Technical Advances and Cost-Effective Monitoring: Results from a Case Study

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Roadmap to CCS Deployment

“This decade is critical for moving deployment of CCS beyond the demonstration phase in accordance with the 2DS”.

“The largest challenge for CCS deployment is the integration of component technologies into large-scale demonstration projects”.

“Urgent action is required…to drive cost-effective CCS deployment”.

IEA, 2013
Cost of CCS

Capture — Transport — Geologic Storage

Cost fundamentally driven by regulatory requirements

2-20% of total cost of CCS

Reference: Geologic CO₂ Sequestration Technology and Cost analysis, US EPA

Site Characterization
Injection Well construction
Define the Area of Review
Monitoring
Permitting
Well Operations
Mechanical Integrity Testing
Well plugging and PISC
Relative Cost of Monitoring

Final EPA GS Rule – Class VI
(percentages calculated from annualized values using a 7% discount rate, 2008)

- Monitoring is 50% of the total cost of geologic storage
- Baseline monitoring is included in site characterization
Monitoring Components
EPA Class VI Rule

Operational
- Monitor injected fluids for compatibility with well material
- Monitor well integrity and corrosion
- Conduct pressure fall off test every 5 years

Technical
- Track extent of CO$_2$ in the reservoir
- Monitor geochemistry above confining zone
- Plan soil gas and surface air monitoring to detect leakage
- Report Findings
Beyond Regulation-Technical

- What amount of data is necessary to address situations where interpretation becomes problematic?
- How can data acquisition, reduction and interpretation be streamlined?
- How to balance cost with areal coverage?
- How can we respond to public claims quickly, accurately and economically?
- How can we quantify leakage if it happens?
Demos vs Industrial

Pilots ➔ Demonstrations ➔ Industrial

Frio Brine Pilot 2004

SECARB Early Test- Cranfield Oilfield

Industrial monitoring application at Hastings Oilfield
Transition to Industrial

- Minimalistic approach relative to research-oriented
- All questions will not be answered
- All tools will not be used
- Balance between regulatory and technical goals
- Balance between cost effective and accurate data collection
Case Study: Upscaling Process-Based Monitoring Technology
Process-Based Monitoring

- Uses simple gas ratios ($\text{CO}_2$, $\text{CH}_4$, $\text{N}_2$, $\text{O}_2$) to identify the processes affecting $\text{CO}_2$ in the vadose zone
- Promptly identifies leakage signal over background noise.
- No need for years of background measurements.
- Method can be applied the same regardless of geologic variability
Process-Based Method Shortfalls

- Time- and labor-intensive
- Requires a manned gas chromatograph
- Requires consumable supplies
- No continuous real-time data
Scaling up Monitoring Methods

Continuous • Real-time • Smart

for **Leakage Detection** (targeted areas of interest)

- Higher degree of assurance than discrete monitoring.
- No data gaps ensures arrival of a leakage signal is detected.
- Demonstrates to stakeholders that monitoring is robust.

for **Leakage Quantification** (sites of known leakage)

- Aid in quantifying total CO₂ loss.
- Supply the data density needed for accurate accounting under variable flux rates.
- Help judge effectiveness of remediation efforts.
Study Objectives

Test continuous real-time Process-Based data collection using currently-available sensors which are:

- compact,
- fully automated,
- can be dedicated to a site,
- have data transmission capabilities
- do not require consumable supplies.

- NDIR – CO₂, CH₄ (Vaisala, Dynament)
- Galvanic Cell – O₂ (Alpha Omega)
- Humidity,
- Temp,
- Pressure
New Data Collection Approach

No currently-available N₂ sensors
Using sensors requires a different approach to the method

Gas Chromatograph

- Measures all gases but H₂O
- Assumes saturated H₂O (2.3%)

Sensors

- Measure all gases but N₂
- Measure P, T, Humidity
- Calculate N₂ by difference
Field Test Design

3-4 days continuous testing at 2 locations

Data loggers for sensors. Data downloaded to PC

Tubing for sampling gas straight into GC. Pumping rate ~ 50-100 ml/min

Sensors for O₂, CO₂, H₂O, P and T

Depth about 1.5 meters

Packers to isolate sampling interval

Screened PVC pipe To allow gas flow into borehole

Peristaltic pump

GC monitoring

Gas Mix | CO₂ (%) | O₂ (%) | CH₄ (%) | N₂ (%)
---|---|---|---|---
Air | 0 | 21 | 0 | 78
Mix 4 | 5 | 1 | 0 | 91
Mix 5 | 0 | 0 | 4 | 96
Mix 6 | 15 | 5 | 1 | 79

GC monitoring
Results

Site 1

CO₂ Mix 6 Test Site 1

CO₂ (Vol %)

7/10/13 9:36
7/10/13 10:48
7/10/13 12:00
7/10/13 13:12
7/10/13 14:24
7/10/13 15:36
Date/Time

Site 2

CO₂ Mix 6 Site 2

CO₂ (Vol %)

7/11/13 15:36
7/11/13 16:48
7/11/13 18:00
7/11/13 19:12
7/11/13 20:24
7/11/13 21:36
Date/Time

Site 1

CH₄ Mix 6 Test Site 1

CH₄ (Vol %)

7/10/13 9:36
7/10/13 10:48
7/10/13 12:00
7/10/13 13:12
7/10/13 14:24
7/10/13 15:36
Date/Time

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Site 2

O₂ Mix 6 Site 2

O₂ (Vol %)

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7/11/13 18:00
7/11/13 19:12
7/11/13 20:24
7/11/13 21:36
Date/Time
Results

- Current technology is over-promising and under-delivering
What if?

• We had monitoring approaches that didn’t rely on years of background data?
• We had monitoring parameters that always reacted to leakage in the same way in spite of geologic variability?
• We knew where to target our monitoring?
• Could replace current labor intensive monitoring methods with dependable real-time continuous smart data collection?
  • Hollow-core glass fiber Raman spectroscopy for soil-gas (Romanak, Mesa Photonics)
  • Fiber Optic Distributed Chemical dissolved CO₂ in groundwater (Yang, IOS)
Summary

• Integrating and upscaling CCS in a cost-effective way is imperative for its timely deployment
• Cost-effectiveness is needed in all areas of CCS.
• Innovative approaches and real-time, continuous, smart data collection are important for cost-effectiveness
• Much of current tool performance is unsatisfactory and should be improved.