Geologic Storage Field Demonstrations of the Midwest Regional Carbon Sequestration Partnership

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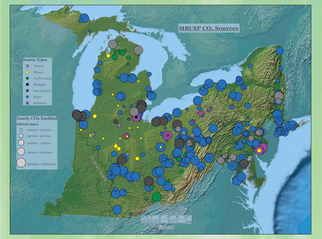
MRCSP Geology Team Members

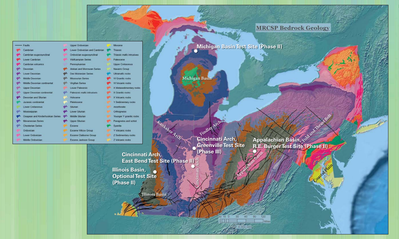
Abstract

The eight states that comprise the Midwest Regional Carbon Sequestration Partnership (MRCSP)—Indiana, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, and West Virginia—represent a large portion of the U.S. economy and its dependence on fossil-fuel-based energy production and resulting significant CO_2 emissions. These states also represent a diverse geologic framework for carbon capture and storage (CCS), which includes two mature deep basins—Michigan and Appalachian—separated by the arches region, Appalachian Valley and Ridge, crystalline Blue Ridge, Piedmont provinces, and the Coastal Plains sediments in the eastern part of the MRCSP. Validating geologic storage potential and testing the applicability of monitoring technologies in this diverse area require regional geologic characterization and site-specific injection demonstrations.

To examine these varied geologic settings, the MRCSP currently is conducting three deep saline reservoir tests in collaboration with energy companies—the potential future users of this technology. Each field test incorporates extensive reservoir and seal characterization, permitting, reservoir modeling, injection, monitoring, and outreach efforts. A Phase II deep test well, drilled in 2007 at FirstEnergy's R. E. Burger Plant in the Appalachian Basin, has provided an opportunity to test multiple deep saline reservoir zones typical of this basin. Also, DTE Energy currently operates a gas processing plant in northern Michigan that produces a pure CO_2 stream used for Core Energy's enhanced oil recovery (EOR) operations (Phase II). During February–March 2008, the MRCSP team injected more than 9,100 mt (10,000 tons) of CO_2 into a dolomitic saline formation at 1,100 m (3,609 ft). Monitoring techniques include cross-well seismic, borehole micro-seismic, PFT tracers tests, wireline logging, fluid saturation profiles, fluid sampling, and continuous pressure-temperature monitoring. Finally, in 2009 the MRCSP will drill injection and monitoring wells at Duke Energy's East Bend Plant in Kentucky to test the Mt. Simon Sandstone in the arches geologic province. For the large-scale demonstration project (Phase III), the MRCSP has proposed using CO_2 from a western Ohio ethanol plant to inject more than 227,000 mt (250,000 tons) per year for four years, with an optional site at an integrated gasification combined cycle (IGCC) plant in Indiana. Geologic assessments at these sites are now underway.



Due to its diverse economy, the MRCSP Region includes a large variety of greenhouse gas sources. Each year, these large, stationary sources—including power plants, refineries, cement plants, ethanol plants, and iron and steel plants—emit more than 680 million mt (750 million tons) of CO_2. Emissions are highest along the Ohio River Valley and Great Lake coastlines where many power plants and industries are located.



Shaded topographic-relief map showing generalized bedrock-geology units (by system) found at or near the surface and bedrock contacts. Major regional geologic features (folds, arches, and basins) are also labeled. Locations of the Phase II and Phase III field demonstration sites are noted.

Introduction

The MRCSP area is diverse in many ways. The Ohio River Valley, industrial northeast, and the Great Lakes shores represent some of the largest remaining manufacturing and power-generating abilities in the nation. These combined industries and utilities produce nearly 820 million mt (900 million tons) of CO_2 per year from large, stationary sources [>91,000 mt (100,000 tons)/yr]. Therefore, understanding carbon sequestration options is critical to the region and the nation as the United States heads toward carbon regulation.

The regional geology contains two major sedimentary basins, the Appalachian and Michigan, with the arches province between. The coastal plains and Atlantic offshore of Maryland and New York rise into the Fold and Thrust Belt of the Appalachian Mountains. Understanding of the subsurface geology varies. Where sedimentary thickness is least, and many oil and gas wells have been drilled, much certainty can be placed on assessments for carbon sequestration potential. But, more often than not, inadequate data exists to properly characterize the geologic potential of a particular area, especially within the middle of sedimentary basins in excess of 6,100-m (20,000-ft)-deep. The partnership seeks to clarify what is known and to identify areas of great uncertainty.

MRCSP tests are part of a national effort sponsored by the U.S. Department of Energy, National Environmental Technology Laboratory (DOE/NETL) to develop robust strategies for mitigating CO_2 emissions that contribute to greenhouse gases. The tests attempt to demonstrate the safety and effectiveness of CO_2 sequestration and to further understanding of the best approaches to its implementation.

Phase II and Phase III efforts focus on conducting field tests at multiple locations while expanding knowledge of regional geologic reservoirs to investigate CO_2 sequestration feasibility. Three small-scale test sites were selected for Phase II and one large-scale test site is now in planning for Phase III. These projects involve a preliminary geologic site assessment; site characterization field work, such as seismic surveys and test wells; permitting; CO_2 injection tests; and monitoring the geologic sequestration process. Field test results will be used to evaluate CCS opportunities and define infrastructure necessary to deploy CCS at a meaningful scale.

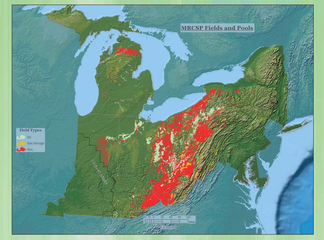
Overview

Located in Belmont County, Ohio, on the western flank of the Appalachian Basin, the FirstEnergy R. E. Burger plant—a 413-MW coal-burning power plant within a prime coal-mining area—has had relatively little oil and gas exploration, especially deep drilling. Extensive oil and gas drilling of Devonian Oriskany reservoirs to the east and Silurian "Clinton" reservoirs to the west provided limited data of what the reservoir properties may be along the Ohio River Valley, an area with numerous coal-burning power plants.

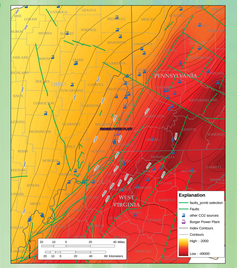
Eleven miles of reflection seismic data were acquired in late 2006, and the test well was drilled in early 2007 to a total depth of 2,555 m (8,384 ft) into the Upper Ordovician Queenston Shale. Geophysical log and sample analyses indicated limited porosity zones as potential CO_2 injection targets within the Oriskany Sandstone, the Middle Salina Carbonate Unit, and the Medina ("Clinton") sandstones.

In November 2008, CO_2 injection tests were completed at the site in these three injection targets. The initial tests showed that pressure in the wells built up very quickly for relatively small flow rates of CO_2 in each target zone. Analyses of the hydraulic responses from the multiple injection tests continues.

While injection test results are not very promising for large-scale injection operations at this important site, the information gained from this well is invaluable to the regional knowledge base. Additional seismic and drilling help define the area's sequestration options. Also, it is equally important to know where large-scale injection operations can be performed and where they can not.



The MRCSP region has several prolific petroleum-producing areas but has never had a widely-available source of CO_2 for enhanced recovery. If flue-gas separation technologies advance sufficiently to make economical sources of CO_2 widely available, CO_2-enhanced recovery may revitalize many regional reservoirs. Hundreds of millions of barrels of additional oil could be produced from the region while sequestering over 900 million mt (1 billion tons) of CO_2.



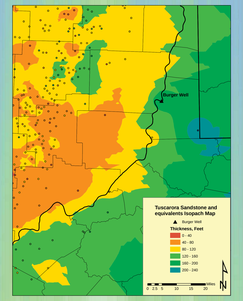
Structure contour map on the top of the Precambrian unconformity within the tri-state area of Ohio, Pennsylvania, and West Virginia. The Burger power plant and other large CO_2 point sources are located.

Preparing for CO_2 injection testing, September 2008. R. E. Burger power plant in the background.

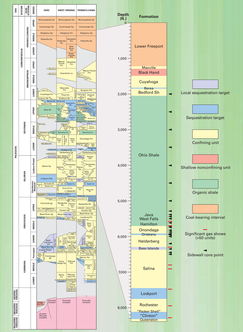
A Snapshot of the MRCSP Region

- Population: 71.3 million (nearly 1/4th of U.S. population)
- Gross Regional Product: $2,672 billion (1/4th of U.S. economy)
- 21.5% of all electricity generated in the United States
- 77% of electricity generated in the region is generated by coal
- 12% of nation's total CO_2 emissions

Appalachian Basin—R. E. Burger Phase II Field Test Site



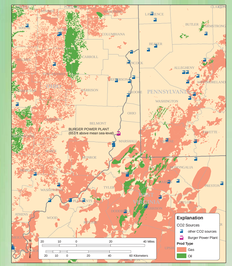
Isopach (thickness) map of the Tuscarora Sandstone and equivalents (the "Clinton" sandstone) near the Burger power plant. Note the large distances in all directions from the Burger test well to the nearest well drilled to this same horizon.



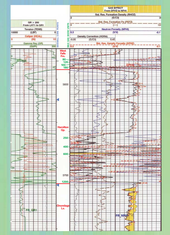
MRCSP stratigraphic correlation and CO_2 sequestration characterization chart of geologic units in Ohio, Pennsylvania, and West Virginia (left) and the units, depths, and thicknesses as drilled within the Burger test well.

The Marcellus Shale at the Burger Test Site

The Middle Devonian Marcellus Shale is the basal unit of the Hamilton Group. The Marcellus Shale is very fissile and characterized by high, natural radioactivity and low density. The Rhinestreet Shale Member of the West Falls Formation disconformably overlies the Hamilton Group in the Burger site vicinity. The Rhinestreet Member is similar to the Marcellus Shale and natural gas production occurs from both. Depth to the Hamilton Group at the Burger Well is 1,702 m (5,583 ft). Numerous gas shows as high as 1,200 units were encountered while drilling through the 10.4-m (34-ft)-thick Marcellus Shale. Gas shows as high as 180 units were observed from the 6.1-m (20-ft)-thick Rhinestreet Shale. The gas shows were short-lived and background gas concentrations returned when the individual black shale tongues were penetrated. One sidewall core was collected from the Hamilton Group at 1,712 m (5,616 ft).

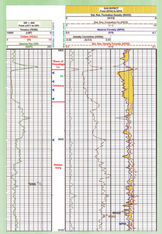


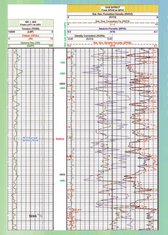
Oil and gas fields at depths greater than 762 m (2,500 ft) (suitable for miscible CO_2 EOR operations) within the Ohio, Pennsylvania, and West Virginia tri-state area. Locations of the Burger power plant and other large CO_2 point sources are indicated. Note the lack of "deep" oil and gas fields along the upper reaches of the Ohio River Valley. The reason for this is two-fold: (1) Most of the mineral regional rights are held by coal-mining interests and (2) prospective oil and gas horizons from the west are much deeper here.



Geophysical log response of the Hamilton Group and lower West Falls Formation from the Burger Well (API number 3401320586). Note the locations of sidewall cores and multiple strong gas shows.

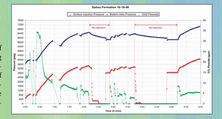
The R. E. Burger Power Plant along the Ohio River.

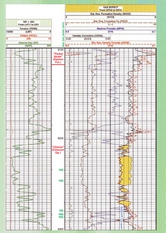




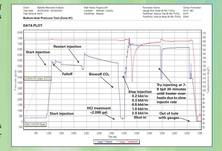
Left: Geophysical log response of the Salina interval exhibiting gas shows.

Right: Chart showing results of pressure and injection testing within the Salina interval. Intermittent pumping was a result of the pumping system overheating. Rapid increase in pressure with limited injection (total volume = 30 barrels).



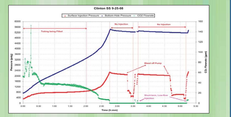


Left: Geophysical log response of the "Clinton" sandstones and gas shows from the Burger test well.



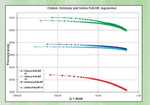
Top right: Chart showing results of step rate test ran with water within the "Clinton" interval.

Bottom right: Chart showing pressure and CO_2 injection testing results within the "Clinton." Slow initial pressures increase as tubing/casing are filled with CO_2. Pressures do not begin to stabilize during short-term injection (3.5 hours). After tubing/casing is filled, low-flow, short-term injection causes rapid wellhead pressure increases.



Left: Geophysical log response of the Oriskany Sandstone from the Burger test well. Note the locations of sidewall cores and a minor gas show.

Right: Chart showing results of pressure and injection testing within the Oriskany. Attempted CO_2 injection while maintaining pressures less than 17 MPa (2,500 psi) and flow rates >18 mt (20 ton)/day (approximately 4.5 gpm). Injection parameters could not be achieved after 8 hours of injection. Flow was reduced several times during injection testing.



Above: Results of pressure fall-off tests for all three tested intervals. Although the Oriskany injectivity was minimal, it may have the greatest potential of the three zones.

Geologic Storage Field Demonstrations of the Midwest Regional Carbon Sequestration Partnership

MRCSP Geology Team Members

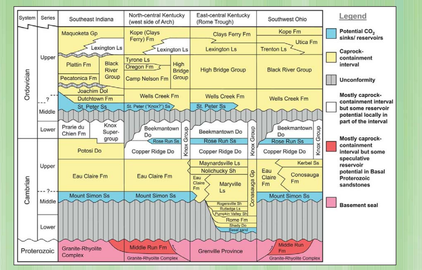
Cincinnati Arch—Duke Energy East Bend Phase II Field Test Site

Overview

The Indiana, Kentucky, and Ohio Geological Surveys, working under the auspices of the MRCSP, completed a preliminary feasibility assessment of geological sequestration as a carbon management strategy for Duke Energy's East Bend power-generation facility. The test site is located on the western flank of the Cincinnati Arch, a regional geologic structure between the Appalachian and Illinois basins, outside of Rabbit Hash, Kentucky, 32 km (20 mi) southwest of Cincinnati. USEPA has recently issued underground injection control permits to drill the injection test well, and drilling operations are scheduled to begin in early summer 2009.

The objective of the feasibility study was to provide a preliminary assessment of known geologic characteristics of the region surrounding the site. An area within a radius of approximately 80 km (50 mi) of the site was included in the study. The primary purpose of the assessment was to determine the presence, configuration, and characteristics of potential reservoirs and confining strata.

Duke Energy East Bend Plant.

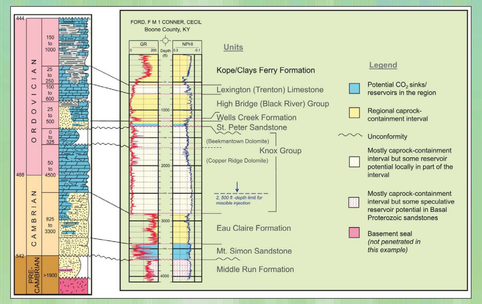


Generalized stratigraphic column of the study area.

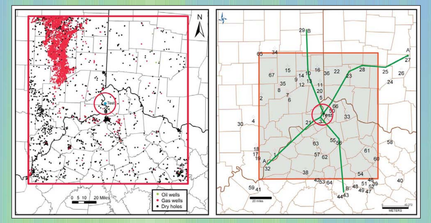
Preliminary assessment

As at many sites on interbasinal arches in the MRCSP region, many of the upper Paleozoic strata are too shallow or eroded to function as potential reservoir targets. A significantly thick [91–122 m (300–400 ft)] section of Mt. Simon Sandstone is projected to exist at the site and is the primary candidate target for injection along this arch. The top of this section is at a depth of approximately 1,036 m (3,400 ft), well below the depth necessary for maintaining CO_2 in a supercritical state. Site-specific porosity and permeability data currently are not available for the sandstone at the study site.

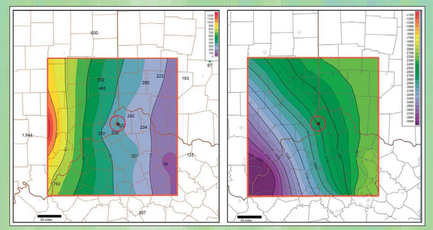
A thick sequence of dense carbonate and argillaceous rock (Eau Claire Formation and basal Knox) directly overlies the Mt. Simon at the study site. The combined thickness of these units exceeds 302 m (1,000 ft). Vertical permeability values below 0.01 md have been determined for core samples from this sequence in adjoining wells, so the interval should function as an effective confining unit.



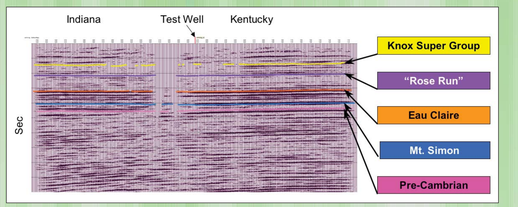
Typical subsurface log signatures for stratigraphic units in the study area.



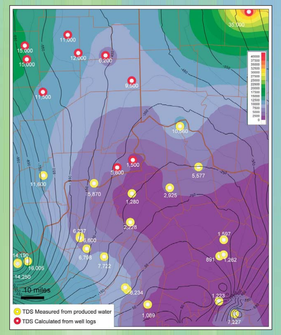
Left: Map showing locations of all oil and gas wells within the tri-state area of Indiana, Kentucky, and Ohio. Most of the wells are too shallow and/or do not have geophysical logs to provide significant data to this analysis. The red (gas) wells to the northwest are from the turn of the century Lima-Indiana oil and gas trend that produced from the Ordovician Trenton Limestone. Right: Locations of significant wells used within this study and lines of cross section.



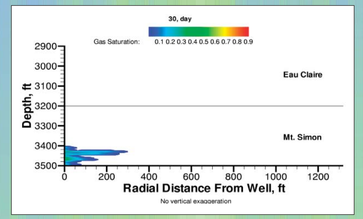
Left: Thickness map of the Mt. Simon Sandstone. Right: Structure map on top of the Mt. Simon Sandstone.



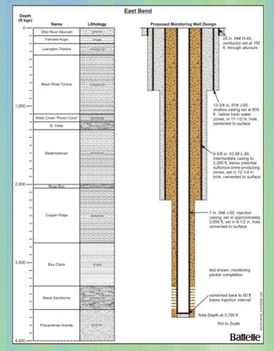
N-S seismic line from East Bend site. Site characterization included a 16-km (10-mile) seismic survey completed in two transects in October–November 2006. No faulting or other major problems were observed. Projections from seismic analyses outside of the study region indicate that the Proterozoic East Continent Rift Basin and Middle Run Formation should underlie the study site. Permeable sandstones have been encountered in the Middle Run in other areas and might exist beneath the Mt. Simon, which is significant because, while the Mt. Simon overlies impermeable crystalline basement in other areas of the region, here an additional interval may exist for injection in this part of the MRCSP region.



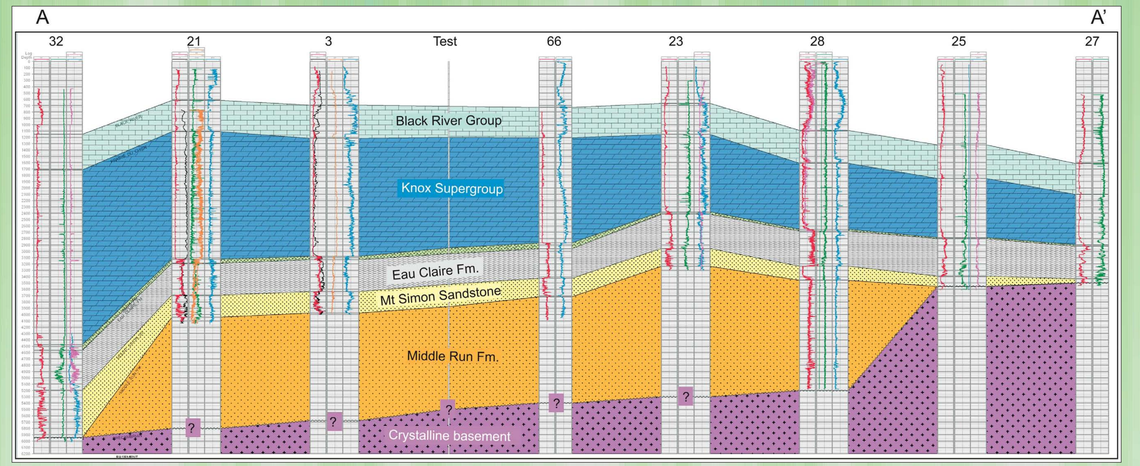
Structure contour map on the top of the Knox unconformity and Knox groundwater total dissolved solids (TDS) values within the tri-state area of Indiana, Kentucky, and Ohio. Based on analyses of recovered brines and log analyses, the base of the underground source of drinking water (<10,000 ppm TDS) is located stratigraphically within the upper portion of the Knox carbonate sequence generally at depths of 609 m (2,000 ft) or more beneath the surface. Although there is no direct measurement data at depth near the study site, calculations from geophysical logs in a nearby well confirm this distribution.



Preliminary model results, using STOMPCO$_2$ simulations, suggests little migration of CO_2 after 30 days of injection at 100 mt (110 tons) per day.



Geologic stratigraphic column showing estimated lithology and preliminary well design.



SW-NE regional cross section A-A'. Broad structural arches in which deep Paleozoic strata rise to near the surface are a major part of the geology of the MRCSP region. Also, structural arches underlie many of the CO_2 sources in the region. Understanding the feasibility for sequestration in these situations as compared to deeper, basinal configurations is important for regional CO_2 sequestration assessment.

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Overview

The Michigan Basin test site is located at an existing gas field in the vicinity of a DTE Energy gas processing plant outside of Gaylord, Ostego County, Michigan. The site sits in the northern portion of the Michigan Basin, a large, mature sedimentary basin that covers most of lower Michigan. Paleozoic sedimentary rocks, up to approximately 3-km (nearly 2-mi)-thick, underlie a 183–244-m (600–800-ft) thick glacial layer in the study area, and Precambrian crystalline basement rocks underlie the Paleozoic rocks. Total thickness of the surficial glacial layer is 203 m (666 ft) near the test site.

The injection site is located in the State-Charlton 30/31 Field, which is a depleted Niagaran oil field now under a CO_2 flood. Natural gas produced from nearby Antrim Shale fields contain 10–15 percent CO_2, which is removed at processing plants before the gas is ready for market. Consequently, high-purity CO_2 is available from the DTE Energy Turtle Lake gas processing plant. Periodically, this CO_2 is piped to the Core Energy Dover 10 Compression facility and used for enhanced oil recovery (EOR) in Niagaran Reef reservoirs. The CO_2 is captured, compressed, and injected in the reefs to flush residual oil out of the reservoir rocks. A significant amount of available infrastructure permits testing CO_2 sequestration in saline formations resting above the Niagaran Reefs.

A new well (State-Charlton #4-30) was drilled in November 2006 for CO_2 injection. While drilling, extensive wireline logging and rock coring allowed geological data gathering to assess CO_2 sequestration potential at the site and the Michigan Basin in general. In addition, the well was designed to fulfill underground injection control (UIC) requirements for Class II and Class V injection wells.

Nearby, the recompleted State-Charlton #3-30 well facilitated monitoring of the CO_2 injection tests. The original well was drilled to a depth of 1,768 m (5,800 ft) for oil production in the Niagaran reefs and later plugged and abandoned. In winter 2007, the well was recompleted with a deviated hole kicking off at 518 m (1,700 ft) and completing at a depth of 1,097 m (3,600 ft) through the Bass Islands dolomite. Consequently, the well terminated at a point approximately 146 m (479 ft) from the injection well.

The primary injection target formation, the Bass Islands dolomite, sits at a depth of 1,049–1,071 m (3,440–3,573 ft), overlain by containment layers that include the Bois-Blanc and Amherstburg-Lucas formations [682–972 m (2,237–3,188 ft)]. Rock units in the interval of interest dip toward the south at approximately 9.4 m/km (17.4 ft/mi). While some regional anticlines and arch trends exist, a well-defined structure does not appear near the site. No faults or pervasive fracture zones have been encountered. Niagaran pinnacle reefs are present in the deeper rocks, but these structures are several hundred meters beneath the injection interval.

Over 10,000 mt (11,000 tons) of CO_2 was injected into the Bass Islands dolomite over an 18-day period, using variable injection rates up to 600 mt (660 tons) per day [~220,000 mt (243,000 tons)per yr]. Maximum injection pressure extrapolation suggests that maximum theoretical injection rates are 2–3 times those observed [~440,000–660,000 mt (485,000–728,000 tons) per yr]. Thus, the Bass Islands dolomite in the northern Michigan Basin has suitable injectivity for CO_2 sequestration at an industrial scale.

Well tests proved useful in analyzing injection potential, even though maximum injection rates were not approached. Injection test analysis was used to define the hydraulic behavior of the reservoir system in terms of flow behavior and leakage. Reservoir simulations provide fairly accurate predictions of hydraulic response to the injection. A cross-well seismic-based velocity anomaly, ~91 m (300 ft) above the perforated interval, may be due to natural gas or CO_2; however, potential upward migration pathways for CO_2 along the wellbore have been eliminated.

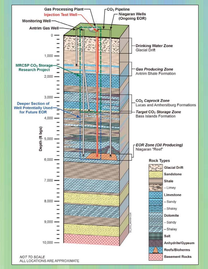
No breakthrough occurred in the monitoring well, and only subtle geochemical changes were observed. More injection would be necessary to investigate these processes.

Michigan Basin Extended Injection

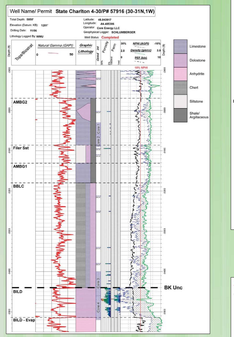
Additional CO_2 injection at this test site is being planned by DOE/MRCSP to further evaluate CO_2 storage behavior:

- Total injection target volume: 50,000 mt (55,000 tons) additional CO_2.
- Duration: 4–8 months, starting early 2009.
- Rate: 0–600 mt (660 tons) CO_2/day.
- Target: Bass Islands dolomite (same injection setup).
- Several monitoring techniques will be included to address questions that arose during the initial test:
  - Breakthrough in monitoring well
  - Geochemical
  - Cross well seismic
  - Injectivity

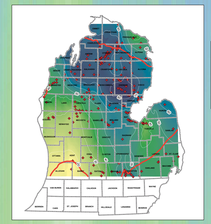
Michigan Basin—DTE Energy and Core Energy Phase II Field Test Site



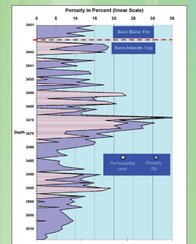
General diagram of the injection well, monitor wells, and stratigraphy at the Michigan Basin test site.



Wireline log section of the Upper Silurian to Middle Devonian section in the injection test well. This figure shows high-resolution natural gamma ray, compensated neutron porosity (NPHI), bulk density, and photoelectric factor (PEF) logs; conventional and sidewall core intervals; lithologic interpretation; and conventional core plug porosity and permeability data. This log provides a high-quality reference section for CO_2 sequestration targets and impermeable cap-rock units in northern lower Michigan.

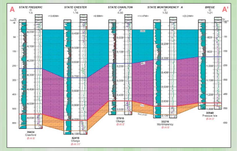


Left: The Bass Islands Group in the Michigan subsurface consists mostly of light brown to buff dolostone with argillaceous dolostone and anhydrite present in parts of the section. The entire Bass Islands interval reaches a thickness of 90–180 m (300–600 ft) in the central basin but thins substantially because of erosional truncation in southwestern Michigan. Historically, subsurface geologists have picked the top of the Bass Islands Group throughout the Michigan Basin at a readily recognized, high-density interval confidently interpreted as anhydrite. This lithotype was captured in core and constitutes a reference marker in this well for regional lithostratigraphic correlation. The upper section of the group, as found in core and logs, is a porous and permeable dolostone unit, informally referred to as the Bass Islands dolostone, the thickness of which is shown.

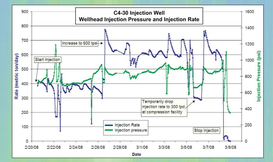


Conventional core plug porosity and permeability versus depth in the Bass Islands dolomite target interval. Based on an analysis of porosity and permeability from test well core samples, the Bass Islands dolomite was confirmed as the primary injection target. For the Bass Islands dolomite core samples, the mean porosity was 13 percent and the mean permeability was 22.6 md. Hydraulic testing by CO_2 pressure shut-in analysis was performed in the field prior to injection. Horner plot analysis of pressure decrease in the well indicates a well with wellbore storage and skin effects in a homogeneous reservoir. The formation permeability was estimated to be 50 md, 2.27 times greater than the average core permeability.

Core samples from the State-Charlton #4-30 well. Top: Cross-bedded, sandy dolograinstone in the Bass Islands dolomite at 1,053 m (3,461 ft). Samples in this interval have good reservoir quality with porosity of 14–17% and permeability as high as 100 md. Bottom: Karst collapse breccia in the Bass Islands dolomite at 1,058 m (3,472 ft). Samples in this interval have excellent reservoir quality with porosity of 30% and permeability greater than 100 md.

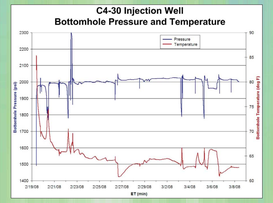


SW-NE cross section through the injection test well State-Charlton #4-30 illustrating the change in thickness of the injection zones and confining units. Orange = Bass Islands dolomite, the primary injection zone. Purple = Amherstburg Fm, the primary confining unit. Blue = Lucas Fm, the secondary confining unit.

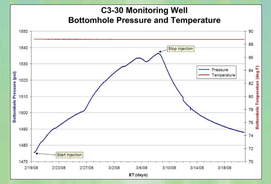


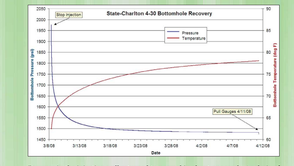
Left:

- 10,241 mt (11,289 tons) CO_2 was injected from February 18–March 8, 2008 (including initial mechanical integrity test volume).
- Injection rate increased from 400–600 mt (441–660 tons)/day after 1 week (some fluctuations in injection rate due to compression facility).
- Injection well was shut-in for 1 month after injection to track reservoir pressures decline and allow stabilization.

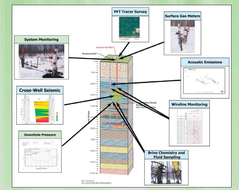


Bottomhole pressures were 13.8–13.9 MPa (2,000–2,020 psi) during injection and generally stable throughout the 18 days of injection. Overall, testing indicates rates of 600 mt (660 tons)/day or higher may be sustained in the Bass Islands dolomite. Pressure response in C3-30 monitoring well showed ~410 Pa (60 psi) increase within the Bass Islands dolomite formation. No temperature change. No direct indication of CO_2 breakthrough was detected at the monitoring well.

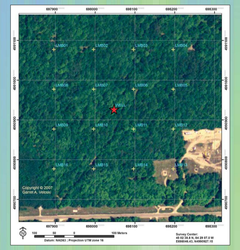




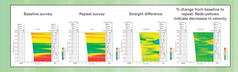
Pressure in the injection well returned to normal in about one week. Analysis of shut-in data suggests similar response to earlier testing.



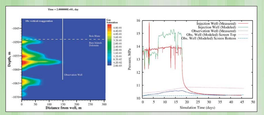
A comprehensive Measurement, Monitoring and Verification (MMV) program was employed at the Michigan Basin test site. Program was designed to track the CO_2 plume movement and to detect any possible leakage from the intended storage zone. Only a few results are shown here for illustrative purposes.



255 mt of PFT tracer (perfluoromethylcyclohexane) was added over 12 hours into injection stream. Soil gas and atmospheric sampling array monitored over several months in 1 pre-injection and 4 post-injection surveys. The detection limit of tracer is nearly one part-per-quadrillion. No evidence of leakage or migration was discernable in this study.



Baseline cross-well survey run between C4-30 and C3-30A in January 2008. Repeat, post-injection survey was completed on May 5, 2008. Excellent signal-to-noise ratio and high-energy source yield resolution of only a few meters. The difference between the two surveys shows a velocity decrease in the Amherstburg formation, approximately 91 m (300 ft) above the perforated injection interval, with no apparent connection with the velocity change area at the injection interval.



Model calibration to actual injection rates and downhole pressures suggests higher reservoir permeability than initially input. Very good calibration to post injection fall-off in the injection well.

Phase III Large-scale Geologic Field Test Site

A large-scale geologic injection test is planned to promote understanding of injectivity, capacity and storage potential in the Mt. Simon Sandstone, a reservoir having broad importance to the region. The MRCSP has proposed a primary and an optional large-scale injection site for Phase III. The primary site is an ethanol plant located near Greenville, Ohio, that was built by a joint venture of The Andersons Ethanol Investments LLC and Marathon Renewable Fuels LLC called The Andersons Marathon Ethanol LLC (TAME). The optional site is a 640-MW (IGCC) plant in Indiana, expected to be on line in late 2011. Work at the optional Duke site will be limited to geologic characterization efforts during the first two years of Phase III to increase knowledge of regional geology and sequestration opportunities at the Edwardsport site.

An early geologic assessment was completed for the TAME site to summarize sequestration capacity, likely injection formations, and other issues pertinent to geologic storage at the site. Currently, seismic acquisition, modeling, and MMV efforts are in the preliminary stages to support project development and planning issues. Overall, the Phase III project is 10 years in duration and will include:

- An initial period of well drilling and testing to characterize the site.
- Injection operations for approximately 4 years, which will include CO_2 compression, transport, injection, and monitoring of approximately 280,000 mt (309,000 tons) CO_2 per yr.
- Post-injection monitoring to ensure that CO_2 is safely and permanently sequestered.
- Permanently plugging the wells and restoring the site according to permit requirements.

Primary Site: Greenville, OH
Possible injection of 907,000 mt (1 million tons) of CO_2 over a four-year period. Target is the Mt. Simon reservoir, the largest deep saline target in the region.

Optional Site: Edwardsport, IN
Extensive site characterization data will be collected from the wastewater well being drilled as part of the IGCC construction. Possible 1.8 million mt (2 million tons) of CO_2 injection over four-year period. Multiple injection zones and caprock layers.

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Wickstrom, L.H., Venteris, E.R., Harper, J.A., and (26) others, 2005, Characterization of geologic sequestration opportunities in the MRCSP region: Final report under DOE cooperative agreement DE-PS26-05NT42255, 152 p., accessed at <http://www.mrcsp.org>.