U. S. Department of Energy=s Pilot Test Efforts to Sequester CO_2 in Geological Formations

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ABSTRACT

Nearly one third of the carbon emissions in the U.S. comes from power plants. Since electric generation is expected to increase and fossil fuels will continue to be the dominant fuel source, there is growing recognition that the energy industry can be part of the solution to reduce greenhouse gas emissions by capturing and permanently sequestering CO_2. Long-term storage of carbon dioxide (CO_2) in underground geologic formations has the potential to be viable concept in the near future. Many power plants and other large point sources of CO_2 emissions are located near geologic formations that are amenable to CO_2 storage. In many cases, injection of CO_2 into a geologic formation can enhance the recovery of oil and gas which can offset the cost of CO_2 capture and storage. The U.S. Department of Energy's (DOE) R & D program for CO_2 sequestration in geologic media is a comprehensive effort to bring about this concept in a timely and acceptable method. The primary goal of the research in this area is to understand and validate the behavior of CO_2 when stored in geologic formations so that CO_2 can be sequestered for the long term in a manner that is secure and environmentally acceptable. Researchers under contract to DOE are trying to determine what effective, safe, and cost-competitive options are available for geologic storage of CO_2 emissions generated from coal, oil, and gas power plants. Currently, the planned and on-going research and technology development includes initiatives to develop baseline information necessary to make decisions about potential demonstration and verification sites for CO_2 geologic storage. This paper presents an update of DOE-sponsored pilot-test opportunities for injection into a pressure-depleted oil reservoir, into deep saline reservoirs, and in unmineable coalbeds. All of these pilot field tests will help to predict, validate, and monitor migration and ultimate fate of injected CO_2.

Background

Climate change issues and concerns have been given increasing attention in the U.S. as well as throughout the world. Carbon dioxide emissions from coal-fired electricity generation represent 81 percent of the total CO_2 emissions produced by the generation of electricity. All regions of the U.S. use some fossil fuels, but several States have almost no fossil fuel generation which results in very low output rates of CO_2. Nearly 60 percent of the total CO_2 emissions in the U.S. are located in the mid-west region. There are many sources of CO_2 in these various regions of the U.S., and there are also many potential geological sinks which could store or sequester CO_2.

There are certain underground geologic formations that have structure, porosity, permeability, and other properties that make them ideal CO_2 storage sites in the U.S. (Figure 1). These are structures that have stored crude oil, natural gas, brine, and CO_2 over thousands of years. Long-term storage of CO_2 in underground geologic formations has the potential to be viable in the near-term. Many power plants and other large point sources of CO_2 emissions are located near geologic formations that are amenable to CO_2 storage. Further, in many cases injection of CO_2 into a geologic formation can enhance the recovery of oil and gas which can offset the cost of CO_2 capture.

The use of CO_2 to enhance oil and gas recovery is a common industrial practice. In the year 2000, 34 million tons of CO_2 was injected underground in the United States as a part of enhanced oil recovery (EOR) and coalbed methane recovery (ECBM) operations. This is approximately equivalent to the CO_2 emissions from 6 million cars in one year. Research and development in this area will move the technology forward to make it applicable to a wider range of formations.

Saline formations do not contain oil and gas resources and thus do not offer the value-added benefit of enhanced hydrocarbon production. However, the potential CO_2 storage capacity of domestic saline formations is huge; estimates are on the order of several hundred years of CO_2 emissions making this a very attractive storage method.

The primary goal of research in this area is to understand the behavior of CO_2 when stored in geologic formations making it possible to store CO_2 in a manner that is secure and environmentally acceptable. The fastest and surest way to obtain the needed understanding is to conduct field tests where a small amount of CO_2 is injected into a formation and its fate and transport are monitored carefully. The program has initiated several such field tests. These tests will provide industry with tools and methods that measure the movement of CO_2 in underground formations. They will also provide field protocols that preserve the integrity of the geologic formation. (Figure 1)

Promising Field Tests for Injection of CO2 into Geologic Formations:

Depleted Oil Reservoirs: Project Site - Hobbs, New Mexico. Participants include Sandia and Los Alamos National Laboratories, Strata Production, Kinder Morgan, Colorado School of Mines, and Solid State Geophysical. This is the first field test within the continental U.S. sponsored under DOE=s Carbon Sequestration Program which will help to ascertain that the safe, long-term sequestration of carbon dioxide emissions in geologic formations is a scientifically and technologically challenging goal. The project addresses the complexity and range of coupled geoprocesses and will use a comprehensive suite of computer simulations, laboratory tests, field measurements and monitoring efforts to understand, predict and monitor the coupled geomechanical, geochemical, and hydrogeologic process associated with downhole injection of CO_2 into a depleted oil reservoir.

The field test takes advantage of unique opportunities in a pressure-depleted oil reservoir to predict and monitor the migration and ultimate fate of injected CO_2 at a micro-pilot scale. The field data will allow for testing, refinement and calibration of the computer models. Both geophysical and geochemical techniques will be employed to monitor the transport and fate of the injected CO_2 plume. Site-specific field observations will be used to calibrate, modify and validate the modeling and simulation tools. Iteration of modeling and field data is crucial to the improvement of simulation tool methodologies as well as for higher quality input data for those models. Ultimately, the models and data will be used to predict storage capacity and physical / chemical changes in reservoir properties, such as fluid composition, porosity, permeability, and phase relations. Science or technology gaps related to engineering aspects of CO_2 sequestration will be identified in this study. In addition, a better understanding of CO_2-reservoir interactions resulting from this project will improve industrial enhanced oil recovery flooding practices.

Saline Formations: Project Site - Liberty County, Texas

The Bureau of Economic Geology at the University of Texas at Austin will lead a research team to create an onshore US CO_2 sequestration field test in a brine formation setting. The selected site in Liberty County 40 miles northeast of Houston, Texas. Participants include the BEG, Texas American Resources, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, and BP. These partners will conduct a series of field monitoring experiments before, during, and after CO_2 injection. These field experiments will test the effectiveness of a spectrum of CO_2 monitoring techniques and compare results to validate the methods.

Non-productive brine (saline) 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. This site will provide the first field scale test in this type of setting. Texas is the lead state in US CO_2 emissions and this project will demonstrate a mechanism for emissions reduction.

The study site provides for a rapid start-up using existing infrastructure and low risk of adverse impacts because injection will take place in a hydrologically isolated reservoir compartment of a well-known geologic structure. Injection will take place in the Frio Formation beneath the thick Anahuac Shale, and lateral migration of CO_2 will be limited by structural compartmentalization along faulting associated with the setting on the flank of a salt dome. Additional safety will be provided by using experienced personnel in CO_2 injection and hazardous waste disposal, and is implicit in the experiment design involving intensive monitoring. An existing 3-D seismic survey and wireline well logs will provide input data for planning phase modeling. Extensive field scale date, brine chemistry, and core are available for the Frio Formation in the region and will be used to guide the study.

Saline Formations: Project Site - New Haven, West Virginia

American Electric Power has volunteered its Mountaineer Plant in New Haven, West Virginia as a field test site to evaluate injection of CO_2 emissions into a deep saline reservoir. In this project, the research team will determine whether the de3ep rock structure in the Ohio River Valley is suitable for storing carbon dioxide. The project team includes Battelle Laboratories, NETL, AEP, BP, Schlumberger, Pacific Northwest National Laboratory, Ohio Coal Development Office, West Virginia Department of Environmental Protection, Ohio State University, West Virginia University, and the West Virginia and Ohio Geological Surveys..

The geology of the region is believed to be very favorable for long-term storage of CO_2 in deep rock formations. This region of the U.S. is significant because the economy is based in part, on power generation from fossil fuels which may be affected by regulations on CO_2 emissions. If the study shows that storage is feasible, it could offer a way for many utilities around the country to reduce carbon emissions. It will be especially beneficial to states such as West Virginia, Ohio, and other nearby Midwestern states which depend heavily on coal for electricity generation.

The project is being done in the Ohio River Valley to collect information that is needed before actually injecting CO_2 into the ground where it would be permanently stored. During this 18-month study, tests will be done to help answer questions such as:

- Are the rocks above the proposed storage area sturdy enough to prevent CO_2 from gradually escaping through it?
- Can the storage area hold enough carbon dioxide to be worth the costs of storing it?
- Is there any possibility that injecting CO_2 will affect seismic activity?
- How much pressure is required to place the CO_2 underground?
- What is the best way to monitor placement and storage?

Unmineable Coal Seams - Project Site: Marshall County, West Virginia

Existing geological information of CONSOL mine properties was used to generate a list of possible locations for a pilot-test site in the Appalachian Basin. Site selection criteria included, but was not limited to the following: community, location, terrain, utilities, water, accessibility, drilling considerations, etc. Final selection for the field test site is in Marshall County, WV.

This field project is evaluating the effectiveness and economics of carbon sequestration in an unmineable coal seam. Directional drilling methods are being employed to develop a grid of horizontal holes within an unmineable seam of coal. The test site provides a platform to evaluate the following:

- Demonstration of slant-hole horizontal drilling of underground coal seams
- Definition of effective CO_2 injection methods and procedures
- Evaluation of the CO_2 adsorption capacity of seam coal
- Measurement of the concentration of CO_2 injection on coalbed methane (CBM) recovery
- Monitoring the concentration of CO_2 in recovered CBM over an extended period of time
- Prediction of economical drilling strategies to maximize both sequestration and CBM recovery
- Assessment of overall effectiveness of CO_2 sequestration ($/ton) and methane production in coal seams

The project will involve development of a field site of adequate size for drilling, injection, and monitoring. The lower seam is an unmineable seam that will be degassed and eventually injected with CO_2 gas to conduct carbon sequestration studies. The upper seam is a mineable coal that will be degassed to produce coal bed methane (CBM), thus avoiding potential future methane emissions when the seam is mined. The upper mineable seam will be isolated from the lower unmineable coal seam in which CO_2 injection will take place. The development of the site will include symmetrically dividing the underground section into four equal quadrants using directional drilling methods from the surface.

A post-injection monitoring program will be conducted on the effectiveness of the CO_2 sequestration. Issues to be evaluated include integrity of the sequestration reservoir over time, confinement of CO_2 within the reservoir, and pressure changes in the reservoir and surrounding geologic strata. This monitoring program at the field site is to continue for approximately 5 years after CO_2 injection and sequestration into the coalbed.

The results of this program will be useful to perform an economic analysis for CBM recovery and carbon sequestration on a large commercial scale. The project will also use data developed to evaluate the CBM production from the wells, determine the recoverable CBM, determine the cost to drill the five-hole pattern, evaluate the tonnage of CO_2 that can be sequestered, and determine all costs associated with the sequestration activity.

Summary

The overall goals of the geologic sequestration program are to 1) lower the risk of geologic sequestration, 2) lower the cost of geologic sequestration, and 3) decrease the time to implement the infrastructure and technology required for this approach (Figure 2). Lowering the risk of geologic sequestration involves providing information needed to select sites for safe and effective storage of CO_2, while increasing confidence in the effectiveness and safety of sequestration by identifying and demonstrating cost-effective monitoring technologies. Lowering the cost of geologic storage of CO_2 will allow for developing innovative methods and technologies with economic benefits such as enhanced oil and gas recovery and enhanced coalbed methane production, while understanding and optimizing trade-offs between CO_2 separation and capture costs, compression and transportation costs, and geologic sequestration alternatives. All of these efforts will be driven with near-term early opportunities for pilot testing with private industry, and most importantly gaining public acceptance.

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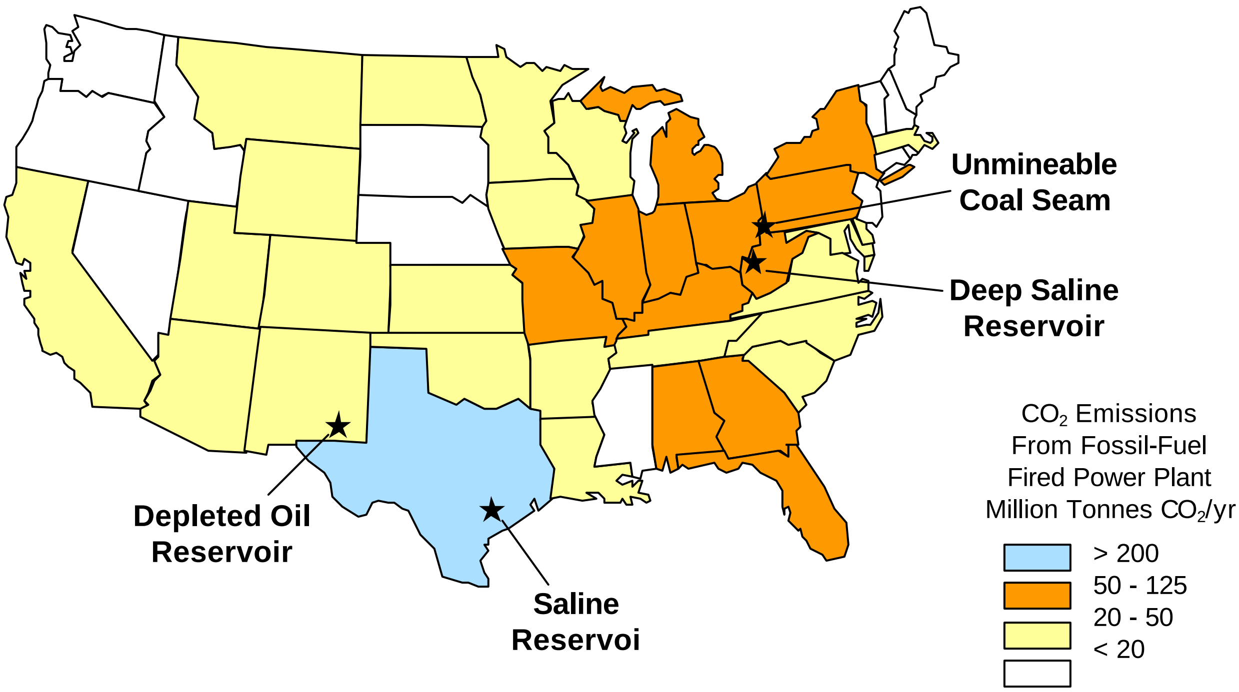

Figure 1. DOE Field Tests: CO2 Injection Into Geologic Formations

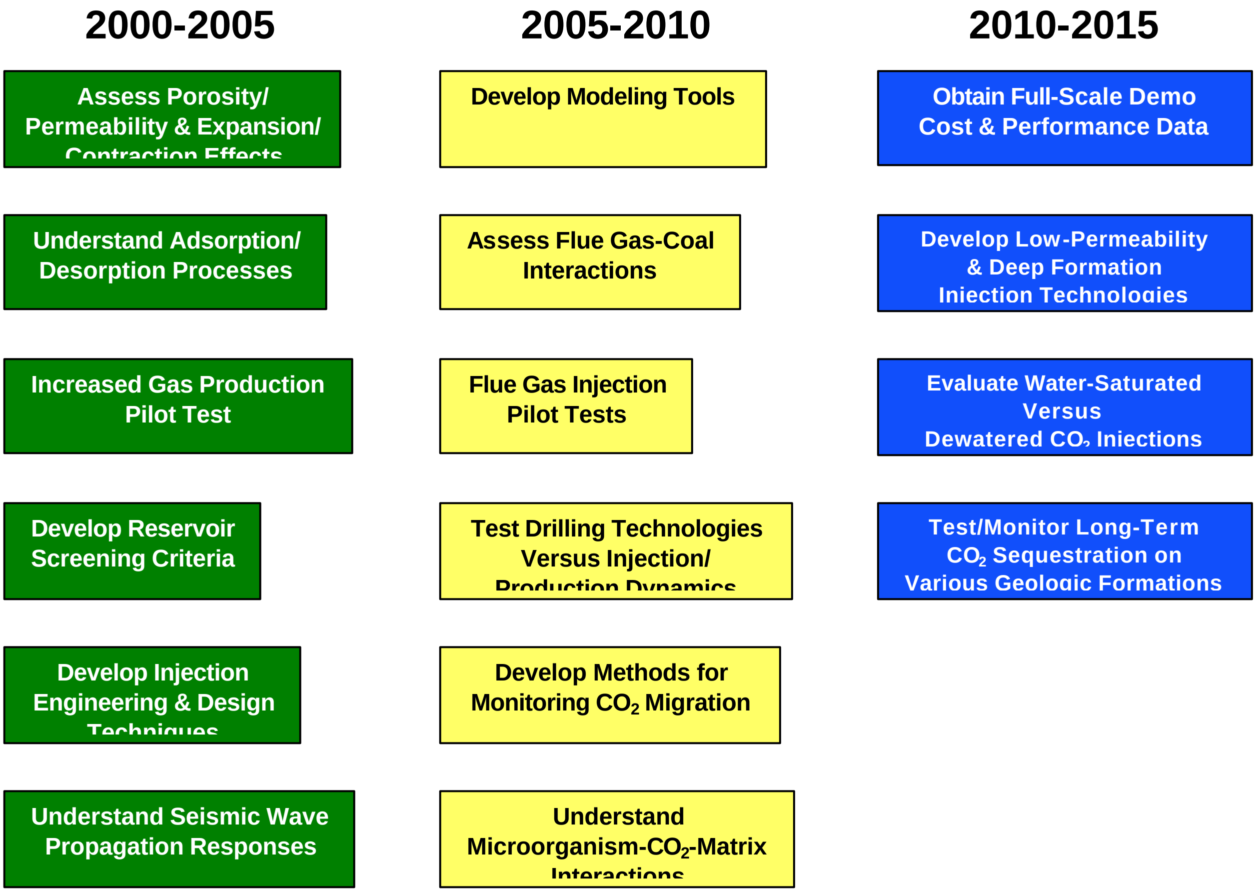

Figure 2. Geologic CO2 Sequestration R&D Priorities