R & D facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

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Geologic and Environmental Science

Description

A significant component of the research conducted by the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) emphasizes geological storage science (GSC), integrated process modeling and simulation, technology to monitor for CO_2 leaks and to mitigate them if they occur, as well as economic assessment of the various options.

The goal of the research conducted within the Carbon Sequestration Science Focus Area of NETL's Office of Research and Development is to identify and remove technical barriers and reduce costs associated with sequestration of carbon from energy processes. Effective carbon sequestration techniques will provide long-term options for reducing atmospheric CO_2 concentrations and mitigate the effects of global climate change.

This research will stimulate innovation and develop novel concepts for carbon sequestration by partnering with universities, Federal laboratories, and private industry. Activities will span the broad carbon sequestration interest area and will focus on improving scientific understanding necessary for proper disposal of CO_2 in appropriate geologic formations (saline aquifers, coal seams, and oil reservoirs) and terrestrial ecosystems.

The purpose of the Geologic and Environmental Science Focus Area at the NETL is to serve as the focal point for carbon sequestration research and development (R&D) activities performed with NETL's in-house resources, coordinating its efforts with DOE's seven Regional Carbon Sequestration Partnerships. http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html As part of this national research activity, the focus area for Geologic and Environmental Science conducts research ranging from fundamental investigations to large-scale deployment studies on selected processing options. Laboratory experiments are conducted to assess storage options and to optimize sequestration effectiveness. Systems analysis via computer modeling and approach simulation will be conducted in-house for use in evaluating existing results and predicting long-term outcomes.

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The specific role of the Geologic and Environmental Science Focus Area is to:

- Identify research directions and construct a balanced portfolio of activities integrated with the national sequestration R&D program,
- Conduct portions of the R&D portfolio with in-house resources,
- Serve as a hub for geologic and terrestrial sequestration activities.

NETL's goal is to have the Geologic and Environmental Science Focus Area, including its partners, recognized as the premier research laboratory in the area of carbon sequestration. This will be accomplished by:

- Providing scientific insights into long-term stabilization of CO_2 and other greenhouse gases (GHG), provide a scientific understanding of processes for storage of CO_2, address geological, chemical, and biological sequestration barrier issues, and provide a scientific basis for sequestration and thereby allow continued use of fossil energy resources,
- Ensuring full attention to potential consequences of sequestration options, and
- Providing scientific information and systems analysis from a non-conflicted perspective.

A continuing investment in this Focus Area will result in the identification of CO_2 sequestration methods that are technically feasible, environmentally acceptable, and economically well defined. Should national decisions be made regarding the need to sequester CO_2, then the capture and sequestration techniques developed as a result of this R&D activity can be deployed commercially in the United States and abroad.

Capabilities

NETL has developed a number of research capabilities in the Geologic and Environmental Science Focus Area to develop and assess technology that will be used to safely and reliably store CO_2 in coal seams, oil reservoirs, and saline aquifers, and to monitor sequestration effectiveness:

- **CT Analysis of Core:** A good technique to observe the actual progression of fluids (movement) inside rocks is to use computer tomography scanning (CT scanning) at successive time intervals to record the displacement or flooding process. NETL possesses a CT scanner that can be used to image rock cores. This technology allows mineral cores to be evaluated at realistic confining pressures while simultaneously observing in situ changes in pore fluids and mineral densities/effective molecular weights. This information is essential to realistic numerical simulation, economic evaluations, and site characterization efforts. Images can be taken while injecting CO_2 into the core to determine the fluid infiltration pattern under different flow conditions. In addition, CT scanning techniques can be applied to enhanced coal bed methane studies to characterize the internal reactions/behavior of coal with CO_2. To evaluate carbon sequestration in inert rocks (such as displacement of brine from sandstone), or oil/gas production by displacement (e.g., water flooding), real-time in situ progress of fluid displacement can be observed. Since the voxels are all recorded in a three-dimensional (3-D) coordinate system, quantitative, volumetric and linear measurements are all available for retrieval. Models will be used to analyze the results and determine the degree of fingering that would occur. Relative permeabilities will be calculated by experimental and modeling analysis.

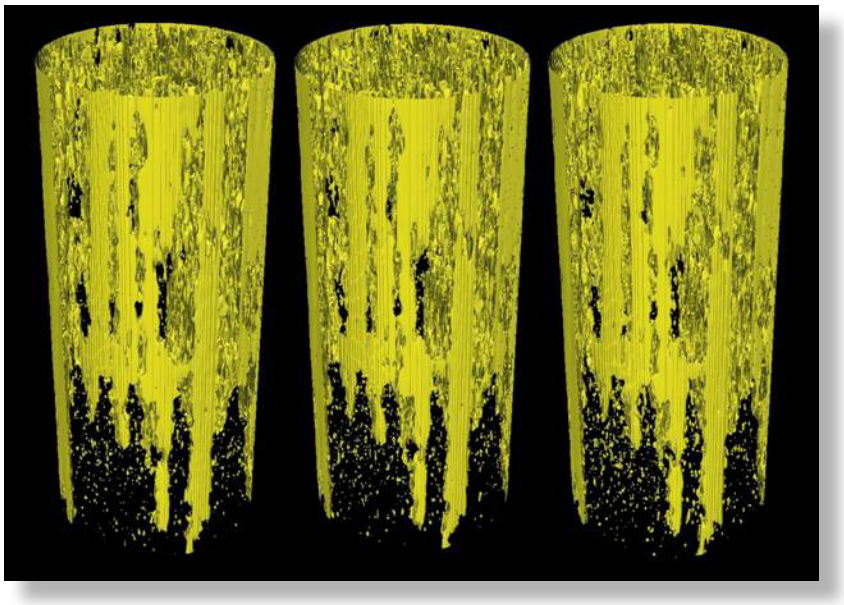

Figure 1. Computer tomography scanning (CT scanning) imaging capabilities for CO_2 sequestration in a sandstone formation.

- **Geologic Sequestration Core Flow Lab (GSCFL):** NETL measures permeability and geomechanical properties of rock core samples obtained from the Regional Carbon Sequestration Partnerships' Phase II & III field injection sites. Geomechanical properties, such as porosity, mineralogy, permeability, mineral/CO_2 interactions, Young's modulus, Poisson's ratio, and changes of any properties with prolonged exposure, are essential in determining overburden response during large-scale injections and in supporting monitoring, measurement, and verification (MMV) work. The GSCFL is used to determine these parameters in a laboratory setting for project site applications. The GSCFL research also simulates the conditions found at depth in the potential geological sequestration sites, including oil and gas fields, unmineable deep coal seams, and brine formations. Test results are analyzed to obtain permeability and geomechanical properties that will be used in computational modeling studies.

- **Seismic Imaging:** NETL is collaborating with the Regional Carbon Sequestration Partnerships to employ seismic studies of CO_2 injection sites in order to determine rock physics and risk assessment. A seismic survey at the Southwest Partnership's SACROC Unit, an oil field in Texas (the seventh largest onshore field in North America), will be completed before injection and repeated six months following CO_2 injection. This survey will be coordinated with a vertical seismic profile. The SACROC Unit has an extensive history of successful enhanced oil recovery (EOR) activities and is an excellent site to test reflection seismic monitoring of a field test. An I/O seismic recording system will be used to collect reflection seismic surveys in support of a CO_2 injection by a regional partnership. These reflection seismic data will be processed using Parallel Geosciences Corporation's and Landmark's pre-stack software. Amplitude variation with offset (AVO) and spectral decomposition advanced processing will be applied to the data to produce a time-variable description of variation in pore filling phases in the target reservoir formation (Desert sandstone) in this region.

- **FRACGEN/NFFLOW Modeling:** NETL has developed a suite of FORTRAN-based codes that generates a reasonable fracture pattern for a gas reservoir (FRACGEN) and solves the material balance for compressible fluid flow in the rock matrix and fractures of the reservoir (NFFLOW). The current reservoir fracture network generator, FRACGEN, implements four Boolean models of increasing complexity through a Monte Carlo process that samples fitted statistical distributions for various network attributes of each fracture set. Termination and intersection frequencies can be

controlled either implicitly or explicitly. NETL has found that its explicit-fracture simulator, NFFLOW, is able to increase the accuracy and reliability of simulations for highly fractured reservoirs because it directly uses descriptions of such characteristics as fracture length, orientation, and aperture as obtained from well logs, outcrop analyses, and other geological data. In addition, by using the real gas potential for fluids, NFFLOW is able to treat compressible fluids. NFFLOW computes transient flow rates or bottom-hole pressures according to user-specified pressure or rate schedules. It assumes that the reservoir is isothermal and one layer and that no flow occurs across the upper and lower boundaries of the reservoir. Each fracture is assumed to span the thickness of the reservoir, and the fracture network is assumed to contain no intersections formed by more than two fractures. Most of the research to date has focused on potential sequestration in unmineable coal seams; NFFLOW is being modified to account for two-phase flow through sandstone and realistically treat the sandstone matrix geometry.

- **Comprehensive Monitoring Techniques:** NETL recognizes the need for accurate and reliable long-term monitoring techniques that can track the integrity of CO_2 underground. The research goal is to develop and demonstrate advanced monitoring techniques to assess the capacity, stability, rate of leakage, and permanence of CO_2 storage in geologic formations. Surface and near-surface monitoring techniques can be used to detect CO_2 leakages from geologic storage formations. These techniques include perfluorocabon tracers, shallow water aquifer chemistry changes, flux of CO_2 at the surface, and natural tracers (radon and methane) in soil-gas. These and other techniques will be employed during Phase II projects of the DOE Regional Carbon Sequestration Partnerships. So far, perfluorocarbons and surface and near-surface monitoring have been tested and both have been shown that they can successfully detect leakages from the geologic storage formation. Development of techniques to monitor the integrity of geologically sequestered CO_2 is needed to assure public health and safety and gain public acceptance of geologic sequestration technology.

- **Risk Assessment Effort:** NETL is working with the DOE Regional Carbon Sequestration Partnerships to develop a risk analysis protocol for field sites in order to identify all *relevant* features, events, and processes that are potential risks. NETL will use modeling capabilities to bind the probabilities of various forms of leakage. For example, a Monte Carlo analysis can be performed for leakage through faults and fracture networks to help bound the probabilities of leakage at the field site. Information from various leakage scenarios will be incorporated into a systems analysis, so that all risks can be identified. Leakage probabilities will be quantified where possible and information from monitoring networks will be incorporated into the analysis, where applicable. Typically, risk assessment work would begin approximately one year before injection occurs, using all available site characterization data. After injection begins, work would continue, but at a reduced rate, depending on information obtained from monitoring.

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