IEAGHG Study Programme Update

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NACAP Workshop
Morgantown 5th – 6th April 2011
Content of Presentation

• Current Studies
  • Global Storage Resource Gap Analysis for Policy Makers
  • Potential Impacts on Groundwater Resources of CO$_2$ Storage

• Future Studies
  • Brine Abstraction
  • Subsurface Resource Interaction with CO$_2$ Geological Storage Technical Review

• Storage in Basalts
Storage Gap Analysis Study

- Study undertaken by Geogreen, and funded by GCCSI, draft report received, currently out to expert review.
- Primary objective - Alert policymakers to the scale, cost and timing of the storage resource assessment, required to enable deployment of 20 commercial-scale CCS projects by 2020 envisaged by G8 Leaders, 2008 and the 100 projects by 2020 as envisaged in 2009 IEA CCS Roadmap.
Storage Gap Analysis

- Mapping Storage Suitability
  - IPCC Prospectivity map
  - World Geological Map
  - Data from world storage assessments
  - Exploration status map
  - Seismicity map
- Storage Projects database
  - Activity Status, project nature, Phase, scale, location
- Cost and time analysis
- Gap analysis to meet bankability targets
Suitability Map
Storage Projects to be assessed
# Bankability Workflow

<table>
<thead>
<tr>
<th>Type of study</th>
<th>Phase</th>
<th>Major costs items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non exclusive surveys</td>
<td>Phase 0 Screening</td>
<td>First desktop studies</td>
</tr>
<tr>
<td></td>
<td>Phase 1 Desk Based assessment</td>
<td>Desktop studies, where possible seismic reprocessing and existing wells logs analysis (including communication on project)</td>
</tr>
<tr>
<td>Licensing Exploration Permit</td>
<td></td>
<td>Administrative engineering and follow-up</td>
</tr>
<tr>
<td>Project based Exclusive surveys</td>
<td>Phase 2 Site confirmation &amp; characterization</td>
<td>Studies and engineering for this phase (including monitoring actions, equipments and monitoring (soil, gravimetric, InSAR))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seismic acquisitions 2D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seismic acquisitions 3D (on CO₂ future plume only)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Civil Engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drilling CO₂ well with rotary rig (including 20% contingency including Mob/demob)</td>
</tr>
<tr>
<td></td>
<td>Licensing Injection test</td>
<td>Injection test permitting</td>
</tr>
<tr>
<td></td>
<td>Phase 2 Injection Test</td>
<td>Studies and monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Injection test duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO₂ injection cost</td>
</tr>
</tbody>
</table>

Bankable
## Development Time for Major Steps of Storage Projects

<table>
<thead>
<tr>
<th>Phase</th>
<th>Deep Saline onshore</th>
<th>Deep Saline offshore</th>
<th>Depleted hydrocarbon field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 0 Site screening / First assessment</td>
<td>0,5 - 1</td>
<td>0,5 - 1</td>
<td>0,8 - 1,2</td>
</tr>
<tr>
<td>Phase 1 Desk Based assessment</td>
<td>0,5 - 1</td>
<td>0,5 - 1</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Licensing Exploration Permit</td>
<td>0,5 - 2</td>
<td>0,5 - 2</td>
<td>0 - 1</td>
</tr>
<tr>
<td>Phase 2 Site confirmation &amp; characterization</td>
<td>1 - 4</td>
<td>1 - 4</td>
<td>0,5 - 1,5</td>
</tr>
<tr>
<td>Licensing Injection test</td>
<td>0,5 - 1,5</td>
<td>0,5 - 1,5</td>
<td>0 - 1,5</td>
</tr>
<tr>
<td>Phase 2 Injection Test</td>
<td>0,5 - 2,5</td>
<td>0,5 - 2</td>
<td>0,5 - 2</td>
</tr>
<tr>
<td>Bankable</td>
<td>3,5 - 12</td>
<td>3,5 - 11,5</td>
<td>2,8 - 10,2</td>
</tr>
</tbody>
</table>
Highly suitable \(X=2\)
Suitable \(X=2\)
Possible \(X=3\)
Global Workflow

Phase 0 Screening
- Phase 1 Desk Based assessment
- Licensing Exploration Permit
- Phase 2 Site confirmation & characterization
- Licensing Injection test
- Phase 2 Injection Test

Typical storage development workflow

Storage suitability map
- Potential storage area

Storage bankability model
- Cost, development timing, failure potential

IEA blue map, 2020 objectives per region/global
G8 objectives

IEA blue map, 2050 objectives per region/global

Recommendation to policy makers in order to achieve the 2020 target

Recommendation to policy makers in order to achieve the 2050 target
Costs

- Cost models are considered for onshore and offshore storage options both in Deep Saline Formations and Depleted Oil and Gas Fields
- Take account of failed storage sites
- Numerous possibilities for each site to reach a successful path
- Cost models include an assessment of the economic uncertainties of project bankability
DFS European project cost

Total cost distribution for onshore bankability for an intensely explored area

The distributions includes estimated failure costs of data acquisition, wells...
Conclusions and Gap Analysis

- From existing projects – 20 bankable 2015-2017. 48 bankable close to 2020
  - Can reach G8 target but not IEA
- Additional source-sink matching using suitability map and source database – 98 bankable by 2025
  - But 50 new projects need to start before 2012
- Assuming no delays due to economic, regulatory or public acceptance reasons
Priority areas for assessment

Deep Saline Formations Capacity Assessment Initiatives
- Characterized
- Theoretical
- Under development

Priority area to launch first depleted fields/DSF assessments
Cost Per Region

- **865 MM€**
  - + 350 MM€
  - 21%
  - 20 projects
  - 21%

- **835 MM€**
  - + 300 MM€
  - 20%
  - 17 projects
  - 18%

- **730 MM€**
  - + 300 MM€
  - 17%
  - 21 projects
  - 22%

- **482 MM€**
  - + 200 MM€
  - 12%
  - 8 projects
  - 9%

- **1,278 MM€**
  - + 550 MM€
  - 30%
  - 28 projects
  - 30%

Legend:
- OECD Europe
- OECD Pacific
- OECD North America
- China & India
- Other Non OECD Countries
Potential Impacts on Groundwater Resources of CO$_2$ Storage

- Aim of study:
  - Review juxtaposition of storage and groundwater resources
  - Address potential impacts – Case studies and modelling review
  - Assess mitigation options
- Study undertaken by CO$_2$GeoNet
- Draft Received; Expert Review
Potential Conflicts

- GIS based approach
- WHYMAP – world hydrological mapping and assessment programme.
- Storage Maps
  - Geocapacity
  - NatCarb
  - Other less detailed maps e.g. China
Combining GEOCAPACITY data on DSF both (pink) with WHYMAP thematic layers representing large, uniform freshwater aquifers (blue).

Combining GEOCAPACITY data on DSF(pink) with WHYMAP thematic layers representing areas with complex hydrogeological structure (green).
Combining data on DSF from the Carbon Sequestration Atlas (pink) with WHYMAP thematic layer representing **large, uniform freshwater aquifers** (blue)

Combining data on DSF from the Carbon Sequestration Atlas (pink) with WHYMAP thematic layer representing areas with **complex hydrogeological structures** (green)
Typologies of potential impacts and conflicts

- Large and uniform freshwater aquifers overlying DSF;
- More complex hydrogeological structures where productive freshwater aquifers (including karst aquifers) may occur in close vicinity to non-aquiferous strata overlying DSF;
- DSF underlying areas with only local/shallow aquifers;
- Formations containing saline groundwater in the vicinity or overlying DSF;
- Over-exploited groundwater resources overlying DSF.
- Areas with no DSF suitable for CO₂ storage.
Future Studies

- Brine Abstraction
  - Literature review
  - Natural and industrial analogues
  - Case studies of regional prospects

- Resource Interaction
  - Literature review
  - Qualitative assessment of potential interactions and impacts using case-study sedimentary basins.
  - Provide policy makers, regulators and developers with a checklist of potential sub-surface resource interactions together with a preliminary explanation of possible impacts and management options
Geological Storage of CO$_2$ in Basalts

• Storage Mechanisms
  • Structural
    o Thick sequences of cyclical volcanic events
    o Brecciated flowtops – high permeability layers
  • Mineral Trapping
    o Permanent
    o Significant quantities of Fe, Mg, Ca, react with CO$_2$ to form carbonates
Lab experiments

- Effects of depth - vary pressure and temperature
- Increased depth → more carbonate precipitates
  - basalts less stable with increasing depth
- Shallower depths calcite is formed - Ca\textsuperscript{2+} is dominant; depth increases concentration of other cations (Fe\textsuperscript{2+}, Mg\textsuperscript{2+}, Mn\textsuperscript{2+}) increases - Indication of certain basalt components, such as pyroxenes becoming less stable
- Reactions with water rich supercritical CO\textsubscript{2} (scCO\textsubscript{2}) are less well understood as those with the aqueous solution,
  - Experiments show distinctly different products.
- Wet CO\textsubscript{2} experiments form smaller, but more abundant minerals, sometimes completely coating basalt surface.
- Further research is being carried out
Potential Storage Locations
## Storage Locations

<table>
<thead>
<tr>
<th>Large Igneous Province</th>
<th>Location</th>
<th>Area, km²</th>
<th>Volume, km³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbia River Basalt Group</td>
<td>Northwestern U.S.</td>
<td>200,000</td>
<td>224,000</td>
</tr>
<tr>
<td>Deccan Traps</td>
<td>India and Pakistan</td>
<td>600,000</td>
<td>512,000</td>
</tr>
<tr>
<td>Emeishan basalts</td>
<td>Southwest China</td>
<td>&gt;250,000</td>
<td>&gt;300,000</td>
</tr>
<tr>
<td>Hannuoba-Chifeng basalts</td>
<td>Northeast China</td>
<td>20,000</td>
<td>1400*</td>
</tr>
<tr>
<td>Kerguelen Plateau</td>
<td>Southern Indian Ocean</td>
<td>2,300,000</td>
<td>9,100,000</td>
</tr>
<tr>
<td>Keweenawan Basalts</td>
<td>Northcentral U.S.</td>
<td>160,000</td>
<td>640,000*</td>
</tr>
<tr>
<td>North Atlantic Volcanic Province</td>
<td>UK and Greenland</td>
<td>1,300,000</td>
<td>6,600,000</td>
</tr>
<tr>
<td>Newark Basin and Hartford Basin</td>
<td>Northeastern U.S.</td>
<td>500*/400*</td>
<td>50*/40*</td>
</tr>
<tr>
<td>Ontong Java Plateau</td>
<td>Southwestern Pacific</td>
<td>1,900,000</td>
<td>44,400,000</td>
</tr>
<tr>
<td>Parana-Etendeka Province</td>
<td>Brazil, Namibia and Angola</td>
<td>2,200,000</td>
<td>&gt;1,000,000</td>
</tr>
<tr>
<td>Siberian Traps</td>
<td>Eastern Siberia</td>
<td>340,000</td>
<td>400,000</td>
</tr>
<tr>
<td>Yemen-Ethiopian Traps</td>
<td>Yemen and Ethiopia</td>
<td>&gt;600,000</td>
<td>&gt;350,000</td>
</tr>
</tbody>
</table>
Locations – Deep Sea Storage

- Blanketing deep-sea sediments form a low-permeability stratigraphic barrier
- If leakage - hydrates (depending on depth) are likely to form trapping leaked CO$_2$
- Water depths greater than 2700m - gravitational trapping - CO$_2$ more dense than seawater.
- Estimated total theoretical total worldwide storage capacity 2000 – 11,000 Gt
Real Projects

• Carbfix
  • Inject dissolved CO₂, 400 – 800m, 1 t CO₂ : 27 t water
  • Initially 2200 t/yr, increase if first test successful
  • Dissolved CO₂ – standard geophysical monitoring techniques difficult - Use of geochemical tracers

• Wallula
  • Inject 1000t scCO₂ - interflow zone of 3 separate flows
  • Seismic processing techniques updated for basalts.
  • Planned injection spring 2011
  • Lab tests show that expected time for complete mineralisation from pilot – 10 years
Conclusions & Recommendations

- Storage in basalts is untested
- Lab experiments & modelling show basalts storage and in-situ mineralisation of CO\(_2\) feasible and Pilot projects expected to start in near future
- scCO\(_2\) reactions – not fully understood, further research ongoing
- IEAGHG keep updated on developments in basalt storage
- Pilot projects not started injection - no real-life data. Therefore any study undertaken by IEAGHG should involve assessing natural analogues as well as lab and modelling studies
- Any study could involve assessment of potential locations for basalt storage and capacity assessments
IEAGHG Studies

• Pressurisation and Brine Displacement; Permedia, Final Report published
• The Effect of Impurities on Geological Storage; NRCan, Final Report to be published imminently
• Caprock Systems for CO$_2$ Geological Storage; CO2CRC, Expert Review complete,
• Quantification of Leakage; CO$_2$GeoNet, final report due June 2011
• Potential Impacts on Groundwater Resources of CO$_2$ Storage; CO2GeoNet, Expert Review
• Global Storage Resource Gap Analysis for Policy Makers; Geogreen, Expert Review
IEAGHG Studies

- Feasibility of monitoring substances mobilised by CO$_2$; CO2CRC, draft report due March 2011
- Brine Abstraction; EERC, due to start May 2011
- Subsurface Resource Interaction with CO$_2$ Geological Storage, recent ExCo approval
- Potential Implications of Gas Production from shales and coal for CO$_2$ Geological Storage, recent ExCo approval
- Induced Seismicity, recent ExCo approval
- Basalt Storage (technical review)
Thank you