FACT SHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Midwest Regional Carbon Sequestration Partnership (MRCSP)

NETL Cooperative Agreement DE-FC26-05NT42589

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Submitted by Battelle

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Cincinnati Arch Geologic Test, East Bend Power Plant	
Principal Investigator	Dave Ball, Battelle (614-424-4901; balld@battelle.org)
Test Location	Duke Energy East Bend Plant, Rabbit Hash, Kentucky
Amount and Source of CO_2	Approximately 1,000 metric tons Source = Commercial source
Field Test Partners (Primary Sponsors)	Duke Energy
	Kentucky Geological Survey, Indiana Geological Survey, and Ohio Geological Survey

Summary of Field Test Site and Operations:

The MRCSP recently injected approximately 1,000 metric tons of carbon dioxide (CO_2) as part of the geologic sequestration field test at the Duke Energy East Bend Generating Station located in Boone County, Kentucky, near Rabbit Hash, Kentucky (Figure 1). The Duke Energy East Bend facility, a 650 MW coal-burning power plant, is located on 1,800 acres on the floodplain along a bend in the Ohio River, with terrain becoming hilly away from the Ohio River Valley. The plant is an industrial setting, with various generating buildings, coal staging areas, and other facilities. The site is located on an active plant, which is providing property access for the field work and other support that should aid in completing the project. The area is moderately developed with a large amount of land available for field work. This site represents a fairly typical setting for the Cincinnati Arch, which is considered a significant feature for CO_2 storage in the region.

The Cincinnati Arch is a regional geologic structure in which sedimentary rocks form an arch between the Appalachian and Illinois Basins. Like most of the MRCSP region, thick sequences of sedimentary rock overlie Precambrian age basement rock at the site. The target reservoir is the Mt. Simon Sandstone, which is an extensive sandstone rock unit that has been historically used for injection of industrial and hazardous liquid waste in the MRCSP region. This unit is expected to have a higher amount of porosity and permeability in the Arches Province, suggesting that it would be suitable for CO_2 sequestration. Geological correlations based on nearby wells indicate that the formation is 300 ft thick at a depth interval of about 3,200-3,500 ft below surface at the site (Figure 2). Precambrian-age sandstones potentially underlie the Mt. Simon sandstone. These rocks are probably too densely packed to serve as storage reservoirs, but they are not that well characterized in the region.

The objective at this site is injection into a deep regional saline formation. The site is representative of the geology of a large part of the MRCSP region. Thus, this test site is exemplary of current or potential future power plants in the MRCSP region.

Figure 1. Left: A temporary supply of CO2 was stored on site in storage tanks. The carbon dioxide that was used for this test was the same in composition as that routinely used in the food industry. It was transported as a liquid by standard delivery trucks. Right: The injection target (Mt. Simon Sandstone) is more than a half mile below ground. The injection well is shown in the center.

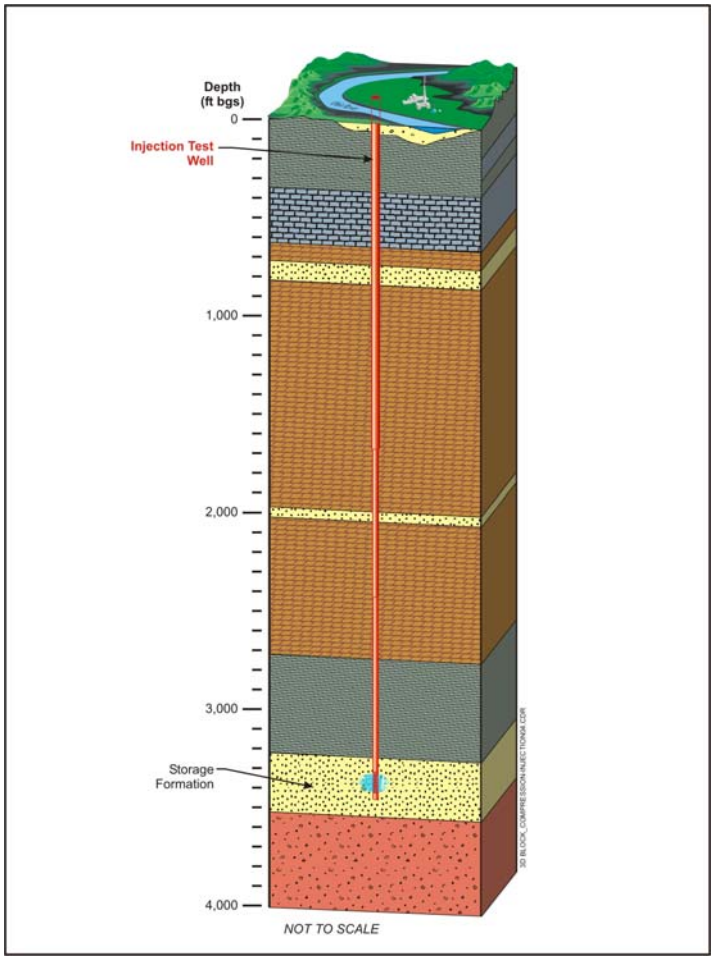

Figure 2. Conceptual diagram of CO_2 sequestration test for East Bend site

The Eau Claire shale provides containment above Mt. Simon Sandstone. This low permeability shale unit is approximately 500 ft thick and extends throughout the region. Minor oil and gas production in the area is limited to shallower rock units. No wells penetrate the Mt. Simon sandstone within 2 miles of the site. Target storage formations in the area are saturated with heavy brines (TDS > 100,000 mg/L) that have no economic value. The deepest underground drinking water source is bedrock units less than 250 ft deep, but most groundwater is obtained from the Ohio River Valley alluvium. No extensive faulting is present in the study area. Rocks dip very gently to the east at less than 40 ft/mile.

The overall test plan for the East Bend Site is to perform a relatively thorough characterization of the site geology and to perform limited injection testing and monitoring, including the following activities:

1) Preliminary Geologic Assessment of Potential Storage Reservoirs and Caprocks − This work involved compiling available well logs, developing geologic cross-sections, delineating target storage reservoirs, and identifying any issues related to geologic storage that may affect the project. Indiana and Kentucky Geologic Surveys completed most of this task because they are the repository for geologic data in the region of interest.

2) 2-D Seismic Survey - In November 2006, the 2-D seismic survey, employing truck-mounted seismic equipment to generate pulses in the ground around the East Bend plant, was performed to develop a geophysical image of the underground geology (Figure 3).

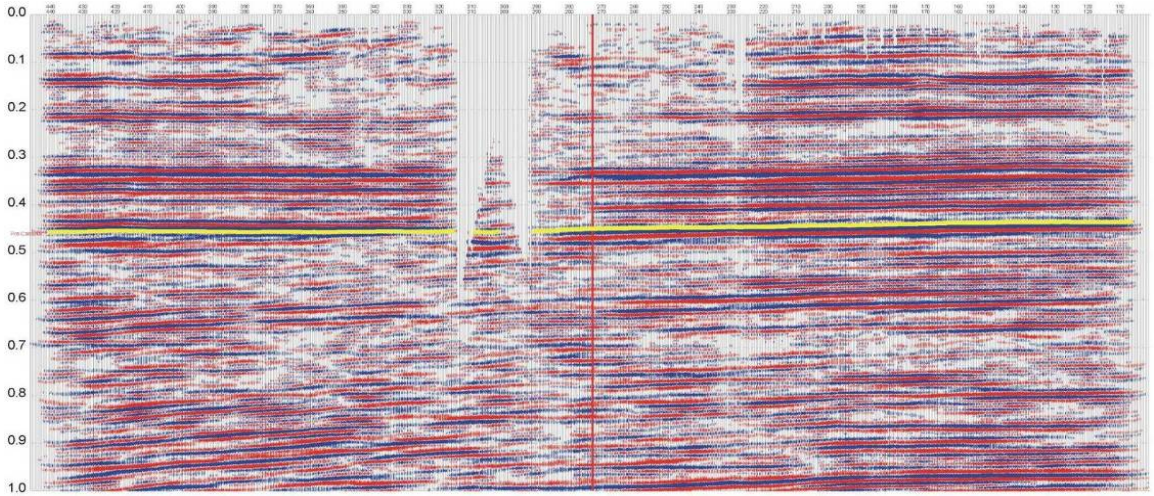

Figure 3. N-S Seismic Line from East Bend site. Red vertical line is proposed well location. Yellow line shows surface of Precambrian rocks. Note: Gap in data coverage is across Ohio River.

3) Permitting - The final Class V underground injection control (UIC) permit was obtained from the U.S. Environmental Protection Agency Region 4 in January 2009 and the drilling permit was obtained from the Kentucky Division of Oil and Gas in June 2009.

3) Site Characterization Field Work − The project team drilled the test well in July 2009. The boring was completed to a depth of approximately 3,700 ft (Figure 3). The sampling and characterization activities performed during the installation of the well focused on determining the geologic, hydrogeologic, and geochemical conditions of the formations encountered during the drilling activities. Rock samples were collected from the storage and caprock formations for laboratory analysis. Geophysical properties such as sonic velocities, density, porosity, and resistivity were measured using wireline tools. Geochemistry of the brine within the storage formation was determined by swabbing the perforated well and collecting brine samples for laboratory analysis. Hydraulic properties of the storage reservoir were determined through short-term brine injection testing into the reservoir. A vertical seismic profile (VSP) was used to obtain high resolution images near the wellbore.

4) CO_2 Injection Testing and Monitoring – Approx. 1,000 metric tons of CO_2 was injected into the Mt. Simon Sandstone in September 2009. The CO_2 was purchased from a commercial source. Several advanced monitoring devices and techniques were used to monitor the injection, delineate the movement of carbon dioxide in the formation, and confirm that the injection was proceeding as planned.

5) Post-Injection Monitoring and Site Closure – Post-injection monitoring is being performed to assess the fate of the injected CO_2. Periodic groundwater monitoring of underground sources of drinking water is required by the UIC permit. Over the next two years, groundwater samples will be collected from 10 monitoring wells in the vicinity of the demonstration site, including a new groundwater monitoring well that was installed 400 ft from the injection well. These wells are screened at various depths, ranging between 70 and 160 ft below the ground surface.

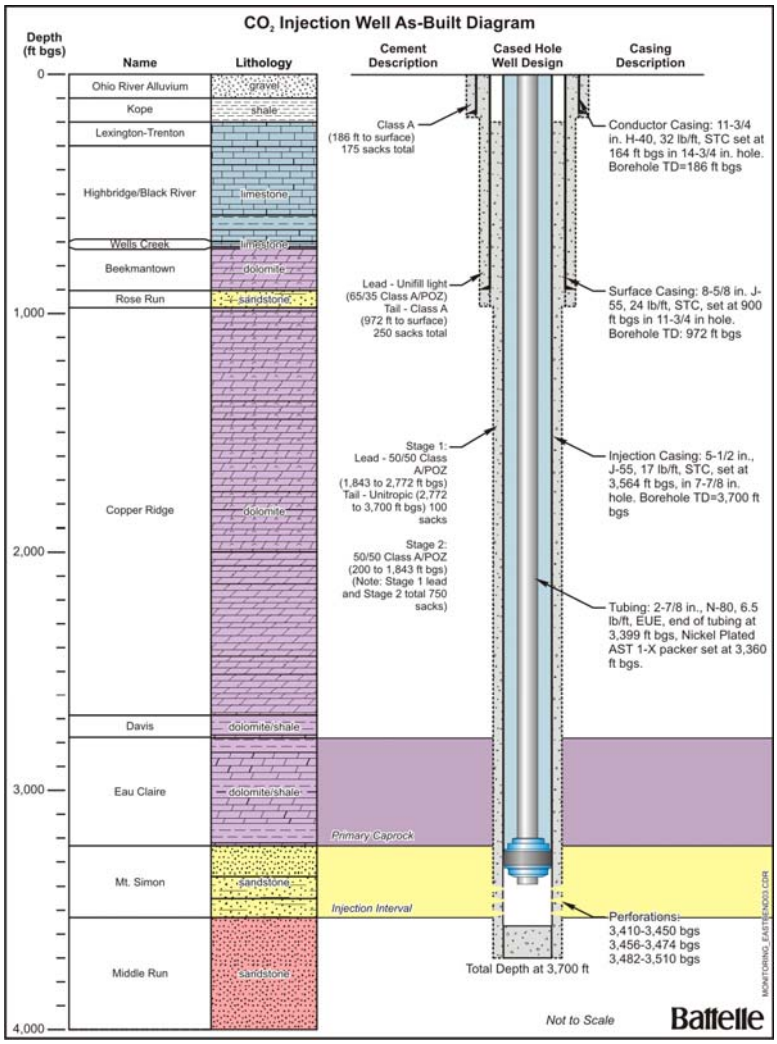

Figure 4. Geologic stratigraphic column and injection well construction diagram

Research Objectives:

The primary research objective is to demonstrate CO_2 sequestration in the Mt. Simon sandstone, a major CO_2 sequestration target for the MRCSP region (and the United States). Since the Mt. Simon sandstone extends throughout the Midwestern United States, much of the information from this test will be useful for other portions of the MRCSP and beyond. In addition to this main objective, the tests are aimed at better understanding regional trends (i.e. permeability, porosity, geochemistry, mineralogy) in the Mt. Simon sandstone.

Summary of Modeling and MMV Efforts:

Initial modeling has entailed simplified STOMPCO_2 simulations based on assumed hydrologic parameters and injection system specifications (i.e. 300 ft sandstone reservoir at 3,200-3,500 ft, 1,000-3,000 tons injection over 30 days, etc.) The objective of this preliminary modeling was to provide guidance on monitoring and liability issues. Initial modeling suggested little migration of CO_2 from the point of injection (100's of feet); thus, the area of review was within the property of the host site (Figure 5). Data from a test well was used to support the modeling before the CO_2 was injected. The model is currently being calibrated to field test data.

Monitoring technologies for CO_2 sequestration were selected based on the proposed injection system specifications and geologic setting (Table 1). Since the injection interval is fairly thick, the monitoring approach involved tracking the upward migration (if any) of the injected CO_2. Accordingly, vertical seismic profiling and wireline methods were considered the most promising for this site. System pressure, temperature, groundwater, and brine geochemistry monitoring were also applied.

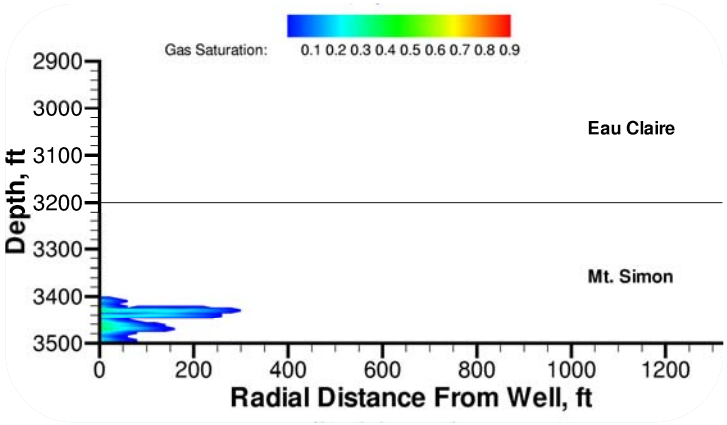

Figure 5. Preliminary reservoir modeling showing CO_2 gas saturation after 30 days of injection at 100 metric tons per day.

Table 1. Measurement Technologies Employed at Field Test Site

Measurement Technique	Measurement Parameters	Application
Water composition	CO_2, HCO_3, CO_3^{2-} Major ions Trace elements Salinity	Quantifying solubility and mineral trapping Quantifying CO_2-water-rock interactions Detecting leakage into shallow groundwater aquifers
Subsurface pressure	Formation pressure Annulus pressure Groundwater aquifer pressure	Control of formation pressure below fracture gradient Wellbore and injection tubing condition Leakage out of the storage formation
Well logs	Brine salinity Sonic velocity CO_2 saturation	Tracking CO_2 movement in and above storage formation Tracking migration of brine into shallow aquifers Calibrating seismic velocities for 3D seismic surveys
Vertical seismic profiling	P and S wave velocity Reflection horizons Seismic amplitude attenuation	Detecting detailed distribution of CO_2 in the storage formation Detection leakage through faults and fractures

Source: IPCC Special Report on Carbon Dioxide Capture and Storage

Accomplishments to Date:

The East Bend project is in the site closure and well plugging phase. Major tasks have involved site preparation, preliminary geologic assessment, seismic survey, and injection and MMV:

2006 Site Preparation and Characterization

- Site preparation activities were completed including survey of the site for suitable test well location, seismic survey lines, and injection system.
- Stakeholder outreach groundwork was completed. This included several meetings with the Duke Energy internal project team, East Bend plant staff, and neighbors. A briefing was held with Boone County officials at their offices in conjunction with the open house.
- A preliminary geologic assessment was completed by the Indiana and Kentucky Geological Survey describing the regional geologic setting, target sequestration rock formations, and other issues.
- A 2-D seismic survey acquisition was completed. The seismic data suggested that the target Mt. Simon interval is continuous through the test site with no faulting or fracturing which would affect the tests. Additional processing of the data was completed to resolve some of the deeper features.

2007-2008 Permitting and Design

- Site characterization data analysis.
- Developed preliminary well construction specifications and a drilling plan.
- Developed conceptual injection test design and MMV plan.
- The UIC permit application was completed and submitted to USEPA Region 4 UIC program on May 1, 2008. The draft permit was issued for public comment on November 25, 2008.

2009 Test Well Drilling and CO_2 field injection testing

- After a 30-day public comment period, the Class V UIC permit was finalized in January 2009. The drilling permit was obtained from Kentucky Division of Oil and Gas in June 2009.
- Test well drilling was completed July 2009. A total of 120 ft of whole core was collected: 30 ft from the Eau Claire and two 30 ft sections from the Mt. Simon. Based on wireline logs, twenty additional sidewall cores were collected in various depths. Baseline monitoring of USDW groundwater wells and CO_2 injectate also was completed per UIC permit requirements.
- In August 2009, two series of injection tests were conducted using a brine solution to determine the fracture pressure of the Mt. Simon injection reservoir and to determine hydraulic parameters of the formation. The baseline VSP survey also was conducted August 2009.
- The CO_2 injection testing was completed in September 2009. Flow rates, pressures, and other operational data were monitored for two 500 metric ton injection events. The well was then shut-in to observe pressure fall-off. A down-hole temperature survey was completed in the well to detect temperature signature of the injectate.

Summarize Target Sink Storage Opportunities and Benefits to the Region:

- The target sink is the Mt. Simon sandstone, a major sequestration target in the MRCSP and Midwestern U.S. Test results may be applied for much of the MRCSP region and the Midwest.
- Added value in performing the test at an active power plant to demonstrate CO_2 sequestration in a real-world setting.
- Added value from partnering with a major power company toward promoting carbon capture and geologic storage (CCS) in the energy industry.

Cost*:

Total Project Cost: $26,320,000

DOE Share: $20,033,000 (76%)

Non-Doe Share: $6,287,000 (24%)

(*) Costs are for overall MRCSP Phase II project

Field Project Key Dates:

Baseline Completed: Summer 2007

Drilling Operations Begin: July 2009

Injection Operations Begin: September 2009

MMV Events: July 2009 through September 2011