approximately 16 personnel will be required;

[1] RAM (Reliability, Availability and Maintainability) model is subject to further evaluation to reconfirm end-to-end availability.

- Goldeneye operations will remain very similar to past operations. The change in operations from extraction to injection and fluid change from hydrocarbon to CO_2 will not change the facility 'Ex classification' as hydrocarbons might be present in the monitoring well tubing;
- Goldeneye shutdown and reset philosophy will be configured to enable remote platform reset, thus improving availability and eliminating unnecessary downtime;
- CO_2 awareness both in design and operations is required and appropriate training material and courses need to be developed;
- Well operations will comply with requirements of the Reservoir Management Plan (Key Knowledge Deliverable 11.126) [1];
- The Operations Philosophy stresses the importance of HSSE, and required collaboration between SSE at Peterhead Power Station and the Company;
- The requirement for Goldeneye simultaneous operations "SIMOPS" during engineering phase has been eliminated. Onshore SIMOPS during construction, start-up and ongoing operations will need to be developed and embedded into both Company and PPS safe work manuals;
- The existing operational management systems in use at St Fergus and Goldeneye will, as much as practicable, be extended for CCS Operations.

Operational Key Performance Indicators (KPIs)

KPI's reporting and performance setting covers all facets of operations: Environment, Health and Safety, Operations Performance, Operating Costs, Training and Competencies; including Clean Electricity Output and Electricity Exported.

Operations performance and reporting will be fully aligned to that used for existing facilities in The Company's portfolio "Northern Systems & Plants" (NSP) assets. KPI's are based on the "SMART" principle, with the emphasis on ensuring objectives are achieved safely, efficiently and economically.

During the engineering and construction phases these KPI's will be re-aligned to reflect the nature of activities at the time.

Operational Risks

The Amine extraction and treatment is similar to facilities at St Fergus, and technically this is not seen as prohibitive. Toxicity of the proposed amine (DC-201) will present operational risks which shall be managed by competent design, equipment isolation, safe work instructions and appropriate personnel protective equipment. Experience exists in the industry and within the Company on how to manage these risks.

The primary operational risks are associated with dense phase CO_2 injection and the lack of intrinsic knowledge operating and working at elevated injection pressures and the potential of cold temperature stress cracking during sudden depressurisation. Design concepts will address low temperature effects at start-up and automation of all CO_2 well flow controls to prevent operation outside safe boundaries, whilst extensive training and collaboration with vendors and operators to overcome intrinsic knowledge deficiencies in operating CO_2 compression.

The single export compressor, due to its high pressure nature and multi stage cylinder arrangement is a potential risk, which is somewhat mitigated by cleanliness of product and historical experience of onshore utility operators with a similar package.

End-to-End system cleanliness during commissioning is of paramount importance and the success of a 'flawless' start-up is dependent on this. The Project will embrace The Company's proven methodology of "Flawless Project Delivery" (FPD) to mitigate and minimise events leading to sub-optimal quality and delayed start-up.

Further Work

Operational risks identified during FEED need to be addressed at future phases of the Project:

- Conduct a Smart Fields Workshop to assess viability of 'Smart' concepts in the project to improve production and to optimise operating costs and manning;
- Timely recruitment and training of Operations staff in preparation for the engineering phase, commissioning and start-up;
- Operations to gain better understanding of CO_2 operations especially those associated with large compression systems previously not seen in the oil and gas sector;
- Align training programs to include the safe handling and operations of amine solutions and by-products.

1. Introduction

1.1. Project Premise

The CCS project entails the construction and operation of a purpose built amine based CO_2 extraction and processing plant within the boundaries of PPS and to transport product via a modified export pipeline to the Goldeneye platform, where the CO_2 is injected into the reservoir. A new near-shore section of pipeline is to be tied between PPS to the existing Goldeneye pipeline to bypass St Fergus and to transport CO_2 directly to the Goldeneye Offshore Platform.

This Operations philosophy document outlines operation strategies and work processes that will be applied to ensure the safe operation and sustained delivery of CO_2 injection targets during the operate phase of the CCS project. During the project *Define* stage (Pre-FID) it is intended for use by the project team, contractor engineering and key stakeholders as input to the design of the intended facilities, pipelines and wells. This document also provides a description of how this is delivered through the *Execution* phase of the project, during which period the document will be further refined.

The CCS project is intended to be included within the Company's St Fergus Northern Systems & Plants Asset and accordingly the operating philosophy will follow and comply with processes and procedures already in place for the asset. Initially the operating philosophy is a standalone document which reflects the operations intent for the project. After Final Investment Decision (FID) is agreed this philosophy document will be merged and updated to reflect existing St Fergus Northern Systems & Plants Asset operating philosophy and procedures. It is recognised that if the Project is taken forward by Shell through a joint venture company appropriate adjustments and arrangements will require to be made to implement such operating philosophy and procedures.

This document is a key project deliverable (and will be managed under the Management of Change Procedure (MOC) to ensure a documented history exists which reflects the operating changes as the project matures through the various stages from early design concepts through to final plant delivery and start-up.

Close proximity to existing SSE facilities and common sharing of utilities will require close collaboration between SSE and the Company. Accordingly, agreements in areas such as Emergency Response, operating communication, equipment availability and downtime etc. will be required. These agreements will be formalised and tested within the framework of safe operations.

1.2. Purpose of the Document

The Operations philosophy document outlines operation strategies and work processes that will be applied to ensure the safe operation and sustained delivery of CO_2 injection targets during the operate phase of the CCS project.

It outlines key areas and processes which will be used to form the basis of safe operations:

- Operations Context for the project;
- Outline of the Operations Objectives & Strategies, Work processes and Functional Requirements to be used during operations;
- Outline of the operate phase related HSSE and Sustainable Development issues especially those aspects impacting Evacuation, Escape & Rescue (EER);
- Outline of Organisational and competence considerations.

1.3. Scope of the Document

The project scope in its entirety entails:

- Extraction and boosting of waste gas volumes from PPS Power Plant to the inlet facilities at the CCS Plant;
- Processing of waste gas volumes and exporting high specification CO_2 to the Export Booster Compressors;
- Compressing CO_2 and transportation to the inlet facilities at Goldeneye offshore platform;
- Filtration and injection into the Goldeneye reservoir.

This philosophy document will apply to the period from conceptual design through to FID where at such point the document will be appended to reflect forward operations of the assets located at St Fergus.

1.4. Description of the project / Project Premises

1.4.1. Project description

The project involves capturing CO_2 from the gas-fired power station at Peterhead, onshore/offshore (subsea) pipeline transportation and storage in a depleted hydrocarbon reservoir in the Central North Sea. The Company has identified its Goldeneye field as the depleted hydrocarbon reservoir for storing CO_2.

CO_2 will be captured and processed from the combustion gases produced at the gas-fired power station of SSE (SSE Generation Limited) located at Peterhead. Transportation of CO_2 will be through an existing multiphase pipeline. This is shown in the project layout in Figure 1-1.

The Company's contribution to the project includes:

- Extraction and transportation of waste gases from GT-13 stack;
- Extraction and Compression of CO_2 from the waste gas stream;
- CO_2 Transportation from CCS Plant to the Goldeneye Offshore Platform;
- CO_2 Injection into the Goldeneye reservoir;
- Reservoir surveillance to monitor containment of the CO_2.

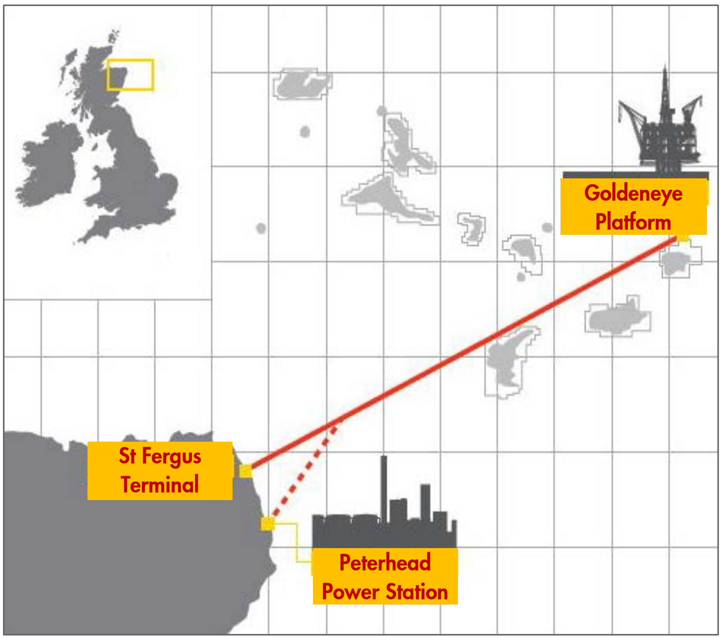


Figure 1-1: Project Layout

1.4.2. Description of Existing Facilities (Brown Fields Only)

The Goldeneye gas-condensate accumulation is located in the Outer Moray Firth circa 100 km north-east of the St Fergus gas plant in a water depth of approximately 100 m. The area is traversed by a number of existing dense-phase gas trunk lines to shore. See Figure 1-2 below.

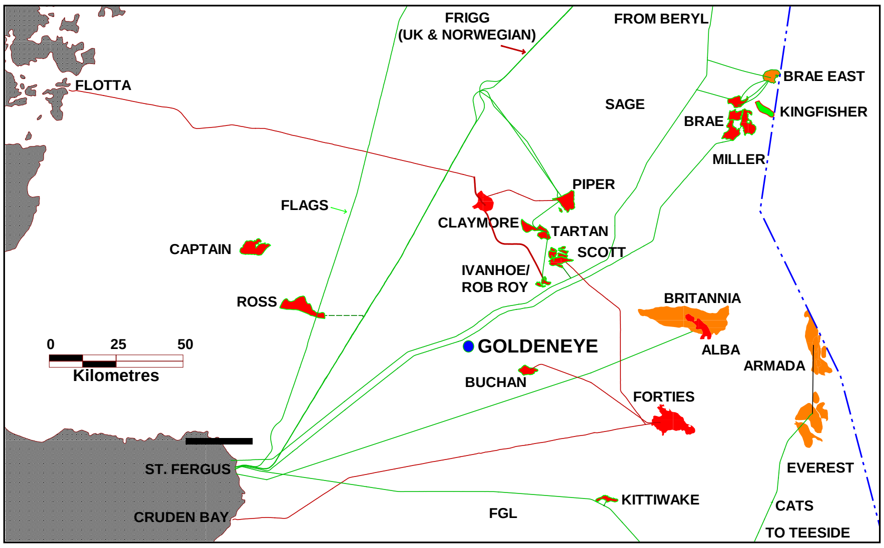


Figure 1-2: Goldeneye Field Location

Goldeneye was developed as a direct tieback to shore, with gas processing at the existing St. Fergus gas terminal, and offshore a normally unattended installation (NUI) with platform supported (jack-up drilled) wells. The existing Goldeneye asset consists of three major areas:

- The offshore platform facilities and wells;
- The two pipeline connecting offshore and onshore facilities;
- The onshore receiving and processing facilities.

Fluid processing was limited to water/MEG/condensate detection and flow metering. MEG and inhibitor injection provided for hydrate and corrosion inhibition of the carbon steel pipeline. All fluids were routed to shore via a single, wet multiphase, pipeline to onshore for processing in the Goldeneye facilities at the St Fergus terminal. The facilities are classified as normally unattended and the control of wells and utilities is via satellite link from St. Fergus. When the platform is attended, control and operation may be transferred locally to the Goldeneye control room.

1.5. Definitions

Throughout this document the words "may", "should" and "shall" have specific meanings:

- "may" indicates one possible course of action.
- "should" indicates a preferred course of action.
- "shall" indicates a mandatory course of action.

2. Operations Context

The O&M philosophy builds on the Initial Operations Assessment (IOA), which was developed during the pre-feed stage and addresses the wide range of subjects relating to the future Operation of the Asset. Its outcomes have been used to rank the various concepts for Peterhead CCS at the time.

A number of assumptions have been made with regards to the application of certain Company standards and the alignment between the Company and SSE in project execution. Those that have a significant impact to this Operations Philosophy include:

1. The Company's General Business Principles on HSSE and local communities will be applied (compromise may be required in locations which are shared with other operators (SSE);
2. The Company's HSSE Control Framework implemented to provide a means to mitigate risk to a level of ALARP:
    a. The Company will operate the facilities from commencement of operations (CoO) at a date after Effective Date (ED). At this time existing risks that are deemed intolerable will be identified, actioned and sufficiently mitigated;
    b. The Operating Model provides sufficient governance to allow the Operations and Projects teams to execute the work within reasonable budget and schedule.
3. Required cooperation between the Company and SSE to address communication and integration requirements when operating in close proximity to each other will be addressed in the commercial agreements between the parties.

2.1. Business Context

The Peterhead CCS Project is part of a competition initiated by the UK Government to fund carbon capture and storage projects and has the potential to be the world's first commercial-scale demonstration of (post combustion) CO_2 capture, transport and offshore geological storage from a gas-fired power station:

The Project proposes to retrofit post-combustion capture equipment to an existing operational gas turbine at Peterhead Power Station. The flue gas stream which would otherwise be discharged into the atmosphere will be routed to an absorber where more than 90% of the CO_2 is removed by application of specialist amine capture technology developed by the Company owned company Cansolv. Utility services such as Low Pressure (LP)/Medium Pressure (MP) steam, utility water, demineralised water, sea water and emergency electrical power needed to operate the CCS chain will be metered and supplied by PPS.

CO_2 will be compressed onshore and transported to the Goldeneye platform, where it is injected into the depleted Goldeneye hydrocarbon reservoir for long-term storage.

Feasibility studies have been carried out to evaluate several pipeline export options between Peterhead and Goldeneye and the far shore tie in option has been selected as the preferred option.

This is a full-chain, industrial scale project from an existing gas fired power station. It is a demonstration project which will provide valuable lessons for further deployment.

The project will capture and store in the region of one million tonnes of CO_2 per annum during a demonstration phase of up to 15 years.

2.2. Physical Environment

The CCS plant is to be constructed on a site within the boundaries of the Peterhead Power Station (PPS) located on the outskirts of Peterhead and some 6 miles from St. Fergus Gas Plant. The Company and SSE have extensive experience in the regions and are aware of environmental impact and required safeguards to operate in close proximity to towns, populated areas and land of scientific interest.

The operation of Goldeneye and pipeline will be very similar to past operations and environmental conditions and exposure will by large remain unchanged.

Physical aspects to consider include:

- The environment is well known (onshore and North Sea) and adjacent to existing assets currently in operation (Peterhead Power Station, St Fergus Gas Plant);
- The close proximity of local villages (Boddam) and towns to CO_2 transportation routes will have an impact for HSSE issues.
- There is a wildlife protection area (SPA - Special Protection Areas) in the proximity of the Peterhead Power Station;
- The power station is also situated near to a harbour that is used both for fishing as well as transportation of goods/supplies;
- The facility will be a combination of both offshore and onshore assets. The Offshore Assets are subject to constraints introduced through adverse weather conditions etc.

2.3. Population, Socio-economic Conditions, and Regulatory Regime

2.3.1. Population

Peterhead and St Fergus are closely associated to the Oil and Gas, Power, Industrial and Fishing industries and within commuting distance of Aberdeen. Employment in the region is buoyant in all sectors of industry. The Company and SSE have extensive experience operating in the region.

2.3.2. Socio Economic Conditions

There will be no major change to the conditions in the regime as a result of operations. Site construction will potentially provide local employment opportunities and other tangible benefits for local hoteliers, suppliers and vendors.

2.3.3. Regulatory Regime

Locating the CO_2 plant in proximity to populated areas, the potential aesthetic impact to Boddam Village, potential safety risk of high pressure CO_2 in proximity to populated areas, discharge of treated water and effluent to the sea and change in operation of Goldeneye will all be considered extensively in the various regulatory documents which will be submitted for the Project. These changes are described in a PCCS Permits and Consents Plan.

2.4. Local Infrastructure and Resources

The Company has extensive experience operating both onshore & offshore facilities in the region. Company's standards and procedures for logistics will be extended to include PPS operations.

The infrastructure available in the region is:

- Local and main roads in region are suitable for supporting current Goldeneye operations and will therefore be suitable for the CCS operation;
- Railroad transportation is only available to Aberdeen or Inverness. Transportation onwards to the offshore facility would continue by vessel/helicopter from either location. Road

transportation if required will be at St Fergus;

- Water Transportation will be handled out of The Company's Torry Dock facilities with material handling via Aberdeen Operations Base (AOB). Both facilities are currently used by the Goldeneye operations and also for service and support to all other ventures by the Company in the region;
- Airport facilities supporting the current venture should remain unchanged with Aberdeen airport servicing the requirements for, fixed wing, rotary wing, local and international operations;
- Multiple hotels are available in the region with certain hotels designated as crew change hotels to be used by staff if required prior to or returning from an offshore visit;
- Aberdeen Royal Infirmary is to be utilised for emergency requirements with helicopter landing facilities available on site and experience in handling offshore incidents;
- The region is currently the European centre for oil and gas operations and as such is home to several oil and gas operating companies and numerous support service companies. Several global contractor companies have Aberdeen as their main base of operations and a large skilled contractor pool is available.

2.5. Contracting Capability

St Fergus operations (including Goldeneye) are optimised to make best use of available resources and provision of support infrastructure. Contracting areas of operations to third party entities may be used to support:

- Security and administration;
- Operations and Maintenance;
- Logistics support, Warehousing, Transportation.

The CCS project will lever on these principles and where practicable and possible implement the same strategy.

2.6. Organisational Capability

2.6.1. Staffing Strategy

Although this will be a world-first project in the UK, the technology and equipment used is not dissimilar to that used in the hydrocarbon and utility industries.

The flue gas pre-treatment has very large fans and associated trunking which is considered unique/novel for hydrocarbon operations but perhaps standard technology power station design and not particularly onerous. The amine capture section is a standard amine treatment plant as used in hydrocarbon processing, very similar to that seen at St Fergus, albeit substantially bigger. The compression stage is a multi-stage integrally geared centrifugal compressor, relatively new to the hydrocarbon industry but widely seen in the utility and specialised gas sectors.

For operations, it is the Company's intent to lever on existing capabilities in this field, supplementing with competent personnel from third party entities where required or through recruitment as part of an on-going succession strategy/plan.

Goldeneye organisation is likely to remain relatively unchanged, though the location of the support team may change. This is subject to further consideration during FEED/detailed design.

The proposed organisation and team structure is shown in Figure 8-1: Management and Support Organisation & Figure 8-2: Operations Team Structure.

For completeness, the project is split into two areas: the onshore facilities at Peterhead Power Station and the offshore platform Goldeneye, which includes the main dense phase pipeline from Peterhead to the offshore facility.

2.6.2. Lessons Learnt

Known issues relating to new developments in proximity to established facilities/companies are generally associated with personnel movement between entities and resulting scheduling and competency gaps which invariably occurs. Both Shell and SSE have experience of such developments within their UK portfolios and shall ensure that lessons learnt from these experiences inform the approach taken on the Peterhead CCS Project.

Additionally, attempts will be made to gather and implement learning/experience specific to CCS from similar projects that have been initiated by the Company in other regions e.g. Canada.

2.7. Stakeholders

The Company, in conjunction with SSE, has developed a Stakeholder Engagement and Communications Plan for the project, and this will be regularly reviewed to reflect an up to date list of external stakeholders, with whom engagement will take place throughout the operations phase. Protocols for engaging with the local community will also be set out and updated as required.

Internal stakeholders are noted as The Company at St Fergus and third party equity holders in any special vehicle created for the project by the Company.

2.8. Future Vision

Improvements have been identified for the Goldeneye platform which will contribute to a marginal improvement in plant availability, OPEX cost reduction and resulting reduction in HSSE risk.

This will be extended to the main CCS plant to seek opportunities to improve on the operations and maintenance concepts and to ensure total alignment between SSE and CCS operations to maximise concurrent activities.

CCS process plant CAPEX savings may be realised by adopting latest initiatives using Wireless Self Organising Mesh Technology which will provide savings in construction time and is inherently easier to maintain, thus reducing OPEX costs.

These improvements when incorporated will provide a window of opportunity to raise contract project availability currently at 80% to a figure commensurate with improvements made in operations uptime.

3. Operations & Maintenance Objectives

The O&M objective for the CCS Project is to treat and inject contracted volumes of CO_2 safely, efficiently, economically and with no harm to people, communities and the environment. This shall be achieved by:

1. **Pursuing the Goal of No Harm to People and Protection of the Environment:**
    - Improving asset integrity, process safety and personal safety by ensuring risks have been reduced to ALARP;
    - Implementation of the Life Saving Rules;

- Implement recovery measures for process facility, medical and other emergency response;
- Implement security threat mitigation measures;
- Adhere to all applicable Environmental Requirements, carrying out an Environmental Social and Health Impact Assessment (ESHIA) in line with international standards and implement the resulting Environmental Social and Health Management Plan (ESHMP).

2. **Improving Asset Integrity and Process Safety:**
    - Technical Integrity: Identify and improve the level of Safety Critical Elements along with associated Performance Standards;
    - Operating Integrity: Develop operating procedures and controls to prevent harmful emissions and releases;
    - Implement applicable Process Safety solutions.
3. **Enhancing Stakeholder Relationships:**
    - Assurance of sufficient stakeholder engagement and management of risks and opportunities.
4. **Improve People Capability:**
    - Develop appropriate training and competency programs specific to CCS processing;
    - Extend team capabilities by cross training to include both onshore and offshore operations to provide greater flexibility.
5. **Manage Operating Costs:**
    - Maintain sufficient controls on operating expenditure to achieve economic objectives for the contract life cycle. Minimise early costs.
6. **Achieve Production Targets:**
    - Meeting the required target injection levels as per contract requirements.
7. **Achieve Flawless Project Delivery:**
    - Ensure a robust plan in contractor scope and manage the commissioning & start-up of the project to achieve a successful first cycle of operation;
    - Ensure personnel are trained and competent in preparation of commissioning and start-up.
8. **Improve Well Reservoir Management Capability:**
    - Meeting the functional requirements for monitoring, analysis, and control in the field to achieve production availability targets.

3.1. Definition of Success for Project phase

Project success will have been reached when agreed HSSE and Operational targets are achieved;

- Zero accidents and harm to the community;
- Unblemished HSSE safety record;
- Implementation of Flawless project delivery;
- Operations Readiness in:
    - Recruitment, training and competencies;

- Development & Implementation of Business Management Systems (SAP);
- Development of Safe Work Processes, Permit to Work, JSA's, etc.

- Seamless start-up, first cycle of operation and achieving contractual CO_2 injection delivery volumes.

3.2. Definition of Success for Operate phase

The Company shall strive to be best in class and every effort will be made to deliver quality performance safely and efficiently. Performance standards are set in line with industry best standards and the Company endeavours to be the industry leader in this regard. This is achieved through a systematic delivery against agreed corporate benchmarks, refer to section 3.1.

3.3. Operations and Maintenance Objectives

The Company's objective is to maximise product delivery economically and with exemplary safety standards and performance. This shall be achieved by defining operations and maintenance objectives which give rise to:

- High Health, Safety and Environment standard and compliance to legislation, Company policies and procedures;
- Manage workers risks to tolerable and "As Low as Reasonably Practicable" (ALARP). This includes minimising risks from transport, major accidents and occupational hazards;
- Ensure injection of CO_2 to meet contractual obligations in the right quantity and quality;
- Operate the asset in the most cost-effective manner;
- Safeguard the technical integrity of all assets owned and operated;
- Ensure appropriate technology is used in the facilities through providing relevant tools and techniques;
- Respect the communities closest to the project;
- Ensure containment of CO_2 within the reservoir.

3.3.1. Operations

Realised by:

- Ensuring a high HSSE standard and compliance with legislation, Company policies, standards and procedures;
- Managing risks to workers to tolerable and ALARP. This includes minimising risks from transport, major accidents and occupational hazards. Staff shall be well trained for occupational hazards of the process with particular attention given to the risks of CO_2 and degraded amine. Products;
- Minimising CO_2 gas releases and venting;
- Ensuring delivery of CO_2 to the reservoir meets contractual obligations in the right quantity and quality;
- Ensuring containment of CO_2 within the reservoir by monitoring of injection quantities, down-hole conditions and plume dispersion down-hole;
- Operating the asset in the most cost- effective manner;
- Safeguarding the technical integrity of all (critical) assets owned and operated. Particular

attention will also be given to the maintenance of safety critical elements that are required to ensure that safeguarding, fire and gas and lifesaving equipment is kept fully functional;

- Optimising the recruitment, development and progression of staff;
- Ensuring appropriate technology is used in the facilities through providing relevant tools and techniques. This does not necessarily mean use of the latest technology available but should be proven technology;
- To be proactive management of socio-environmental impacts (both positive and negative) on local communities (e.g. emissions, venting);
- To minimise Unit Operating Costs;
- To maximise local content with employment opportunities, training and competence development;
- To apply the Company's HSSE & SP Control Framework.

3.3.2. Maintenance Objectives

Realised by:

- Compliance with all applicable legislation and Company policies regarding health, safety and the environment;
- To safeguard the technical integrity of facilities and installation over the asset life cycle.
- To contribute to meeting the production specification in terms of availability, reliability and product quality and quantity;
- To provide an auditable system of asset performance and maintenance control;
- To record and analyse maintenance data on asset performance in order to input such data into further Company developments;
- To eradicate incipient failures by applying proactive maintenance and integrity management.

4. Operations & Maintenance Philosophy

The O&M Philosophy is intended to give an overview of the way in which the CCS assets will be operated, to describe the operational requirements to be applied to the design, and to document the philosophy for commissioning and operating the new facilities. The Operations Philosophy is a key document in the Operations Readiness (OR) process.

4.1. Operations Philosophy

The CCS plant, Pipelines and Goldeneye platform are intended to be managed within the St Fergus section of the UK Northern Systems and Plants Asset; existing management and operating processes in use at St Fergus will be extended to include the CCS chain.

Operations are responsible for ensuring the fulfilment of injection targets by maintaining plant availability and responding to any issues that may prevent the injection of CO_2.

4.1.1. CCS Operations

CCS Asset Management is currently intended to be based at Shell St Fergus whilst day to day operations and control for processing, transportation and injection is to be located at the CCS plant.

The CCS facility will contain adequate provision for management and supervisory offices along with adequate provision for workshop and canteen facilities.

Initially design intent was to locate CCS control room function (DCS control Panels, ESD Panels, Instrument Interface Panels & Communications) within the PPS control building, however, following an internal SSE review which identified potential commercial trading risks, SSE could not support the design. The base case has been amended to provide an independent control building located within the plot boundary. (The location will be subject to necessary studies e.g. QRA).

Procedures and processes will be developed jointly with SSE to support this mode of operation.

Goldeneye will remain as a NUI facility; however instrumentation control and communications will be changed to directly communicate from the CCS control room and not St Fergus as currently configured. The exception will be the control of methanol injection pumps, where cost saving has been identified by retaining existing arrangements at St Fergus.

Operating premise requires total remote operation and control of Goldeneye facilities.

Visits to Goldeneye will be minimised and when required advantage will be made to maximise any maintenance opportunity. An adequate number of personnel will be trained and deemed competent to act as the facility base crew to allow operations flexibility and especially during the engineering phase when the platform may be occupied for extensive periods.

4.1.2. O&M Personnel

The CCS plant is closely aligned to processing streams at St. Fergus Gas Plant and efforts will be made to maximise replication of existing strategies which will benefit CCS operations. The Company is seeking to replicate manning practices in use at St Fergus by minimising staff personnel to supervisory and key positions only and to outsource remaining personnel to third party entities, similar to current practice in use at St. Fergus.

The operations of Goldeneye will largely remain unchanged and existing organisation structure to support Goldeneye operations will be used. There is a requirement to review manpower requirements during Goldeneye modifications to address potential shortfall of competencies required for satellite operations. This will be reviewed during detailed design.

Section 9.2 describes an indicative organisation structure.

4.1.3. Operations Logistics

Operations logistics will largely remain unchanged to existing processes, and these are consistent to industry practice in the region. Detailed concepts are noted in section 4.4.

4.1.4. Reservoir & Well Surveillance

A detailed reservoir and well surveillance process has been developed during FEED. This will include monitoring of the injection performance of each active well and potentially monitoring of the CO_2 plume in the reservoir to ensure storage integrity.

4.1.5. Production Chemistry

The carbon capture design is based on a conventional absorber /stripper process using amine as the CO_2 absorber. The design uses proprietary branded chemicals of specific composition and dilution which are common to CCS. The one exception is composition of the Amine DC-201 solution which is unique to the CCS project and classified as a proprietary product. Other chemicals used in the process are industry standard such as Sulphuric acid, Sodium Hydroxide, Ammonium Hydroxide, Hydrogen and those required for waste water treatment.

Offshore chemical usage is minimal and limited to Methanol for hydrate inhibition . During well workovers additional down-hole chemicals will be used, these are considered transitional and do not impact day to day operations.

4.2. Maintenance Philosophy

As previously outlined, the project consists of a mature offshore asset "Goldeneye", Onshore/Offshore pipeline and the CO_2 treatment and compression plant at PPS. The Company has defined operations and maintenance policies and procedures for both Goldeneye and pipeline and the intent is to extend these to include the CCS plant.

In general, and as a guide for engineering design, Company follows best industry practice of minimum intervention, the use of reliability centred maintenance (RCM), use of condition based monitoring (CBM) and interrogation and risk based inspection methodologies.

4.2.1. Maintenance Execution

The operations premise is based on minimum manning and as such maintenance activities will likely be restricted to first line routine maintenance and any activity required to support initial equipment intervention. Maintenance of key plant and any activity beyond the normal capacity of the maintenance team will be contracted to third party entities and vendors.

Offshore maintenance shall follow existing best practice campaign maintenance where effectiveness of offshore visits is maximised to make best use of platform visits.

Exact maintenance requirements will be fully determined during detailed design when equipment technical specifications are mature with better information available to assess vendor maintenance requirements.

The maintenance philosophy is summarised as:

- To design-out maintenance by careful selection of equipment which is appropriate for the application and environment, and which embraces proven technology to minimise and reduce maintenance burden. e.g. replacing conventional lighting with LED lighting etc.;
- To undertake the selection of maintenance strategies through a structured auditable technique - e.g. Maintenance Strategy Review (MSR) using Reliability Centred Maintenance (RCM) to support the designed availability;
- The use of On-Line condition monitoring for key equipment where it is demonstrably cost effective. Staff will be made competent and appropriate diagnostic tools will be provided to facilitate rapid fault finding and rectification;
- To maximise opportunistic maintenance during plant outages (CCS & PPS) by appropriate planning and spare parts holding;
- To monitor system and equipment availability and reliability against design intent and to evaluate the effectiveness of that design, the equipment and the maintenance and operations activities;
- The Designed Availability, developed at facility conceptual design stage, will determine the criticality of certain equipment. Equipment criticality will be taken into account during the Maintenance Strategy selection.

Table 4-1: Typical Maintenance Philosophy

System	Sub-System	Maintenance Type
Structures	Underwater	Visual, Risk Based Inspection (RBI)

System	Sub-System	Maintenance Type
	Above water	Visual, Risk Based Inspection (RBI)
Pipelines	Submarine	Visual, Intelligent Pigging, Side-scan sonar, Risk Based Inspection (RBI), Corrosion monitoring (Coupons, & Sampling)
	Buried	Intelligent Pigging, Risk Based Inspection (RBI), Corrosion monitoring (Coupons, & Sampling)
Process & Utility Piping	Piping	Visual, Risk Based Inspection (RBI), Corrosion monitoring (Coupons, & Sampling)
	Valves	Leak Testing, (TSO Performance Standard), ESD Function Testing.
Electrical Equipment	All Systems	Visual, Condition Monitoring, Thermal Imaging, Risk Based Inspection (RBI), Ducter Testing, Earth Loop Impedance, Rogowski Coils.
Instrumentation	All Systems	Visual, Function Testing, Earth Loop Impedance, RBI, Smart Technology
Rotating Equipment	Turbines	Condition Monitoring, Oil Analysis, Running Hours, Performance, Vibration Monitoring
	Pumps	Condition Monitoring, Oil Analysis, Running Hours, Performance, Vibration Monitoring
Wellhead	Integrity	Valve Leak Testing (Performance Standard), Visual, Risk Based Inspection (RBI)

With the exception of equipment governed by frequencies set by statutory regulations, inspections will be reviewed using tools such as RBI to optimise the inspection programs. The evaluation will be carried out based on experience, historical data and criticality to derive a cost effective inspection frequency without compromising technical integrity.

4.2.2. Planning and Execution

Long term planning and short term scheduling will be used to provide effective maintenance with minimum disruption to production.

The major maintenance activities requiring extended planning such as a total plant shutdown will be incorporated into a long term maintenance plan and integrated into the Company wide use of these resources. Campaign maintenance for example on the Goldeneye platform will be used where economically attractive.

Technicians will carry out first line maintenance including trouble shooting, breakdown and preventative maintenance work. Specialist vendor support will be made available for work requiring specialist skills, equipment or measuring techniques.

CCS operations will be integrated into the Northern Systems and Plant management system and CMMS will be developed and populated to mirror existing processes. Company uses SAP Blueprint as the Computerised Maintenance Management System (CMMS).

4.3. Contracting & Procurement Philosophy

The Asset (St. Fergus Supply Chain Management) is responsible for the management and execution of the entire network of material, services and information from vendor and suppliers. Contracting and procurement requirements to support CCS operations will, subject to arrangement to be agreed with the government, adopt existing strategies and processes already in use.

4.3.1. Standardisation & Variety Control

4.3.1.1. Standardisation

Where possible and practicable, the project shall strive to minimise and standardise the variety of equipment in use. This is a key enabler of operability and maintainability, through the ability to standardise operations (production and maintenance) activities and to:

- Reduce the need for different types of spare parts and hence minimise stockholdings;
- Allow inter-changeability of equipment;
- Maximise familiarity with equipment thereby simplifying maintenance efforts;
- Increases the prospect for long term service contracts and supply chain management opportunities;
- Local/regional specialist expertise and capability.

4.3.1.2. Inventory and Spare Parts

The sparing philosophy is determined following review of the results of the project RAM (Reliability Availability and Maintainability) model which determines equipment uptime. A key output of the model is the ability to identify the contribution equipment and components have with regards to equipment downtime. The information provided is used to determine the spare parts requirement.

In addition to the RAM process to establish equipment uptime, spares parts holding requirements will be determined using Reliability Centred Maintenance (RCM) techniques taking into consideration replacement time and lifecycle costing for each of the components.

Spares are categorised into three distinct categories, Guarantee or Insurance spares, Commissioning and Start-up spares and Two Year Operating spares. Insurance spares are generally of high value with extended lead times and are normally purchased with the main equipment.

For any new equipment, it will be a condition of purchase for vendors and manufacturers to populate and provide Electronic Spare Parts and Interchange ability Records, E-SPIR.

E-SPIR is a mechanism to readily identify common spare parts and components across the sector so that duplication is minimised and thus optimising stock holding and inventory costs.

4.4. Logistics & Infrastructure Philosophy

The Company has extensive experience operating St Fergus and the Goldeneye offshore platform and the intent is to include CCS within St Fergus operations, using existing processes and procedures already in place. Logistic strategies and agreements will remain unchanged and there are no foreseeable changes required in work processes for CCS operations. Further studies may be called upon to assess any specific changes due to operations in a CO_2 process environment.

The CCS project will involve efforts to reduce the logistics related operating costs by:

- Optimum integration of the logistics requirements with other Company assets and operations;
- Enhanced planning and coordination to maximise seat and cargo capacity and to minimise

non-essential routine operations;
- To provide Logistics at an optimised cost throughout the CCS Life Cycle;
- Risk Assess all logistics options so as to reduce risk to ALARP;
- To continuously improve HSSE, Diversity, Sustainable Development, Social Performance and Local Content in Logistics whether managed or executed by own or contractor staff;
- Implement common Logistics policies, processes, standards and IT systems;
- Develop competent Logistics personnel;
- Utilise global Logistics contracts to maximise leverage opportunities;
- Sharing of Practices worth Replicating (PWR).

4.4.1. Offshore Logistics

Existing logistics framework is described in the St. Fergus & Goldeneye Operations and Maintenance Philosophy. At present, Goldeneye logistics involves the transportation of personnel by helicopter, the provision of Standby Vessels (SBVs) and the provision of Platform Support Vessels (PSVs). Logistics & Infrastructure Philosophy is to reduce all risks associated with logistics to ALARP.

Due to infrequent requirements to visit Goldeneye, there are no specific contracts in place for these services and use is made of available capacity of existing resources contract within Company NSP assets. Where for operational reasons it is not possible to draw on these contracts or there is no spare capacity, the requirements are met by ad-hoc spot markets. Spot market costs can escalate by around 80% of normal contract rates. In the past delays of up to five days have occurred due to unavailability of standby vessels. It is worth noting that a high proportion of the OPEX for the project is driven by offshore logistics costs, therefore a key challenge during detailed design is to reduce the number of platform visits by implementing improvements identified from past operations.

4.5. Well and Reservoir Management Philosophy

The Well and Reservoir Management (WRM) plan is an integral part of the Monitoring, Measurement and Verification (MMV) plan.

The WRM philosophy for the project is to ensure optimal CO_2 injection to meet the contractual agreement while maintaining overall system integrity (wells, reservoir and facilities). This will be accomplished through an active well and reservoir monitoring program implemented from project start up through acquisition of baseline data during the work over operations and continuous acquisition of pressure, temperature and other required data in the wells and reservoirs. The acquired data will be used to calibrate the well and reservoir models for active well and reservoir monitoring.

WRM is tailored to the management of the well, reservoir and facilities for the medium period of time (1-3 years). Surveillance plan will generally be updated every year.

Key Value drivers are:

- Ensuring well integrity;
- Ensuring facility (platform) integrity;
- Maintaining CO_2 delivery for injection; and
- Active well and reservoir models update.

4.5.1. Objectives of Well & Reservoir Management (WRM)

Objectives of the Well and Reservoir Management plan are:

4.5.1.1. Integrity management of the CO_2 in the injector wells.

1a. Minimise well failures

The initial well design is the main barrier against well failures. During the injection phase adequate maintenance and well servicing should reduce the risk of failure.

1b. Integrity issues identification

Well surveillance is required to identify potential well integrity issues as early as possible.

1c. Remedial integrity activities

Once the action is properly identified then remedial plans can be executed.

4.5.1.2. Optimise CO_2 injectivity during the life of the project.

2a. CO_2 Downhole Injectivity

Downhole injectivity needs to be monitored and maintained during the life of the project. Early deviations to the plan need to be recognised for planning of remedial activities if required.

Filtration and hydrate inhibition are important elements to maintain the integrity of the injection. Surface rate control might be required to avoid 'hot spot' erosion of the sand screens installed in the lower completion.

2b. Understand the CO_2 behaviour in the well

The injection is to be carried out in the dense phase and the wells will be operated in a way to ensure that this phase is maintained.

Under normal injection conditions the CO_2 should be in dense phase along the well because of the created friction. As such the minimum wellhead pressure will always be above a specified pressure, which will be continuously monitored to ensure it is always exceeded. The maximum pressure available at the wells is ~115 bara.

2c. Manage CO_2 arrival rates

PPS operation may not always be at Base Load. Fluctuations in the CO_2 arrival rate to the platform are expected. The arrival rates will be monitored and optimisation of the well carried out to manage the injection rates.

4.5.1.3. Monitor the reservoir performance under CO_2 injection.

3a. Reservoir pressure increase (re-pressurisation)

The reservoir pressure will increase during the CO_2 injection phase. The reservoir pressure will be monitored to ensure that it does not exceed the initial reservoir pressure.

3b. CO_2 monitoring

The focus is to monitor the exact location of the CO_2 plume to calibrate reservoir modelling.

3c. Reservoir Modelling

The calibrated reservoir model would then be able to predict further CO_2 plume movement in directions where wells do not exist.

4.5.1.4. Surface Facilities

4a. CO_2 rates

Quantification of in-flow CO_2 both in absolute terms and well allocation, through use of appropriate flow metering.

4.5.2. Well and Reservoir Surveillance Strategy

Goldeneye wells and reservoir surveillance strategy will be based on the following well operating premise-

- Four of the existing five wells will be re-completed. Three wells will be allocated for CO_2 injection, a fourth for reservoir monitoring and the fifth will be abandoned;
- Single slim tubing will be used for each completed well;
- Well remote monitoring capability;
- Routine and non-routine data acquisition capability;
- Monitoring of plume migration in the monitoring well to enable calibration of reservoir models;
- Wells are operated to the agreed best practice such as management of transient conditions, opening and closing of wells, well testing and SSIV testing specific to CO_2 injection wells.

4.6. Field Development

The project involves the capture, treatment, compression, transportation and injection of CO_2 into a depleted reservoir. The project is the first full scale post combustion Carbon Capture Plant in the United Kingdom. Accordingly lessons learnt in designing and operation of the facility and understanding reservoir characteristics is the primary focus of operations.

The capture operation is not designed for expansion and process equipment sizing is based on the capacity of the flue gas from a single gas turbine (GT-13). Future expansion is not a consideration of the project, though if required there is spare capacity in the pipeline and Goldeneye wells.

5. Operations Functional Requirements

This chapter addresses key operations functional requirements that must be incorporated in the facility design to meet Top Quartile Operating Excellence.

5.1. Operating and Technical Integrity

Technical Integrity shall be defined as achieved when, under specified operating conditions, the risk of failure endangering safety of personnel, environment or asset value is as low as reasonably practical (the ALARP principle).

Controls to assure required level of integrity is being addressed throughout the life cycle of the Project shall include;-

- Design controls: assurance of design standards;
- Maintenance and inspection controls: assurance of maintenance and inspection programmes;
- The methods for isolation, maintenance, inspection, and replacement for every piece of equipment will be documented in the design phase;
- Production operations controls: assurance of staff competency assessment and process parameters are kept within production design envelopes;
- Audits to ensure compliance with standards and procedures.

Process parameters shall be kept within pre-defined envelopes by control and safeguarding systems, and are the design shall be inherently ‘fail-safe'. Temporary deviations from design intent shall be managed in accordance with Company procedures, and industry code of best practice.

5.1.1. Standards

The CCS project is split into three distinct areas which are governed by a number of entities and of differing standards. The intent is where possible to follow Company and industry best practice. Goldeneye Offshore facilities and pipeline are already in use by the Company and operated and maintained in accordance with Company and applicable UK Offshore and HSSE regulatory standards and accordingly there is no foreseeable change to existing processes.

CCS plant operations, will follow and comply to requirements set out under Control of Major Accident Hazards (COMAH) regulations and will also include any specific standards and design concepts identified and used in the Power Generation and Carbon Capture industries. I.e. the onshore facilities will be designed to industry (non-Company) standards and the Project specific Process Safety Project Specification (PSPS).

5.1.2. ALARP

The facility design shall eliminate all identified hazards by following best engineering practices and by ensuring the design is appropriate for the intended operating envelope. Where risk cannot be eliminated, the design shall demonstrate that the risk can be managed through suitable controls. A Quantitative Risk Assessment shall be conducted so that residual risk is quantified and shown to be tolerable.

Ergonomic (Human Factors) and accessibility studies shall be an integral part of all facilities design.

HAZOP studies shall be executed throughout all phases of the project and all actions stemming from such HAZOP’s shall be captured and recorded in a controlled document which shall be regularly reviewed to ensure all actions are closed in a timely way. Design modifications initiated from a HAZOP shall be included in final design. Instrumented Protective Function (IPF) review will be carried to ensure adequate and optimal safeguarding instrumentation is installed.

HEMP studies shall also be carried out in the design and construction phases as well as just prior to commissioning and any hazards identified shall be reviewed and recorded. Hazards which are identified to have too high a residual risk shall be eliminated by re-designing the facilities. Prior to facility commissioning and start-up, design reviews and a start-up audit shall be conducted.

5.1.3. Maintenance Strategy

Maintenance strategies will make a substantial contribution to the economic operation of the facilities and will vary depending upon equipment type, service, location equipment criticality, and required availability. Activities will be fully aligned with RCM efforts.

It is expected that the core team O&M staff will handle all routine maintenance, requiring only specialised or contract maintenance personnel for the non-routine and any major maintenance activity (e.g. Turnarounds, Campaign Maintenance etc.).

The strategy appropriate to each item of equipment will be established based on Inspection Maintenance Practices (IMP), RCM results, manufacturers recommendation, etc. and will be included in the maintenance reference plan. The strategies will result in a combination of all or some of the following maintenance options:

- On-line condition based performance monitoring of key equipment will be employed where it is demonstrated to be cost effective. Appropriate diagnostic tools and staff competencies will be developed to facilitate rapid fault finding and rectification;
- Off-line condition based performance monitoring;
- Intelligent predictive maintenance tools to predict incipient failures and/or give early warnings based on inputs from on-line & off-line condition-base monitoring;
- Non-intrusive monitoring;

- Preventive maintenance;
- Corrective maintenance (following breakdown or condition assessment);
- Opportunity maintenance during outages;
- On failure repair.

The maintenance strategy may evolve or change during the operating life of the asset due to influences from regulatory requirements, technology, age of asset, changes in operating condition, economic considerations, resource availability and capacity. Whatever the influencing factor or combination of factors are, the following precepts shall be adhered to in formulating a fit-for-purpose maintenance strategy:

- The Designed Availability, developed at facility conceptual design stage, will set the criticality of certain equipment. This criticality will be taken into account during the Maintenance Strategy selection;
- The monitoring of system and equipment availability and reliability against design intention in order to evaluate the effectiveness of the design, the equipment and the maintenance and operations activities;
- As a minimum, inspection and maintenance activities shall be undertaken to adhere to all applicable statutory and legislative stipulations as well as Company Inspection and Maintenance Practices (IMP).

The following table illustrates the maintenance strategy that shall predominantly be applied to different equipment types/classes.

Table 5-1: Maintenance Strategies

Maintenance Strategy	Equipment Type/Class
On-line condition based monitoring and remote assistance	Large rotating equipment, Turbo machinery
Off-line condition based monitoring	Static equipment – vessels, heat exchangers, piping and valves
Non-intrusive monitoring	Static equipment - piping
Preventive maintenance	Instrumentation, electrical equipment (including motors) & rotating equipment
Corrective maintenance	All equipment following breakdown or condition assessment
Opportunity maintenance	All equipment provided maintenance routine is not unduly compromised
Operate to failure	Not practiced

5.1.4. Operating Envelope

The operating envelope is constrained around the delivery of contracted volumes of CO_2 at the correct composition, pressure and temperature.

Operating envelope of facilities and associated pipelines shall be developed to plot equipment range and constraints against actual operating points in which the equipment is designed to operate. This will allow the mechanism to assess whether current or recent operation has been or will be within the allowed operating area. Production systems simulation and modelling shall identify reliability and availability envelopes.

Sufficient temperature and pressure sensors, level and flow meters shall be installed at strategic points in the facility for the purpose of plant performance monitoring and the monitoring of continuous and non-continuous emissions. The necessary instrumentation required to allow performance monitoring for each and every piece of equipment against its operating envelope shall be provided.

To verify the monitoring system meets its performance specifications, a performance and acceptance test shall be executed in the commissioning phase.

5.1.5. Operations Integrity

The project will rigorously adhere to the application of established standards and approved specifications, for all equipment and adopt Asset Integrity Management Framework for the life cycle operations

Criticality ranking will be performed during FEED to assess the impact of failure of a facility and any of its plant components on achieving design availability. Criticality analysis will be carried out by system at the plant, unit and equipment level. Production Critical Elements (PCE) are identified as:

- GT-13 and ST20 Turbines;
- Grid Power supplies;
- PPS steam process and utility supplies;
- GT-13 Turbine exhaust extraction fans and front end processing (including the pre-scrubber);
- Amine CO_2 extraction and treatment;
- CO_2 compression plant; Pipeline operation, critical to maintain the CO_2 in the dense phase;
- Well Integrity including a SSSIV and down-hole tubing;
- Well and Reservoir Management including Metering and Allocation;
- Utilities and communications equipment uptime and reliability including Goldeneye diesel supply, power generation, satellite link and Hydraulic Power Unit (HPU), etc.

Consideration shall be given to the installation of Closed Circuit Television (CCTV) systems in order to give a continuous overview of key operated and remote facilities to enable a reduction in the number of site visits.

5.2. Availability & Reliability of Production Systems

The design premise is based in capturing, processing and injecting over one million tonnes per year of flue gas emitted by the Peterhead Power Station (operated by SSE) containing approximately 4% vol. CO_2.

The waste exhaust gas will be routed through a Cansolv amine-based capture plant located adjacent to the power station facilities. After capture, CO_2 is routed to compression, also located at the Peterhead Power Station site where it will be compressed, cooled, conditioned and transported to the Goldeneye Platform for injection to the reservoir.

A Reliability, Availability and Maintainability (RAM) model is developed to support initial design basis. As the project matures the model will be subject to a number of iterations until the optimum design concept is agreed and finalised.

Basis of design assumptions:

- Pumps, Fans (excluding Main Inlet Fan) , and ancillary equipment :- ‘n+1’ or 100% sparing;

- Main Process Vessels, Towers and Inlet Booster Fan :- No sparing;
- Export Compressor :- No sparing;
- Utility Supplies (to be supplied by SSE) *(Availability will be confirmed during detailed design);*
- Pipeline :- No sparing;
- Goldeneye Utilities :- No change from initial design;
- Goldeneye Process: - No change from initial design.

The following key performance results for the full PCCS Chain have been generated:

Table 5-2: End to End Availability

Key Performance Parameters	
Availability	86% +/-1%
	304 days
Availability Losses	17%
	61 days

Assuming a 2019 first injection and a 15 year production period, the annualised average availability over 15 years lifetime period for the PCCS chain is 83.3% with an average of 48 days per year below 138 tph. Annual average availability over the 15 year project life is as follows:

Table 5-3: End to End Availability Over Field Life

Time	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Availability %	88	79	81	87	89	79	88	87	81	79	88	77	88	79	81

The highest contributors to the full PCCS Chain unavailability are the station outages and the GT Scheduled maintenance.

The following factors have been considered to potentially influence availability. These will be further evaluated during detailed design.

Offshore

- Single diesel tank installed on the platform (representing possible single point of failure (SpoF) for power generation etc.);
- Single deck crane, potential failure which may impact diesel bunkering;
- Closure or failure to operate Subsea Pipeline Isolation Valve & Associated Hydraulic functions;
- Unexpected changes in reservoir parameters (pressure, temperature, injectivity, etc.);
- Hydrate formation during initial well injection caused by failure of methanol inhibition system;
- Limited availability of Standby Vessels to support offshore visits following an initiated emergency shutdown.

Onshore

- Single export compressor;
- Single Process Vessels;
- Unplanned total shutdown of PPS leading to potential total shutdown of CCS Plant;
- Spares availability and longer turnaround time of equipment or component repair (notional mobilisation times and spares have been assumed);
- Unanticipated failure rate of valves and seals in CO_2 service. Sensitivity analysis with be conducted further during FEED to evaluate the impact of any sparing requirements;
- Changes to planned shutdown dates in any section of the CCS chain leading to cumulative effect with the potential of additional unplanned shutdowns over time.

5.3. Layout of Facilities, Operability and Maintainability

5.3.1. Plant Layout

The scope is distinctly split between the new Carbon Capture, Compression and Conditioning (CCCC) Plant onshore and the transport, injection and storage facilities offshore.

Plant layout is designed to comply with applicable industry standards and where environmental and aesthetic considerations have been incorporated to minimise visual and noise impact to the community.

The opportunity to change Goldeneye layout is limited and, by and large, will remain unchanged to existing arrangements other than those changes required to locate metering, the CO_2 filters, a new CO_2 vent pipe and Subsea hydraulic power pack. Base case design is to simplify the layout as much as possible. As described in the Technical Standards Strategy (TSS) Standard, the following strategy has been adopted:

i. The Peterhead project team will use International/Industry standards for the CCCC plant to allow a more universal application for future replication. Applicable DEM1/2 requirements not covered in the selected Industry/International standards will be specified in a supplementary Process Safety Project Specification (PSPS).

ii. The Company's Design and Engineering Practices as well as applicable international standards will be used for the new offshore pipeline and Goldeneye platform and well modifications.

Note: - Company and industry standards are described in The Technical Standards Selection Report which covers the entire CCS chain downstream of the economiser section of the existing Heat Recovery Steam Generator (HRSG) of gas turbine GT-13 up to the injection wells on the Goldeneye platform.

5.3.1.1. Carbon Capture Plant (Peterhead)

Site selection screening studies identified seven possible plant layout configurations and following a coarse selection workshop, the option identified as the optimum solution to take forward into FEED was one which fully satisfied all HSE and Environmental requirements as well as being the most cost benefit option for the project..

Final endorsement will take place during detailed design when all factors have been considered. The plant layout shall achieve the following requirements:

- Plant orientation will ensure occupied buildings such as control rooms, administrative offices, temporary refuges, workshops and the likes are upwind or crosswind of the prevailing wind direction of the processing facilities;

- The layout is to provide maximum practical separation and protection between high risk Process Function Groups and:
  - Control buildings and occupied offices and workshops;
  - Safety Critical Functions such as Safety Utilities and Vents;
  - Access roads and mustering areas.
- Segregation and separation between hazardous inventories for the control of any incident;
- Segregation between sources of ignition and areas of potential releases;
- Segregation between hazardous and non-hazardous areas;
- Location of vital services and control building in non-hazardous areas;
- Escape routes designed such that minimal use of staircases and ladders is required;
- Provision of suitable barriers to prevent escalation of events from fires, explosions or leakages from the hazardous areas towards support functions and relevant safety-critical support systems;
- Location of hazardous stores should preferably be in close proximity with end users to minimise manual handling activities and reduce exposure to staff;
- The layout configuration (if possible) should allow for expansion, i.e. adequate space required for any future equipment.

5.3.1.2. Goldeneye Offshore Platform

The layout will remain largely unchanged other than the inclusion of a dual cartridge CO_2 filter located adjacent to the well bay area and the installation of a low temperature CO_2 vent to be located alongside existing vents in the vent stack. Base case design is to simplify the layout where possible.

The change from a hydrocarbon fluid to inert CO_2 has operations implications, especially in the event of a major pipe fracture where the lower platform areas down to sea level may be shrouded in CO_2 cloud which may impair conventional evacuation routes to sea and/or helicopter. Further studies will be required to assess any change in operational requirements with regards to the design of Temporary Emergency Refuge and the use of lifeboats in the event of emergency evacuation by sea. These shall be finalised during detailed design.

5.3.2. Operability and Maintainability

A plant Operability & Maintainability study has been completed to ensure and confirm the facilities in their entirety are capable of delivering product volumes in accordance to contractual agreements.

Plant operability and maintainability studies are performed to ensure:

- Plant capacity is appropriate to fully meet all product contractual agreements;
- Appropriate and adequate isolation to minimise plant disruption;
- Provision of adequate walkways, platforms and pathways to facilitate safe operations;
- Provision of adequate roads and lay down areas for vehicle safe access.

The design of all columns, vessels etc., shall allow for proper access for internal inspection, including nozzles. Proper attention shall be paid to accessing individual and grouped vessels to ensure safe, simple and quick removal of spool pieces, valves, connecting up of flushing hoses, air circulation vents etc., in order to avoid dismantling of other pipe-work, structural members and such like. The need for spectacle blinds will be reviewed to enable isolation of a single plant item /train without incurring a full shutdown.

Special consideration shall be made for lifting access and any hard standing required for heavy lift cranes and the likes. Areas identified for spotting cranes shall have appropriate foundation load design.

Skid mounted package equipment such as air compressors, chemical injection skids, emergency generators and the likes shall be designed for quick removal for maintenance or equipment change out.

Design shall cater for maintenance of over side fittings and equipment and where required access platforms shall be provided. Over side lighting and walkway lighting and the likes shall be designed such that fittings change out is possible inboard of any safety barrier / handrail.

Vessel and pipe-work design shall also allow for non-intrusive external inspections. Where possible, equipment shall be standardised to minimise spare parts requirements.

Other considerations for accessibility include:

- Access routes, road widths and bends shall be appropriate for the largest expected vehicle;
- Where pumps and other maintainable equipment are located in open areas with no direct provision for lifting, adequate spacing shall be provided for Fork Lift trucks /Mobile Crane etc.;
- Adequate means of mechanical handling equipment, storage/lay-down areas and space management must be incorporated within the design to ensure that lifting and handling operations can be performed in a safe and effective manner. Particular attention is to be given to intelligent pig launching, well interventions, breakdown maintenance of large items and major maintenance campaigns;
- Suitable separation distance between items of equipment to allow one item to be maintained whilst the other is operating;
- Removable spool pieces at nozzles of process vessels should be considered to facilitate internal inspection;
- Appropriate vent, flushing and draining connections to be provided to ensure that vessels can be made safe for internal inspections;
- Adequate access to all equipment requiring removal by crane needs to be ensured, also taking future modifications into account;
- Allow ease of access to vessels (sizing of manholes, provision of davits etc.) and nozzles for internal inspections;
- Proper attention shall be paid to accessing vessels to ensure safe, simple and quick removal of spool pieces, valves, connecting up or flushing hoses, air circulation vents, etc., in order to avoid dismantling of other pipe work, structural members and such like;
- The number of leak paths shall be minimised. This is to be achieved by fully welded piping as far as it is reasonably practical within the requirements of the isolation philosophy.

5.4. SMART

Smart Fields technology will be used where appropriate and where benefits can be demonstrated.

Instrumentation and smart control field selection will be optimised for:

- Reservoir surveillance;
- Well and field surveillance;
- Equipment health, instrumentation and asset integrity;
- Performance monitoring;

- Data analysis requirement especially for CO_2 monitoring / surveillance.

The level of smartness will be commensurate to the operating need and will be further refined during detailed design. Present level in current design is optimised and further refinement is not expected to influence CAPEX.

5.4.1. Reservoir Surveillance

Reservoir surveillance will typically be within an accuracy of +/-20 %vol.

5.4.2. Well and Field Surveillance

Due to their remoteness and infrequent planned intervention, wells will be fully automated. Well automation will include DCS functionality to control fluid flow whilst maintaining pipeline and flow lines at optimum operating pressure and temperature.

Instrumentation required for data acquisition and reservoir management will be permanently installed where required.

5.4.3. Process and equipment health surveillance

The process plant will be designed for minimum intervention and process control will be fully automated, thus paving the way for a highly efficient, cost effective and safe operated facility. In reality it means that an Operations Technician will not be spending time to acquire routine data in the field from processes and utilities. Data gathering and Production measurements will be fully automated and integrated into the Integrated Production System (IPS).

Data, which is required infrequently or data that cannot be obtained accurately, will not be automated. Only parameters that add value shall be measured.

5.4.4. Performance Monitoring

Studies shall be conducted to assess equipment performance monitoring requirements which addresses the means by which equipment performance is measured. Where there is a requirement to correlate against manufacturers performance data such as large centrifugal compressors, pumps, motors, etc., appropriate instrumentation (pressure, flow, temperature, motor current & voltage) shall be specified, these may be used as direct inputs to online performance programs or offline computational calculations.

5.4.5. Metering

CO_2 injection quantity and quality measurements are a contractual requirement. Accurate metering shall be provided at entry to the export pipeline whilst offshore at the Goldeneye facility, individual well allocation metering shall be provided with an accuracy required for reservoir purposes only. The means of establishing CO_2 quality will be developed during detailed design. The fiscal and allocation metering system will be fully integrated into the production optimisation system.

Note: Fiscal metering parameters will be made available on the data historian in the DCS.

5.4.6. Routine Sampling

Process, utility and waste stream sampling is a normal occurrence in the processing environment and is either automated or performed manually. Manual routine sampling and measurement will be required where it is demonstrated that permanent sampling is not viable or economically justifiable or where there is a need for quality control purposes.

For these purposes manual-sampling devices, capable of extracting on-line representative sample will be installed.

Automated sampler data handling and data hand-off will be fully automated via the DCS.

In addition to process sampling, consideration must be made on requirements for monitoring environmental emissions such as (SOx, NOx, CO_2, etc.). Where practicable and cost effective, these shall be automated via the DCS.

5.5. Flow Assurance

Flow assurance strategies have been developed to ensure efficient and effective flow of fluids through the entire process stream during steady state and transient conditions of start-up and shut-down. Studies shall be conducted to confirm adequate production turndown, ramp up and reduced production during process upsets.

Quick and safe re-start will be a consideration in the design and will incorporate upset recovery considerations. Efficiency will not compromise operability i.e., equipment selection will consider issues such as fast restart and high turndown.

All future tie-in points, with isolation valves, shall be provided on the facilities to avoid difficult tie-in construction work at a later date and avoid where possible the shutdown of the facilities. Instrument junction boxes and cabling shall also carry anticipated sparing in addition to that specified for the overall facilities.

All systems (facilities, wells, risers, etc.) shall have appropriate mitigation measures to prevent degradation due to erosion, corrosion, scale and hydrates. Flow assurance steps will be included in all appropriate procedures (e.g., operating, maintenance, etc.).

Pipeline pigging facilities are retained, used for initial cleaning, dewatering, drying and base line intelligent pig surveys and subsequent surveys as and when deemed necessary. Highest risk in operations involves potential carbonic acid corrosion during initial start-up following the pipeline dewatering. Processes shall be established to minimise such risk.

Potentially there is a risk of salt deposition within the reservoir during the initial displacement of brine and other deposition as result of chemical reaction of CO_2 with reservoir fluids and sands (carbonates). This will lead to injectivity issues that might require periodic treatment to maintain optimum injectivity and flow assurance. A detailed geo-chemical study will be carried out to determine any issues and their magnitude.

5.6. Process Automation, Control and Optimisation (PACO)

5.6.1. CCS Chain Automation

The operation of the CCS chain will be managed from the CCS control room through a fully integrated DCS control system. The DCS system and its Human-Machine Interface will provide the Control Room Operator full monitoring and remote start/stop and process-control capability of the whole process from the point of receipt at PPS to the injection wells at Goldeneye.

The associated Human-Machine Interface and Supervisory Control system will provide full process mimic display of real-time process parameters. The system will provide operation of the CCS plant and full remote control of the pipeline and Goldeneye platform.

Tullos and other Company locations are serviced with PI Servers from a master history database. The service is provided as an integrated network by an outsourced provider. For monitoring purposes only, the DCS shall be interfaced with the PI Server hosted remotely in the Company's Data Centre via the DCS Object Linking and Embedding for Process Control (OPC) interface. The complete list of required parameters shall be developed during FEED/Detailed Design.

Gains in minimising interventions and plant uptime is possible by enhancing the remote monitoring capability in conjunction with applications, such as Asset Management Systems (AMS), Alarm management, rationalisation and summarisation, Advisory and Event management and remote diagnostics for systems and associated equipment. These will be developed during FEED/detailed design.

Enhancement of the automated control and especially the remote monitoring functionality, combined with on-line injection/process optimisation applications, implies a high level of integrity and security of the telecommunications network and associated Data Acquisition & Control Architecture (DACA). The operation of the CCS facilities has interfaces with SSE for the CO_2 supply and for utilities to the CCS plant. The control and management of these interfaces and services will require defining during detailed design

Consideration should be given to the integration and optimisation of existing PPS systems to enhance any possible integration of existing control systems such as:

- Fire & Gas Systems Rationalisation;
- Instrumented Protective Function (IPF) Rationalisation;
- Instrument & Control Upgrade;
- Control & Protective Systems upgrade;
- Alarm Management;
- Advanced Process Control (APC);
- Dynamic Process Simulator.

Final architecture of the integrated control and safeguarding systems will be confirmed prior to detailed design. The business case for a Multi-Purpose Dynamic Simulator will be further investigated, and if deemed beneficial in enhancing operations capability it will be included within the in the training cost for the project. If incorporated it shall be developed closely with the EPC Control and Automation Engineers.

5.6.1.1. Goldeneye Process Automation (Existing Facilities)

Goldeneye is classified as a Normally Unattended Installation (NUI) and accordingly the design incorporates full remote operation functionality. The installation is monitored by the DCS, ESD and F & G systems provided by Honeywell.

- Fire and gas detection monitors the process areas and the accommodation module internally and the air intakes for smoke and gas;
- The ESD system monitors the process parameters and is autonomous. Various levels of shutdown are available along with Emergency Depressurisation;
- The DCS allows the operator to continuously monitor the process via the screen with alarms to give advance warning of potential problems.

At present these systems are controlled and monitored by both the St Fergus Control Room and, if manned, can be controlled and monitored on the installation.

The ESD system is independent and based on IPF and is separate from the process control system.

Presently there are three types of shutdown:

- **Production Hold** – Initiated manually at the ESD matrix panel in the Local Control Centre, manually by operators offshore or remotely from St. Fergus control room;

- **Surface Process Shutdown (SPS)** – Initiated automatically, manually by local push buttons or remotely from the DCS on the platform or at St. Fergus;
- **Total Platform Shutdown (TPS)** - Initiated automatically, manually by local push buttons or remotely from the DCS on the platform or at St. Fergus.

In its present form, whenever a platform shutdown is initiated (remotely from CCS or locally from the ESD system), reset requires a platform visit. History has shown the majority of platform shutdowns have been initiated due to a requirement from St Fergus and not from any malfunction on the platform. Resetting has not always been possible and there is history of extensive delays mobilising to the platform waiting for standby boats, helicopters and the likes.

In addition to the systems noted above, other third party control functions link to the DCS network:

- The Generators supplied by Tilsley & Lovatt have Allen-Bradley computers in the Unit Control Panels for control and monitoring of each Generator;
- The HVAC system supplied by North Sea Ventilation has an Allen-Bradley computer for control and monitoring of the accommodation heating and ventilation.

Monitoring and recording devices applicable for Hydrocarbon extraction are no longer required for the CCS project.

Platform maintenance is optimised to coincide with mandatory visits such as those required to reset the platform, when required to top up utility systems such as water and diesel oil. This philosophy is consistent to best industry practice to limit individual exposure and risk.

However, based on the risks presented by the potential release of CO_2, the current ESD Philosophy may have to be reviewed during detailed design to establish the application of alternative Escape, Evacuation and Rescue methodologies in an emergency situation.

5.6.1.1.1. Goldeneye Process Automation (Modification Requirements)

The proposed operating mode is completely different from past operations in that CO_2 product is injected into rather than extracted from the reservoir. Unlike a hydrocarbon gas, the risks and mitigation are somewhat more onerous in that a severe CO_2 gas leak could potentially shroud the whole platform down to sea level which might impact any means of emergency evacuation.

An initial assessment has been carried out for the Longannet EERA. Provisional screening would indicate minimum or no change to that proposed in the assessment.

Studies shall be required to assess impact this may have on design noting that initially during early operations there will be a phase mixture of both Hydrocarbons and CO_2.

Studies shall be required to assess any impact change on:

i. Goldeneye HVAC Philosophy;
ii. Goldeneye Temporary Refuge;
iii. Goldeneye TEMPS;
iv. Goldeneye Gas Detection Philosophy;
v. Goldeneye ESD Philosophy.

Company operating intent is to solely operate the CCS plant from the Peterhead control room and accordingly the existing control functional links between St Fergus and Goldeneye will be severed.

The facility to remotely view DCS screens, etc. will be made available through GIS links.

5.6.1.2. Well Operations

The control and monitoring of wells shall be made available from both the remote control room at Peterhead CCS and from the local control room at Goldeneye. This is a fundamental change to the original design concept in that the wells shall now be capable of being **fully** remotely operated.

Process instrumentation shall, in addition to normal well monitoring of pressure, temperature and flow shall be provided with additional functionality of a DCS automatic ramp-up and flow control. This is to ensure at process start-up, upsets and shutdowns process fluid flow is appropriately controlled and optimised to meet the required performance and to minimise the potential risk of low temperature excursions which could lead to premature failure.

Table 5-4: Operational Requirements

Function	Operational Requirement	
Overall Platform Operation	Peterhead Control Room	Goldeneye Platform
Remote Start-up under a pressurised condition (Hot start)	O	O
Start-up platform from a depressurised condition	O	O
Shutdown platform	O	O
Adjustment of platform flow rate (FCV)	O	O
Process surveillance (CCTV Camera)	O	O
Process CO_2 Inlet Filter Changeover (Remote Manual)	O	O
Methanol Injection Control	O	O
Pipeline Depressurisation	O	O
Pipeline Pigging Operation (Manual Operation[1])	O	O
Well Operation		
Open SCSSSV under pressurised condition (Hot start)	O	O
Open SCSSSV from a depressurised condition	O	O
Operate Production Master & Wing Valves	O	O
Monitor well flow rate	O	O
Adjust individual well flow rate	O	O
Monitor well THP and CHP	O	O
Carry out leak test of SCSSSV		O
Downhole Reservoir Monitoring (Petr. Engineering) [1]	O	O
Integrity Testing		
Testing of Fire and gas system		O
ESD system function test		O

Note [1]: Some details are to be confirmed during the detailed design phase.

5.6.2. Shutdown & Safeguarding

The system shall be independent to other controls and should function automatically on parameters that are defined using HEMP. Ideally to minimise design changes and for operations continuity, a similar Emergency Shutdown philosophy to that in use for Goldeneye shall be considered for the whole development, noted as:

- ***Production Hold*** – Initiated manually at the ESD matrix panel in the Local Control Centre, manually by operators on site or for Goldeneye remotely from PPS control room;
- ***Surface Process Shutdown (SPS)*** – Initiated automatically, manually by local push buttons or for Goldeneye remotely from PPS control room;
- ***Total Facility Shutdown (TFS)*** - Initiated manually by local push buttons or for Goldeneye remotely from PPS control room.

Note: For Goldeneye *Both SPS and TFS require an intervention visit in order to restart the platform. Operating philosophy is to minimise risk and any potential exposure to a CO_2 release, and accordingly from operations perspective process automation and well control shall focus in reducing interventions to the absolute minimum. This shall be achieved by* ***enabling*** *remote Goldeneye platform resets from the CCS control room.*

Considerations and parameters to initiate manual or automatic shutdown may vary from current philosophy. The system will conform to established practices and any agreed design standards in the CCS project.

No level of shutdown shall stop the operation of safety systems. The Safe Guarding System (SGS) shall be a dedicated system, although alarms and their resultant effects shall also be displayed on the main process control system (DCS). All automatic process shutdowns parameters shall have pre-alarms to permit possible avoidance of shutdown by operator intervention.

Means of depressurisation process fluids (manual/auto) shall be provided, suitably instrumented and controlled to maintain piping material temperature within design limits. The CO_2 released shall be routed to the vent header or other remote location away from any risk to people.

During detailed design due consideration will be given to restart requirements at the different levels of shutdown. This includes amongst others 'black start' requirements. Particular attention shall be paid to potential flow assurance issues that will be caused by a cooling effect during start-up e.g. CO_2 solidification and also potential excessive pressure as stationary fluid warms up during shut down.

A strategy review will be carried out during detailed design, as part of the ESD philosophy, to assess performance validation requirements such as ESD and SSSV leak and function tests.

It should be investigated whether fully automatic testing of the ESD system is feasible and cost effective.

5.7. Isolation Requirements

Project specific, Isolation Philosophies are developed to address design requirements to facilitate the safe isolation of process plant, subsea pipelines and electrical systems.

The isolation philosophy is compliant with Company and industry best practices to ensure all work on any equipment is adequately isolated to prevent injury and exposure of operating personnel to any possible risks arising from toxicity of the process fluids.

5.7.1. Electrical Isolation

Equipment electrical isolation requirements and standards shall comply with Company Electrical Procedure Manual and applicable national/industrial standards which describes in detail specific requirements and practices to be followed to isolate electricity energy sources.

With respect to Electrical hardware such as local isolation/maintenance switches and the likes, this shall be fully defined during detailed design.

5.7.2. Equipment and Process Isolation

The Process Isolation Philosophy addresses the process design for the isolation of equipment and piping components when required for maintenance, inspection, replacement or removal from service. Its purpose is to establish the minimum acceptable standard for providing personnel safety while servicing or performing maintenance on equipment that must be isolated to prevent the unexpected release of energy.

The isolation philosophy is based on the latest Company Design and Engineering Practices (DEPs), and Health and Safety Executive (HSE) guidance.

In addition to the safety element of plant isolation, a major factor in determining equipment isolation relates to the criticality of that equipment within the production system and the means by which isolation may be timely applied to minimise equipment/plant downtime,. Particular attention shall be given to the design of isolation boundaries to minimise inventory to reduce draining volumes to allow access to equipment.

Isolation shall also be provided for critical systems where installed sparing cannot be justified.

5.7.2.1. Safe Isolation Principles

In general, it is preferable to carry out maintenance work only on process plants and systems that have been shut down, isolated, depressurised to atmospheric pressure, drained, and free of flammable, inert and toxic gases. When a shutdown is not practical, the design should incorporate facilities to ensure adequate isolation of a completed train or individual piece of equipment.

The design of the isolation requirements shall be the result of a task analysis of the actions required to isolate, depressurise and purge the system. This shall also take into account the service conditions (e.g. corrosive, fouling). Except as noted below, isolation facilities shall include a means for **"positive isolation".**

Valves identified for isolation shall be provided with locking facilities to facilitate installation of a secure device to prevent inadvertent operation of the valve. The practice of locking valves by their handles shall be discouraged as in practice this usually allows tampering.

Valves designated as locked open (LO) or locked close (LC) and shown on PEFS drawings are always associated with a safety feature so as to prevent mal-operation. Typical examples include isolation valves on relief valves, instrumented trip functions such as HIPPS transmitters and where a common valve can isolate ESD and DCS transmitters.

5.7.3. Interlocks

Interlocks are required to prevent inadvertent operation of a valve by normal manual or automatic means. Company standard specifies the use of interlocks for relief valves and sphere launchers and receivers.

The design of mechanical interlocks shall be such that environmental conditions are considered so that their use is not hampered by corrosion and debris.

5.7.3.1. Equipment Guarding

Rotating equipment shall be appropriately guarded to prevent any possibility of direct contact with rotating elements. Guarding shall be of adequate strength to contain or deflect any projectiles which may emanate from the rotating shaft elements. Due consideration will be made to material of construction for coupling guards to ensure selection of non-sparking material.

Plant and equipment surface temperature areas which are designated V-Hot or V-Cold shall be adequately protected to prevent contact with operating personnel. This may be in the form of heat insulation or by mechanical means such as wire mesh guards. The specification of such guards shall be specified during detailed engineering design.

5.8. Packaged Unit considerations

Where there are demonstrable benefits in operability and cost, the design shall seek to maximise opportunity of utilising packaged equipment. Typically these shall include equipment and systems such as: - Air Compressors, Air Dryers, Nitrogen & Inert Gas Generators, Utility Pumps, Filters, Power Generation, Chemical Injection Pumps etc..

Vendor packages are generally more compact, optimised in weight, transportable, better build quality, and readily commissioned on site. The benefits are not always aligned to Company exact requirements and specifications and there is invariably a level of trade off required in the selection process. As a general rule vendor packages are less flexible and seldom will the specification fully meet Company requirements such as DEM 1. Invariably there will be sacrifices, not so much in quality more often than not in equipment selection such as instrumentation and fittings, pressure gauges, transmitters, etc. Where there is derogation in standard, this shall be considered case by case. In all cases there shall be compliance to DEM 2 standards.

When specifying a package unit consideration must be made in ensuring any limitations imposed by inherent design, for example compactness is not detrimental to the availability brought about by extended downtime due to poor access for repairs.

In principle package specification shall follow the guidelines:

- There shall be no or minimal derogation from standards;
- Equipment maintainability shall not be compromised;
- Equipment accessibility shall not be compromised;
- Vendor shall where possible comply with Company equipment commonality standard such as instrumentation, motor drivers, electrical starters, isolators, gaskets and the likes;
- There shall be strict quality control and pre-shipment & post shipment inspections.

Design and construction engineers shall ensure foundations are appropriate especially when considering the effects of harmonics and transmitted vibrations. In addition consideration shall be made on the installation and removal of the package and the requirements for any adjacent load bearing crane pads.

Where a package is deemed suitable for removal to a workshop, for example an air compressor skid, the design shall facilitate for quick connect / disconnect i.e. Skid boundary connections are minimised and readily accessible.

5.9. Buildings and other Facilities

Location is separate to the PPS control room. The design is based on operations input whilst positioning has been based on the risk study and Carbon dispersion / release studies

Where possible, Company is seeking to maximise usage of existing facilities and infrastructure at Peterhead Power Station. Some services have been identified as suitable for sharing and these include Fire Water System, Telecommunications/ Public Address, Utility and Surface Drains, Distilled/Demineralised Water, Steam Supplies and Power Supplies.

Extensive discussions have been held jointly with SSE to locate the CCP Control Station, Instrument Interface Room, Communications Room and Company Supervisory Office and it has been agreed to house these facilities in a separate Control Room Building.

Other requirements that have been agreed jointly with SSE include provision of:

- Engineering / Vendor Offices;
- Dining/Kitchen facilities;
- Changing Rooms;
- Vehicle Parking and Access;
- Gate and Security;
- Switch rooms;
- Workshops (Mechanical, E&I);
- Battery Rooms.

5.10. Information Management / Information Technology

Information Management (IM) refers to the control, retention and delivery of data during project execution through to commissioning, start-up and final operations. IM processes shall facilitate timely delivery and management of documents so that information is made available to end users at the correct time for populating business management systems such as SAP Blueprint Plant Maintenance (PM) Development of Safe Operating Procedures, etc. This process of information management shall start at a very early stage of the project and for this purpose the Information Management Plan (IMP) is a key deliverable both in FEED and Detailed Design.

All documents required at the hand-over phase to operations shall be provided in electronic native format compatible for direct input in the corresponding Company Electronic Documentation Management System, except where hard copy is specified.

A list of documents to be handed over shall be specified and agreed as part of the handover requirements. All the key documents required by Operations shall be updated to as-built status and included in the deliverables for the asset handover. Deliverables shall typically include the following:

5.10.1. Operations & HSE Data Requirements

- Basis for Design and Basic Design and Engineering Package (Key Knowledge Deliverable 11.003) [2];
- Mechanical isolation and spading plan;
- Final as-built drawings including equipment layout, escape routes and firefighting equipment layout, hazardous area classifications;
- Asset Register;
- Instrumentation logic diagrams;
- Instrumentation trip and shutdown setting list;
- Cause and Effect diagrams;
- Updated plant operating procedure;
- Operations HSE Case;
- Asset Manuals;
- Emergency Response Procedures.

5.10.2. Maintenance Development (SAP Build)

- Asset / Equipment Register;

- Spares parts lists and Spare Parts Interchange-ability;
- Maintenance Reference Plan;
- Bill of Materials;
- Equipment dossiers;
- Completed computerised maintenance management system datasheets and planned maintenance routines;
- Equipment datasheets and specification;
- Vendor equipment dossiers consisting of:
    - Operating and maintenance/trouble shooting manuals;
    - Fabrication and installation drawings.

During steady state, any data residing in EDW/EDS will remain and will be available for other applications and systems like the CMMS, CMS, etc.).

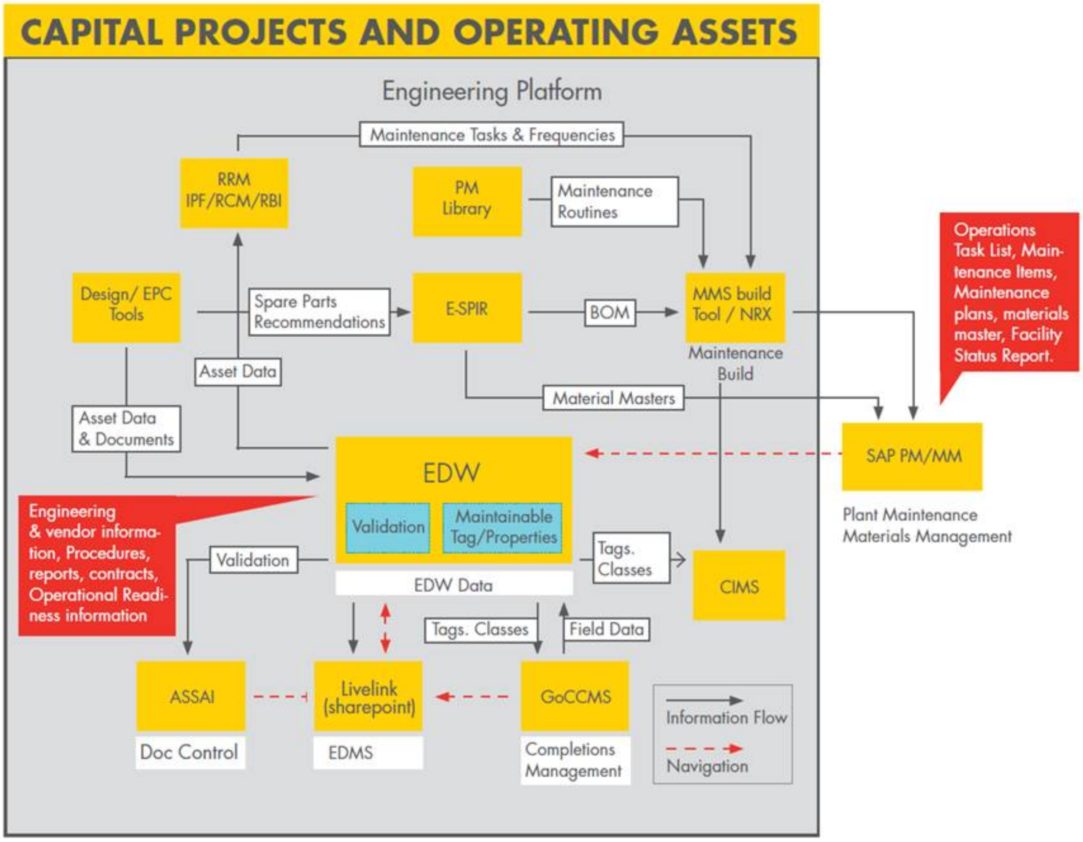


Figure 5-1: Typical Project EDW Data Management Architecture

5.11. Software Applications

Supporting Software applications shall be based on existing Company common systems (e.g. Energy Components, SAP etc.) running on IT infrastructure suitable for the level and functionality involved. The typical applications portfolio will be as illustrated below:

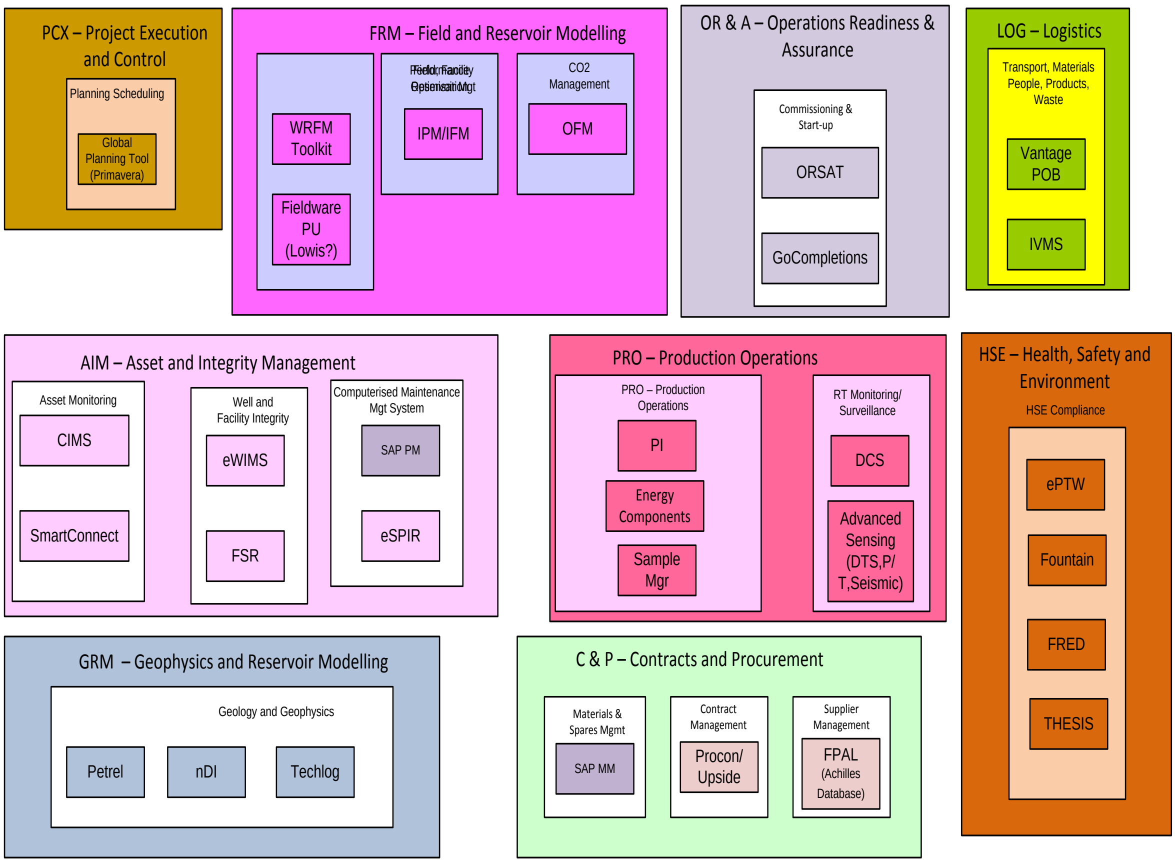


Figure 5-2: Applications Portfolio

5.12. IT Infrastructure and Telecommunications

5.12.1. Communications Infrastructure

Existing communication network comprises of two systems A & B, both carrying the same traffic and based on VSAT technology.

System A: **VSAT from Goldeneye to St Fergus.**

This is Company owned equipment with direct connection for Process and GID to the St Fergus systems.

System B: **VSAT from Goldeneye to St Fergus via Earth station at Tullos and land line from Tullos to St Fergus.**

This is Company owned equipment with direct connection for Process and GID to the St Fergus systems.

The above arrangement has fulfilled past requirements when Goldeneye export gas was processed at St Fergus and for the remote operation of Goldeneye from the St. Fergus control room.

The CCS project totally bypasses St. Fergus, and there is no apparent tangible benefit in maintaining existing communication links. Engineering proposal is to redirect data links directly from the CCS plant to Goldeneye, thus totally bypassing St. Fergus. Communication links to St Fergus will still be possible via the BT network, similar to existing Company links to St. Fergus.

Modified configuration

System A: **VSAT from Goldeneye to VSAT Vendor and by Landline to Peterhead**

This system shall be by VSAT vendor at its own premises. (Current Bandwidth supplier Caprock).From vendor premises to Peterhead traffic will be carried over landline

System B: **VSAT from Goldeneye to Tullos and by Landline to Peterhead**

This system shall be by VSAT to Tullos. (Current bandwidth supplier Caprock) and land line from Tullos to Peterhead.

5.12.2. CCS Communication Requirements

The various aspects that will need to be considered for communication are mentioned in the following sections:

5.12.2.1. Hazardous Area Classification

The CCS plant is largely hydrocarbon free; however given the uncertainty regarding access between CCS and PPS which has hydrocarbon areas, the design premise shall assume all communication equipment is Ex. classified.

5.12.2.2. Public Address and General Alarm (PAGA)

A public address system shall be installed site wide to cover all process areas, buildings and machinery spaces, beacons will be utilised in noisy areas to bring attention to announcements.

The general alarms for fire or process fluid leak will be signalled over the PA system supplemented by beacons in noisy areas.

The telephone system will have dial up access to the PA system.

5.12.2.3. Control Room & Emergency Response Room

Peterhead control room will require to be equipped with:

- UHF radio base station;
- Telephony (PABX);
- GID PC Stations (Global Infrastructure Desktops) with interface links to process applications;
- Visual display screens & boards.

5.12.2.4. CCTV / Intrusion Detection

Currently PPS has site wide CCTV coverage and the possibility of extending to include CCS facilities will need to be investigated. Since CCS operations is totally segregated and fenced from PPS, there is sufficient justification to support an independent CCTV system.

5.12.2.5. Access Control

The need for access control is dependent on site operations agreements with PPS. If the sites are designated independent and separated by boundary fence then a specific CCS access control system will be required, and if the CCS plant is unfenced and contained within the PPS site then the PPS access control systems shall be implemented. This shall be finalised during detailed design.

5.12.2.6. IT Infrastructure

Specific operational IT Infrastructure Production information systems, data administration and quality control and network LAN and WAN, Ethernet. All need to be DACA compliant.

Systems for telecommunication and data-transmission require a high level of availability (>99.9%).

These requirements shall be clearly defined during detailed design.

5.13. Utilities

Utility systems are consistent to that seen on petrochemical processing plants. Project cost reduction may be realised by maximising opportunities to share utility services which ultimately reduce not only CAPEX but also ongoing OPEX costs.

In principle Company will be seeking to maximise sharing of the following utility systems:

- Fire Water System;
- Plant and Instrument Air;
- Telecommunications/ Public Address;
- Utility and Surface Drains (including those for hazardous fluids);
- Distilled/Demineralised Water;
- Steam Supplies (MP and LP);
- Power Supplies.

6. HSSE & SP

Company intends to operate and manage the CCS project following the same management processes in use at St. Fergus Gas Plant and Goldeneye Offshore facilities. Applicable Company HSSE & SP Control Frameworks shall be the overriding principles to follow.

Within the HSSE & SP Control Framework, the Management System (MS) Manual describes specific requirements regarding the management of HSSE & SP risks in projects where the HSSE & SP Control Framework applies. In particular:

- The HSSE & SP Control Framework Projects Manual requires that the HSSE project risks be assessed in line with the Managing Risk Manual;
- The Managing Risk Manual requires that a documented demonstration of ALARP is provided for all Red and Yellow risks on the Company Risk Assessment Matrix (RAM);
- The Asset Integrity Process Safety Management Application Manual (AIPSM) focuses on those activities and assets where hazards can result in risks in the red or yellow 5A and 5B areas of the RAM. These risks require a documented demonstration that they are managed to ALARP.

The Company ALARP Guide document describes the means by which ALARP may be demonstrated to meet the requirements of the HSSE & SP Control Framework Manuals. It further provides a description of the ALARP demonstration process and risk management tools that may be used to support an ALARP demonstration.

6.1. HSSE & SP Premises

The HSSE & SP Premise is structured in accordance with the Company Control Framework including a foundation of Standards and supporting documents. Supporting documents include Manuals, Specifications, Guides, Assurance Protocols and Learning Materials.

6.2. Health, Safety and Security Management

6.2.1. Health

There are a number of potential hazards associated with exposure to chemicals during CCS operations, especially those at initial filling, commissioning and during plant turnarounds where exposure to fluids is greatest. By large the design has considered the mechanism to reduce exposure by ensuring leak paths from process vessels and piping are minimised such as the inclusion of all welded heat exchangers, flange guards where required, welded joints instead of flanges, diaphragm seals, etc.

Personnel health and safeguard requirements will be managed in accordance with the Company HSSE & SP Control Framework and local regulatory requirements. Risks around the "normal Operational tasks" like loading/unloading chemicals will be managed by adhering to strictly controlled and approved procedures.

Key health hazards anticipated for the CCS activities include:

- Potential workforce accidental exposure to amine degradation compounds (e.g. Nitrosamines);
- Exposure to process chemicals (Sulphuric acid, Caustic soda, Methanol, etc.);
- Exposure to CO_2, specific risks see below;
- Noise during CO_2 maintenance venting and accidental release;
- Stress to personnel due to working with a new substance.

It may be noted that both St Fergus plant and Goldeneye platform are existing installations where the health hazards are managed in accordance with the Company HSSE & SP management systems. Interfaces between CCS plant and SSE power station will require implementation of appropriate interface management processes. .

The major health related aspects covered under the Company HSSE & SP control framework are as follows:

6.2.1.1. Health Impact Assessment

A Health Impact Assessment (HIA) shall be carried out as part of the ESHIA for the Project. The HIA shall identify and assess the potential impact of the Project on neighbouring communities, including local people. Due consideration shall be given to both the construction and operations phases and potential short-term and long-term impacts.

Measures to enhance potential benefits and avoid or mitigate impacts shall be identified during the impact assessment process.

6.2.1.2. Health Risk Assessment (HRA)

The HRA provides a systematic approach to the identification and assessment of health hazards. Focus is placed on control measures necessary to prevent or at least control the risks to health from the identified hazards and provides specific recommendations to manage risk. The HRA protocol is a Company health document that describes the steps required to manage health risks during the life cycle of a project. The outcome of the protocol is a Project specific HRA and is stored in *one*Health[IT], the HRA is an evergreen document which is updated during construction, commissioning and operational phases when change occurs or knowledge and or understanding of a particular hazard or risk changes.

Two key areas of consideration for the HRA are:

a) Amine;
b) Carbon Dioxide (CO_2).

Amine

The selected amine is harmful if swallowed, toxic in contact with the skin; it is corrosive and has the potential to cause severe skin burns and eye damage if direct contact occurs. When the Amine is in direct contact with oxides of Nitrogen (present in flue gas and in the atmosphere) there is a potential for the formation of degradation products called Nitrosamines. Nitrosamines represent a large and diverse family of synthetic and naturally occurring compounds. These potential emissions will be carefully monitored and managed in accordance with limits agreed with the Scottish Environment Protection Agency (SEPA). Approximately 90% of the 300 Nitrosamines tested have shown carcinogenic effects in bioassays Impact of routine plant operations such as maintenance, equipment isolation and breaking containment will require HRA assessment during design to ensure activities can be performed within the framework of safe operations.

Carbon Dioxide (CO_2)

CO_2 is a toxic gas at high concentrations, as well as an asphyxiant gas when oxygen is displaced to dangerous levels. At concentrations above 7% in air (i.e. > 70 000 ppm) CO_2 poses a significant danger to humans. At this level exposed workers become incapable of making rational decisions or carrying out action to promote escape or evacuation. HSE have set Workplace Exposure Levels (WEL's) for CO_2 as 5,000 ppm for 8hr Time Weighted Average and 15,000 ppm for Short Term 15 minute time weighted average.

In addition to hazards posed by inhalation of CO_2, there are additional hazards associated with dense phase CO_2 that are likely to occur when CO_2 is handled in large quantities and at high pressure. These hazards can arise when a release occurs and the pressure suddenly falls or is lost completely. These hazards include cryogenic burns, embrittlement of pipe work and toxic contamination.

6.3. Environment

Company objective is to deliver and operate the Peterhead CCS project without any adverse impact on the environment and to fully comply with relevant UK regulations, International obligations, Company Project Standards and the Company HSSE & SP Control Framework.

- The risk of exposure to the environment (fugitive emissions, leaks, spills) from equipment is managed through rigorous control of process venting, depressurisation and systems draining. Records are maintained of all reportable emissions and spills. Also the amount of potential leak paths is minimised by design choices, e.g. fully welded heat exchangers;
- Regular fugitive emissions surveys are carried out to determine the extent of loss through valve packing, tank venting, etc.;
- Process and hazardous waste are disposed in accordance to the Company waste management plan.

6.3.1. Environmental Management System (EMS)

Environmental management will be controlled and aligned to the Company's corporate Environmental Management System (EMS) which is accredited to ISO 14001, the International Standard for Environmental Management. ISO 14001 provides guidance in the implementation of EMS and describes the general requirements of environmental management ensuring:

- Legal compliance;
- Prevention of pollution;
- Continuous environmental improvement.

CCS operations including pipelines and Goldeneye offshore platform will be compliant to Company EMS.

6.3.2. Legal Framework Related to CCS

International, regional and EU legal frameworks are potentially relevant to CCS activities and many definitions and prohibitions within these frameworks are sufficiently broad to encompass and regulate CO_2 capture and storage activities. Some of the most prominent of these are:

- The London Convention;
- The London Protocol;
- UN Framework Convention on Climate Change;
- Kyoto protocol;
- Oslo and Paris (OSPAR) Convention;
- EU Marine Strategy Directive;
- EU Waste Directive;
- EU Landfill Directive;
- EU Water Framework Directive;
- EU Liability Directive.

There is a clear drive within the EU and UK to promote CCS activities and this has resulted in the recent introduction of new legislation, and amendment of existing legislation, in order to provide a framework for CCS. These include the introduction of:

- EU Directive on Geological Storage of CO_2;
- UK Energy Act.

And amendments to:

- The London Protocol and the OSPAR Convention.

6.3.3. UK Environmental Legislation

Applicable UK regulatory requirements are detailed in the Peterhead CCS project Permits and Consents Plan. Regulations specific to the project are noted in the following sections.

6.3.3.1. Onshore

The environmental impacts associated with the construction, operation and decommissioning of the onshore components, namely the capture plant, conditioning and compression will be subject to a full Environmental Impact Assessment (EIA) in accordance with the *Environmental Impact Assessment (Scotland) Regulations 1999* as part of the project ESHIA.

6.3.3.2. Offshore

The EU Directive 2009/31/EC on the Geological Storage of Carbon Dioxide has been introduced to provide a framework for CCS regulation, and within the UK this has been enabled through the introduction of the Energy Act 2008.

The Energy Act 2008 (Consequential Modifications) (Offshore Environmental Protection) Order 2010 (Energy Act 2008) updated a suite of offshore regulations, extending the influence of the regulations to encompass Carbon Capture and Storage. The following acts were updated by the Energy Act 2008 to include Carbon Capture and Storage:

- Offshore Petroleum Production and Pipelines (assessment of Environmental Effects) Regulations 1999;
- Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001;
- Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007;
- Offshore Combustion Installations (Prevention and Control of Pollution) Regulations 2001;
- Offshore Chemicals Regulations 2002;
- Offshore Installations (Emergency Pollution Control) Regulations 2002;
- Greenhouse Gases Emissions Trading Scheme Regulations 2005;
- Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005;
- REACH Enforcement Regulations 2008;
- Fluorinated Greenhouse Gases Regulations 2009.

6.3.4. Environmental, Social and Health Impact Assessment (ESHIA)

ESHIA is required under the Company HSSE & SP Control Framework. The ESHIA Impact Assessment (IA) Screening conducted during FEED has classified the project as category 'A', which requires mandatory onshore and offshore ESHIAs to be prepared during FEED.

6.3.5. Company Standards

Under the Company HSSE & SP Control Framework, nine standards are identified specifically relating to the environment and one standard under Project controls. The environmental standards cover the following nine areas:

1. Biodiversity;
2. Continuous Flaring and Venting;
3. Greenhouse Gas and Energy Management;
4. Ozone Depleting Substances;
5. Soil and Groundwater;
6. Sulphur Oxides (SOx) and Nitrogen Oxides (NOx);
7. Volatile Organic Compounds;
8. Waste;
9. Water in the Environment.

A number of the standards are aimed at operating oil and gas assets and will not be applicable to the project. The standard applicable to the environment is: "Impact Assessment".

6.4. Security

Project security will be managed in accordance with the Company Group Security Standard (as well as potential inputs from SSE). The Standard governs the protection of people, property, information and reputation against security threats to Company businesses worldwide. Such threats include armed conflict, terrorism, violent crime, organised crime, militant activism, civil unrest and theft of information.

6.4.1. Security Strategy

The following principles will underline all aspects of the approach to the security of the project:

- Security management will be threat-led and all proposed counter-measures will be commensurate to ensure security risk is managed to ALARP;
- Compliance with Life Saving Rules and all other HSE policies and procedures;
- Best endeavours will be made to manage security through existing resources.

Security operations shall be conducted in full compliance with national legal requirements, international standards and in accordance with the Voluntary Principles on Security and Human Rights (VPSHR).

An initial security strategy has been developed to outline the basic principles to be followed; this will be further developed during detailed design and at any period where change in security circumstances may dictate.

6.5. Emergency Response

Company operates comprehensive Emergency and Crisis management plan for all assets. Goldeneye Emergency and Crisis Management plans will be modified to incorporate CCS operations and to reflect the change in operations from a hydrocarbon process to high pressure CO_2 operation.

Plans will be developed for the CCS plant which will address the close proximity and required interactions between Company and SSE facilities at Peterhead. Contractual agreements will need to be developed to address Command and Control concepts.

Emergency plans shall be developed prior to any construction activity and credible scenarios practiced to ensure all aspects of command and control are operative and personnel are trained and competent to deal with incidents.

The introduction of new CO_2 related hazards will require a different mind-set to that of a hydrocarbon and utility process plant. The natural behaviour of CO_2 upon release will require an adjustment in emergency response. There will need to be wider consultation with Emergency services and the public to address emergency response methods in a CO_2 environment.

The project will provide the appropriate organisation, facilities, procedures and training.

6.6. Simultaneous Operations (SIMOPS) and Manual of Permitted Operations

The SIMOPS strategy defines boundaries and activities where simultaneous operations may take place which will allow concurrent activities to be performed safely and without interference.

SIMOPS cover multitude of tasks ranging from crane activities to wire line operations and accordingly during FEED/detailed design, these activities and the means in which they are performed need to be considered which may dictate the facility layout and in the case of new projects the project execution schedule, since it determines the activities that will take place concurrently and those that will take place sequentially.

SIMOPS in practice requires extensive and detailed consideration of various activities to be performed and these are described in the "Manual of Permitted Operations" (MOPO) which is prepared as a separate document during FEED and updated during detailed design.

MOPO defines the cautionary operating thresholds and the party to be notified where a risk escalation requires acceptance. MOPO is a manual of procedural responses which identifies stages where reduced defences or increasing hazards could adversely affect the operations to that point where normal operations must cease. Continued safe operation of the facility can be jeopardised if appropriate responses to escalating hazardous situations are not recognised and acted upon. MOPO is created by identifying a list of possible concurrent activities and to then consider the possible escalation factors that would affect the activities. This is achieved with the aid of a Matrix that considers the escalation factors, recovery measures and the consequences to people, assets, environment and reputation of Company, against the concurrent activities. The list of activities considered are drawn from various scenarios, which may be from HSE cases, Quantitative Risk Assessments (QRA), Operations philosophies and past experiences of similar facilities but relate to the particular facility.

The existing Goldeneye safety case does not include a MOPO but does include section relevant to concurrent operations, which should form an input to the SIMOPs strategy and MOPO for the new CO_2 operation.

6.7. Permits & Consents

This paragraph intends to emphasise the development of a management system to handle the Operational Permits, Consents and Regulatory Compliance. It suggests the need to develop a tracking system which shall be used to ensure timely application for new permits and consents, and renewal of expired ones.

Under existing legislation, Peterhead Power Station and the Goldeneye installation have a number of Permits or Consents. There is a need to comply with requirements stated in the existing Permits and Consents, facilitate revisions to the existing Permits and Consents, or successfully apply for and obtain new Permits and Consents for the proposed CCS activities. Any modification to the existing, or issue of new, Permits and Consents will require acceptance by the appropriate United Kingdom Regulator.

6.8. Social Performance (SP)

Social performance (SP) is the term used to describe the management of the impacts of operations on the communities and societies in which we operate. The impacts may be positive or negative, which may affect the wellbeing of our neighbours – and ultimately of our business. Company commitment and policy aspiration in this matter is to be a good neighbour.

In accordance with Company HSSE & SP Control Framework, the following activities will be carried out in order to manage the potential social impacts that could arise from the CCS activities:

1. Define the social environment with the objective of identifying the potential stakeholders that could have an interest in CCS activities;
2. Carry out Social Impact Assessment (SIA).

In addition to the requirements of the HSSE & SP Control Framework the project will undertake a Reputational Management Plan. A Reputation Management Plan identifies and manages the projects reputation (political) risks and opportunities in accordance with the requirements set out in the Group Reputation Standard. This includes issues identification and management, stakeholder engagement, Impact Assessment communications and social performance. Resourcing needs, manning levels, timing and costs will also be incorporated into the plan.

7. Operations Management System

Operations Management System (OMS) will mirror on existing operations management systems currently in use for Northern Systems and Plant, specifically St Fergus and Goldeneye.

It focuses on the safe & cost effective delivery of planned production volumes to the required specifications in support of Operational Excellence and Integrity.

The OMS is the management framework for all operations which includes the tools, organisational functions and systems that are needed to be ready at start up in order to operate the facility/asset.

The OMS defines:

- The activities to be performed (processes);
- The way Operations is structured to perform them (organisation);
- The life cycle performance of the assets (asset management).

These are key deliverables which require implementation during the project phase in preparation for construction, commissioning and start-up. Typical processes and functional requirements are:

- Operations Business Planning;
- Production Operations Management;
- Maintenance and Integrity Management;
- Subsea and Pipelines Operation & Intervention Management;
- Wells Operations & Intervention Management;
- Production Chemistry Management;
- Information Management;
- Contracting and Procurement;
- Materials and Inventory Management;
- Logistics & Infrastructure;
- Well, Reservoir & Facilities Management (WRM);
- Cost Management;

7.1. Operating Expenditure (OPEX) and Cost Management

Commencing the project select phase an operating model report was developed to frame the parameters used in developing the life of field operating model, a key deliverable for evaluating project economics. The report will outline assumptions and data source for developing the life of field OPEX cost estimate.

The CCS project is modelled assuming the period from 2017 to 2055 end of year, which includes:

- 15 Years CO_2 Injection;
- 3 Years reservoir monitoring;
- 25 Years reservoir monitoring.

7.2. Methodology

The OPEX Work Breakdown Structure is a tree type structure linking resources through activities as can be seen in the figure below. An Asset can be a physical or non-physical item such as a separator or Insurance. Each asset can have related activities such as maintenance activities, in the case of the separator, or annual payments, in the case of insurance. Each activity requires resources which call on material, manpower, equipment or services which are linked to quantities and rates and therefore Cost. Building up the model from bottoms up year by year in this way produces an activity based cost model for the life of the venture.

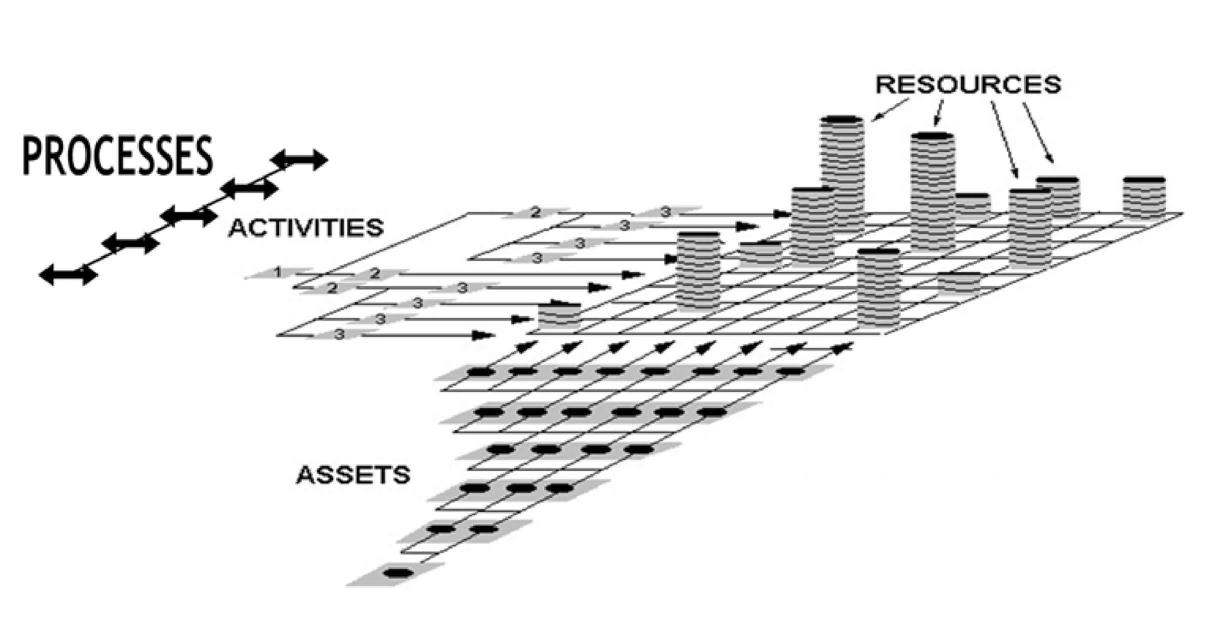


Figure 7-1: OPEX Work Breakdown Model

The year on year OPEX spend is expected to remain around the same value during the injection period (First 15 years) with some year on year variance due to well service work, seismic surveys and rotating equipment overhauls. Post injection the OPEX reduces significantly as manpower requirements, equipment maintenance requirements and offshore visits reduce for the 3 years post injection. The platform is then decommissioned and the 3 injector wells and monitoring well are plugged and abandoned Monitoring of the reservoir will continue at this point for a further 25 years utilising the agreed monitoring well and 2 planned seismic surveys in this period.

The accuracy of the model result has been assessed at +25%/-15%.

The model and accompanying report will be updated to a more detailed Level 3 later in preparation of detailed design.

7.3. Exclusions

Table 7-1: Exclusions

Category	Description
Major Capital Developments	• Facility refurbishment / modifications • Additional wells • Post injection period reservoir interventions
Others	• Customs duty • Research & Development • Carbon credits • Commissioning and Start-up • Operations Pre-Start up • Group support fees • Region based Tax requirements • Costs sharing between the Company and other partners / stakeholders • Inflation.

8. Organisation Philosophy

8.1. Organisation Philosophy

The organisational philosophy is to ensure organisational effectiveness of the assets by employing competent and well trained manpower and having a structure in place to realise project objectives.

The CCS project will be managed under the umbrella of the Company's Northern Systems and Plants portfolio and accordingly wherever possible existing business processes and procedures will follow those of the asset. Day to day CCS management will replicate the model in use at St Fergus with the asset manager operating from Company offices at Tullos, Aberdeen whilst day to day operations is managed by the St Fergus Plant Manager. Day to day site management will be by the Company Operations Supervisor based at the CCS plant management offices.

Engineering and Logistics support will be provided and these may be located either at Tullos or St Fergus. Initially during construction, commissioning and start-up, support personnel may be required at site, as and when the need arises.

Goldeneye operations & intervention will largely remain unchanged from the current support structure with an assigned team of competent practitioners based at St Fergus Gas Plant and mobilised to the Goldeneye platform as and when required. The option of co-locating this team to Peterhead will be reviewed by the asset.

The Operations & intervention team will be led by a dedicated Goldeneye operations lead reporting directly to the CCS Operations Supervisor.

Early in the project and during the development phase the operations supervisor will be assigned with the responsibility to develop and implement the Operations, Recruitment and Development Plan.

Lessons learnt from past projects has identified the late recruitment of competent operations personnel implanted to the project team has resulted in sub optimum decisions being made and the repeat of recurring design flaws. Delays in personnel recruitment and mobilisation inevitably results in commissioning flaws, poor start-ups, poor maintenance systems and scant operating procedures.

With this in mind the emphasis will be on early recruitment and competency development.

8.2. Organisation Model

The CCS plant is located within the operating boundaries of Peterhead Power Station and unlike conventional standalone developments not only is the process plant within a 3rd party operated asset, there is also the complexity of shared services and resources such as Utilities, Fire Water, Roads and Security, etc.

The uniqueness of this arrangement requires careful consideration and planning to address day to day issues as well as the required collaboration for dealing with the wider aspects of planning for escalating events such as for example a major CO_2 gas release, Fire and Explosion and the likes.

These and amongst others will be fully discussed and agreed as the project matures towards initial start-up. Key agreements will include;

- Site emergency plans and leadership;
- Provision of emergency response team;
- Daily event / work communication;
- Permit to work synergies;
- Site security and gate access.

The operations manager / supervisor are responsible for site HSE activities. They are supported by a base office asset HSE team with competencies to support all aspects of HSE engineering , operations and training.

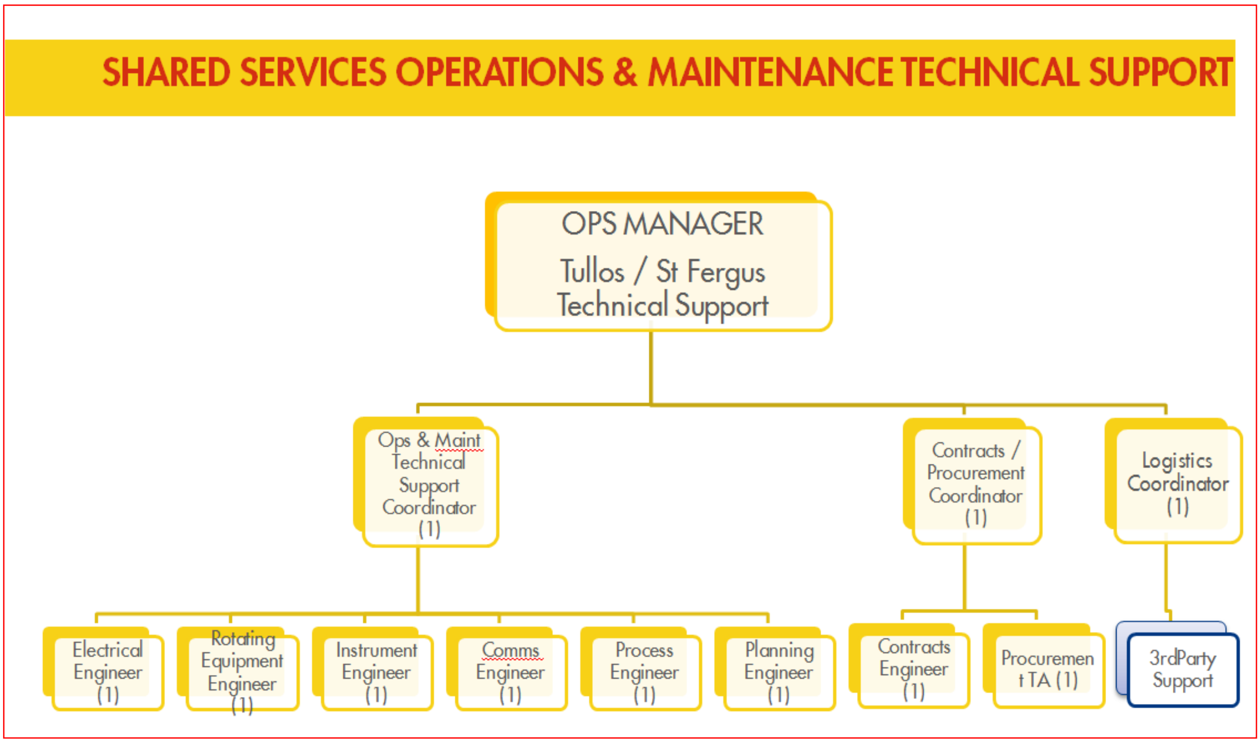
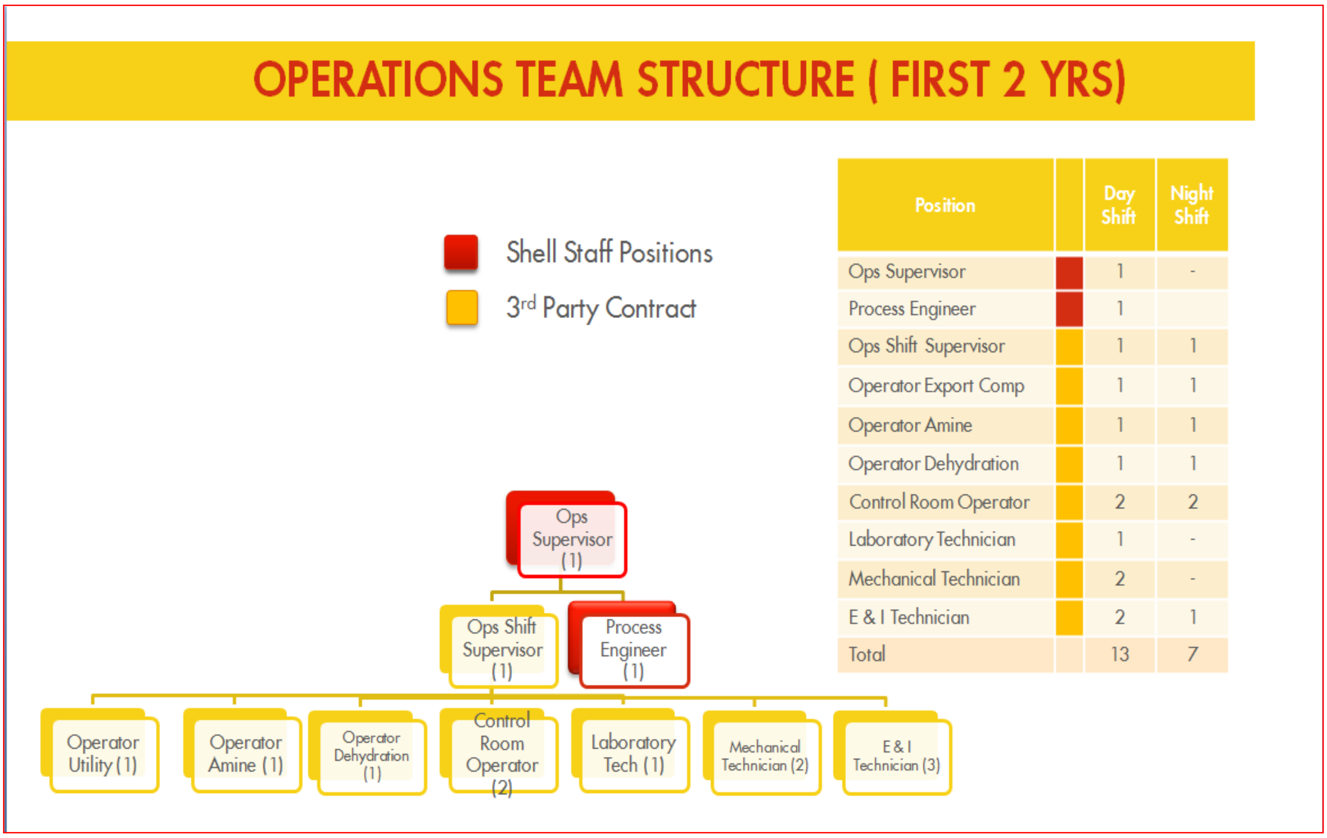


Figure 8-1: Management and Support Organisation

Note: Support roles are expected to be shared between Tullos and St Fergus



Position		Day Shift	Night Shift
Ops Supervisor		1	-
Process Engineer		1	
Ops Shift Supervisor		1	1
Operator Export Comp		1	1
Operator Amine		1	1
Operator Dehydration		1	1
Control Room Operator		2	2
Laboratory Technician		1	-
Mechanical Technician		2	-
E & I Technician		2	1
Total		13	7

Figure 8-2: Operations Team Structure

Note: The onsite team are to be based at Peterhead.

For completeness the project is split into two areas, the onshore facilities at Peterhead Power Station and the offshore platform Goldeneye which includes the main dense phase pipeline from Peterhead to the offshore facility.

8.3. Mobilisation and Recruitment

8.3.1. Manning Philosophy

Operational phase manning levels will be formally assessed using an appropriate assessment tool. The assessment will reflect the following:

- Minimisation of environmental and safety risks;
- Facility complexity and geographic separation;
- Facility operation strategy and out of hours support requirements;
- Operations capability for normal operations and for any abnormal condition such as a process upset and emergency incident management;
- Engineering and manning philosophy that addresses; commissioning, start up and follow on operations phases;
- The philosophy of multi-skilled workforce and the means to assess competency and skills;
- Offshore unmanned operations and minimum manning competency requirement and numbers for platform interventions;
- Operations contracting strategy.

The Operations Organisation Design and Recruitment Mobilisation Plan, has been developed in FEED. This plan describes Manning requirements, training needs and the method of implementation. Utilisation of competent staff and the establishment of an appropriate Company culture in the early stages of production is a pre-requisite to achieve success.

A manpower strategy encompassing operations phases, will be further developed to cover all relevant aspects of manning, recruitment, training, rotations, competency and development. Company intent is to minimise direct Company employees and to subcontract the majority to third party entities.

Key objectives of the manning strategy is to ensure lifecycle costs are optimised by minimising levels of manning on the Asset commensurate with the control technology adopted.

This will be achieved by:

- Adopting a "bottom up" approach to establishing manning requirements;
- Evaluating manning levels through an assessment of actual operational activities associated with the installed facilities, (i.e. MEF Count);
- Establishing a competency framework /matrix by which all new staff will be assessed and verified;
- Adopting strict staff competence assessment and development methods.

Company intent is to minimise staff personnel and to subcontract works to third party entities. It is likely Company personnel will be limited to Operations Supervisor and Process engineer with all other disciplines provided by third party contract.

Shift rotations and contractor general terms and conditions will be comparable to that of St Fergus /Peterhead Power Station. This is an important consideration to prevent cross movement of personnel and discord amongst workers. Personnel will be locally based and within easy commute to the plant.

Initial commissioning will require some short duration personnel in first line positions.

Close geographical proximity to existing SSE plant and the use of shared services such as utilities, roads, control rooms & site security, etc. may require some deviation from normal Company procedures to fulfil requirements set out by SSE.

Site emergency response capabilities are likely to be met by an integrated emergency response team. This requirement shall be determined early in the project (detailed design) and implemented during the construction phase.

8.4. Competency Development & Assurance

The Company UIO UK Competence Assurance Policy aims to ensure that all Positions and Tasks are performed by personnel who can discharge their responsibilities in compliance with HSE requirements and effectively. This applies equally to both contractor and Company staff.

In accordance to the policy, all standards produced for Surface Operations purposes comply with Oil & Gas UK requirements and are minimum threshold levels.

The CCS project falls within the framework of St Fergus operated assets and accordingly existing competence and assurance processes in use at St Fergus will be extended to include operations of the Peterhead CCS plant. The operation of Goldeneye pipeline and platform will largely remain unchanged to existing requirements other than additional competency requirements for high pressure CO_2 receipt and injection.

8.4.1. Competence Framework

Carbon Capture processing is very similar to the Amine Processing plant at St Fergus and accordingly most if not all of existing St Fergus competence processes will apply.

St Fergus already operates a comprehensive competency and training framework detailed in Company Staff Competence Standard.

Continued competence will be demonstrated through observation during normal work activities and evaluated by Line Supervision through normal staff appraisal processes. Line supervisors are responsible in addressing and bridging any competence gaps within an individual's Development Plan.

For technicians, it is not sufficient to assume competence through the possession of a Processing Hydrocarbons Vocational Qualification. Continued competence must be demonstrated and maintained at system and process levels. An individual who has changed location shall not normally require re-assessment unless there is a location specific knowledge requirement. In such circumstances the individual will initially be deemed Not Yet Competent and will be directly supervised until location/area specific competence is assured. Technicians transferring from other assets must undertake location/area specific assessments where appropriate. The Line Supervisor must record verification of competence for the task or in the position

In managing the competence of the team, a GAP analysis is used to identify variances to standards. It is the responsibility of the Asset Manager to ensure that deviation from all Tasks identified within the competency requirements is documented and recorded in FSR and managed accordingly.

The Asset Manager is responsible for recording all deviations to standards, in the Deviation Register.

8.4.2. Competency Standards

Industry vocational qualifications and trade specific standards are used to ensure that both Company and third party alliance personnel in critical positions or undertaking critical tasks are deemed competent via a robust competence assurance process.

The competence assurance plan will be developed for the asset detailing exact competency requirements to be attained before commencement of operations. A deliverable of the assurance plan is the Asset Competence Matrix, which specifically describes the required competency against each position, an example is shown in Figure 8-3. Where there is a requirement to focus on specific aspects of operations (because of major impact on the optimisation of production and recovery), then more emphasis can be directed to these specific areas. This can be identified in the early stages of the learning project and key topics / areas for focus can be highlighted and planned into the competence programme.

The matrix will require updating to reflect any specific requirements of the project, such as operations of high pressure CO_2 process streams.

8.4.3. Project Specific Competency

It is recognised equipment sizing is far bigger to that normally experienced in the hydrocarbon sector and Shell will be addressing this by ensuring personnel are timely recruited to provide adequate time for training in preparation for a flawless start-up.

Whilst O&M principles will largely remain unchanged, Shell recognises the substantial change in equipment sizing, hazards associated with normal operations and lack of intrinsic CO_2 operations knowledge. Mitigation will be by recruitment of competent personnel supported by extensive training and support by Cansolv subject matter experts in the field.

Onshore Plants	HSE										Technical			
	Environmental Awareness Waste Management	Environmental Awareness Chemicals	Environmental Awareness Atmospheric Emissions	Radiation Awareness for Managers	Radiation Awareness for Operators	Radiation Awareness for RPSs	Chemicals HSE Management	ETS (Emissions Trading Scheme) Awareness	Location Specific Environmental Permit Awareness	Oil Spill Response	Permit to Work	HV Switching and Isolation	Electrical Relay Protection	Hoisting and Lifting Awareness
Plant Manager	x	x	x	x			x	x	x	x	x			x
Duty Manager	x		x	x			x	x	x	x	x			x
Production Co-ordinator (General)	x		x	x			x	x	x	x	x			
Operation and Marine Co-ordinator	x				x						x			x
Permit Activity Co-ordinator	x		x		x						x			x
Operations Supervisor/ Shift Supervisor	x		x		x		x	x	x	x	x			
Control Room Operator	x		x								x			
Operations Technician (Process)	x		x		x						x			x
Operations Technician (Electrical)	x		x		x						x	x	x	x
Operations Technician (Mechanical)	x		x		x						x			x
Operations Technician (Instrument)	x		x		x						x			x
Laboratory Technician	x		x		x						x			
Maintenance Co-ordinator	x		x		x						x			
Maintenance Team Leader	x	x	x		x	x					x			x

Figure 8-3: An example of a typical Competency Matrix

9. Conclusion

This O&M philosophy sets out the Company's intent to manage and operate CCS facilities. It is consistent with Company aims of delivering a project which fully embraces Company and industry best HSSE practices and standards whilst delivering optimum product at the most economical and cost efficient practical way.

The Company along with strategic support from SSE have experience operating in the Peterhead locality with the nearby Gas Plant at St Fergus, the offshore platform Goldeneye and SSE power station at Peterhead. Operating intent is for both the Company and SSE to build on the collaboration already seen during the FEED stage of the project and to extend this through into life of field operations.

The Company has a proven record in this field, having developed and operated the St Fergus gas plant which is in relative close proximity to Peterhead Power Station, the Goldeneye offshore platform and many other assets in the North Sea.

Though novel in the oil and gas sector, the design of the capture plant draws on the experience of Cansolv, a Company subsidiary Company based in Canada which has developed similar CCS facilities, notably the recent Boundary Dam project (Canada), which is a near replicate design to Peterhead CCS and which commenced operations in October 2014. Lessons learnt from the Boundary Dam project and the Company's experience in operations will be applied to improve Peterhead CCS design and operability.

Operations intent is of a minimum manned facility. Operations will be managed by a site based Operations supervisor supported by a competent team of skilled personnel selected and trained in CO_2 operations. The operations supervisor will be responsible for all CCS operations and will also be the liaison between CCS and PPS operations, in addition will play a key role for command and control activities. Overall asset management and engineering support will be located at both St Fergus and Tullos. Enabling systems such as SAP management, corrosion management, asset integrity, personnel, HSE, etc., to mirror Company systems already in use at St Fergus. These systems will be phased during engineering, populated and fully functional in preparation for commissioning and start-up. The North East of Scotland as a whole, and especially immediate communities of St Fergus and Peterhead have industry track record in operations and maintenance, where possible personnel will be recruited locally, trained and competent assured.

10. References

[1] Well and Reservoir Management Plan, Key Knowledge Deliverable 11.126.

[2] Basic Design and Engineering Package, Key Knowledge Deliverable 11.003.

11. Glossary of Terms

Term	Definition
AIPSM	Asset Integrity Process Safety Management Application Manual
ALARP	As Low As Reasonably Practicable, and is a term often used in the environment of safety-critical and high-integrity systems. The ALARP principle is that the residual risk shall be as low as reasonably practicable
AMS	Asset Management System
AOB	Aberdeen Operations Base
APC	Advanced Process Control
Barrier	Barriers prevent of mitigate the probability of each threat or prevent, limit the extent of, or provide immediate recovery from the Consequences
BP	Beyond Petroleum
CAPEX	Capital Expenditure
CBM	Condition based monitoring
CCCC	Carbon Capture, Compression and Conditioning
CCP	Change Control Procedure
CCS	Carbon Capture and Storage
CCTV	Closed Circuit Television
CHP	Casing Hanger Pressure
CMMS	Computerized Maintenance Management System
CMS	Completions Management System
CO_2	Carbon Dioxide
COMAH	Control of Major Accident Hazards
Completion	The conduit for production or injection between the surface facilities and the reservoir. The upper completion comprises the tubing and packer, etc. The reservoir completion is the screens, etc., across the reservoir interval.
CoO	Commencement of operations
DACA	Data Acquisition & Control Architecture
DCS	Distributed Control System
DECC	Department of Energy and Climate Change
DEM	Design and Engineering Manual
DEP	Design and Engineering Practice
ED	Effective Date
EDS	Engineering Data Storage
EDW	Engineering Data Warehouse
EER	Evacuation, Escape & Rescue
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EPC	Engineering, procurement and construction
Escalation Factor	Factors that defeat, or reduce the effectiveness/reliability of a Barrier
ESD	Emergency Shutdown
ESHIA	Environmental, Social and Health Impact Assessment
ESHMP	Environmental Social and Health Management Plan
E-SPIR	Electronic Spare Parts and Interchange ability Records

EU	European Union
EX	Electrical Classification for Hazardous Areas
FCV	Flow Control Valve
FEED	Front End Engineering Design
FID	Final Investment Decision
FPD	Flawless Project Delivery
GID	Global Infrastructure Desktop
GIS	Geographic Information System
GT	Gas Turbine
HAZARD	The potential to cause harm, including ill health and injury, damage to property, products or the environment; production losses or increased liabilities. In this report: buoyant CO_2
HAZOP	Hazard and Operability Study
HEMP	Hazard and Effect Management Process
HIA	Health Impact Assessment
HIPPS	High Integrity Pressure Protection System
HPU	Hydraulic Power Unit
HRA	Health Risk Assessment
HRSG	Heat Recovery Steam Generator
HSE	Health, Safety and Environment
HSG	Health and safety guidance
HSSE	Health, Safety, Security, and Environment
HVAC	Heating, ventilating, and air conditioning
IA	Impact Assessment
IM	Information Management
IMP	Inspection Maintenance Practices
Injection phase	The injection phase includes the period of site preparation for injection, the injection period itself and the period of well abandonment
IOA	Initial Operations Assessment
IPF	Instrumented Protective Function
IPS	Integrated Production System
JSA	Job Safety Analysis
KPI	Key Performance Indicators
LAN	Local area network
LC	Locked close
Leakage	Migrated CO_2 out of the containment that leaks into the biosphere (shallow subsurface and atmosphere). In contrast to seepage, leakage involves medium fluxes and medium concentrations
LED	Light Emitting Diode
LO	Locked open
LP	Low pressure
MEF	Mechanical equivalency factor
MEG	Mono Ethylene Glycol
MMV	Measurement, Monitoring and Verification
MOPO	Manual of Permitted Operations
MP	Medium Pressure
MS	Management System

MSR	Maintenance Strategy Review
NOx	Nitrogen Oxides
NSP	Northern Systems & Plants
NUI	Normally unattended installation
O&M	Operations & Maintenance
OMS	Operations Management System
OPC	Object Linking and Embedding for Process Control
OPEX	Operating expense
OR	Operations Readiness
OSPAR	Oslo and /Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
PA	Public Address
PABX	Private Automated Branch Exchange
Packer	A device that both anchors and seals the tubing to the production casing. The term production packer is still used even when the well is in injection mode
PACO	Process Automation, Control and Optimisation
PAGA	Public Address and General Alarm
PCCS	Peterhead Carbon Capture and Storage
PCE	Production Critical Elements
PEFS	Process Engineering Flow Scheme
PM	Plant Maintenance
PPS	Peterhead Power Station
Production casing	The casing providing the secondary wellbore barrier during production or injection (valid term even in injection mode)
PSPS	Process Safety Project Specification
PSV	Platform Support Vessels
PWR	Practices Worth Replicating
QRA	Quantitative risk assessment
RAM	Reliability, Availability and Maintainability
RBI	Risk Based Inspection
RCM	Reliability Centred Maintenance
Risk management	Risk management is the human activity, which integrates recognition of risk, risk assessment, developing strategies to manage it, and mitigation of risk using managerial resources
RO	Reverse Osmosis
SAP	Systems, Applications & Products in Data Processing (software package for the automation of internal Company resources)
SBV	Stand-By Vessels
SCSSSV	Surface-controlled subsurface safety valve
Seepage	Migrated CO_2 out of the containment that seeps into the biosphere (shallow subsurface and atmosphere). In contrast to leakage, seepage involves low fluxes and low concentrations
SGS	Safe Guarding System
SIA	Social Impact Assessment
SIMOPS	Simultaneous Operation
SOx	Sulphur oxides
SP	Social performance
SPA	Special Protection Areas

SpoF	Single point of failure
SPS	Surface Process Shutdown
SSE	Scottish & Southern Energy
SSIV	Subsea Isolation Valve
SSSV	Subsurface Safety Valve
TFS	Total Facility Shutdown
THP	Tubing Head Pressure
Threat	Means by which a hazard can be released and thus cause the top event
Top Event	Incident that occurs when a hazard is realized, or the release of the hazard. The Top Event is typically some type of loss of control or release of energy. If this event can be prevented there can be no effect or consequence from the hazard
TPS	Total Platform Shutdown
TSO	Technical Standard Order
TSS	Technical Standards Strategy
UHF	Ultra high frequency
UIO	Upstream International Operated
UN	United Nations
VPSHR	Voluntary Principles on Security and Human Rights
VSAT	Very Small Aperture Terminal
WAN	Wide area network
WEL	Workplace Exposure Level
WRM	Well and Reservoir Management