the ENERGY lab

PROJECT FACTS

Carbon Storage - RCSP

Midwest Geological Sequestration Consortium—Development Phase

Illinois Basin – Decatur Project Site

Background

The U.S. Department of Energy Regional Carbon Sequestration Partnership (RCSP) Initiative consists of seven partnerships. The purpose of these partnerships is to determine the best regional approaches for permanently storing carbon dioxide (CO_2) in geologic formations. Each RCSP includes stakeholders comprised of state and local agencies, private companies, electric utilities, universities, and nonprofit organizations. These partnerships are the core of a nationwide network helping to establish the most suitable technologies, regulations, and infrastructure needs for carbon storage. The partnerships include more than 400 distinct organizations, spanning 44 states and four Canadian provinces, and are developing the framework needed to validate geologic carbon storage technologies. The RCSPs are unique in that each one is determining which of the numerous geologic carbon storage approaches are best suited for their specific regions of the country and are also identifying regulatory and infrastructure requirements needed for future commercial deployment. The RCSP Initiative is being implemented in three phases, the Characterization Phase, Validation Phase, and Development Phase. In September 2003, the Characterization Phase (2003–2005) began with the seven partnerships characterizing geologic and terrestrial opportunities for carbon storage and identifying CO_2 stationary sources within the territories of the individual RCSPs. The Validation Phase (2005–2013) focused on evaluating promising CO_2 storage opportunities through a series of small-scale field projects. Finally, the Development Phase (2008-2018+) activities are proceeding and will continue evaluating how CO_2 capture, transportation, injection, and storage can be achieved safely, permanently, and economically at large scales. These field projects are providing tremendous insight regarding injectivity, capacity, and containment of CO_2 in the various geologic formations identified by the partnerships. Results and assessments from these efforts will assist commercialization efforts for future carbon storage projects in North America.

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PARTNERS

Ameren Corporation

American Air Liquide

American Water Works Association

Archer Daniels Midland Company

Aventine Renewable Energy, Inc.

Baker Hughes, Inc.

Biorecro

Blue Source

British Petroleum America

Caterpillar, Inc.

The Cline Group

Conoco Phillips Company

Continental Carbonic Products, Inc.

Drummond Company

Duke Energy Corporation, Inc.

Edison Mission Energy

Electric Power Research Institute, Inc.

Environmental Defense

GE Energy

Halliburton

Illinois Clean Coal Institute

Illinois Corn Growers Association Illinois

Department of Commerce and Economic

Opportunity, Office of Coal Development

Illinois Department of Natural Resources,

Office of Scientific Research and Analysis

Illinois Department of Transportation

Illinois Oil and Gas Association

Indiana Gasification, LLC

Indiana Geological Survey, Indiana University

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The Midwest Geological Sequestration Consortium (MGSC) is led by the Illinois State Geological Survey in collaboration with the Indiana, and Kentucky State Geological Surveys, and has a research focus on the entire state of Illinois, southwest Indiana, and western Kentucky. This partnership was established to assess carbon capture, transportation, and geologic carbon storage options in deep coal seams, mature oil fields, and deep saline formations in the Illinois Basin. Regional point source emissions in the MGSC area account for more than 267 million metric tons of CO_2 per year, or about nine percent of the total point source CO_2 emissions from all of the RCSP regions. The MSGC has determined that the Illinois Basin's regional geology offers exceptional geologic opportunities to safely and permanently store these emissions.

Project Description

Project Summary

MGSC has partnered with the Archer Daniels Midland (ADM) Company, an agricultural product processing company, and Schlumberger Carbon Services to conduct a large-volume, saline reservoir storage field project at ADM's agricultural products processing complex in Decatur, Illinois. The Development Phase project, also referred to as the Illinois Basin – Decatur Project (IBDP) involves the injection of 1 million metric tons of CO_2 over three years into a deep saline formation of the Illinois Basin. This large-volume CO_2 storage project is being undertaken in an effort to prove the injectivity and capacity of the Mt. Simon reservoir, demonstrate security of the injection and confining zones, and contribute to best practices.

Site Description

The project site is located on the ADM industrial facility and corporate headquarters within the city of Decatur, Illinois, a city with a population of over 74,000 people. The injection well and verification wells are located in a field north of the industrial facilities (Figure 1). ADM's Decatur complex consists of various processing facilities including a corn wet milling plant with ethanol production which is the source of the CO_2 for the project. Additional primary facilities include cogeneration of electricity and steam, bioproducts, oilseed processing, and vegetable oil refining. Previously this field had been used for corn/soybean farming or had lain fallow. Other land uses within one mile of the project site include agricultural, commercial, and residential. The site, located in the Bloomington Ridged Plain of the Till Plains Section of Illinois, has approximately 25 feet of relief and is less than two miles west of Lake Decatur. Lake Decatur is a surface impoundment of the Sangamon River, which is the major surface water feature in east-central Illinois. The site is underlain by approximately five feet of loess, 30.5 feet of glacial drift (Wisconsin and Illinoisan Episode), and Pennsylvanian bedrock. The deepest Underground Source of Drinking Water (USDW) being monitored at the site is at a depth of about 140 feet in the Pennsylvanian bedrock.

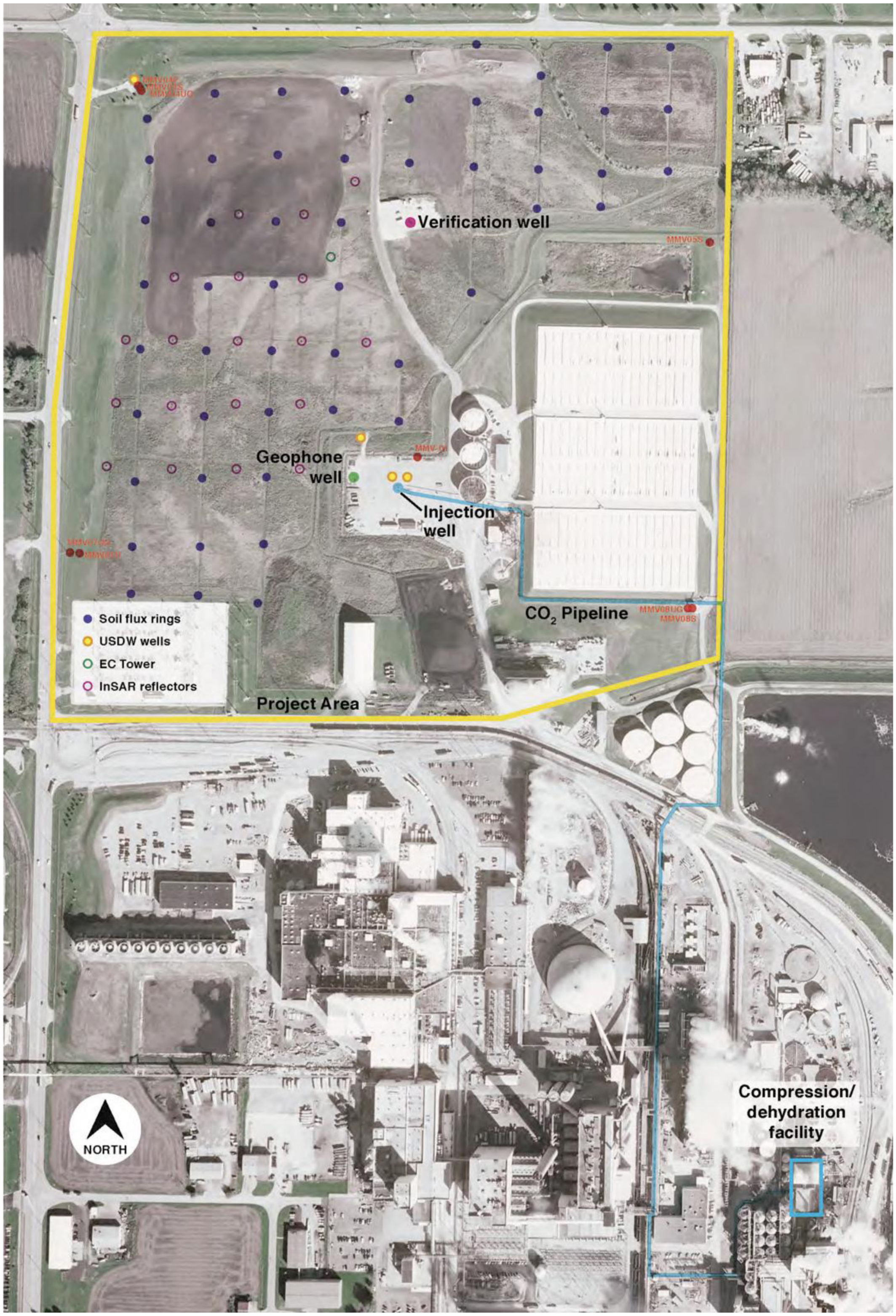

Figure 1. Overview of the Illinois Basin – Decatur Project showing critical project infrastructure elements and monitoring locations.

PARTNERS (cont.)

Indiana Oil and Gas Association

Interstate Oil and Gas Compact Commission

Kentucky Oil and Gas Association

Korea Institute of Ocean Science and Technology (KIOST)

Lincoln and Agri-Energy, LLC

Louisville Gas and Electric Company, LLC

Natural Gas Pipeline Company of America, LLC

Natural Resources Defense Council

Peabody Energy

Peoples Gas

Power Holdings, LLC

Praxair, Inc.

Schlumberger Carbon Services Spectra Energy Corporation

Tenaska Taylorville, LLC

Total Gas and Power Ventures USA, Inc.

Vectren Corporation

PROJECT DURATION

Start Date

12/17/2007

End Date

12/16/2017

COST

Total Project Value

$109,963,889

DOE/Non-DOE Share

$87,318,797 / $22,645,092

AWARD NUMBER

FC26-05NT42588

Description of Geology

The target formation is the Cambrian-age Mt. Simon Sandstone, the thickest and most widespread saline reservoir in the Illinois Basin (Figure 2). It is overlain by the Eau Claire Formation, a regionally extensive, low-permeability shale, siltstone and tight limestone, and is underlain by Precambrian granitic basement. To date, the upper Mt. Simon has been used extensively for natural gas storage in the northern half of Illinois. Detailed reservoir data from a few wells at these storage sites shows that the lower Mt. Simon has the necessary porosity and permeability to be a good storage target. A regional isopach map of the Mt. Simon initially suggested there are probably more than 1,000 feet of Mt. Simon reservoir available for injection at the ADM site and 1,650 feet was actually measured (Figure 2). The injection well was drilled to a total depth of 7,236 feet. Data from a well drilled 17 miles from the ADM site and a second well drilled 51 miles south of the ADM site indicate that there is generally good porosity in the Mt. Simon. MGSC found that the average porosity of the Mt. Simon injection zone at the IBDP site is around 12 percent. The top of the Mt. Simon Sandstone at the ADM site is estimated to lie at a depth of 5,500 feet. A storage capacity of 11 (P_{10}) to 150 (P_{90}) billion metric tons has been assessed for the entire Illinois Basin.

Within the Illinois Basin, the Devonian-age New Albany Shale, Ordovician-age Maquoketa Formation, and the Cambrian-age Eau Claire Formation all contain shales that function as the primary confining zones. There are also many minor, thinner Mississippian- and Pennsylvanian-age shale beds that form local confinement for known hydrocarbon traps within the basin. Subsurface wireline correlations suggest the three primary confining zones are continuous within a 100-mile radius of the project site. At the injection site the Eau Claire, which will be the primary confining zone, was found to be 500 feet thick. The Ordovician Maquoketa Shale and the New Albany Shale act as secondary and tertiary confinement. There are no seismically resolvable faults or fractures within a 25-mile radius of the ADM site.

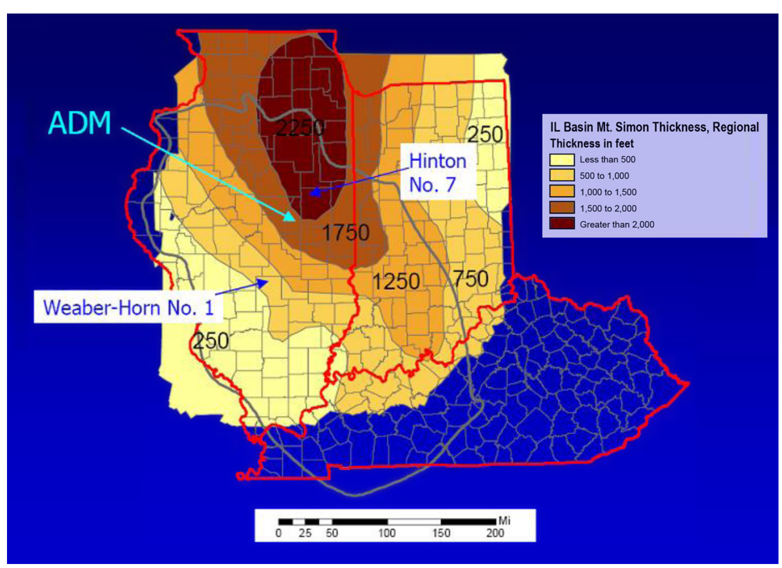

Figure 2. Thickness of Mt. Simon Sandstone in Illinois Basin.

Source of CO_2

The source of CO_2 for the project is ADM's corn wet milling plant with ethanol production. The CO_2 is taken from downstream of the product recovery scrubbers that follow the ethanol fermentation units. The CO_2 stream from these units is typically 99%+ pure and is saturated with water vapor at 80°F and 1.5 psig. Common impurities are ethanol and nitrogen in the range of 600 to 1,000 parts per million by volume (ppmv) each. Other impurities in lesser amounts often include oxygen, methanol, acetaldehyde, and hydrogen sulfide (H_2S).

Injection Operations

The CO_2 stream from the fermentation units was routed to a dedicated dehydration/compression facility where it is dried and compressed. The CO_2 stream was routed to a multistage centrifugal blower with one 632 kW motor that raises the CO_2 pressure to 18 psig. Following the blower, the CO_2 was compressed to a supercritical fluid (~1,400 psig) by two 4-stage reciprocating compressors running in parallel and powered by 632 kW motors. Glycol dehydration occurred between the third and fourth stages of compression. The compressed CO_2 fluid was then transported to the injection wellhead through a 6,000 foot steel pipeline (Figure 3). An additional pump was integrated into the system just downstream of the compressors to boost pressure above 1,400 psi if additional pressure is needed to maintain the desired injection rate of 1,000 metric tons per day. Shakedown of the newly constructed facility was completed in October 2011. On November 2, 2011 the Illinois EPA granted approval to begin injection operations, and on November 17, 2011 injection operations were initiated at 1,000 metric tons per day. On November 26, 2014, injection ceased after a total of 999,215 metric tons of CO_2 was injected into the Mt. Simon Sandstone.

Simulation and Monitoring of CO_2

MODFLOW and GFLOW are being used to develop a conceptual model for shallow groundwater flow and to estimate CO_2 migration in the subsurface. The modeling results provide information used in developing risk mitigation strategies for nearby water supplies in the unlikely occurrence of a CO_2 leak either during or following CO_2 injection. Geochemical models, such as Geochemist's workbench, PHREEQCI, and TOUGHREACT, are being used to conduct thermodynamic modeling of shallow groundwater and injection-formation brine. These models provide insight on the long-term fate of injected CO_2 and are used to study the regional impact of multiple injection wells on flow within a saline reservoir across the Illinois Basin. At present, 55 feet of perforations have been opened in the lower Mt. Simon, and plume modeling is proceeding based on porosity and permeability data from sidewall cores and well log information. Porosities in the lower Mt. Simon are 15-25 percent, and permeabilities are primarily in the range of tens to several hundred millidarcies, up to about 1,000 millidarcies.

The IBDP has an extensive Monitoring, Verification, Accounting (MVA), and Assessment program focused on the 0.25 mi^2 project site and critical locations in the surrounding area. Program goals include establishment of the environmental baseline conditions to evaluate potential impacts from CO_2 injection, demonstration that project activities are protective of human health and the environment, and demonstration of an accurate accounting of stored CO_2. MVA efforts were conducted during the pre-injection and injection phases and are continuing during the post-injection phase. Effectiveness of long-term storage of CO_2 in the Mt. Simon is being evaluated through an in-zone verification well designed to monitor the injection formation and formations immediately above the primary caprock using pressure monitoring and fluid sampling. A dedicated geophone well has been drilled to facilitate repeat seismic imaging over the life of the project. Microseismic monitoring was initiated after injection began at the site and is providing insight into pressure propagation and distribution. Surface deformation is also being measured using InSAR satellite imagery. Monitoring of the near-surface environment includes color infrared aerial imagery, high-resolution electrical earth resistivity, shallow groundwater quality (Figure 4), soil CO_2 fluxes, net exchange CO_2 fluxes, and vadose zone CO_2 concentrations. Characterization of near-surface CO_2 conditions is important to determine baseline conditions for detecting any potential CO_2 leakage to the atmosphere.

Goals and Objectives

The primary objective of the DOE's Carbon Storage Program is to develop technologies to safely and permanently store CO_2 and reduce Greenhouse Gas (GHG) emissions without adversely affecting energy use or hindering economic growth. Specific programmatic goals of Carbon Storage research are: (1) develop and validate technologies to ensure for 99 percent storage permanence; (2) develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness; (3) support industry's ability to predict CO_2 storage capacity in geologic formations to within 30 percent; and (4) developing Best Practices Manuals (BPMs) for MVA, and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

Figure 3. Completed CO_2 pipeline at the ADM site.

MGSC's overall goal is to carry out a fully integrated demonstration of monitored geological carbon storage in the largest-capacity saline reservoir in the Illinois Basin. Specific objectives include:

- Inject 1 million metric tons of supercritical CO_2 from an industrial source into a regionally significant saline reservoir to demonstrate the safety, effectiveness, and efficiency of the process of isolating the CO_2 stream from the atmosphere.
- Inject a volume of CO_2 such that the plume will be of sufficient size to monitor geophysically and will adequately emulate larger volumes in terms of requirements for compression/dehydration, injection well construction, and environmental monitoring, and project results can be effectively extrapolated to commercial-scale operations and multiple sites within the Illinois Basin.
- Establish a project development model for site characterization, permitting, drilling and completion, environmental monitoring, and outcome assessment that will inform the public, scientists, regulators, and legislators on regional, national, and global scales about geologic carbon sequestration, and that will additionally support energy facility development.
- Demonstrate the development and use of a dynamic geologic model for the site that evolves as new data are acquired and incorporates advanced understanding of the fate of the injected CO_2 and its interactions with reservoir, seal, and subsurface fluids.

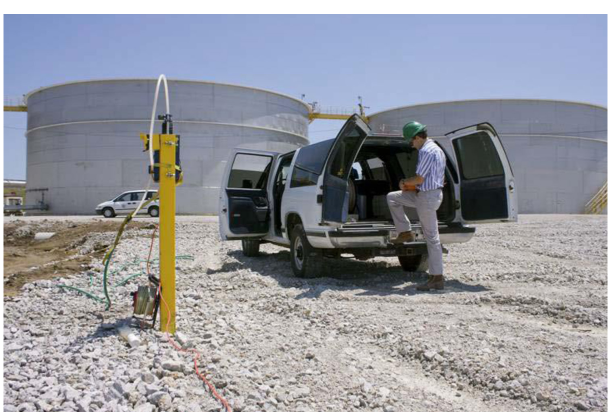

Figure 4. Groundwater sampling efforts at the ADM site.

Accomplishments to Date

- Injection well drilled and completed in May 2009.
- Geophone well completed and geophone array installed in November 2009
- 3D seismic baseline data acquired in January 2010.
- Verification well drilled, cased, and fitted with Westbay™ fluid sampling and P/T sensor instrumentation in January 2011.
- Construction of compression/dehydration facility and pipeline completed in summer 2010.

- Illinois EPA Class I Underground Injection Control (UIC) Permit issued in April 2011.
- Baseline fluid samples from injection target zone collected from verification well in summer 2011.
- Initiated satellite interferometry baseline data collection for imaging ground displacement in summer 2011.
- Compression/dehydration facility commissioned in October 2011.
- Illinois EPA completed review of as-built specifications and granted approval to begin injection operations on November 4, 2011.
- Injection operations at 1,000 metric tons per day initiated on November 17, 2011.
- Submittal of UIC Class VI permit December 2011.
- First 3D vertical seismic profile and cased-hole logging completed in March 2012.
- Second 3D vertical seismic profile completed in April 2013.
- Surface seismic monitoring instrumentation installed in September 2013 as a precaution for responding to larger induced seismic events detectable at surface.
- Final EPA Region V UIC Class VI Permit (for post-injection monitoring) became effective February 12, 2015.
- Ceased injection on November 26, 2014 after injecting 999,215 metric tons of CO_2.
- No CO_2 leakage or adverse impacts have been detected to date.
- Post-injection 3D surface seismic data acquired in February 2015.

Benefits

The MGSC region currently emits more than 267 million metric tons of CO_2 annually. The target Mt. Simon Sandstone is estimated to have a regional potential CO_2 storage capacity in the Illinois Basin of 11 to 150 billion metric tons. Based on the region's current emissions rate, 50 percent of the regional emissions for the next 100 years amounts to 13.3 billion metric tons, a total amount that is roughly equivalent to the low end of the basin's estimated storage capacity. Thus, it is vital to determine the storage capabilities of the Mt. Simon Sandstone. The previously described large scale field project is critical to understanding that adequate injectivity, containment, and capacity exist in the Mt. Simon Sandstone. Furthermore, the results can be leveraged to improve understanding of storage formations throughout the United States. Overall, this project will further commercial deployment of carbon capture and storage (CCS) technologies at an adequate scale to reduce GHG emissions from industrial plants.