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

IEA Greenhouse Gas R&D Programme
John Gale, Tim Dixon, Brendan Beck, Mike Haines

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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
# Projects identified

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<th>Project Name</th>
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**Notes:**
- **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 100ktCO$_2$

Injection over 10ktCO$_2$ for storage

Monitored EOR over 10ktCO$_2$

Capture over 10ktCO$_2$ from flue gas

Coal bed storage over 10ktCO$_2$
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 CO₂ from industrial processing (Natural gas separation, ammonia, LNG, hydrogen production)
- Multiple fuels represented
  - Hard coal
  - Lignite
  - Natural Gas
  - Industrial processes
- Over 10Mt of CO₂ 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

![Pie chart showing injection purposes](www.ieagreen.org.uk)
Extent of coverage – Storage Formations

- A variety of storage formations
  - Sandstone
  - Carbonate
  - Coal

![Pie chart showing distribution of storage formations](image-url)
Permeability

![Graph showing permeability values with min, typical, and max markers.](image-url)
Reservoir Depth

![Graph showing reservoir depth](image-url)
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
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

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### Extent of coverage vs ZEP project matrix

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<th>Archetype 2</th>
<th>Archetype 3</th>
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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

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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 CO$_2$ plume - where it can be used
  - Not quantitative beyond a certain resolution
  - Expensive

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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$_2$ environments
• Well designing, placing, monitoring

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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