Carbon Sequestration

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PROJECT facts

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

NETL

Optimal Geological Environments for Carbon Dioxide Storage in Saline Formations

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Background

For carbon dioxide (CO_2) sequestration to be a successful component of the United States emissions reduction strategy, there will have to be a favorable intersection of a number of factors, such as the electricity market, fuel source, power plant design and operation, capture technology, a suitable geologic sequestration site, and a pipeline right-of-way from the plant to the injection site. The concept of CO_2 sequestration in saline water-bearing formations (saline reservoirs), isolated at depths below potable aquifers, became of widespread interest in the early 1990s. It is now in the process of maturing from a general concept to one of the options available to reduce the amount of CO_2 released as a result of fossil fuel combustion at a variety of stationary sources.

Description

The Bureau of Economic Geology (BEG) at the University of Texas at Austin is developing criteria for characterizing optimal conditions and characteristics of saline formations that can be used for long-term storage of CO_2. Phase I of this project included identifying prospective regional locations for CO_2 injection wells and better defining saline-formation conditions suitable for CO_2 disposal and sequestration. During Phase II, injection and seal properties of a selection of representative saline water-bearing formations of on-shore U.S. sites were characterized in a geologic information system (GIS) database.

Recent research and development (R&D) efforts have demonstrated the technical feasibility of the process, defined costs, modeled the evolution of the CO_2 plume in the subsurface, and inventoried the appropriate monitoring technology needed to sequester CO_2 in saline formations. Still, field demonstration is needed to validate these understandings and increase public confidence. Phase III efforts have focused on field testing the R&D findings by injecting small amounts of CO_2 into a deep saline reservoir within the state of Texas, using the best available tools to measure what happened in the subsurface, and matching modeled to observed subsurface plume evolution.

DEPARTMENT OF ENERGY • UNITED STATES OF AMERICA

PARTNERS

University of Texas at Austin

BP America

Schlumberger

Austin Texas

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Livermore National Laboratory (LLNL)

Oak Ridge National Laboratory (ORNL)

Core Labs

Paulsson Geophysical

Praxair

Sandia Technologies

PERFORMANCE PERIOD

07/15/1998 to 05/30/2008

COST

Total Project Value
$5,756,553

DOE/Non-DOE Share
$5,756,553 / $0

Primary Project Goal

This project has developed and applied criteria for characterizing saline formations for long-term sequestration of CO_2. The first injection experiment (October 2004) was focused on conducting an early successful injection into a high-permeability, high-volume sandstone. This site was representative of a broad area that is an ultimate target for large-volume sequestration and monitoring, and also for modeling the resulting subsurface plume of CO_2. The second injection and monitoring period (May 2006–2007) further refined the quantification of key rock-fluid properties and tested additional monitoring technologies.

Objectives

- Demonstrate to the public and other stakeholders that CO_2 can be injected into a brine formation without adverse health, safety, or environmental effects.
- Measure subsurface distribution of injected CO_2 using diverse monitoring technologies.
- Test the validity of conceptual, hydrologic, and geochemical models.
- Develop experience necessary for the development of the next generation of larger-scale CO_2 injection experiments.

Benefits

Nonproductive brine-bearing formations, below and hydrologically separated from potable water, have been widely recognized as having high potential for very long-term (geologic time scale) sequestration of greenhouse gases. However, before such formations can be utilized, robust models must be developed to predict the behavior of CO_2 injected into them. Also required are monitoring techniques which can follow the spread of CO_2 in the formation and detect any leaks that might occur. The whole concept of carbon capture and storage (CCS) will benefit from this project through the modeling and monitoring capabilities being developed. This project is the first field-scale test with intense monitoring.

Phases I and II of this project have provided data on basins that have been refined by the Regional Carbon Sequestration Partnerships to extend the national inventory of geologic sinks in the National Carbon Sequestration Database and Geographical Information System (NATCARB). The results of the Frio Brine Pilot test have provided data for the development of the next generation of CO_2 injection tests to be conducted within the Partnerships. Confidence in the correctness of conceptual and numerical models and the effectiveness of monitoring tools tested will encourage the next pilots to investigate more complex factors, such as stratigraphic and structural heterogeneity, and upscaling. The Frio Pilot results provide a model for participants in the Partnerships, as well as international collaborators, to design test programs in various settings.

Accomplishments

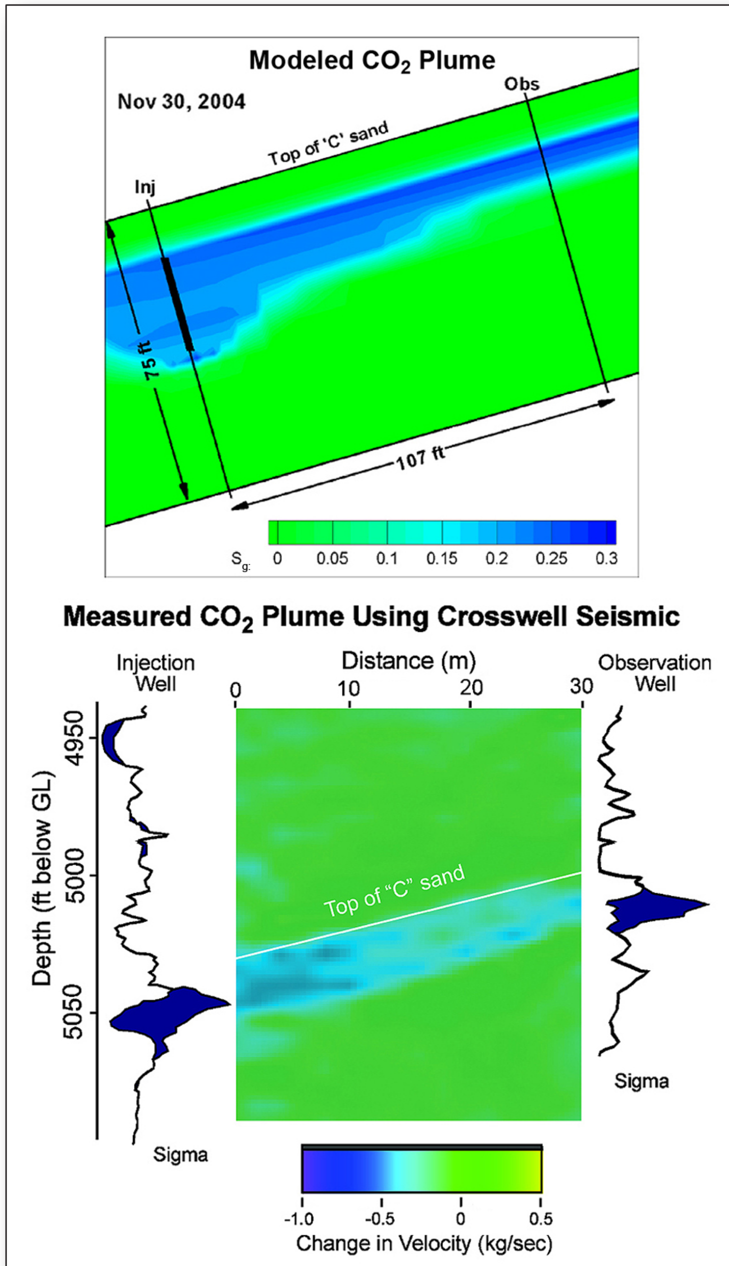
Phase I of the project developed a first set of geologic screening criteria for identifying suitable saline water-bearing formations for CO_2 sequestration. The pilot study confirmed that information is available, either as basin-specific data sets or as products of geologic analogs and play analysis.

Phase II involved a regional inventory of geological properties of saline water-bearing formations targeted for CO2 injection. This effort compiled data at basin scale to describe the injectivity and isolation of 21 diverse and representative saline formations in 19 onshore U.S. basins, and served as a precursor to NATCARB.

The Phase III field test, known as the Frio Brine Pilot Test, involves 20 research institutes and corporate collaborators and is conducting 2 short test injections. The contributors to this project include: four Department of Energy National Laboratories (Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, National Energy Technology Laboratory); the U.S. Geological Survey (USGS); two international collaborators (Alberta Research Council and the Cooperative Research Centre for Greenhouse Gas Technologies (CO_2 CRC) from Australia; and industry collaborators Texas American Resources, Sandia Technologies, LLC, Praxair, Schlumberger, BP, Paulsson Geophysical, and Core Labs.

From October 4–14, 2004, the Frio Brine Pilot team injected 1,600 tons of CO_2 1,500 meters (m) below the surface into steeply-dipping, high permeability brine-bearing "C" sandstone of the Frio Formation beneath the Gulf Coast of Texas, USA. A dedicated bottom-hole sampler, the U-tube, was developed by LBNL to allow high frequency collection of high quality samples of multiphase fluids supporting a tracer and geochemical program. Analysis completed during the 15 months following the end of injection showed that by using wireline reservoir saturation tool (RST) pulsed-neutron techniques, a high percentage of CO_2 is retained and immobilized by two-phase capillary effects.

A second injection test was initiated on September 25, 2006. The Frio-II test injected 250 tons of CO_2 into the Frio "Blue" sandstone at 1650 m underground, and researchers closely monitored the CO_2 flow for the next 12 months. The low injection rate was selected to simulate processes at the edge of the plume, where attenuated injection pressure has a significant influence of buoyancy on flow processes, as observed in the results. The project used an array of techniques to provide information about CO_2 flow, trapping, and dissolution: wireline saturation logs, cross well seismic, downhole pressure and temperature monitoring, geochemical sampling with U-Tube, and a tracer program. One new tool tested, a tubing-conveyed source and receiver string (continuous active source seismic monitoring—developed by LBNL—was designed to fully integrate seismic measurements with other downhole data. In this application of seismic tomography, the seismic source is fixed downhole, above the packer. Since the seismic source is fixed,



Schematic of Frio-II Continuous Active Source Seismic Monitoring (CASSM)

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error from the placement and replacement of equipment using traditional means is minimized. In addition, real-time data is collected every 10 seconds, allowing researchers to know exactly when CO_2 breaks a given ray-path between the source and receiver as it rises in the reservoir.

The first objective was accomplished through outreach, which included site visits by researchers, local citizens, and environmental groups; media interviews; an online log (www.gulfcoastcarbon.org); a technical e-newsletter; and an informal non-technical "neighbor newsletter." Public and environmental concerns were moderate, practical, and proportional to minimal risks taken by the project, and included issues such as traffic and potential risks to water resources. Press coverage was balanced and positive toward research goals. Professional vendors provided safe site operation.

The second objective, which was the measurement and monitoring of the subsurface CO_2 plume, was accomplished using a diverse suite of technologies in both the injection zone and in the shallow near-surface environment. Each monitoring strategy used pre-injection and post-injection measurements.

Wireline logging, pressure and temperature measurement, and geochemical sampling were also conducted during injection. In-zone objectives were to measure changes in CO_2 saturation through time, in cross section, and areally, and to document accompanying changes in pressure, temperature, and brine chemistry during the months following injection. The in-zone measurement strategy was designed to test the effectiveness of selected suites of monitoring tools in measuring these parameters. A feasibility test of near-surface monitoring in this setting measured soil gas fluxes and concentrations, introduced tracers, and shallow aquifer response. High complexity was noted in this high-water-table, warm, perturbed environment. Introduced tracers were used to document no leakage to the surface using Praxair Seeper Trace technology.

The third objective is to test the validity of conceptual hydrologic and geochemical models. Reservoir characterization by BEG to provide inputs to the simulations used existing and newly collected wireline logs, an existing three-dimensional seismic survey, baseline geochemical sampling by USGS and Schlumberger, and core analyses by Core Labs. A drawdown interference test and a dipole tracer test conducted by LBNL researchers provided interwell permeability estimates and confirmed the critical importance of good reservoir characterization for model validation. Using TOUGH2, detailed modeling by LBNL supported all phases of the project and yielded good matches between modeled and observed CO_2 saturation, the test conclusions improved and validate model approaches to prediction of CO_2 movement and permanent storage.

As the Frio experiment analysis and modeling is completed, it supports the fourth objective, which is the development of the next generation of larger-scale CO_2 injection experiments. Extensive presentations and publication have supported this effort.