What have we learnt to date from large-scale CCS projects?

IEA Greenhouse Gas R&D Programme
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What have we learnt to date - 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>CASTOR Project</td>
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Captions:
- Capture over 100ktCO₂
- Injection over 10ktCO₂ for storage
- Monitored EOR over 10ktCO₂
- Capture over 10ktCO₂ from flue gas
- Coal bed storage over 10ktCO₂
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 so far (6th March 2009)

- 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
Porosity

- Min
- Typical
- Max
Extent of coverage – Storage amounts

• There are six projects that store over 40,000t CO$_2$ per year
• All projects combine store almost 6Mt per year
• Total of 57 project years of CO$_2$ storage experience
• Over 40Mt of CO$_2$ stored
Net CO₂ Storage per Year
Extent of coverage – Monitoring

- 2D seismic
- 3D seismic
- 4D seismic
- Vertical seismic profiling
- Cross-well seismic
- Electrical conductivity
- Microseismic
- Passive seismic
- Soil gas sampling
- Detector arrays
- Eddy covariance

- Observation wells
- Time lapse microgravity
- Well temperature and pressure
- Well logs
- Tracers
- Ground water geochemistry
- Interferometry
- Satellite imaging
- Tilt meters
### Extent of coverage vs ZEP project matrix

<table>
<thead>
<tr>
<th>Archetype</th>
<th>Lignite/co-firing with Biomass</th>
<th>Pre-combustion, variant A</th>
<th>Cross-border pipeline</th>
<th>Offshore depleted oil &amp; gas field</th>
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</thead>
<tbody>
<tr>
<td>Archetype 1</td>
<td>Red</td>
<td>Green</td>
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<tr>
<th>Archetype</th>
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<th>Pipeline</th>
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<tr>
<th>Archetype</th>
<th>Hard Coal</th>
<th>Oxy-fuel, variant A</th>
<th>Shlp</th>
<th>Offshore open deep saline aquifer</th>
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<tr>
<th>Archetype</th>
<th>Lignite</th>
<th>Oxy-fuel, variant B</th>
<th>Pipeline</th>
<th>Onshore structural deep saline aquifer</th>
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<tr>
<td>Archetype 4</td>
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<td>Archetype 5</td>
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<td>Archetype 7</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 CO$_2$ per year
Learning From Projects
- preliminary and not yet complete

• Commonalities
• Areas for additional collaboration
• Areas for additional future consideration
• Themes in key learning points
Commonalities

- Injectivity
  - Very important
  - Multiple examples of issues and solutions
- Material corrosion
  - Less problems than expected
- Seismic
  - Effective for monitoring the CO₂ plume - where it can be used
  - Not quantitative beyond a certain resolution
  - Expensive
Commonalities cont.

- Electrical conductivity
  - Seen as promising, not yet used commercially
- Microseismic
  - Doesn’t add a lot to monitoring portfolio
- Monitoring overlying layers
  - Very good way of demonstrating seal integrity (Especially to non-experts)
- Downhole sampling
  - Better sampling at reservoir conditions valuable
  - Not yet practiced by many projects
Areas for Additional Collaboration

- 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
Areas for Additional Collaboration cont.

• 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
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 CO\textsubscript{2} environments
- Well designing, placing, monitoring
What has not been covered

• More on capture and on regulatory issues

• Commercial gasification processes
  • Have not been reviewed here but offer considerable learning for pre-combustion capture

• CO$_2$ transport by ship
Preliminary 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
IEA Greenhouse Gas R&D Programme

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