IEAGHG activities and networks in CCS and highlights of recent studies

Neil Wildgust, Project Manager – Geological Storage

Mustang Consortium Meeting 3
Montpellier, June 2010
IEAGHG Research Networks

• Facilitate discussions between international researchers and operators on key CCS topics
• Meet annually in various locations worldwide
• Participation open to all with professional interest in CCS
• Minimal registration fee for meetings
IEAGHG Modelling Network

- First meeting in Orleans, Feb 2009
- Second meeting in Utah, Feb 2010
- 2011: offer to host by Shell and University of W Australia
- Network details at www.ieaghg.org
Risk Assessment Network

- First meeting in Utrecht, Aug 2005
- 2010 meeting in Colorado, May 2010
- 2011: offer to host by BRGM, Orleans
- Network details at www.ieaghhg.org
Monitoring Network

- First meeting in California, Nov 2004
- 2010 meeting in Natchez, Louisiana
- 2011: offer to host by CO2Store, Ketzin
- Network details at www.ieaghhg.org
Wellbore Integrity Network

- First meeting in Houston, Apr 2005
- 2010 meeting in The Hague, Apr 2010
- 2011: offer to host by Shell and University of W Australia
- Network details at www.ieaghg.org
Social Research Network

- First meeting in Paris, Dec 2009
- 2010 meeting in Japan, Nov 2010
- Network details at www.ieaghg.org
IEAGHG Study Programme

- Study ideas/proposals welcome from any source
- Typical duration 6 months, cost £50k to £100k
- Proposals put through ExCo voting process every 6 months
- Typically 10 to 20 studies published per year
- Majority of studies contracted out
Recent CO$_2$ Storage Studies

- Storage Capacity Coefficients
- Global Storage Potential for CO2-EOR
- Injection Strategies
- Brine Displacement and Pressurisation
- Potential Impacts on Groundwater Resources
- Effects of Impurities
- Storage Resource Gap Analysis
- Caprock Systems for Storage
Storage Capacity Coefficients Study

- CSLF and US DOE storage resource estimation methodologies require development of coefficients
- Study undertaken by Energy and Environment Research Centre, University of North Dakota
- Co-sponsored by US DOE
- Main aims of the study:
  - Review storage resource estimation methodologies and associated resource classification schemes;
  - Compile database of key parameters from injection projects and associated modelling studies;
  - Develop a series of storage coefficients that can be applied to regional resource surveys;
  - Consider hydrocarbon fields and saline formations
Deep Saline Formations
Methodology

• Paucity of ‘real-world’ projects and data
• Approach employed: modelling from database of likely DSF characteristics developed from HC field databases and literature search
• Provided statistical datasets for modelling
• Uniform injection and evaluation scheme developed for modelling runs
• Coefficients for Effective Capacity (CSLF) or Resource (US DOE) derived at site scale and extrapolated to formation scale
Modelling

- Initial homogeneous models to test parameter sensitivity
- Approximately 200 simulations run with statistically-derived heterogeneous models
- Coefficients derived for 3 rock-types
- Structural setting found to exert biggest influence on storage efficiency at site scale
- Site scale modelling results extrapolated to formations scale, assuming open system
## Formation Scale Coefficients

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Storage Coefficients (%) by probability percentile</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>P10</td>
</tr>
<tr>
<td>Clastics</td>
<td>1.9</td>
</tr>
<tr>
<td>Dolomite</td>
<td>2.6</td>
</tr>
<tr>
<td>Limestone</td>
<td>1.4</td>
</tr>
<tr>
<td>All</td>
<td>1.7</td>
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</tbody>
</table>
Injection Strategies Study

- Study completed in 2010 by CO2CRC, project team led by Karsten Michael

- Assessed parameters that can influence injection,

- Consider methods of design of injection strategies,
  - Case studies to demonstrate different strategies,

- Assess technical aspects of well design,

- Cost estimation tool:
  - Comparative rather than predictive.
Moving up in scale

- Key issue for considering injections strategies;
- Injection rates on the order of 10 MtCO₂/year for many sites;
- CCS infrastructure will need to be of the same scale as that of the current petroleum industry;
- Storage process will need to be optimised by multi-well schemes and enhancement of dissolution;
- Management of reservoir pressures (water production) to avoid fracturing, seismic events and impact on resources (groundwater, petroleum).
### Active projects, early 2009

**Capture over 100ktCO₂**
- Bellingham Cogeneration Facility

**Injection over 10ktCO₂ for storage**
- IFFCO CO₂ Recovery Plant – Aonla
- CASTOR Project
- Great Plains Synfuel Plant
- IMC Global Soda Plant
- In Salah
- K12-B
- Ketzin Project
- MRCSP - Michigan Basin
- Nagaoka
- Otway Basin Project
- Pembina Cardium Project
- Petronas Fertilizer Plant
- IFFCO CO₂ Recovery Plant - Phulpur
- Chemical Co. “A” CO₂ Recovery Plant

**Monitored EOR over 10ktCO₂**
- chemical Co. “A” CO₂
- Great Plains Synfuel Plant
- IMC Global Soda Plant
- In Salah SECARB - Cranfield II
- Ketzin Project Sleipner
- MRCSP - Michigan Basin Snohvit LNG Project
- Nagaoka SRCSP - Aneth EOR-Paradox Basin
- Otway Basin Project SRCSP - San Juan Basin
- Pembina Cardium Project Sumitomo Chemicals Plant

**Capture over 10ktCO₂ from flue gas**
- chemical Co. “A” CO₂
- Great Plains Synfuel Plant
- IMC Global Soda Plant
- In Salah SECARB - Cranfield II
- Ketzin Project Sleipner
- MRCSP - Michigan Basin Snohvit LNG Project
- Nagaoka SRCSP - Aneth EOR-Paradox Basin
- Otway Basin Project SRCSP - San Juan Basin
- Pembina Cardium Project Sumitomo Chemicals Plant

**Coal bed storage over 10ktCO₂**
- chemical Co. “A” CO₂
- Great Plains Synfuel Plant
- IMC Global Soda Plant
- In Salah SECARB - Cranfield II
- Ketzin Project Sleipner
- MRCSP - Michigan Basin Snohvit LNG Project
- Nagaoka SRCSP - Aneth EOR-Paradox Basin
- Otway Basin Project SRCSP - San Juan Basin
- Pembina Cardium Project Sumitomo Chemicals Plant

**Active projects, early 2009**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellingham Cogeneration Facility</td>
<td></td>
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<tr>
<td>IFFCO CO₂ Recovery Plant – Aonla</td>
<td></td>
</tr>
<tr>
<td>CASTOR Project</td>
<td>Prosint Methanol Plant</td>
</tr>
<tr>
<td>Great Plains Synfuel Plant</td>
<td>Rangely CO₂ Project</td>
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<tr>
<td>IMC Global Soda Plant</td>
<td>Schwarze Pumpe</td>
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<tr>
<td>In Salah</td>
<td>SECARB - Cranfield II</td>
</tr>
<tr>
<td>K12-B</td>
<td>Shady Point Power Plant</td>
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<tr>
<td>Ketzin Project</td>
<td>Sleipner</td>
</tr>
<tr>
<td>MRCSP - Michigan Basin</td>
<td>Snohvit LNG Project</td>
</tr>
<tr>
<td>Nagaoka</td>
<td>SRCSP - Aneth EOR-Paradox Basin</td>
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<td>SRCSP - San Juan Basin</td>
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<td>Pembina Cardium Project</td>
<td>Sumitomo Chemicals Plant</td>
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<tr>
<td>Petronas Fertilizer Plant</td>
<td>Warrior Run Power Plant</td>
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<tr>
<td>IFFCO CO₂ Recovery Plant - Phulpur</td>
<td>Weyburn</td>
</tr>
<tr>
<td>Chemical Co. “A” CO₂ Recovery Plant</td>
<td>Zama EOR Project</td>
</tr>
</tbody>
</table>
Net CO$_2$ Storage per Year

- Weyburn-Midale
- Sleipner
- Snøhvit
- In-Salah
- Rangely
- SEACARB Cranfield

Annual Net CO$_2$ Storage Rate (Kt)
Injection Strategy Concepts

- Injectivity: the ability of a geological formation to accept fluids by injection through a well or series of wells.
- Primary influence is bottom-hole pressure, influenced by injection rate, permeability, formation thickness and depth, CO$_2$/brine viscosity, compressibility....
- Heterogeneity
- Pressure maintenance
- Co-injection
- Dissolution in formation brine
- Injection below oil-water contact
Pressure Maintenance - Gorgon Proposal

- 4 water producers
- 9 CO₂ injectors
Pressurisation and Brine Displacement Study

- Overall study aim will be to investigate potential problems of pressurisation and brine displacement in multiple injection scenarios
- Some specific assessment objectives:
  - Evolution of pressure fields with time
  - Effects on caprock integrity, faults
  - Magnitude of brine displacement
  - Storage capacities, engineered solutions
- Study undertaken by Permedia Research
# Shale Permeability

<table>
<thead>
<tr>
<th>CO₂ Storage</th>
<th>Model</th>
<th>Depth (m)</th>
<th>Boundary k (m²)</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thibeau &amp; Mucha, 2009</td>
<td>Analytical</td>
<td>-</td>
<td>E-17</td>
<td>Dynamic capacity</td>
</tr>
<tr>
<td>Holloway et al., 2009</td>
<td>Bunter Fmn</td>
<td>1,000-3,000</td>
<td>E-19</td>
<td>Dynamic capacity</td>
</tr>
<tr>
<td>Zhou et al., 2008</td>
<td>Analytical</td>
<td>-</td>
<td>E-17 to E-19</td>
<td>Dynamic capacity</td>
</tr>
</tbody>
</table>

| Economides, 2009       | Analytical | -         | <<E-22          | Loss of injectivity|
| van der Meer, 2006     | Analytical | -         | <<E-22          | Loss of injectivity|

<table>
<thead>
<tr>
<th>Overpressure</th>
<th>Model</th>
<th>Caprock (m)</th>
<th>Caprock k (m²)</th>
<th>Duration (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corbet &amp; Bethke, 1992</td>
<td>W. Canada</td>
<td>500</td>
<td>E-20</td>
<td>3</td>
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<tr>
<td>He &amp; Corrigan, 1995</td>
<td>Analytical</td>
<td>100-1,000</td>
<td>E-19 to E-21</td>
<td>1</td>
</tr>
<tr>
<td>Swarbrick et al., 2000</td>
<td>Central North Sea</td>
<td>450</td>
<td>E-21</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Threshold Pressure</th>
<th>Observation</th>
<th>Depth (m)</th>
<th>Pth range (MPa)</th>
<th>Equivalent k (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nord' Bolas et al., 2005</td>
<td>North Sea (55)</td>
<td>2,000-4,000</td>
<td>2 to 18 (5 to 15)</td>
<td>E-17 to E-19</td>
</tr>
<tr>
<td>Bunney &amp; Cawley, 2007</td>
<td>Forties Field</td>
<td>2000</td>
<td>15</td>
<td>E-19</td>
</tr>
</tbody>
</table>
Empirical porosity-permeability relationship

(Yang and Aplin, Marine and Petroleum Geology, in press)
Conclusions

- Are closed boundaries a good approximation for storage sites?
  - E-21: yes  E-18: no
- Is the rock matrix porosity the principle flow medium in shales?
  - Probably not
- Are micro-to-mesoscale measurements valid constraints for macroscopic flow simulations?
  - Not for shales

IEAGHG Case Study, 17 x 27 km
Storage Resource Gap Analysis Study

- Contract awarded to Geogreen
- Aims of study:
  - Alert policymakers to the scale, cost and timing of the storage resource assessment tasks required to enable the initial deployment by 2020 of 20 commercial-scale CCS projects (G8) and the 100 projects (IEA Technology Roadmap)
  - Actions to launch in order to reach the IEA CCS target by 2050
  - Have sufficient storage sites identified and characterized to bankable status no later than 2015
  - Give insight of how resources can be effectively targeted, for each major world region, to ensure that wider implementation of CCS will be supported by an adequate availability of technically viable storage sites
Status of Information on storage capacity mapping

- **Limited info available**
- **NO info available**
- **Info available**

Legend:
- **NO info available**
- **Limited info available**
- **Info available**

Capacity mapping: 01/06/10

World map with regions color-coded for the status of information on storage capacity mapping.
Concluding Remarks

• For storage in DSF, closed-system models are unlikely to be representative of most sites;
• Nevertheless, pressure build-up is most influential factor on injectivity and storage potential;
• Pressure management will therefore prove a vital element of injection strategies,
• Large scale demonstrations will enhance knowledge and understanding.
Thank you