



the **ENERGY** lab

PROJECT FACTS  
Carbon Sequestration

## Midwest Geological Sequestration Consortium—Validation Phase

### Background

The U.S. Department of Energy (DOE) has selected seven partnerships, through its Regional Carbon Sequestration Partnership (RCSP) initiative, to determine the best approaches for capturing and permanently storing carbon dioxide (CO<sub>2</sub>), a greenhouse gas (GHG) which can contribute to global climate change. The RCSPs are made up of state and local agencies, coal companies, oil and gas companies, electric utilities, universities, private companies, and nonprofit organizations that form the core of a nationwide network helping to establish the most suitable technologies, regulation, and infrastructure needs for carbon sequestration. The partnerships include more than 350 organizations, spanning 43 states and four Canadian provinces. The RCSPs are developing the framework needed to validate and deploy carbon sequestration technologies. The RCSPs will determine which of the numerous sequestration approaches are best suited for their specific regions of the country and identify regulatory and infrastructure requirements that will be needed should policy and economics indicate that sequestration be deployed on a wide scale. The RCSP initiative is being implemented in three phases. The Characterization Phase began in September 2003 with the seven partnerships working to develop the necessary framework to validate and potentially deploy carbon sequestration technologies. The Validation Phase of the RCSP effort (2005–2009) is focused on evaluating promising CO<sub>2</sub> sequestration opportunities through a series of field tests in the seven partnership regions. Presently, activities in the Development Phase (2008–2017) are proceeding and will continue the validation process to determine that CO<sub>2</sub> capture, transportation, injection, and storage can be achieved safely, permanently, and economically at a large scale. These tests will promote understanding of injectivity, capacity, and storability of CO<sub>2</sub> in the various geologic formations identified by the partnerships. Results and assessments from these efforts will assist commercialization efforts for future sequestration projects in North America.

### Description

The Midwest Geological Sequestration Consortium (MGSC) is led by the Illinois State Geological Survey, in collaboration with the Indiana and Kentucky Geological Surveys, and focuses on geologic sequestration potential in Illinois, southwest Indiana, and western Kentucky. This partnership was established to assess the safety and capacity of geologic carbon sequestration options in the Illinois Basin, including unmineable coal seams, mature oil fields, and deep saline reservoir formations. The MGSC is testing the ability of these types of reservoirs to serve as sinks for some of the more than 334 million tons (304 million metric tons) of annual CO<sub>2</sub> emissions from fixed sources in the Illinois Basin. A series of six small-scale pilot

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 Power Holdings, LLC  
 Praxair, Inc.  
 Schlumberger Carbon Services  
 Spectra Energy Corporation  
 Tenaska Taylorville LLC  
 Total Gas and Power Ventures USA, Inc.

## COST

### Total Project Value

\$26,176,137

### DOE/Non-DOE Share

\$20,035,895 / \$6,140,242

field tests are being conducted during the current Validation Phase. These pilot projects include the testing of unmineable coal seams to adsorb gaseous CO<sub>2</sub> and the ability to enhance oil production or recovery from old fields by CO<sub>2</sub> flooding. Injection into deep coals is expected to produce additional methane to augment natural gas supplies. Injection into mature oil fields is expected to recover some of the approximately 10 billion barrels of oil remaining in Illinois Basin reservoirs. The deep saline pilot test originally planned for the Validation Phase was upgraded to a large-scale injection demonstration of one million metric tons of CO<sub>2</sub> injected into deep saline formations at a depth of 6,000 to 7,500 feet below the surface during the Development Phase (2008–2017).

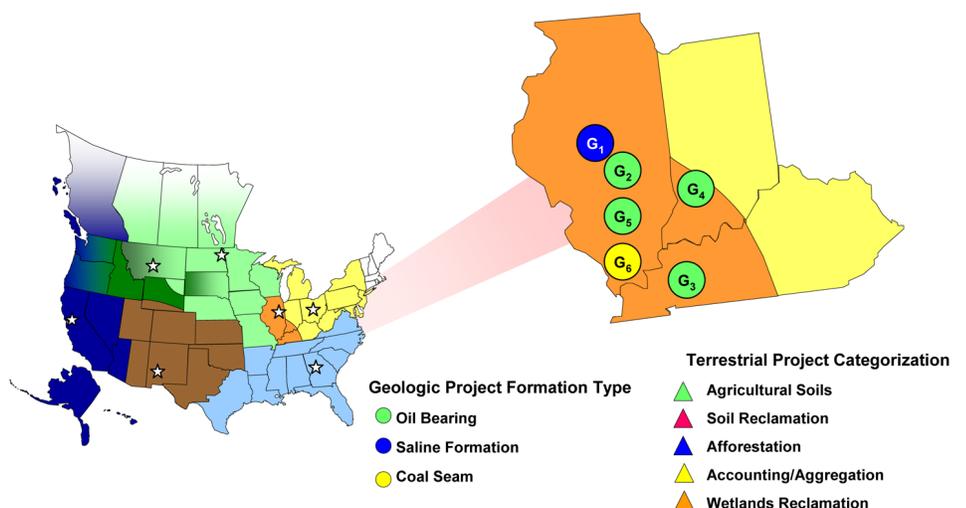
## Primary Project Goal

The MGSC's Validation Phase is a targeted, coherent validation of geologic sequestration that will meet regional needs, as well as contribute to a broader generic understanding of carbon sequestration in depleted oil reservoirs, unmineable coal seams, and deep saline reservoirs.

## Objectives

- Assess and validate aspects of geological CO<sub>2</sub> storage in the Illinois Basin.
- Continue investigations into the methods and economics of CO<sub>2</sub> capture at facilities, such as coal-fired power plants.
- Examine the costs of transporting large quantities of CO<sub>2</sub> via pipeline.
- Develop monitoring, verification, and accounting (MVA) protocols to ensure safe and effective sequestration operations.
- Conduct carbon storage assessments for each of the three geological sinks: coals, oil reservoirs, and saline reservoirs.
- Link options for capture, transportation, and geological storage within the environmental and regulatory framework.

## Field Projects



\*G<sub>1</sub> will also serve as Deployment Phase Project

*MGSC Validation Phase Test Locations*

## Geologic Sequestration Opportunities

Data gathered during the Characterization Phase (2003–2005) indicate that the geology of the Illinois Basin is favorable for CO<sub>2</sub> sequestration. MGSC's research estimated 484 million tons (440 million metric tons) of potential storage capacity in existing depleted oil and gas reservoirs, 2.64 billion tons (2.4 billion metric tons) of potential unmineable coal bed storage, and 128 billion tons (117 billion metric tons) of storage potential in saline formations. In some locations, two or more potential CO<sub>2</sub> sinks are stacked vertically. A particular focus is on formation properties that control CO<sub>2</sub> injectability, total storage capacity near major CO<sub>2</sub> sources, the safety of injection and storage processes, and the integrity of the overlying strata that acts as a seal. The integrity of these seals is critical for safe and effective isolation of CO<sub>2</sub>. MGSC is engaged in six geologic field tests during the Validation Phase to assess geologic sequestration opportunities in the Illinois Basin. Each test will have an extensive monitoring program for air, shallow ground water, oil and water produced from oil reservoirs, and for saline water produced from deep reservoirs to provide data to enhance understanding of the fate of injected CO<sub>2</sub> at the test sites. The entire process will be scrutinized to determine what contribution Illinois Basin geological sinks can make to national and international carbon sequestration goals in achieving carbon emissions reductions and how technology developed by the MGSC can be exported to other regions. MGSC's geologic tests are summarized below.

### Saline Formation Tests (G1)

The saline formation test originally planned for the Validation Phase is currently under development as the MGSC Development Phase project in collaboration with Archer Daniels Midland Company (ADM) and Schlumberger Carbon Services. The Mt. Simon Sandstone saline formation has been selected for this project, which involves the injection of approximately one million metric tons of CO<sub>2</sub> into the formation during a three year period at a depth of 7,500 feet. Mt. Simon is one of the most significant potential carbon storage resources in the United States. This project will employ groundwater and geochemical modeling along with monitoring, verification, and accounting (MVA) protocols. The location for this project has been selected and is proceeding in Decatur, Illinois on the ADM property. Carbon dioxide will be provided from the ADM ethanol production facility. An underground injection control Class I – Non-Hazardous permit has been issued by the Illinois Environmental Protection Agency, and the drilling of the injection well began in February 2009. Two-dimensional seismic has been conducted at the site and the MVA program has been collecting data since spring 2008. In the fall of 2009, 3D seismic will be collected, and injection is expected to begin in early 2010.

### Enhanced Oil Recovery Test (G2)

This mature oil field enhanced oil recovery (EOR) test, also known as a "Huff 'n Puff," evaluated the potential for geological sequestration of CO<sub>2</sub> in mature Illinois Basin oil reservoirs as part of an EOR program. During the process, CO<sub>2</sub> is injected (normally as a gas) into a producing well (the "Huff" phase), the well is shut, and CO<sub>2</sub> is allowed to penetrate the formation, and

then the well is placed back on production (the "Puff" phase). The test was conducted at the Loudon Field in Fayette County, Illinois. A total of 43 tons (39 metric tons) of CO<sub>2</sub> was injected over a five-day period into the Mississippian Weiler Sandstone formation at a depth of approximately 1,550 feet.

#### *Accomplishment Highlights:*

- Oil production during the first two months following the soak period was 93 barrels.
- Results indicate that the Illinois Basin oilfield may have an added-value benefit as a precursor to build and invest in the infrastructure to establish a sequestration industry within the Basin.

### Enhanced Oil Recovery Test (G3)

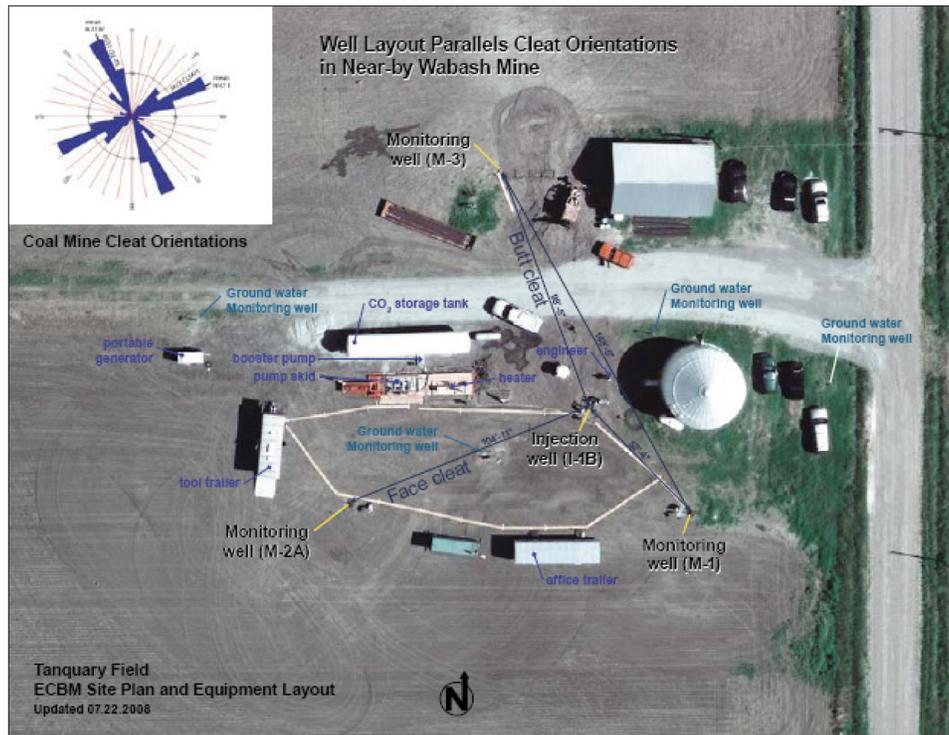
The well conversion EOR field test does not require the drilling of any new wells because available well(s) will be converted to handle CO<sub>2</sub> injection and because the pattern and spacing of existing wells is adequate to test EOR processes in the reservoir. The MGSC has selected the pilot site at the Sugar Creek oilfield near Madisonville, Kentucky. It is designed to be an immiscible CO<sub>2</sub> flood, as the CO<sub>2</sub> is expected to be in the gas phase in the reservoir. CO<sub>2</sub> injection is planned for about 6-10 months; followed by water injection. Provided that CO<sub>2</sub> injection rates are relatively high, CO<sub>2</sub> is planned for injection into one existing water injection well. There are eight oil producing wells and three monitoring wells surrounding the centrally located injection well. Eight thousand metric tonnes (8,820 tons) of CO<sub>2</sub> have been budgeted for this pilot. The Kentucky Geological Survey will be providing additional funding and field and lab support to the MVA shallow groundwater program of this pilot.

#### *Accomplishment Highlights:*

- Completion of site-screening-process in order to determine a site with the highest probability of CO<sub>2</sub> response during operations.
- A project site has been selected and the MVA program is currently under development.
- Site development has begun and injection is anticipated to begin in May 2009.

### Enhanced Oil Recovery Test (G4)

Depending on reservoir properties, management scheme of the existing waterflood, reservoir geology, and assessment of where in the reservoir unrecovered oil resides, a new well may not be required to create an optimum field test. A site will be sought to optimize the test pattern and provide an opportunity to collect additional data, such as advanced well logs, which are needed to assess the reservoir and understand sequestration potential. Additional data will be particularly useful to characterize and understand flow in carbonate reservoirs that are often more diagenetically complex compared to sandstones. A comprehensive MVA plan will be implemented in all phases of the pilot.



Site of ECBM project in Wabash County, Illinois

**Accomplishment Highlights:**

Site selection and project design in progress. The Bald Unit in Indiana and Loudon field in Illinois are under consideration.

**Enhanced Oil Recovery Test (G5)**

The second pattern flood test allows for a complementary test to be carried out for a different class of reservoirs among miscible or immiscible conditions and sandstone or carbonate reservoirs. Many reservoirs in the Illinois Basin represent immiscible or near-miscible conditions, so this test will contrast with miscible conditions if the latter are selected for Pattern Flood I. Reservoirs of interest for immiscible flooding will also be under waterflood and, as in the miscible case, will be judged for testing suitability based on the material balance of water injected compared to water produced. Even if the reservoir pressure is below the thermodynamic minimum miscibility pressure, CO<sub>2</sub> is known to somewhat reduce the residual oil saturation through increased vaporization. A comprehensive MVA plan will be implemented in all phases of the pilot.

**Accomplishment Highlights:**

Site selection and project design in progress. Bald Unit in Indiana and Loudon field in Illinois are under consideration.

**Enhanced Coalbed Methane Tests (G6)**

The purpose of this project was to determine the CO<sub>2</sub> injection and storage capability and the enhanced coalbed methane recovery potential of Illinois Basin coal seams. The target was the Pennsylvanian Carbondale formation at a

drilling depth of 900–1,000 feet (in 7-foot thick Springfield Coal). Injectivity was tested with water in a pressure transient test followed by a short nitrogen injection test. Finally, a CO<sub>2</sub> micro pilot to assess coal swelling and permeability reduction was done. The test site was located at Tanquary field in Wabash County, Illinois.

**Accomplishment Highlights:**

- Pre-injection site MVA began in February 2007.
- Four total wells (three monitoring and one injection) drilled and completed by May 2008.
- Injection began in fall of 2008 and a total of 100 tons (91 metric tons) of CO<sub>2</sub> was injected. Methane gas production was noted at the face and butt cleat monitoring wells, and CO<sub>2</sub> was observed at all monitoring wells.

**Benefits**

Injection of CO<sub>2</sub> into depleted oil fields will help recover some of the approximately 10 billion barrels of oil remaining in Illinois Basin reservoirs, and injection into unmineable coal seams will help produce trapped methane to augment natural gas supplies. These activities will validate CO<sub>2</sub> sequestration while also helping to meet the nation's need for fossil fuels. Value added benefits include a potential of 200 to 1,000 million stock tank barrels (MSTB) of oil and 3,000 to 11,000 billion cubic feet (Bcf) of natural gas.