
What Have We Learnt from Large Scale Operational Projects

EU Network in Global Context

EU CCS Demonstration Network 3 Dec 2009
IEA Greenhouse Gas R&D Programme

• A collaborative international research programme founded in 1991
• Aim: To provide information on the role that technology can play in reducing greenhouse gas emissions from use of fossil fuels.

• Producing information that is:
  ➢ Objective, trustworthy, independent
  ➢ Policy relevant but NOT policy prescriptive
  ➢ Reviewed by external Expert Reviewers

• IEA GHG is an IEA Implementing Agreement in which the Participants contribute to a common fund to finance the activities.
• Activities: Studies and reports (>120); R&D networks :- Wells, Risk, Monitoring, Modelling, Oxy, Capture, Biofixation; Communications (GHGT conferences, IJGGC, etc); facilitating and focussing R&D and demonstration activities
Contracting Parties and Sponsor Organisations of IEA GHG
Practical R&D Activities

Systems Studies/Capture
- DYNAMIS
- International Test Centre

Storage Projects
- WEYBURN
- SACS/CO2STORE
- CO2REMOVE
- CO2SINK
- MOVECBM

Technical Reviews
- US REGIONAL PARTNERSHIPS
- US EPA VUNERABILITY ASSESSMENT FRAMEWORK
- OTWAY BASIN PILOT PROJECT
- WEYBURN
- RECOPOL
IEA GHG Research Networks

• Bring together international key groups of experts to share knowledge and experience
• Identify and address knowledge gaps
• Act as informed bodies, eg for regulators
• Benefit experts and wider stakeholders
• Depend on experts’ time and inputs – valuable and widely appreciated

• CO2 geological storage networks:
  • Risk Assessment; Monitoring; Wellbore Integrity; Modelling
  • Also networks on Post-Combustion Capture; Oxyfiring; High Temp Solid Looping Cycles; Biofixation; Social Research
2009 Monitoring Meeting Agenda

1. Reports from other initiatives
2. Reports from Projects
3. Update on Japanese CCS Progress
4. What Regulators Want
5. Reality Check – What can and can’t monitoring do
6. Emerging and Innovative Technologies
7. Key Learning Points and Workshop Conclusions

Nagaoka Site Visit
Monitoring Meeting Conclusions

- Recommendation to use pilot-scale projects to focus and learn on post-injection CO2 behaviour, as at Nagaoka
- Benefits of multi-scale integration of multiple datasets, eg combining seismic and electrical resistivity
- Regulations are based more on qualitative performance than quantitative, and need expert opinion to make decisions
- More work needed to understand faults and overburden leakage pathways.
- Uncertainty over defining acceptable match of predictions and reality of CO2 behaviour, first regulated projects will set precedence.
- Pressure front monitoring will be required.
- Atmospheric and surface monitoring can provide assurance for public
- Monitoring can be good enough to get on with projects
Greenhouse Gas Technologies Conference (GHGT)

- Premier International GHG conference
- Focused on CCS
- Held every two years
- GHGT-8, 2006 – Trondheim, Norway
  - 950 Delegates
- GHGT-9, 2008 – Washington, USA
  - 16th – 19th November
  - ~1500 Delegates
- GHGT-10, 2010 – Amsterdam, Netherlands
- [www.ieagreen.org.uk/ghgt.html](http://www.ieagreen.org.uk/ghgt.html)
Education and Capacity Building

- Summer Schools
  - Germany 2007
  - Canada 2008
  - Melbourne 2009
  - Norway 2010

- CCS in Africa. Workshops in Senegal and Botswana, 2007

- Capacity building elements to GHGT9 and GHGT10
Communications

- Web sites
- Newsletter
  - 7500 paper copies
- Glossy Reports
  - Geologic Storage Safety, Natural Analogues, etc
- International Journal on Greenhouse Gas Control
- GHGT -10, 2010 – Amsterdam, Netherlands
Collaborations

• GCCSI

• CSLF
  • Collaboration Arrangement with CSLF Technical Group
  • Collaborate/contribute in Risk, Capacity, Academic Task Forces,
  • IEA GHG Student Forum planned with CSLF, web-based

• IEA/CSLF/GCCSI-G8

• APP Programme – Oxy Fuel working group
  • Shadowing our Oxy Fuel network meeting

• EU ZEP

• IEA, and IEA Regulators Network

• IPAC
What Have We Learnt from Large Scale Operational Projects

Tim Dixon, Neil Wildgust, Mike Haines, Brendan Beck

3 Dec 2009
What have we learnt to date from Large Scale Operational Projects?

- Review current operational large-scale CCS projects
  - Assess learning from projects
  - Identify gaps in the global CCS project portfolio
- Focus on projects relevant to full-commercial scale operation
  - Includes:
    - Large-scale pilot
    - Demonstration
    - Commercial
  - Excludes
    - Small and medium pilot
    - Lab scale
- Define criteria – Identify projects – Collect information - Analyse
Criteria for large-scale operational projects

- Indicative criteria defined for ‘large-scale operational projects’

- Was, or had been, operational by the end of 2008, and either:-
  - Captures over 10,000 tCO₂ per year from a flue gas
  - Injects over 10,000 tCO₂ per year with the purpose of geological storage with monitoring
  - Captures over 100,000 tCO₂ per year from any source
  - Coal-bed storage of over 10,000 tCO₂ per year
  - Commercial CO₂ EOR is excluded unless there is a monitoring programme to provide learning.
  - Does not need to be fully integrated

- Added term ‘large-scale operational’ to IEA GHG Projects database
<table>
<thead>
<tr>
<th>Projects identified</th>
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<tbody>
<tr>
<td>Bellingham Cogeneration Facility</td>
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<td>Ketzin Project</td>
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<tr>
<td>Sleipner</td>
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<tr>
<td>MRCSP - Michigan Basin</td>
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<td>Snohvit LNG Project</td>
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<td>Nagaoka</td>
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<tr>
<td>SRCSP - Aneth EOR-Paradox Basin</td>
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<td>SRCSP - San Juan Basin</td>
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<td>Warrior Run Power Plant</td>
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<tr>
<td>Weyburn</td>
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<td>Chemical Co. “A” CO2 Recovery Plant</td>
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- **Capture over 100ktCO₂**
- **Injection over 10ktCO₂ for storage**
- **Monitored EOR over 10ktCO₂**
- **Capture over 10ktCO₂ from flue gas**
- **Coal bed storage over 10ktCO₂**
Project Locations

- Capture over 100ktCO₂
- Injection over 10ktCO₂ for storage
- Monitored EOR over 10ktCO₂
- Capture over 10ktCO₂ from flue gas
- Coal bed storage over 10ktCO₂
Information Gathering

- 28 large scale operational projects identified
- Each project has been asked to provide information using a questionnaire
- 18 Responses

- Analysis of projects in 2 parts:
  - Extent of project coverage
  - Key learning from projects
Extent of coverage - Capture

- 13 plants capturing from combustion processes
  - 11 post-combustion
  - 1 pre-combustion
  - 1 oxyfuel
- 9 projects source CO$_2$ from industrial processing (Natural gas separation, ammonia, LNG, hydrogen production)
- Multiple fuels represented
  - Hard coal
  - Lignite
  - Natural Gas
  - Industrial processes
- Over 10Mt of CO$_2$ captured per year
Extent of coverage - Transport

- Pipeline
  - Single sink source pipelines
  - Multiple source-multiple sink pipeline networks
- Truck
- Cross-border transport
- Transport over 860km
Extent of coverage – Injection

- Over 10Mt injected per year
- Multiple purposes for injection
  - Storage
  - EOR
  - ECBM
Extent of coverage – Storage Formations

• A variety of storage formations
  • Sandstone
  • Carbonate
  • Coal
Reservoir Depth

Depth (m)

Min  Avg  Max

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Extent of coverage – Storage amounts

- There are six projects that store over 40,000t CO\textsubscript{2} per year
- All projects combine store almost 6Mt per year
- Total of 57 project years of CO\textsubscript{2} storage experience
- Over 40Mt of CO\textsubscript{2} stored
Net CO₂ Storage per Year

- Weyburn
- Sleipner
- In Salah
- Snohvit LNG Project
- Rangely CO₂ Project
- SECARB - Cranfield
- SRCSP - Areth
- Olway Basin Project
- Kelzin Project
- SRCSP - San Juan
- Pembina Cardium Project
- MRCSP - Michigan
- Nagaoka
### Common Monitoring Techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>No of Sites</th>
<th>Positive comments</th>
<th>Negative comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DH temp/pressure</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface seismic</td>
<td>10</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Soil gas</td>
<td>9</td>
<td></td>
<td></td>
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<tr>
<td>Geochemical</td>
<td>8</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>VSP</td>
<td>8</td>
<td></td>
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<tr>
<td>Microseismic</td>
<td>7</td>
<td></td>
<td>1</td>
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<tr>
<td>Gravity</td>
<td>4</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Crosswell seismic</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Satellite</td>
<td>3</td>
<td>1</td>
<td></td>
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### Extent of coverage vs ZEP project matrix

<table>
<thead>
<tr>
<th>Archetype 1</th>
<th>Archetype 2</th>
<th>Archetype 3</th>
<th>Archetype 4</th>
<th>Archetype 5</th>
<th>Archetype 6</th>
<th>Archetype 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite/co-firing with Biomass</td>
<td>Gas</td>
<td>Hard Coal</td>
<td>Hard Coal</td>
<td>Lignite</td>
<td>Hard Coal</td>
<td>Hard Coal</td>
</tr>
<tr>
<td>Pre-combustion, variant A</td>
<td>Post-combustion, variant A</td>
<td>Oxy-fuel, variant A</td>
<td>Post-combustion, variant A</td>
<td>Oxy-fuel, variant B</td>
<td>Pre-combustion, variant B</td>
<td>Post-combustion, variant B</td>
</tr>
<tr>
<td>Cross-border pipeline</td>
<td>Pipeline</td>
<td>Shlp</td>
<td>Pipeline</td>
<td>Pipeline</td>
<td>Pipeline</td>
<td>Pipeline</td>
</tr>
<tr>
<td>Offshore depleted oil &amp; gas field</td>
<td>Onshore structural deep saline aquifer</td>
<td>Offshore open deep saline aquifer</td>
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**Demonstrated in operational large projects**

**Not demonstrated in operational large projects**

Extent of Coverage

- If integrated CCS from electricity production is a 4 link chain:
  - Electricity production
  - Capture
  - Transport
  - Storage
- 2 and 3 link chains have been demonstrated over 1Mt CO₂ per year
Themes in Key Learning Points

• Effectiveness of monitoring techniques – what to drop and what to develop

• Injectivity – prediction, restoration and enhancement

• Dealing with hydrates

• Performance of materials in CO₂ environments

• Well designing, placing, monitoring
Areas for Additional Collaboration

- Injection performance
  - Different issues of impairment
  - Varied experience of injecting into depressurised formations
- Material corrosion
  - Successful management of material selection and corrosion - could reduce costs for future projects
- Design of a monitoring programme
  - Proving integrity
  - Enough experience to move on from expansive research programmes to start designing commercial monitoring programmes
- Comparison of hydrate experience
Conclusions

• Elements of CCS are operating at large scale

• Integrated CCS is operating at large scale, just not from power plant

• There is a lot that has been learnt from existing projects, but more can be done to share the learning

• CCS industry can build on existing projects’ experience

• Increasing IPR issues will affect sharing learning
Next steps

• Report of Phase 1a out (Nov 2009)

• Phase 1b
  • Conduct second round of information focussing on specific areas
  • Based on results of Phase 1
  • By email or telephone interview
  • Repeat every 2 years in conjunction with Phase 1

• Phase 2
  • Create a new Operational Large Scale Projects Network?
  • Will now be done by GCCSI activities
EU Network in Global Context

- Support EU/EC International Policy, ie with key developing countries – China NZEC
- GCCSI activities
- IEA GHG
  - **Research Networks**, for specific areas – EU Network input; EU Network Topic-based events, Research Networks can provide input
    - GHGT-10
    - International peer review of Network/Projects
    - International Communication
    - Information brokerage
- US Carbon Sequestration Regional Partnerships ? Via IEA GHG?
IEA Greenhouse Gas R&D Programme

- General - www.ieagreen.org.uk
- CCS - www.co2captureandstorage.info