5.3 MM FOR GEOLOGIC CARBON SEQUESTRATION

Technology Description

Introduction

Storing CO_2 in geological reservoirs (oil/gas reservoirs, coal beds, saline formations, etc.) requires that concentrated CO_2 streams be available[1]. These will result from separation and capture at fossil-fuel power plants and advanced concepts such as fuel cell or hydrogen facilities. Methods to fully account for carbon sequestration in these systems will require analysis of energy costs and full GHG accounting for separating, capturing, and transporting CO_2 as well as during the injection to below-ground reservoirs. In addition to direct injection, there are concepts being proposed that involve storage of other carbon sources in deep reservoirs that would promote the generation of CH_4 for energy. These concepts face many of the same challenges as injection and storage of concentrated CO_2 streams. Once stored, the focus is on methods to measure and monitor (MM) for long-term storage or leakage. The challenge is to be able to detect the transport or small releases of carbon dioxide from great depths that may be highly variable in space and time.

System Concepts

- Separation and Capture: Dual focus of (1) methods based on process knowledge to fully account for energy penalties and carbon costs to obtain CO_2 streams and (2) sensors to monitor fugitive emissions around the facility.
- Transportation: Leak detection from pipelines or other transportation systems will include mass balance methods (in/out measurements), pressure transducers, remote detectors, and addition of specific gaseous tracers enabling remote leakage detection.
- Geologic Storage: Multiple approaches will be necessary and include (1) direct detection of surface leakage (probably requires area or remotely sensed approach due to heterogeneity of release pathways), (2) indicators of leakage based on natural and induced tracers, (3) seismic/ electromagnetic (EM)/electrical resistivity (ER)/pressure monitoring networks, (4) intensively monitored validation sites (with those known to be leaky) may be required to confirm monitoring methods. For enhanced oil/gas recovery systems, robust measurements need to be made on both the injected CO_2 and on the produced hydrocarbons to get an accurate carbon change balance because of measurement challenges on gases that are changing pressures/temperatures along their production pathways.

Representative Technologies

- For leak detection from capture/separation, pipelines, and surface leaks from reservoirs there are options within traditional leak-detection technologies, advanced technologies (e.g., hand-held infrared remote imaging spectrometer, portable tracer gas detectors, inexpensive time averaged activated carbon traps for tracer gases), and aircraft or satellite-based sensors for CO_2. Improved leak detection needed in produced hydrocarbon streams as well.
- Indirect indicators for subsurface performance could include (1) observable effects on soil gas compositions and ecosystems (microbial and vegetation systems), although it is likely that changes would be observable only under high leakage rates, (2) deviations from model-predicted biogeochemical conditions of the subsurface fluids using either naturally occurring tracers/indicators or tracers induced during injection that have a well-predicted behavior pattern, (3) geophysical methods (pressure transient tests, seismic, EM, ER, etc.) methods to detect pressure changes and map migration pathways, (4) altered geochemistry of candidate receptor formations, and (5) detection of added tracers in control sites at various depths and within formation fluids from depth to the near surface.

Technology Status/Applications

- Leak-detection technologies are available but are too labor-intensive for routine use at a global scale.
- Even excellent leak detection technologies currently provide spot measurements over very small parts of very large geographic sampling areas.

[1] The discussion of separation, capture, and transportation of CO_2 here also applies to the option for direct injection of CO_2 into deep ocean regions.

- Time-averaged traps that absorb and retain tracer gases that have been added to the sequestered CO_2 could be readily developed/deployed for quarterly or annual verification procedures.
- Process flow information is evolving that should result in accurate estimates of CO_2 costs associated with capture and separation.

Current Research, Development, and Demonstration

RD&D Goals

- Develop ability to assess the continuing integrity of subsurface reservoirs using integrated system of sensors, indicators, and models.
- Improve leak detection from separation and capture and pipelines systems (many opportunities to take advantage of accomplishments from other technology development efforts).
- Apply remote sensors for other purposes to fugitive emissions from reservoirs and capture facilities.
- Improve/develop/implement tracer addition and monitoring programs.
- Evaluate microbial mechanisms for monitoring and mitigating diffuse, wide-area GHG leakage from geologic formations.
- Determine "acceptable" leakage percentages since dissolution of CO_2 into shallower formation fluids through a "diffusion grating" sequestration horizon enhances sequestration capacities many fold.
- Document dissolution/mineral trapping potential that will remove CO_2 from the formation fluids.

RD&D Challenges

- Low leakage rates occurring at spatially separated locations makes full detection difficult (this applies to both pipelines and reservoirs) likely requiring time averaged detection of added tracers.
- Heterogeneity of leakage pathway and probable alteration over time makes detection and quantification difficult for reservoirs (local vs. large area measurement capability).
- Indicators (e.g., seismic, EM, tracers) need further development for quantitative application or time averaging.
- Null results are expected, but this makes it difficult to "prove" that sample frequency and locations are not missing leak emanations.

RD&D Activities

- Significant efforts are ongoing for separation and capture technology development.
- Demonstration tests for geologic storage are ongoing and planned, which should provide test beds for MM options.
- Seismic testing methods are well-developed for exploration, and can be deployed for evaluating integrity of geologic formations for long-term storage of CO_2.
- Geochemical studies in deep formation environments are investigating the evolution of potential mineral trapping of CO_2.

Recent Progress

- Seismic methods are being used at the Sleipner test to map the location of the injected CO_2 gas phase, but such methods are not capable of aiding mass balance over the long-term performance periods.
- Geophysical methods need to be developed to track supercritical CO_2 in a diffuse (fingered) configuration that will be most typical of extended injection.
- Models, geophysical methods, and tracer indicators are being developed through the GEO-SEQ project.
- Development of innovative coatings for activated carbon particles within beads that may improve passive time-averaged sampling.
- Detection of CO_2 emission from natural reservoirs has been investigated by researchers at the Colorado School of Mines, University of Utah, and the Utah Geological Survey, including attempting isotopic discrimination of biogenic CO_2 from microbial respiration.
- Fundamental research on high-resolution seismic and electromagnetic imaging and on geochemical reactivity of high pCO_2 fluids is ongoing in basic science programs.
- ORNL application of PFT tracer gases to Frio tests and NETL PFT testing at surface during injection (Frio and New Mexico).

Commercialization and Deployment Activities
• Sleipner demonstration ongoing – seismic methods in qualitative mapping of CO_2 volume and integrity of geological formations. • Sleipner demonstration ongoing – seismic methods in qualitative mapping of CO_2 volume and integrity of geological formations. • GEO-SEQ field tests at Frio site. • SNL-LANL field tests. • Australian demonstrations. • Canadian demonstration at Weyburn, Saskatchewan, in collaboration with the North Dakota gasification plant. • A system of CO_2 capture and geologic reservoirs has a vast potential for storing CO_2. Demonstrations are in place or planned and offer outstanding opportunities for early development and testing of MM methods, so that wide-scale implementation of the technology will be acceptable to the public in the future.