Peterhead CCS Project

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Executive Summary

The Health, Safety and Environment report describes how Shell demonstrate the systematic management of health, safety and environmental risks specific to the Peterhead Carbon Capture & Storage (PCCS) Project through compliance with internal Health, Safety, Security, Environmental and Social Performance (HSSE&SP) Management System procedures. These procedures have been developed to support project teams to identify, manage and integrate all aspects of HSSE&SP in the development of a Project, including identifying associated risks, managing them, and demonstrating that they are As Low As Reasonably Practicable (ALARP). Many of the aspects of HSSE&SP are covered within the Onshore and Offshore Environmental Impact Assessments (EIAs) [1].

This report also provides a summary of the HSSE&SP activities listed below for the PCCS Project to date. This includes key elements of the conclusions drawn from the HSSE&SP related Front End Engineering Design (FEED) documents.

HSSE&SP Activity Plan

The Project HSSE&SP Activity Plan was developed to provide a full chain overview of how the PCCS Project managed the HSSE&SP activities and subsequent outputs (deliverables) to ensure HSSE&SP was fully integrated into the Project.

The objective of the plan was to identify and carryout deliverables/activities to be undertaken during the FEED phase that would:

- Assess and manage HSSE&SP risks and control them to ALARP;
- Systematically identify and assess Health risks, and apply Human Factors engineering principles to all elements controlling them to ALARP;
- Ensure that the design of the new facilities and modifications to existing assets was in accordance with relevant industry Health, Safety and Environmental regulations / standards and internal Shell standards; and
- Develop an impact assessment that covered the environmental, social and health aspects in accordance with UK standards.

HSSE&SP Premises

The HSSE&SP Premises document sets out the HSSE&SP compliance requirements for the Project, which were scoped to comply with Shells internal project standards, the Shell HSSE Control Framework, the Shell Discipline Controls and Assurance Framework (DCAF), UK regulations and international obligations.

Design ALARP (As Low As Reasonably Practicable) Demonstration Reports

Design ALARP Demonstration studies were performed for the full chain PCCS Project during FEED as part of the process of identifying, managing and integrating all aspects of HSSE&SP into the development of the Project.

The FEED ALARP Report built upon the Concept phase ALARP Demonstration Report, which covered the major decisions made prior to commencing the FEED Phase of the Project. This document was broken down into Onshore (Peterhead Power Station), Onshore (St Fergus), Subsea

and Offshore elements. The key factors that influenced the design were highlighted, as well as the issues that were carried forward, which will be addressed in the next detailed design phase.

Health Plan

The PCCS Health Plan was produced and implemented to facilitate the management of health deliverables for the Project. It detailed the location of documentation and the actions to be taken to manage the risks identified for human factors engineering, occupational health and hygiene, health risk assessment, chemical hazards, noise, vibration, catering and food hygiene, medical emergency response, treatment facilities, human factors design studies and activities that were required throughout the design stages.

HSSE&SP Hazards and Effects Register

The HSSE&SP Hazards and Effects Registers list the Project's hazards, and how they will be managed in the detailed design phase. The registers identify the hazards and possible scenarios for occurrence; describe the potential consequences; summarise the control and recovery measures for managing risk; and assess the residual risk using a Risk Assessment Matrix.

HAZID and HAZOP Close-Out Reports

Hazard analysis during FEED involved the review of planned or existing processes or operations and consisted of a structured, formal and systematic examination of the process and engineering intentions, in order to identify and evaluate hazards and problems that represent risks to personnel or equipment. The analysis was broken down into each of the CCS chain elements. Output from the HAZID (Hazard Identification) and HAZOP (Hazard and Operability) process was used to develop the FEED designs.

COMAH

Peterhead Power Station (PPS) does not currently qualify as a Control of Major Accident Hazards (COMAH) site under current (2015) regulations. However, the quantities of chemicals and sub-chemicals associated with the Carbon Capture Conditioning and Compression (CCCC) plant will lead to an upper-tier COMAH site classification, requiring written demonstrations with regard to the adequacy of hazard management to be made to a Competent Authority comprising the Health & Safety Executive (HSE) and the Scottish Environmental Protection Agency (SEPA). These demonstrations need to be accepted by the Competent Authority before construction or operations can commence.

Construction HSSE Readiness Review Report

The Construction HSSE Readiness Review Report outlined the plan for HSSE Readiness of the Contractor for implementation in the FEED and Execute phases of the Project. It provides an overview of the HSSE management processes within the Safety Roadmap that are being implemented within the Peterhead CCS Project to achieve Construction Readiness up to the execution (pre-mobilisation), and focuses specifically on the capability and system and for the entire PCCS chain. It also sets out the scope and term of reference for Construction Readiness Review.

CO_2 Dispersion Modelling Review

CO_2 vent dispersion modelling studies were performed during FEED for the relief and vent systems associated with the Onshore and Offshore facilities of the CCS Chain. Workplace Exposure Limits (WELs) were applied in consideration of both Onshore and Offshore locations in accordance with the UK Health and Safety Executive (HSE) guidelines. The dispersion studies show that venting can be carried out safely at either location with no risk to personnel or the public.

1. Introduction

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

As the Goldeneye gas-condensate field has ceased production the facility will be modified to allow the injection of dense phase CO_2 captured from the post-combustion gases of PPS into the depleted Goldeneye reservoir.

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

Once at the platform the CO_2 will be injected into the Goldeneye CO_2 Store (a depleted hydrocarbon gas reservoir), more than 2 km under the seabed of the North Sea. The Project layout is depicted in Figure 1-1 below:

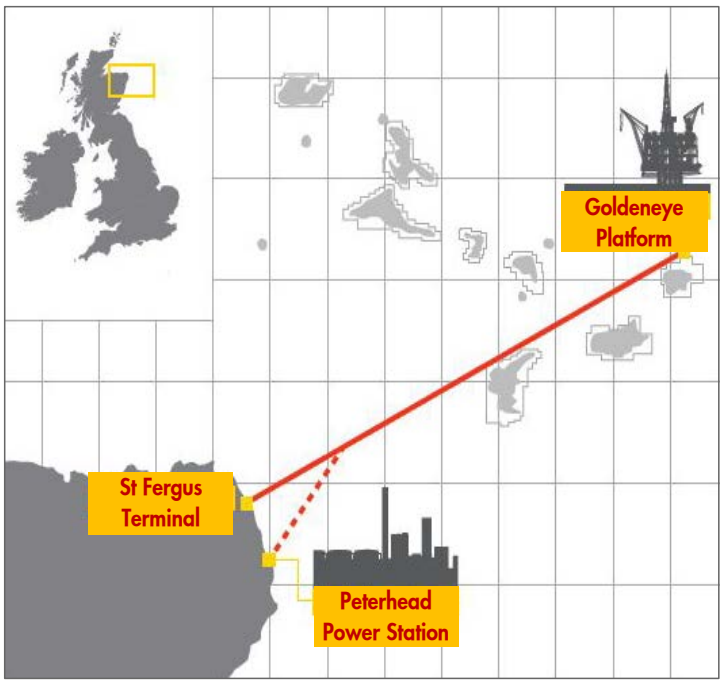

Figure 1-1: Project Location

2. Health, Safety & Environment Report Objective

The objective of the Health, Safety and Environment report is to demonstrate the systematic management of health, safety and environmental risks specific to the PCCS Project per Key Knowledge Deliverable (KKD) 11.120. To achieve this objective, Shell has complied with internal Health, Safety, Security, Environmental and Social Performance (HSSE&SP) Management Systems. This requires the project team to identify all foreseeable associated risks, manage them, and demonstrate that they are reduced to ALARP (As Low As Reasonably Possible).

The report summarises the HSSE&SP activities that have been carried out to date and incorporates the following:

- Design ALARP Demonstration Reports (HSSE&SP cases) for Onshore and Offshore;
- Concept ALARP Demonstration Report;
- Project HSSE&SP Management System (MS);
- PCCS Project HSSE&SP Activity Plan;
- Health Plan;
- HSSE&SP Hazards and Effects Register;
- Process Safety Review Report;
- HAZOP (Hazard and Operability) study;
- Construction HSSE Readiness Review Report;
- HAZID (Hazard Identification) Close-out Report (summary detailing key actions specific to the application of CCS)
- Summary HAZOP close-out report (summary detailing key actions specific to the application of CCS);
- COMAH (Control of Major Accident Hazards) Review;
- H, Safety and Environment Project Plan;
- CO_2 vent dispersion modelling report; and
- Environmental Impact Assessment (EIA) or Environmental Statements (ES) [1] (**Note**: The EIA has been made public as part of the regulatory permits and consents process).

Where relevant, reference is also made to Project Key Knowledge Deliverables (KKDs) and other documents that are available in the public domain.

3. HSSE&SP Management System Requirements

The Shell HSSE&SP Management System requires that the project identifies all foreseeable significant HSSE&SP risks associated with the project activities that will be undertaken, and assess and control these to ALARP levels.

To this end, the processes are implemented to ensure that:

- Significant HSSE&SP Risks associated with business activities are assessed and controlled to ALARP;
- Individuals who have responsibilities for HSSE&SP are competent and have the resources to perform their roles;
- A Permit To Work process is used to manage the risks of hazardous work;
- Changes to facilities, processes and organisations are managed to maintain risk controls;

- Emergency response plans, including those for medical emergencies and spills or releases to the environment, are established and exercised to maintain preparedness;
- Incidents are investigated and analysed to identify improvements;
- HSSE and SP data is prepared and reported in conformity with the Shell Group and relevant regulatory requirements applicable to such data; and
- Assurance is provided to the Board of Royal Dutch Shell plc that HSSE&SP Controls, including Process Safety Controls, are effective.

3.1. HSSE&SP Lead

Shell requires that an HSSE&SP Authorised Person be appointed by the Project Manager. They are responsible for establishing, maintaining and executing the appropriate HSSE&SP studies and/or activities in order to adequately identify, assess, and document the HSSE&SP risks of the Project. These activities and deliverables were documented in the Project HSSE&SP Activity Plan, to ensure that the Project complied with Shell's HSSE&SP requirements. A fulltime HSSE&SP Authorised Person was integrated into the Project team from the outset of the FEED phase to ensure that risks and opportunities were identified and managed early.

3.2. Risk Management

Project HSSE&SP risks have been and will continue to be identified as early as possible and entered into the HSSE&SP Hazards and Effects Register. Creation of the register aids the active management of risks throughout the design phases, such that they are reduced to ALARP levels at handover to the operators.

HSSE&SP has been integrated into Project decisions and associated project deliverables throughout each phase.

The ALARP Demonstration Report includes HSSE&SP aspects and was developed to demonstrate the integrated decisions taken by the Project to reduce risk and mitigate consequences to ALARP levels. The initial Concept Report was prepared pre-FEED to support the concept selection and has subsequently been developed during FEED to support the Final Investment Decision. The ALARP Demonstration Report will be updated during the detailed design phase to provide design information into the operating asset. The ALARP Demonstration Report is maintained throughout the life of the asset.

3.3. Environmental Impact Assessment

The Environmental Impact Assessment (EIA) process is required in the UK and is aimed at identifying the Project activities that are likely to result in significant impacts to the natural and social environment throughout the life of the Project and subsequent operation of the plant. In accordance with EIA best practice and guidance, the EIA assessed the significance of the impacts identified in relation to their magnitude and sensitivity.

3.4. Health Plans

Health aspects (including Human Factors Engineering) have been managed in accordance with Shell HSSE&SP Management System and local regulatory requirements. The key health hazards identified for the CCS activities include process chemicals and by-products, noise during CO_2 maintenance venting and accidental release and working with a new substance. Potential exposure to the identified hazards will be managed to ALARP during the detailed design phase to ensure that there is no risk to people or the environment.

The potential for public exposure to emissions will be assessed and managed beyond the boundaries of the Project installations, principally the PPS site although other locations (such as St Fergus) are also considered.

3.5. HSSE&SP Input to Technical Deliverables

HSSE&SP input has been provided to all formal Project deliverables. Project HSSE&SP Assurance was provided through contributions to formal reviews, peer reviews and audits contributing to Shell's decision gate process. HSSE&SP input to the Project's technical design aspects was also considered during the Project within the risk management process, for example through the application of hazard analysis. This builds upon an initial Hazard Identification review (HAZID), and provided input to the Hazard and Operability studies (HAZOP) performed during FEED as the design details matured. A summary of the FEED HAZID and HAZOP close-out reports is included within this report.

4. HSSE&SP Premises

4.1. Introduction

The principle of the HSSE&SP Premises was to set out the minimum HSSE&SP requirements for the PCCS Project. It was scoped to comply with UK regulations and international obligations as well as Shell's internal HSSE&SP Management System. It sets out HSSE&SP compliance requirements for the Project along with details of some of those key requirements. A summary of the key elements within the FEED HSSE&SP Premises document are detailed below.

4.2. Health

Health aspects for the personnel (including Human Factors Engineering) have been managed in accordance with the Shell HSSE&SP Management System and local regulatory requirements. The key health hazards anticipated for the CCS activities include potential exposure to process hazards of the amine cycle and chemicals, exposure to CO_2, noise during CO_2 maintenance venting and accidental release, stress to personnel due to working with a new substance, etc.

Beyond the boundaries of the Project installations, principally the PPS site although other locations such as St Fergus are also considered, the potential for public exposure to emissions such as process chemicals and bi-products will be assessed and managed.

4.3. Security

Security aspects of the PCCS Project are primarily concerned with the two existing Onshore site locations:

- The PPS site, where the power generation and Carbon Capture, Compression and Conditioning (CCCC) activities will be carried out; and
- St Fergus Terminal, where limited support services operations are required (related to the procurement of methanol and its storage prior to injection).

Carbon Capture, Compression and Conditioning (CCCC) activities will be carried out at the existing PPS site. SSE's existing security arrangements at the site follow standard power sector industry practice. These security arrangements have been reviewed during FEED. The proposed security arrangements will be reviewed again during the Execute project phase which may result in changes being proposed to the current security provision. The existing gas terminal at St Fergus is one of the UK's centres for receiving gas from the North Sea and is designated a Category 5 site as dictated by CPNI and the UK Government. Consequently, it is already identified as requiring a higher level of security than the PPS site. It is anticipated that the PCCS Project will be required to work under the existing security arrangements and procedures which are in place. The existing St Fergus terminal security arrangements will be applied.

Notes:

1. CPNI- the Centre for the Protection of National Infrastructure (CPNI) protects national security by providing protective security advice.
2. Category 5 is defined as an infrastructure, the loss of which would have a catastrophic impact on the UK. These assets will be of unique national importance whose loss would have national long-term effects and may impact across a number of sectors.

The Goldeneye Platform and infrastructure has established systems for security management, threat identification and risk mitigation. These systems have continued to be implemented throughout the course of the FEED phase, and shall remain in place going forward.

4.4. Environmental

The team goal in the FEED phase was to deliver the PCCS Project without any adverse impact on the environment and to fully comply with relevant UK regulations, International obligations and Shell's HSSE&SP Management System.

4.5. Asset Integrity/Process Safety Management

The PCCS project Asset Integrity / Process Safety Management (AIPSM) is based upon Shell's HSSE&SP Management System and is structured on the Hazards and Effects Management Process (HEMP) resulting in effective barriers to manage identified Major Accident Hazards (MAH). The essential elements of these barriers, Safety Critical Elements (SCEs) are designed, constructed and maintained in accordance with the specified performance standards. This incorporates effective design, quality assurance, maintenance, verification and deviation processes.

4.6. CO_2 Specific Hazard Management

In the United Kingdom, CO_2 is classed by the Health and Safety Executive (HSE) as a 'substance hazardous to health' under the Control of Substances Hazardous to Health Regulations 2002 (COSHH). The HSE publication 'EH40/2005 Workplace exposure limits' [2] provides Workplace Exposure Limits (WELs) for CO_2. WELs are limits to airborne concentrations of hazardous substances in the workplace and are set in order to help protect the health of workers. Workplace exposure is calculated by taking an average over a specified period of time. The WELs defined by HSE for CO_2 are:

- Long-term exposure limit (8-hr reference period) of 5000 ppm; and
- Short-term exposure limit (15 minute reference period) of 15000 ppm.

The HSE also states that:

"*In CCS operations it is likely that CO_2 will be handled close to, or above, its critical pressure (73.82 bara) where many of its properties are similar to that of a liquid. In this state it is often referred to as 'dense phase', whereas above critical temperature (31.04°C) and pressure it is referred to as 'supercritical'. Significant hazards associated with dense phase or supercritical CO_2 arise when pressure falls suddenly or is lost completely.*

CO_2 is not defined as a dangerous substance under the Control of Major Accident Hazards Regulations 1999 (COMAH) or as a dangerous fluid under the Pipelines Safety Regulations 1996 (PSR)."

In June 2011 HSE published the report "Assessment of the major hazard potential of Carbon Dioxide" [3]. This report concluded that CO_2, based on the evidence available at that time, has major accident hazard potential if released at, or above, its critical pressure. However, where the risks are properly controlled the likelihood of a major hazard incident is expected to be very low, as in other similar processes in the energy, chemical and pipeline industries.

More information can be found on the HSE website where the HSE advises that it is committed to keeping CCS risks under review and will consider extending existing major accident hazard legislation to cover CCS if this is justified by future evidence.

As a result, in order to mitigate the risk of HSE reclassifying CO_2 under future changes to the COMAH legislation, Shell has decided to treat CO_2 as if it were defined as a dangerous substance under COMAH in terms of regulatory engagement.

The current understanding of the main regulations relevant to the control of major accidents has been considered and the necessary actions required are summarised below:

- Onshore Plant - Consultation took place with the local authority during FEED to determine consenting requirements;
- Peterhead Power Station is not presently registered with the HSE under the COMAH regulations. However, the chemicals and quantities proposed for use within the PPS plant boundary were checked against COMAH requirements. Regardless of COMAH classification it is necessary under the Health and Safety at Work Act to demonstrate that the risks are being managed to ALARP;
- The Carbon Capture Plant, which will be situated adjacent to PPS on part of the existing site, will be classified as an upper-tier COMAH site due to the process chemicals in use.
- Pipelines - Engagement with HSE resulted in the advice that there are no plans to change the CO_2 classification from that in the present Pipelines Safety Regulations 1996 (PSR) and that a

Major Accident Prevention Document is not required to be submitted. Engagement will continue to ensure that this stance is also understood with the local inspectors; and

- Offshore Platform - Engagement with the HSE resulted in the advice that COMAH requirements do not apply and that a COMAH Safety Report will not be required to be submitted to the HSE for CCS operations due to their interpretation of the Offshore Installations (Safety Case) Regulations 2005. Engagement will continue to ensure that this stance is also understood with the local inspectors.

The COMAH requirements of PPS and the Carbon Capture, Conditioning and Compression (CCCC) plant are discussed in greater detail under Section 13.

4.7. Construction and Occupational Health

During the design and construction phases of the Project, safety management has been a key responsibility as defined in the UK in the CDM regulations, with a Construction Design and Management Coordinator (CDM-C) being appointed for the FEED phase of the Project in accordance with the CDM 2007 regulations. The Construction (Design and Management) Regulations 2015 (CDM 2015) came into force on 6 April 2015, replacing the CDM 2007 regulations, which applied during the FEED phase of the Project.

A key change in the CDM 2015 regulations is the creation of a Principal Designer role and discontinuation of the CDM-C role. This change will be reflected in the safety management approach developed for the construction phase of the Project.

Occupational hazards to personnel are being minimised through the application of the HEMP and the hierarchy of hazard management. This includes hazards associated with Concurrent Operations on site(s) – at PPS, the Goldeneye offshore platform and at St Fergus – where construction and commissioning activities will take place adjacent to existing operational equipment.

An effective occupational health and safety management system will be implemented during the construction and commissioning phases, which is in accordance with the principles, policies and standards prescribed in Shell's HSSE&SP Management Systems and interfaced with the existing SSE HS&E management system for PPS, the Goldeneye offshore platform and at St Fergus (if required).

4.8. Social Performance

In accordance with Shell's commitments and policies on HSSE&SP, Shell aspires to be a 'good neighbour'. In accordance with Shell HSSE&SP Management System, the following activities have been carried out in order to manage the potential social impacts that could arise from PCCS related activities:

- Definition of the social environment with the objectives of understanding the social environment we work in (culture, background, ways of living etc.) and identifying the potential stakeholders that could have an interest in CCS activities;
- Completion of a Social Impact Assessment (SIA) as a part of the integrated Project Impact Assessment (IA); and
- Development of a Social Performance Plan for the Project, which outlines the key social impacts, risks, mitigation measures and action plan to deliver benefits.

The Social Performance Plan was created prior to FEED and updated as the FEED matured. The key social performance goals are defined as:

- Gaining local community buy-in for the construction of Onshore and Offshore infrastructure for the PCCS Project;
- Supporting smooth Project delivery for all phases of the world's first full-chain carbon capture and storage Project on a gas-fired power station; and
- Ensuring social impacts are minimised and effective societal benefits are realised, meeting both social and business needs.

Stakeholder engagement is an essential tool to communicate and consult about the Project to and with external parties. The Social Performance Plan is aligned with the Project's Stakeholder Engagement Plan (Key Knowledge Deliverable 11.063) [4].

5. HSSE&SP Activity Plan

5.1. Introduction

The aim of the PCCS HSSE&SP Activity Plans was to identify and assess HSSE&SP related risks associated with the Project FEED scopes so that an inherently safe design was developed and taken forward to detailed design, construction and ultimately operation. The activity plan covered all deliverables identified for completion by the Health, Safety, Security, Environmental and Social Performance disciplines.

A full chain HSSE&SP Activity Plan was developed as an overarching document detailing the activities and deliverables to be undertaken through the HSSE&SP Activity Plans for each of the FEED sub-scopes. These were developed and agreed as follows:

- between the Shell Project Manager and the Shell HSSE&SP authorised person/PCCS HSSE&SP Lead (contained in this overarching HSSE&SP Activity Plan);
- between Shell and Technip (contained in the Technip HSSE&SP Activity Plan);
- between Shell and Wood Group Kenny (WGK) (contained in the Subsea HSSE&SP Activity Plan); and
- Between Shell and Shell's Design Office (contained in the Goldeneye and St Fergus HSSE&SP Activity Plans).

The full chain HSSE&SP Activity plan also:

- Acted as an activity schedule and resource commitment that delivered the HSSE&SP objectives and strategy to demonstrate how the key HSSE&SP issues were to be managed over the lifecycle of the PCCS Project; and
- Linked together the FEED HSSE&SP deliverables for the various FEED sub-scopes through their discreet HSSE&SP Activity Plans to prevent gaps from occurring.

The Shell and FEED Contractor HSSE&SP Activity Plans required the involvement and participation of the following Shell HSSE&SP disciplines to fulfil their requirements:

- Occupational Health & Hygiene (OHH);
- Operational Safety (OS);

- Technical Safety (TS);
- Human Factors Engineering (HFE);
- Environment (E);
- Security (S); and
- Social Performance (SP).

There were also interfaces with other disciplines that were responsible for management of non-technical risks including Communications, Commercial and Economics.

5.2. Objectives

The key objectives of the HSSE&SP Activity Plan were to:

- Define the HSSE&SP activities to be performed during the FEED phase;
- Ensure that the Project facilities were designed so that HSSE&SP risks are both tolerable and ALARP during all subsequent Project phases, and that this can be clearly demonstrated;
- Outline organisational arrangements, responsibilities and accountabilities for HSSE&SP management during the FEED phase;
- Identify applicable HSSE&SP activities with respect to the scope of the Project;
- Define HSSE&SP deliverables for the Project and ensure that all HSSE&SP documentation was provided for the decision gate reviews;
- Assign roles and responsibilities in relation to delivering the HSSE&SP activities;
- Identify work that will be contracted to others;
- Schedule all HSSE&SP related activities within the overall Project work plan; and
- Create a budget based on the timing, resourcing and support activities needed for the Project.

5.3. Summary

The Project HSSE&SP Activity Plan provided a full chain overview of how the PCCS Project was to manage the HSSE&SP activities and deliverables that ensured HSSE&SP was fully integrated into the PCCS Project.

The activities proposed during the FEED phase are broadly listed below:

- HSSE&SP risks will be assessed and managed throughout the FEED phase and controlled to ALARP;
- Health risks will be systematically identified, assessed and controlled;
- Human factors engineering principles will be applied right from the FEED phase;
- Design of new facilities and modifications to the existing assets will be in accordance with industry standards and also to ensure compliance with Shell internal standards; and
- Impact assessment covering environmental, social and health aspects will be carried out in accordance with UK standards.

The outputs from the HSSE&SP activities carried out during FEED are summarised within this report. However, reference should also be made to the Risk Management Plan and Risk Register (Key Knowledge Deliverable 11.023) [5] and also the Onshore and Offshore Environmental Statements [1], which were produced during FEED and have been published in the public domain.

The Shell HSSE&SP team provided support and input to the FEED phase delivery, and provided full chain Technical Assurance reviewing the HSSE&SP aspects of all FEED deliverables in order to ensure that all foreseeable risks were identified, assessed and mitigated to ALARP. This was achieved by:

- Attendance at and input to workshops;
- Regular updates and reviews;
- Technical assurance of produced deliverables;
- General support;
- Input to scope of key deliverables as appropriate; and
- Involvement in incident investigation and cross learning.

6. ALARP Demonstration Reports

6.1. Introduction

The concept of reducing risk levels to ALARP (As Low As Reasonably Practicable) is that HSSE&SP risks are demonstrated to be both tolerable (that is, within all legislative and other Project requirements), and also further reduced as low as reasonably practicable.

This process was documented by Shell in an ALARP Demonstration Report which was required for internal decision gate review and often for external regulatory approval.

An ALARP Demonstration report was developed by the Project to demonstrate the integrated decisions taken by the Project to reduce risks and mitigate consequences to ALARP levels. An ALARP Demonstration Report was created to support Concept Selection (pre-FEED), and this document has been updated during FEED to support the Final Investment Decision which will take place at the end of the FEED phase. Should the Project proceed to implementation, the ALARP Demonstration Report will be further updated to develop a final deliverable that will provide design information and will be the reference documentation once the Asset enters commercial operations. It is Shell's normal practice to maintain the ALARP Demonstration Report in various forms (COMAH Safety Report, Platform Safety Case etc.) throughout the life of the asset. This document provides a summary of the ALARP Demonstration report which was produced during FEED.

6.2. Objectives

Design ALARP Demonstration studies were performed for the full chain PCCS Project during FEED as part of the process of identifying, managing and integrating all aspects of HSSE&SP into the development of the Project.

In general, the Design ALARP Demonstration studies are carried out to:

- Demonstrate that there has been a systematic application of the Hazards and Effects Management Process (HEMP) during the Identify, Assess, Select and Define phases of the Opportunity Realisation Process (ORP);
- Demonstrate that HSSE&SP has been integrated into Project decisions;
- Confirm that the lowest risk option has been selected, or alternatively demonstrate that the risks of the selected option are ALARP; and
- Demonstrate that the design solutions are reducing risk levels through the remaining Project phases (including decommissioning) to ALARP.

During FEED, the safety risk studies that were carried out for the Project were split into categories, each representing a specific scope, as follows:

- Onshore, covering the Peterhead Power Station and the Carbon Capture and Compression Plant;
- Subsea, covering the onshore pipeline, shore crossing, new pipeline from Peterhead to tie-in point, and pipeline to Goldeneye platform;
- Offshore, covering the Goldeneye platform; and
- Methanol at St Fergus.

The FEED ALARP Reports build upon the Concept ALARP Demonstration Report that covered the major decisions made prior to commencing the FEED Phase of the Project.

The following sections provide further detail on the Concept and Design ALARP work which has been carried out for PCCS.

6.3. Concept ALARP Demonstration Study

The Concept study was primarily focused around potential for loss of containment, how a loss of containment could affect personnel at work or on the pipeline route, and how those risks could be perceived. Prior to commencing FEED, both of the CO_2 transportation options that involved onshore transportation of CO_2 were discounted due to the potential for negative public perception.

6.4. Design ALARP Demonstration Study (Onshore)

The Onshore ALARP demonstration report covers the PPS plant modification works and scope of work for the carbon capture, compression and conditioning plant.

The main areas covered in the ALARP demonstration study were:

- Release of CO_2;
- Release of amine, exposure of personnel to amine;
- Asbestos; and
- PPS accidents (fire and explosion) including new flammable hazards on the carbon capture plant.

The key issues that are carried forward and need to be addressed in Execute phase are:

- Process plant isolations to optimise the provision of double block and bleed, positive isolation and where single isolation may be tolerated;
- Minimise exposure of personnel to leaks by such protective measures as the use of flange guards, especially in the Thermal Reclaimer area;
- Revised Quantative Risk Assessments (QRA) base case for future modifications; and
- The compression and conditioning area (and the compressor building itself) needs to be treated as restricted for personnel access in terms of awareness training and the carrying of personal escape sets (or the provision of breathing apparatus sets), as well the requirement for rapid escape.

6.5. Design ALARP Demonstration Study (Subsea)

The Subsea ALARP demonstration report covers the scope of work for the offshore pipeline. This is limited between the onshore maintenance valve and the riser Emergency Shutdown Valve (ESDV).

The main areas covered in the subsea ALARP study were:

- Subsea Pipeline Routing/Tie-in Point;
- Control of Thermal Expansion in Riser System;
- Location of Onshore Valve Station;
- Isolation strategy;
- Subsea Tie-in Type; and
- SSIV structure reuse vs. new.

The key subsea HSSE&SP issues that are carried forward and need to be addressed in Execute phase are:

- Location of venting of pigging process; and
- Shore crossing method (HDD or open cut).

6.6. Design ALARP Demonstration Study (St Fergus)

The existing Mono Ethylene Glycol (MEG) facilities located within Shell's Goldeneye module at St Fergus Terminal are no longer in use. For PCCS it is proposed that the existing facilities will remain largely unchanged with modifications proposed to existing systems where required to meet design requirements for methanol use.

The purpose of the methanol design ALARP demonstration report is to:

- Demonstrate that there has been a systematic application of the Hazards and Effects Management Process (HEMP) through the various phases of the Project;
- Demonstrate that HSSE&SP has been integrated into Project decisions;
- Confirm that the lowest risk option has been selected, or alternatively demonstrate that the risks of the selected option are As Low As Reasonably Practicable (ALARP); and

- Demonstrate that the design solutions are reducing risk levels through the design, construction and operational phases (including decommissioning) to ALARP.

The main areas covered in the study include the following:

- Active fire protection of the storage tank and bund;
- Retaining full storage tank bund capacity; and
- Overpressure protection of the St Fergus to Goldeneye methanol pipeline.

No identified hazards were assessed to have high risk and/or high severity consequence. However, a leak of methanol with subsequent ignition at St Fergus is a recognised Major Accident since methanol is a named dangerous substance under the COMAH regulations.

The key St Fergus issues that are carried forward and need to be addressed in Execute phase are:

- Fire detector mapping will be required; and
- Any actions not closed as identified in the Action close-out report.

6.7. Design ALARP Demonstration Study (Offshore)

The Offshore ALARP scope includes modifications to the existing Goldeneye platform to allow the flow of dense phase CO_2 from the pipeline to the storage complex. Various modifications to topsides equipment and piping will take place to prepare the platform for CO_2 and methanol injection. Four out of the five suspended production wells will be re-completed for injection and reservoir monitoring. The subsea and methanol scopes provide the primary interfaces to the Offshore systems.

The key Offshore ALARP factors that influenced the design include the following:

- Operation of the Subsea Isolation Valve (SSIV);
- Pig receiver material;
- CO_2 gas detector type and configuration;
- Control panel location;
- Pipeline depressurisation tip location;
- Telecommunication configuration equipment choice and siting;
- Welfare provisions; and
- Methanol fire and explosion management.

New Major Accident Hazards (MAHs) have been identified and assessed in the FEED phase of the Project. These are associated with release of CO_2 from pipeline/riser, topsides and wells; and methanol releases.

The key Offshore HSSE&SP issues that are carried forward and need to be addressed in the Execute phase are:

- Procedure to highlight the use of Very Small Aperture Terminal (VSAT) during well interventions;

- Detailed layouts for CO_2 detection end elements;
- Resolution of low temperature escalations to vulnerable equipment and hydraulic lines;
- Updates to emergency response planning, procedure, training etc. for CO_2 will be required;
- Finalise well design, including trip settings, Subsurface Safety Valve (SSSV) design and hydraulic fluid type; and
- The pig receiver design included in the Basic Design and Engineering Package (BDEP) [6] and the conclusions of the fracture mechanics report need to be aligned (as the design included in the BDEP preceded the detailed conclusions from the fracture mechanics report).

7. Health Plans

7.1. Introduction

The PCCS Health Management Plan has been produced to facilitate the management of health deliverables for the PCCS Project. It is based upon Shell's standard Health Management Plan approach and has been modified to reflect the occupational health elements of the PCCS Project.

This document is:

- Based on an approach that includes all potential health deliverables as per the Shell's HSSE&SP Management System;
- Developed specifically for the PCCS Project and covers the full CO_2 chain (i.e. Onshore Carbon Capture, Compression and Conditioning; Offshore Transport and Subsea and Subsurface Storage);
- Developed to consider foreseeable health risks to individuals working on the PCCS Project; and
- Developed to support the Project in complying with HSSE related legislation and regulations.

The Shell plan does not specifically cover SSE's Onshore PPS scope. This is subject to a separate plan which has been developed by SSE. However, any health risks identified from the ongoing Onshore SSE operations that are a risk to individuals undertaking work on behalf of the PCCS Project have been assessed, mitigated and controlled as part of the Shell plan.

7.2. Objectives

The objectives of the PCCS Health Management Plan are to:

- Systematically identify, assess and control health risks at all stages of the Project lifecycle;
- Establish fitness to work evaluations and apply these where there are significant health or safety risks;
- Establish policies and programmes covering the use of alcohol and drugs as appropriate;
- Provide access to medical services that take account of the risks associated with the type and location of work; and
- Ensure that the principles of Human Factors Engineering are applied during the design phase of the Project.

7.3. Summary

The deliverables that have been identified as required by the Health Management Plan for the PCCS Project in the FEED phase are detailed below along with a summary of the identified actions to manage the risk.

7.3.1. Human Factors Engineering

General advice on assessing risks to health arising from Human Factors in the workplace is included in the Human Factors Engineering Section of the Shell HSSE&SP Management System. A Human Factors Engineering (HFE) Co-ordinator has been nominated for the PCCS Project. During FEED, individual HFE Co-ordinators were appointed for each of the elements and they were responsible for delivery of this role with support from Shell's UK Human Factors Engineer and Regional Human Factors Engineer.

7.3.2. Occupational Health & Hygiene

Health Standards were adopted and implemented by the PCCS Project covering, as appropriate, chemical, physical, ergonomic and biological health hazards. The Project complied with requirements set out in Shell's HSSE&SP Management System and also relevant local, national and international standards.

A Health Impact Assessment was undertaken as part of the Health Plan in accordance with Shell's Impact Assessment (IA) methodology in accordance with Shell's HSSE&SP Management System. The results of this impact assessment are reported in the Onshore and Offshore Environmental Statement documents which have been published for the PCCS Project.

7.3.3. Health Risk Assessment

A Health Risk Assessment (HRA) has been carried out to assist with the identification of occupational health hazards and to control exposure from an activity or process during all stages of the Project. Identified relevant standards were adopted and implemented covering; chemical, physical, ergonomic and biological health hazards as appropriate to make these ALARP.

7.3.4. Chemical Hazards

The elimination or substitution of hazardous substances, as well as minimisation of exposure to chemicals by the use of closed systems and engineering controls was adhered to in the design, as far as deemed technically achievable and practical.

Usage of highly toxic and hazardous substances, in particular carcinogens, mutagens and substances toxic to reproduction, was avoided by using less hazardous material where practical and technically achievable.

7.3.5. Hazardous Bacteria

The HRA for the PCCS Project included a review of the potential for the creation of hazardous bacteria that may occur as part of the process. The review focussed on the dense phase compression system and absorber tower, as the key area where it was identified that bacteria could occur, although the review was not limited to these elements of the process. This was primarily done using Shell's internal guidance on water management as included in the Shell HSSE&SP Management System.

7.3.6. Noise

Noise Assessments were carried out for the Onshore and Offshore elements of the PCCS Project during FEED. The results of these assessments were utilised in the developed FEED design with the

aim of preventing noise induced hearing loss once the dense phase compression system and Offshore equipment are in the operational phase.

It is a Project requirement that worker exposure to noise shall as a minimum meet the standards and procedures adopted in the UK Health and Safety Executive, Control of Noise at Work Regulations 2005 (CoNAWR 2005).

The Project also made reference to Shell's internal guidance on the control of noise as included in the Shell HSSE&SP Management System.

7.3.7. Catering and Food Hygiene

During the Execute phase, the PCCS Project will require the construction of temporary offices and construction support facilities. A residential camp is not foreseen as a requirement. Local established offsite accommodation is proposed for the accommodation of the workforce of up to 600 individuals at any one time. A walk-to-work vessel shall be utilised when the offshore construction work is taking place.

All locations shall be managed in accordance with the Shell's HSSE&SP Management System.

7.3.8. Medical Emergency Response and Treatment Facilities

The PCCS Project medical emergency response procedures and treatment facilities shall be provided as follows in order of increasing severity:

Onshore

- Initial response will be provided from onsite first aiders who shall be part of the PCCS Construction Contractor personnel;
- Minor injuries - local medical facilities in Peterhead Medical Centre (Links Terrace, Peterhead, Aberdeenshire AB42 2XA - 01779 474841);
- Emergencies 999 – transportation by ambulance or helicopter dependent on severity of injury to Aberdeen Royal Infirmary, (Foresterhill Road, Aberdeen AB25 2ZN 0845 456 6000);

Offshore

- As per the current Goldeneye Medical Emergency Response (MER); and
- As per the contracted Vessel MER where vessels are outside the 500 m zone of the platform.

During Execute, a Medical Emergency Response strategy shall be developed in accordance with the requirements of Shell's HSSE&SP Management System.

8. Hazard and Effects Registers

8.1. Introduction

The HSSE&SP Hazards and Effects Register has been developed to list the Project's hazards, and how they will be managed.

The registers are split into categories, each representing a specific area. These are:

- Onshore, covering the Peterhead Power Station and the Carbon Capture and Compression Plant;

- Subsea, covering the onshore pipeline, shore crossing, new pipeline from Peterhead to tie-in point, and pipeline to Goldeneye platform; and
- The Goldeneye platform.

8.2. Objectives

The objectives of the HSSE&SP Hazards and Effects Register are as follows:

- Identify and describe the scenarios leading to possible incidents which could potentially occur as a result of this hazard;
- Describe the potential effects (consequences) of those scenarios;
- Describe the control and recovery measures that are provided for managing the risks; and
- Provide an assessment of the residual risk (using the Risk Assessment Matrix).

8.3. Summary

A comprehensive Hazards and Effects Register was developed for each area of the FEED covering the above objectives. The registers identify the hazards and possible scenarios for occurrence; describe the potential consequences, before describing the control and recovery measures for managing risk, and assessing the residual risk against set criteria in a Risk Assessment Matrix.

The assessment in the risk matrix allowed the appropriate hazards to be taken forward into the ALARP Demonstration Report (discussed in greater detail under Section 6).

9. HAZID and HAZOP Close-Out Reports

9.1. Introduction

HAZID is an identification of hazards or potential causes of harm to people, damage to property, or loss of Company reputation, with the aim of planning safeguards, control and mitigation measures, and recommending actions towards risk mitigation if the current Project proposed control measures are not deemed to be sufficient to control the hazard.

HAZOP is an analysis of a planned or existing process or operation using a structured, formal, systematic examination of the process and engineering intentions, in order to identify and evaluate hazards and problems that represent risks to personnel or equipment.

Separate HAZIDs and HAZOPs were conducted, over multiple sessions at different times during Front End Engineering Design (FEED), due to the fact that the drawings required (Process Flow Diagrams (PFDs), and Piping and Instrumentation Diagrams (P&IDs)) were produced according to each FEED scope requirement and thus were ready for review at different times. Also, there were differing requirements for personnel to attend to ensure that suitable expertise was present. In order to ensure that the interfaces between the Onshore and Offshore designs are suitably managed, some individuals from each team attended multiple sessions.

Each of the main reports covered a specific scope. These are:

- Onshore - Power Station Modifications;
- Onshore - Carbon Capture and Compression Plant;
- Subsea - CO_2 pipeline from downstream of the compressor to Goldeneye platform;

- St Fergus - Methanol scope located at St Fergus, including the methanol pipeline; and
- Offshore - Goldeneye offshore platform.

9.2. Objectives

The purpose of the HAZID study was to:

- Identify all potential causes of: harm to people, damage to property, or loss of Company reputation resulting from the Peterhead CCS Project;
- Record safeguards, control and mitigation measures which are planned to be in place for each HSE hazard; and
- Recommend suitable actions towards risk mitigation if the current Project proposed control measures are not deemed to be sufficient to control the hazard.

As part of the HAZID, a qualitative risk assessment was undertaken using the SHELL Risk Matrix to consider all aspects of the additional facilities on the existing SSE facilities during their construction, commissioning and operational phases.
The HAZOP Study sought to identify potential safety and operability problems within the design of the plant as represented on the Process and Instrumentation Diagrams (P&IDs) and/or other design documents and made recommendations for appropriate corrective actions.
These recommendations are targeted to achieve a reduction in the overall risk to people, the environment, the assets and Company reputation or operating cost/complexity.

9.3. Summary

In the HAZID, hundreds of items were recorded and from these numerous recommendations were raised in relation to improvements in the management of hazards or to improve the understanding of the risk during the design.

The following sections summarise the HAZOP reviews:

9.3.1. Onshore Power Station

A total of 29 process nodes were reviewed and 415 actions recorded in relation to improvements in the management of hazards or to improve understanding of the risk during the design.

9.3.2. Onshore Carbon Capture and Compression Plant

A total of 44 process nodes were reviewed and 594 actions recorded in relation to improvements; in the management of hazards or understanding of the risk during the design.

9.3.3. Subsea

A total of three process nodes were reviewed and 35 actions recorded in relation to improvements; in the management of hazards or understanding of the risk during the design.

9.3.4. St Fergus

A total of three process nodes were reviewed and 28 actions recorded in relation to improvements; in the management of hazards or understanding of the risk during the design.

9.3.5. Offshore

A total of seven process nodes were reviewed and 75 actions recorded in relation to improvements; in the management of hazards or understanding of the risk during the design.

10. Construction HSSE Readiness Review Report

10.1. Introduction

The Construction HSSE Readiness Review report provides an overview of the HSSE management processes for the entire CCS chain that will need to be implemented at the various stages of the Project.

10.2. Objectives

The objective of the Construction HSSE Readiness Review report provided an independent method for assessment of construction contractors before sanction of any major construction contract award, based upon assessment of the Project requirements. The following elements are outlined below:

- Selected processes within Shell's HSSE&SP Management Systems that will be implemented within Peterhead CCS Project to achieve Construction HSSE readiness up to execution (pre-mobilisation);
- Scope and Terms of Reference for Construction Readiness Review;
- Contractor HSSE Management;
- Asset Integrity and Process Safety;
- Worksite Hazard Management;
- Fitness to Work;
- Emergency Response;
- Land Transport; and
- Journey Management.

10.3. Summary

A series of processes has been identified by the Shell Safety Roadmap in order to make an appropriate assessment of potential construction contractor. These are as follows:

- Pre-award Contractor Engagement;
- Kick-off Leadership Engagement Workshop and Project Leadership;
- Care for People Strategy;
- HSSE Organisation Roles and Responsibilities;
- HSSE Training Matrix;
- Construction Safety Master Class;
- Contractor HSSE Performance Reviews and Contract Holder Engagement;
- Construction Site Layout Review;
- Traffic Management Plan; and
- Construction HSSE Readiness Review.

11. Construction Contractors HSSE Management Plan

11.1. Introduction

The Construction Contractors' HSSE Management Plan has been developed to outline specific management plans and/or execution premises for specific focus areas in order to mitigate identified risks. Based on the focus areas and the planned execution premise, it provides an indicative construction execution organisation for the Execute Project phase and identifies opportunities in simplifying the construction execution model where applicable.

11.2. Objectives

The plan was intended to provide an overview of construction management execution strategy and/or philosophy on key construction and HSSE focus areas during the Execute phase up to the handover to the commissioning team(s). The construction management and HSSE focus areas are areas specific to the Project that cannot be managed by normal risk management processes and construction HSSE procedures.

11.3. Summary

Assessment on the construction management areas (including HSSE aspects) for the overall Peterhead CCS Project indicate that the key focus areas are associated scope executed at the Peterhead Power station site namely:

- The modifications to PPS;
- Carbon Capture, Compression and Conditioning Plant; and
- The HDD/offshore pipeline landfall scope.

The complexities in the construction management at this area arise from the number of execution parties and contractors likely to be involved, and consequently the execution governance required within the same area and with overlapping execution schedules.

In addition to the specific management plans to address the various construction management areas, specific opportunities have been identified to enable simpler and safer construction execution within this area – focusing on execution governance:

1. Simplification of the number of execution parties active on-site at PPS at any one time; and
2. Simplification in the number of execution contractors active on-site at PPS at any one time.

If simplification cannot be achieved in either of these areas then simplification will be sought across the lower-tier contractors such as civil, scaffolding, and welfare.

To align and accelerate the early part of the execute schedule, the use of common early works and/or demolition contractors will be considered.

12. Environmental Impact Assessment reports

12.1. Introduction

Separate Environmental Impact Assessments have been carried out for the Onshore and Offshore elements of the PCCS Project and have been published in the public domain titled Onshore and Offshore Environmental Statements [1].

13. COMAH Review

13.1. Introduction

The COMAH regulations aim to limit the consequences of a major accident to people, local communities and the environment and are based on the quantities of what are termed 'dangerous substances' stored or in use on site or potentially generated during an accident event. The substances are either specifically named substances or categories of substances. A comparison of the threshold quantities specified in the Regulations and the quantities associated with the proposed activities on-site determines whether COMAH applies. Sites falling under COMAH regulations are classified as "lower" or "upper" tier dependent upon the quantities of designated 'dangerous substances' which are stored and used on a specific site, upper-tier being the more onerous with additional responsibilities and requirements for Operators.

13.2. Objectives

The objective of FEED COMAH review was to identify the maximum inventory of the chemicals used in the existing Peterhead Power Station site and proposed Carbon Capture, Compression and Conditioning plant. The chemical inventories were then compared against the COMAH specified thresholds to determine whether the site falls within the scope of current recently published COMAH 2015 Regulations. The new regulatory requirements under COMAH 2015 were also reviewed and their implications for the Project considered.

13.3. Summary

PPS does not presently qualify as a COMAH site (under any tier definition) under the COMAH 2015 Regulations. Following the modifications that would be required for it to be ready for operation to supply the CCS plant, it is considered that the status of PPS would not be changed. This is because of the limited change to the site aggregate scoring that results from the modified diesel and natural gas inventories of the new auxiliary boiler house and the new vanadium pentoxide catalyst required for the Selective Catalytic Reduction (SCR) unit.

Based on the consultation document on the COMAH Regulations 2015, the CCCC plant when operational, would qualify as an upper-tier COMAH site because it is anticipated that the combined amount of process chemicals in the Thermal Reclaimer waste product will be in excess of 5% by weight and more than two tonnes of inventory at any one time. The COMAH review concluded that the proposed CCCC plant would be the sole reason for the COMAH Regulations applying to the Project. This will be taken into account in determining how the existing and proposed PPS facilities will be treated – i.e. whether they will be a combined establishment with a single operator or two separate plants with separate operators.

Additionally, according to current interpretation of application of the COMAH Regulations, the fresh and circulating amine inventories were classed as dangerous substances under the 1999 Regulations but not under the recent 2015 Regulations. There is therefore uncertainty over the classification of these substances and tests were ongoing at the time of production of this document to analyse the likely impact of released amine – for example with regard to marine life. Until firm clarification on the proposed 2015 Regulations is available, the fresh and circulating amine inventories are being considered in accordance with the 1999 COMAH regulations as good practice and are being considered as having Major Accident Hazard potential.

In a similar vein, whilst CO_2 is not classified a dangerous substance under either issue of the COMAH Regulations it does have major accident hazard potential for personnel working on site, either inside the compressor house or in the vicinity of the dense phase pipework and pipeline. CO_2 has therefore also been included within the MAH list for the facilities.

14. CO_2 Vent Dispersion Modelling Reports

14.1. Introduction

CO_2 vent dispersion modelling studies performed for the relief and vent systems on the Onshore and Offshore facilities of the PCCS Chain considered normal operating conditions with particular focus given to venting of dense and gaseous phase CO_2. The results of the performed studies are detailed more fully in the Relief and Vent Study Report (Key Knowledge Deliverable 11.037) [7].

14.2. Objectives

The purpose of the dispersion studies was to analyse the dispersion of CO_2 from vents given a range of operating pressures and temperatures, vent sizes and vent stack heights. The information obtained from the dispersion studies was used to assist in the definition of vent requirements and to provide input into various safety assessment studies. Two dispersion modelling studies were carried out, one focusing on the depressurisation scenarios for the onshore CO_2 systems, and the other considering offshore depressurisation scenarios.

14.3. Summary

The Relief and Vent Study Report encompasses the design of the relief and vent systems for the entire PCCS chain. It covers the main features of the design of the relief and vent systems on the Onshore and Offshore facilities of the PCCS Chain for venting of dense and gaseous phase CO_2. Relief design has also been undertaken for the 'business as usual' aspects of the Project – such as for steam and fuel gas systems. Such aspects are not the main focus of the report but were considered within the overall document scope.

The Relief and Vent Study Report only covers controlled venting of CO_2 under normal operational conditions. Emergency venting of CO_2 is not part of the Project operation philosophy. Non-operational release of CO_2 (i.e. accidental events) is detailed separately in the Project Onshore and Offshore Environmental Statements which have been published in the public domain. As CO_2 is not flammable, there is little risk of a fire starting as a result of release, and therefore no flare system is required for the CO_2 system.

The primary PCCS CO_2 vent locations are:

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

Both the Onshore and Offshore dispersion modelling work was performed using the proprietary Process Hazard Analysis Software Tool (PHAST [1]software). The information obtained from the dispersion studies has been used to assist in the definition of vent requirements and to provide input into various safety assessment studies. Workplace Exposure Limits (WELs) have been applied in consideration of both Onshore and Offshore locations in accordance with the UK Health and Safety Executive (HSE) guidelines.

For the Onshore scope the results of the dispersion modelling study confirm that vents directed vertically will have a negligible impact. This is because the momentum of the vertically vented CO_2 will entrain air such that rapid mixing and dispersion will occur. Little or no slumping back to the ground is predicted to occur provided that there is some air movement – giving rise to predicted CO_2 concentration levels which are lower than the eight hour HSE exposure limit. Operational restrictions are proposed to prevent venting of CO_2 on completely still days when the vented CO_2 could potentially slump to ground. Onshore CO_2 venting takes place via the existing 170m stack or a new compression plant stack. Therefore, the risk to persons (on or off site), buildings or structures is considered to be minimal and can be controlled under normal site operations. Other proposed mitigation measures include installation of CO_2 detection at the Peterhead Power Station site and use of personal CO_2 detectors for site staff once the carbon capture plant is operational. These measures will be reviewed further and finalised during Detailed Design.

Dispersion modelling has also been carried out for the Offshore scope. Although the Goldeneye platform is a Normally Unmanned Installation (NUI) the modelled venting scenarios also apply the WELs provided in the HSE guidelines. As for the Onshore dispersion studies, it was found that operational venting from vent tower or underdeck thermal relief have a negligible potential impact on personnel on the platform or vessels that may be in the vicinity.

[1] Proprietary Software from DNV-GL, for use in Process Hazard Analysis.

15. Glossary of Terms

Term	Definition
AIPSM	Asset Integrity / Process Safety Management
ALARP	As Low As Reasonably Practicable
BDEP	Basic Design and Engineering Package (Key Knowledge Deliverable 11.003)
CCCC	Carbon Capture Conditioning and Compression
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CDM	Construction Design and Management
CDM-C	Construction Design and Management Coordinator
CO_2	Carbon dioxide
COMAH	Control Of Major Accident Hazard (Regulations)
CoNAWR	Control of Noise at Work Regulations
COSHH	Control of Substances Hazardous to Health
CPNI	Centre for the Protection of National Infrastructure
DCAF	Discipline Controls and Assurance Framework
EIA	Environmental Impact Assessment
ES	Environmental Statements
ESDV	Emergency Shut-Down Valve
FEED	Front End Engineering Design
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HEMP	Hazards and Effects Management Process
HFE	Human Factors Engineering
HS&E	Health, Safety and Environment
HSE	Health and Safety Executive
HSSE	Health, Safety, Security, Environment
HSSE&SP	Health, Safety, Security, Environment & Social Performance
KKD	Key Knowledge Deliverable
MAH	Major Accident Hazards
MEG	Mono Ethylene Glycol
MER	Medical Emergency Response
NUI	Normally Unmanned Installation
OHH	Occupational Health & Hygiene

ORP	Opportunity Realisation Process
OS	Operational Safety
PFDs	Process Flow Diagrams
PHAST	Process Hazard Analysis Software Tool
P&IDs	Piping and Instrumentation Diagram
PCCS	Peterhead Carbon Capture and Storage
PPS	Peterhead Power Station
Project	The Peterhead Carbon Capture and Storage Project
PSR	Pipelines Safety Regulations
SCEs	Safety Critical Elements
SCR	Selective Catalytic Reduction
SEPA	Scottish Environmental Protection Agency
SIA	Social Impact Assessment
SSE	SSE Generation Limited
SSIV	Sub-Surface Isolation Valve
SSSV	Sub-Surface Safety Valve
TS	Technical Safety
VSAT	Very Small Aperture Terminal (Satellite Communications System).
WEL	Workplace Exposure Limits
WGK	Wood Group Kenny

16. References

[1] Shell, Environmental Impact Assessment (Onshore and Offshore) available from, http://www.shell.co.uk/energy-and-innovation/the-energy-future/peterhead-ccs-project.html (Accessed 08/06/2015).

[2] Health and Safety Executive, EH40/2005 Workplace exposure limits, available from http://www.hse.gov.uk/pubns/books/eh40.htm (Accessed 29/05/2015).

[3] Health and Safety Executive, Assessment of the major hazard potential of carbon dioxide (CO_2), available from http://www.hse.gov.uk/carboncapture/assets/docs/major-hazard-potential-carbon-dioxide.pdf (Accessed 29/05/2015).

[4] Shell, Stakeholder Engagement Plan (Key Knowledge Deliverable 11.063)

[5] Shell, Risk Management Plan and Risk Register (Key Knowledge Deliverable 11.023), 2015.

[6] Shell, Basic Design and Engineering Package (Key Knowledge Deliverable 11.003), 2015.

[7] Shell, Relief and Vent Study Report (Key Knowledge Deliverable 11.037), 2015.

