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SHELL EXPERIENCE BASE - LARGE SCALE CCS PROJECTS

- Quest
- Peterhead
- Gorgon
- Mongstad

- Barendrecht
- Draugen
- Dubai
- Zerogen
- Monash
- Longannet

Industrial scale projects operating
Industrial scale projects under construction
Industrial scale projects planned
Industrial scale projects stopped
GOING FORWARD – COMPLEXITY WILL INCREASE

**Capture**
- Company ‘A’

**Transport**
- Company ‘A’
- Company ‘A’
- Company ‘A’

**Storage**
- Company ‘A’
- Company ‘A’
- Company ‘A’

**Simple**
- ‘A’
- ‘B’
- ‘C’
- ‘D’

**Complex**
- ‘A’
- ‘B’
- ‘C’
- ‘D’
- ‘E’
- ‘F’
- ‘G’
RISK ANALYSIS: MUST CROSS THE FULL PROJECT LIFECYCLE

Pre-Injection
- Site Selection
- Characterisation & Baseline data collection

Injection
- Monitor to Verify Site Performance

Closure
- Monitor to Inform Site Closure Process

Post-Closure
- Minor Project Monitoring May Be Needed

Illustration: Benson 2007 WRI Presentation
CCS SEQUESTRATION WORKFLOW

Communication and Consultation
Company, Government, Regulator, Landowners ....

Site Characterisation
- Evaluate Storage Feasibility
- Select Storage Site
- Evaluate Site-Specific Storage Risks
- Characterise Geological Safeguards
- Select Engineered Safeguards
- Evaluate these Initial Safeguards
- Storage Risks Suitable?

MMV Plan
- Establish Monitoring Requirements
- Select Monitoring Plans
- Establish Performance Targets
- Identify Contingency Monitoring
- Identify Control Measures
- Evaluate these Additional Safeguards
- Storage Risks Acceptable?

Performance Review & Site Closure
- Evaluate Monitoring Performance
- Monitoring Performance Acceptable?
- Adapt Monitoring Plans
- Evaluate Storage Performance
- Storage Performance Acceptable?
- Implement Control Measures
- Site Closure

Performace Review & Site Closure
- yes
- no
- final yes
- continue
- yes
- no
- final yes
- continue
- no
- yes
Many independent containment safeguards in-place

Legend
- Passive safeguards; these are always present
- Active safeguards; these are only present when a decision to intervene is made triggered by monitoring information

Numbers
- Preventative safeguards: 34
- Corrective safeguards: 31

Migration along a legacy well
- Migration of CO2 or brine above the Upper Lotsberg Salt

Migration along a MMV well
- Hydrocarbon resources impacted

Migration along an injector
- Soil impacted

Migration along a matrix pathway

Migration along a fault pathway

Induced stress re-activates a fault

Induced stress opens fractures

Acidic fluids erode geological seals

Migration due to 3rd party activities

Numbers
- Preventative safeguards: 34
- Corrective safeguards: 31
Based on collective expert judgement
Informed by appraisal data and feasibility studies

<table>
<thead>
<tr>
<th>Risk Metric</th>
<th>Number of Safeguards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive safeguards</td>
<td>1 in 10⁴ per year</td>
</tr>
<tr>
<td>Active safeguards</td>
<td>1 in 10⁶ per year</td>
</tr>
</tbody>
</table>

- Unacceptable
- Tolerable
- Broadly Acceptable
MMV CONTRIBUTES TO RISK ACCEPTANCE

- Based on collective expert judgement
- Informed by appraisal data and feasibility studies

![Graph showing risk acceptance with passive and active safeguards.]

- Unacceptable: 1 in 10^4 per year
- Tolerable: 1 in 10^6 per year
- Broadly Acceptable
• Commercial operators can not bear unlimited liabilities
  • EU legislation proposes that operator will have to compensate for any leakage by providing emissions allowances, this could result in unlimited liabilities for operators.
  • There are uncertainties such as available technology/costs long term, scope of financial contribution for MMV at handover to government etc.
  ⇒ Solutions include capping the emissions allowance repurchase price at level agreed pre injection and agreement on MMV costs

• Commercial Operators can not bear indefinite liabilities:
  Recent legislation in some countries/areas of the world have planned a handover of storage liabilities to local authorities at some points, however:
  ⇒ Transfer needs to be effective / clear cut (cf. EU ambiguities).
  ⇒ Criteria for transfer need to be pre-agreed & achievable (“stable condition”).
Risk & Uncertainty needs to be addressed at every phase of the project.

Different stakeholders will focus on different risk elements:

- **Landowners** – HSSE, Containment
- **Government, Regulator** – HSSE, Containment, Capacity and long term liability
- **Proponent** – HSSE, Containment, Capacity, Injectivity, Financial, Long Term liability

An Industrial Scale Integrated project needs to address them all:

- **Site Selection** – Reduction/elimination/isolation from risk
- **Site Characterisation** – Reduction in uncertainty and remaining risk
- **MMV** – Risk monitoring and mitigation
- **Site Closure** – Risk Transfer