THE GOLDENEYE MMV PLAN
FOR THE PETERHEAD CCS PROJECT
RISK-BASED MONITORING FOR A
DEMONSTRATION PROJECT

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Open Forum

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Peterhead CCS Project & Goldeneye Storage Complex
Project and storage complex overview

Risk-Based Measurement, Monitoring and Verification (MMV) Plan
Objectives (Ensure Conformance and Containment)
Identified Threats and Evaluation
Bowtie Method, the Goldeneye Bowtie
Base Case Monitoring, Contingency, Corrective Measures and Post Closure Plans

Front End Engineering Design (FEED) Phase & the MMV Plan
Challenges/Risks: costs, operational constraints, data management
Opportunities: emerging technologies (4D DAS VSP)

Summary
1.0

PETERHEAD CCS PROJECT
GOLDENEYE STORAGE COMPLEX
OVERVIEW
PETERHEAD CCS PROJECT

- **World First** – first full-scale CCS project on a gas-based power station
- **Where** – capture at Peterhead Power Station; storage in depleted Goldeneye gas reservoir (100km offshore North Sea, at a depth of more than 2km)
- **Impact** – At least 10 million tonnes of CO$_2$ emissions captured over ten years
- **Funding** – UK Government support for both capital & operating expenses
- **Technology** – post-combustion capture using amines
- **Status** – February 24, 2014 Shell and UK Government signed agreement allowing project to enter the Front-End Engineering Design (FEED) phase which is expected to last until 2015
**GOLDFENEYE STORAGE SITE & COMPLEX**

- **Storage site (green):** Volume area within a geological formation used for the geological storage of CO\textsubscript{2} and associated surface and injection facilities. 
  - Vertically bounded by storage seal.

- **Storage complex (purple):** Storage site and surrounding geological domain, which can have an effect on overall storage integrity and security, i.e.
  - Vertically bounded by complex seal formations.
**GOLDENEYE STORAGE SITE & WELLS**

- **Storage Site** – Includes the reservoir within the Captain Sandstone Member and rocks down to the base of the Cromer Knoll Group.

- **Closure** – Structural dip closure is provided to the east, west and south with pinchout of the Captain reservoir sands to the north.

- **Goldeneye Wells** – Of the five development wells, three are planned to be converted as injector wells, one will function as a monitoring well and one will be abandoned.

- **Abandoned Wells** – E&A have been assessed for the presence of effective barriers.

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**Top Reservoir** – Depth Map showing the Goldeneye Storage Site, fluid contacts and wells.
2.0
THE GOLDENEYE MEASUREMENT,
MONITORING & VERIFICATION (MMV)
PLAN
OBJECTIVES, RISK ASSESSMENT, BASE PLAN,
CONTINGENCY PLAN & CORRECTIVE MEASURES
MMV PLAN OBJECTIVES

■ ENSURE CONTAINMENT
  ■ demonstrate effective and secure CO₂ storage
  ■ containment risks affect project license to inject

■ ENSURE CONFORMANCE
  ■ demonstrate actual storage performance is consistent with expectations about injectivity, capacity and CO₂ behavior inside the storage complex
  ■ provide support for transfer of liabilities

■ VERIFY SAFEGUARDS
  ■ Verifying the expected effectiveness of existing safeguards created by site selection, site characterization and engineering designs
  ■ Creating additional safeguards using monitoring systems to provide

The Monitoring Plan covers all phases and domains of the CO₂ storage operation
- **Top Event**: CO$_2$ leaving the storage complex
- **Threats**: mechanisms (migration paths) that lead to top event; identify potential leak paths
- **Consequences**: adverse effects to environment, people and reputation
- **Preventative Safeguards**: these decrease the likelihood of a threat leading to the top event
- **Corrective Safeguards**: these decrease the likelihood of significant consequences after top event
Acidic fluids
Faults, fractures & features
Stress of injection
Diffusion
Lateral migration

1

Sub-surface release of CO$_2$

CO$_2$ released from complex

2

Sub-surface release of CO$_2$

3

CO$_2$ release at seabed

Abandoned wells
Injection wells

4

Sub-surface release of CO$_2$

5

CO$_2$ release at seabed

Abandoned wells
Injection wells

6

CO$_2$ release at seabed

Abandoned wells
Injection wells

7

CO$_2$ release at platform
**Example Hazard and Barriers** – Extract from bowtie analysis illustrating preventive safeguards

- **AW-01 Flow up abandoned exploration and appraisal (E&A) wellbores to near surface**
  - B-PP Four of the wells in Goldeneye field are in contact with Captain reservoir and have good plug(s) across the primary seal. Fifth well is on the border and does not see Captain. It too has plug(s) across the primary seal.
  - Koster
  - Engineered
  - Drilling Reports
  - End of Well Reports
  - Cement Reports

- **B-ASP! Additional shallower plugs (well-specific)**
  - Koster
  - Engineered
  - Dynamic Modelling Report

- **B-SH Sub-hydrostatic**
  - Tucker
  - Natural
  - Pressure Data (Downhole Gauges)

- **B-SS Squeezing shales**
  - Davison
  - Natural

- **B-BS Baseline survey**
  - Susanto/Dean
  - Detect

- **B-MF Monitoring for CO2 plumes**
  - Susanto/Dean
  - Detect

- **Flow could occur even when sub hydrostatic if there is a small gas leak at the top of an abandoned well bore and a large gas leak at the bottom**
  - Susanto/Dean
  - Correct
  - MMV

- **B-MI Monitoring and intervention**

- Release outside complex (subsurface) - well-related threats
# BASE CASE MONITORING PLAN

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<th>Pre-Injection</th>
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<td><strong>ROV gas leak (bubble) detection under the platform</strong></td>
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<td><strong>Seabed surveys (MBES/SSS)</strong></td>
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- **Start of injection**
- **Mid-injection**
- **1 Year post-injection**
CONTINGENCY, CORRECTIVE MEASURES & POST CLOSURE PLANS

- **Contingency Plan**
  - Provides necessary information for corrective measures in case of suspected irregularities

- **Post Closure Plan**
  - Includes two post-injection seismic surveys: (~1 and ~6 years post injection) to confirm absence of any irregularities and conformance to dynamic models
  - First post-injection survey after store has seen highest injection pressures and plume has largest footprint

- **Corrective Measures Plan**
  - Informed and triggered by contingency monitoring, risk assessment, and regulatory engagement

Modelled distribution of CO₂ at the end of injection.
3.0 FRONT END ENGINEERING DESIGN (FEED) PHASE & THE MMV PLAN
SUMMARY
FRONT END ENGINEERING DESIGN (FEED) PHASE AND THE MMV PLAN

Besides technology feasibility assessments and cost/benefit analysis, during FEED, additional considerations require attention:

- **Costs**
  - 4D surface seismic is the preferred technology (balance frequency of repeats with high costs). Alternatives?
  - Need monitoring technologies that are operationally feasible and automated

- **Operational constraints**
  - Unmanned platform with limited space: rack space for Fiber Optics (FO) interrogator boxes, access to monitoring data
  - Power requirements on platform, battery life, biofouling, trawling activities

- **Data management**
  - Large volumes of data from FO monitoring (DAS, DAS VSP, DAS microseismic), bandwidth requirements and potential latency issues
Emerging technologies offer potential low-cost containment monitoring solutions

- Opportunities
  - Multi-well DAS VSP can provide high fold image of ~2km² around wells at reservoir level and ~0.5Km² at the level of secondary storage
  - Should CO₂ leak vertically out of Captain, a 4D DAS VSP is expected to resolve 4D anomalies as the CO₂ enters secondary storage
  - Ability to monitor if CO₂ leaks out of abandoned wells in image area
  - Early deployment: requires field trial
SUMMARY

Monitoring for the Goldeneye Storage Complex

- **Risk-based** MMV plan according to identified and assessed threats using the Bowtie Method (key technology: 4D seismic)

- **Regulatory compliant** covering all phases and domains of CO₂ storage operation to demonstrate the absence of any irregularities and conformance

- **Diversified monitoring technologies complement** each other in space and time to reduce uncertainties and reduce risks to acceptable levels

- **Contingency and Corrective Measures** to identify the source/cause of any irregularities, assess likely evolution and then plan remediation in consultation with the regulatory authorities

- **Post Closure Plan** in support of handover to confirm absence of any irregularities and conformance to dynamic models

- **FEED Phase Challenges** on MMV plan such as operational constraints, costs, data management, etc.