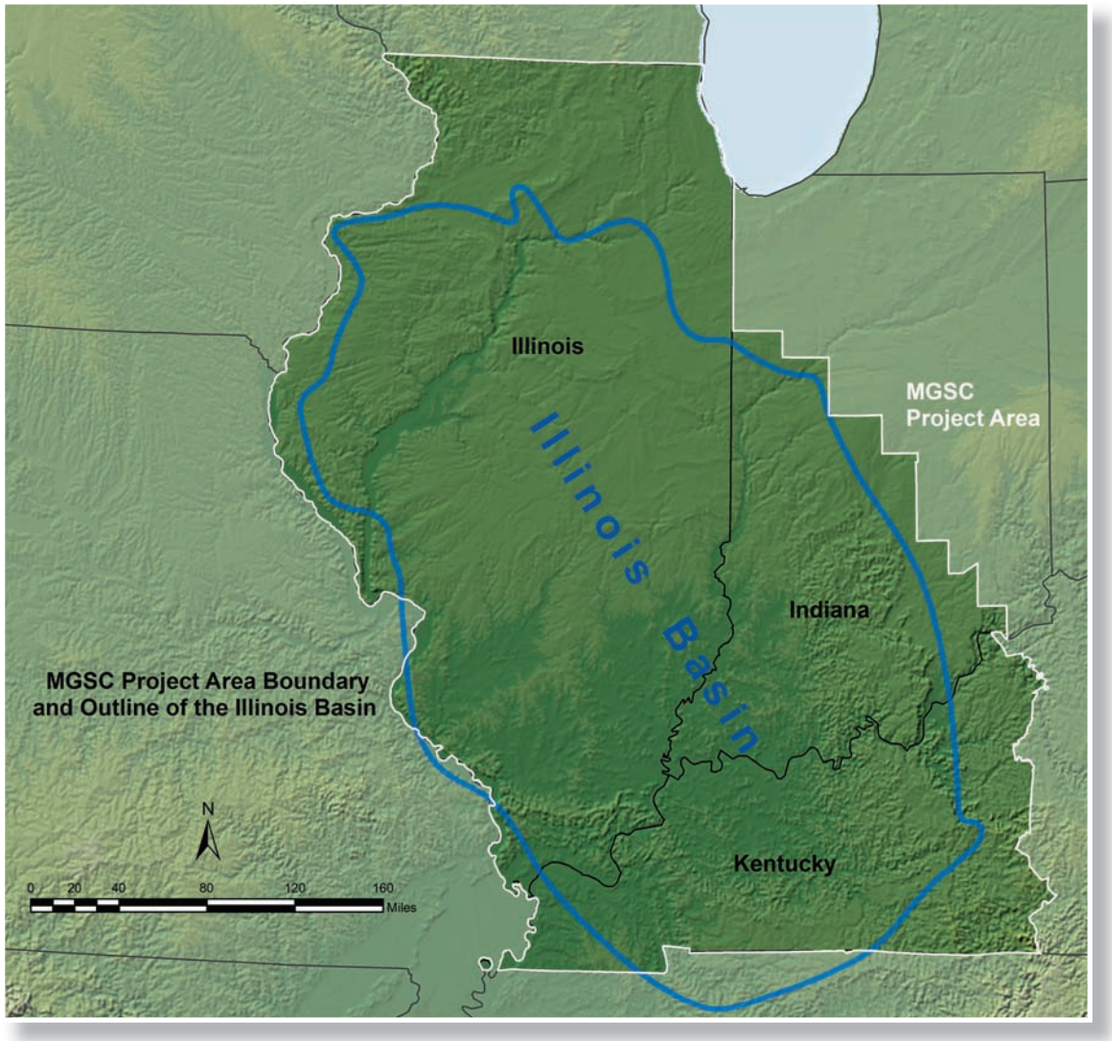


Midwest Geological Sequestration Consortium

The Midwest Geological Sequestration Consortium (MGSC) is a consortium of the geologic surveys of Illinois, Indiana, and Kentucky joined by private corporations, professional business associations, the Interstate Oil and Gas Compact Commission, two Illinois state agencies, and university researchers to assess carbon capture, transportation, and geologic storage processes and their costs and viability in the three-state Illinois Basin region. The Illinois State Geological Survey is the Lead Technical Contractor for the Consortium. The MGSC covers all of Illinois, southern Indiana, and western Kentucky.

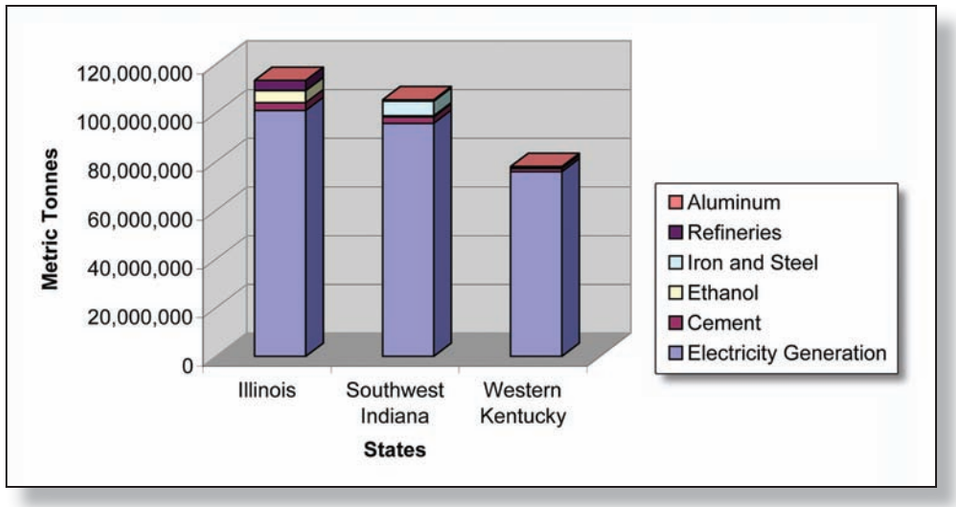
To avoid atmospheric release of CO_2 from fossil-fuel combustion and thereby reduce the potential for adverse climate change, the MGSC is investigating options for geologic CO_2 sequestration in the 155,400 km^2 (60,000 mi^2), oval-shaped, geologic feature known as the Illinois Basin. Within the Basin are deep, uneconomic coal resources, numerous mature oil fields, and deep saline reservoirs with potential to store CO_2. MGSC's objective is to determine the technical and economic feasibility of using these geologic formations for long-term storage.

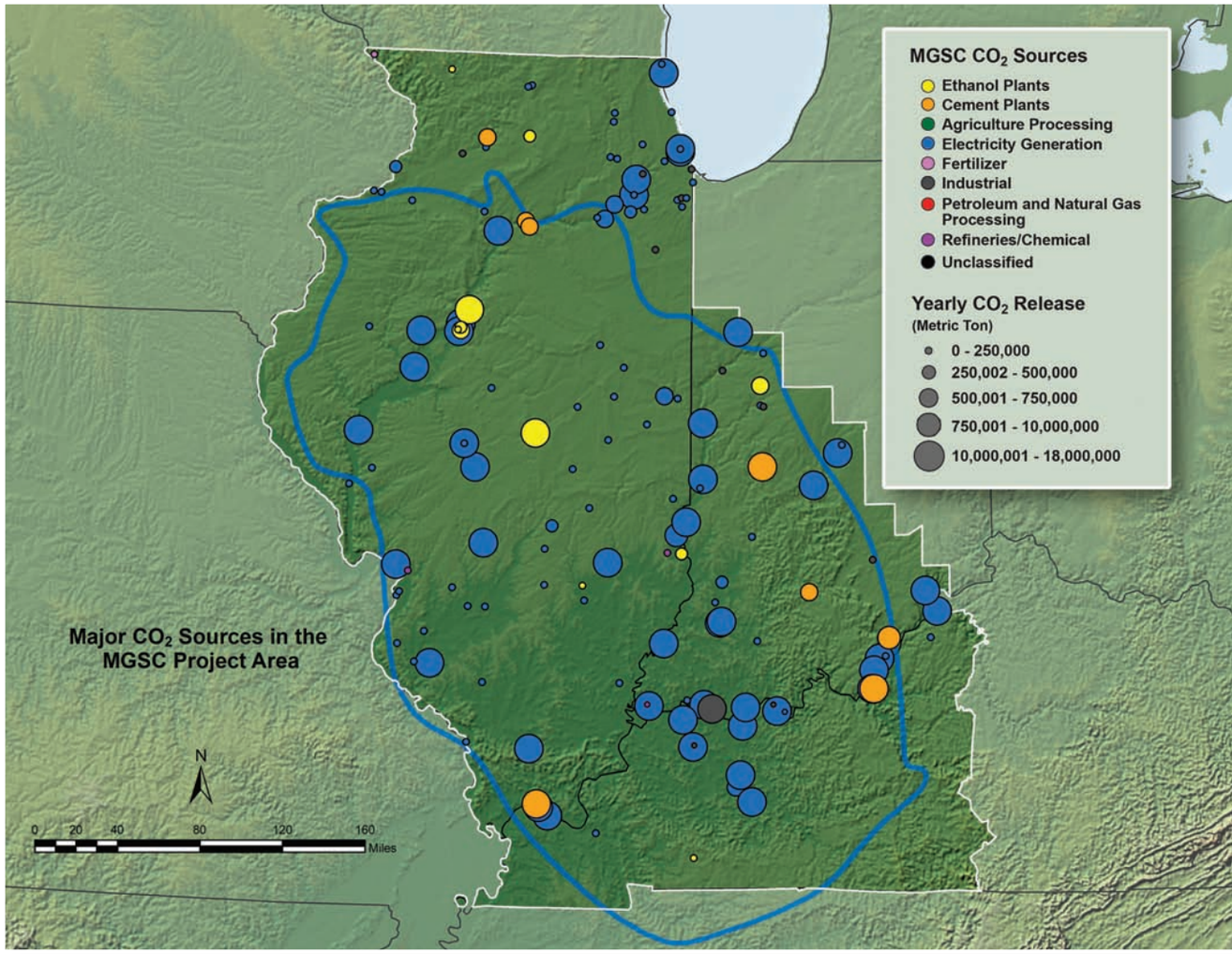
The Illinois Basin is geologically unique because all three potential geologic storage opportunities exist in close proximity to substantial CO_2 sources and in some cases may be accessed from one site.

Typical central Illinois Basin landscape.

MGSC Sources

The Illinois Basin region has annual emissions exceeding 296 million metric tons (326 million tons) of CO_2 (>80 million metric tons [88 million tons] carbon equivalent) from fixed sources, primarily from 126 mostly coal-fired, electric generation facilities which emit >10,000 metric tons (11,000 tons), some of which burn almost 4.5 million metric tons (5 million tons) of coal per year. The distribution of emissions from these plants is highly skewed. The 4 largest plants, in megawatt capacity, emit about 22 percent of total CO_2 emissions; the 13 largest plants emit >50 percent of total CO_2 emissions; and the 30 largest plants emit >80 percent of total CO_2 emissions. The Illinois Basin contributes about 11.4 percent of the total U.S. CO_2 emissions from electric power generation plants. Coal is the dominant fossil fuel for electric power plants and contributes 98 percent of the Illinois Basin CO_2 emissions from fixed sources. CO_2 emissions from manufacturing industries in the Illinois Basin vary from industry to industry.

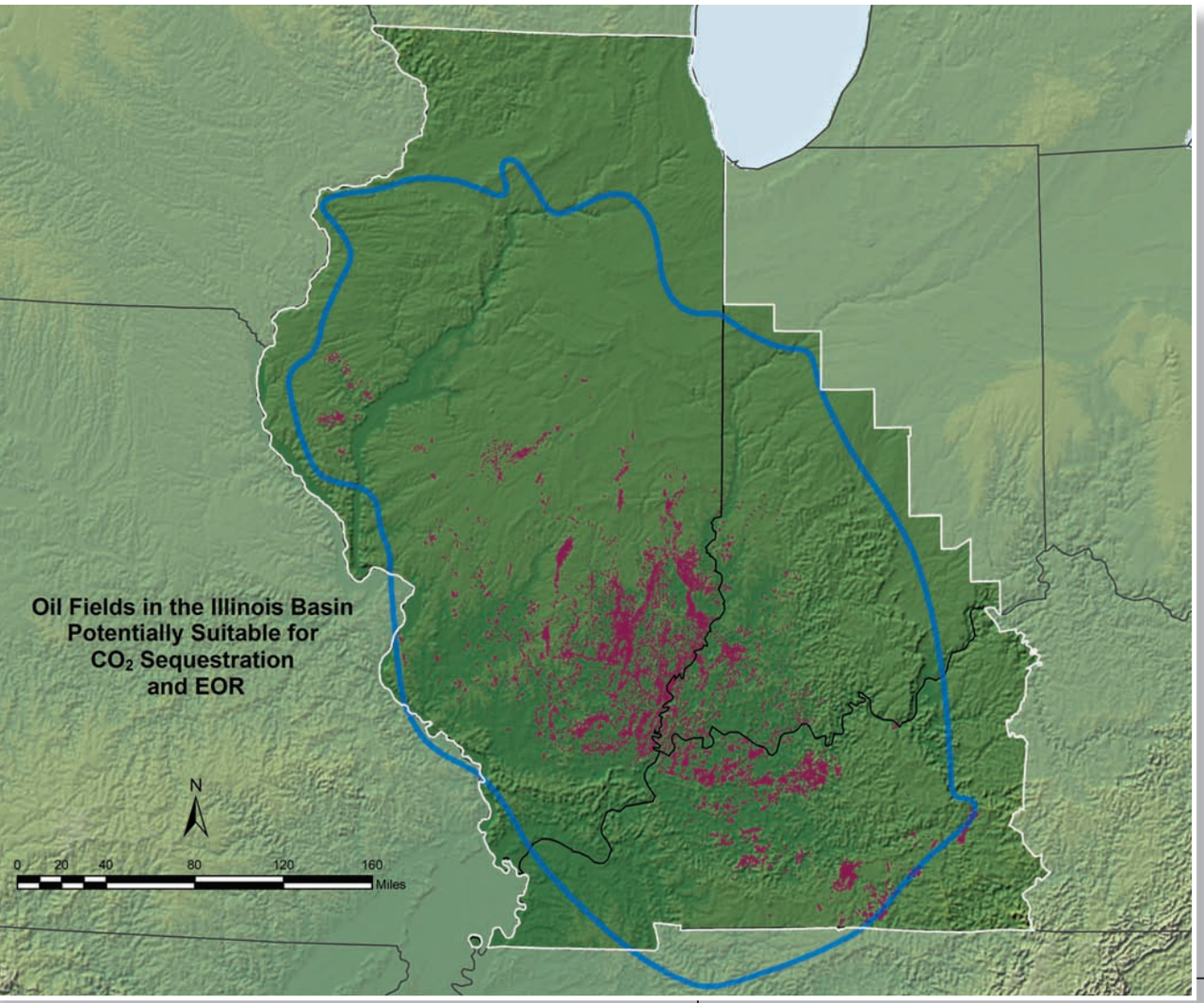




Illinois Basin (MGSC) CO_2 Emissions (metric tons), by State and CO_2 Source Type

Source Type	Illinois Basin Annual CO_2 Emissions			
	Illinois	Southwest Indiana	Western Kentucky	TOTAL
Electricity Generation	100,911,055	95,688,706	75,786,443	272,386,203
Cement	3,255,000	2,565,000	1,256,000	7,076,000
Ethanol	4,933,541	556,100	199,454	5,689,095
Iron and Steel	139,361	5,967,475	0	6,106,836
Refineries	4,109,702	94,676	0	4,204,378
Aluminum	0	475,860	677,600	1,153,460

The Illinois Basin hosts significant oil refining capacity.

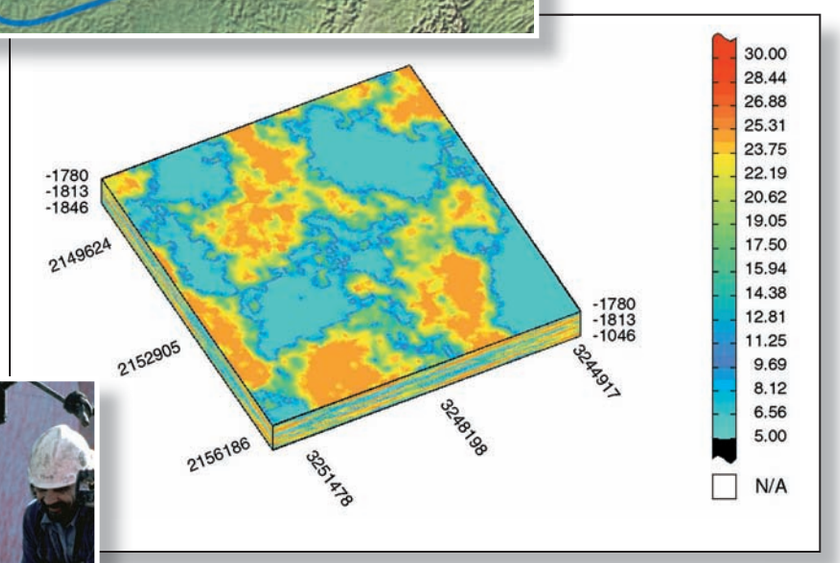


MGSC: Illinois Basin Oil and Gas Reservoirs

Because of the established effectiveness of CO_2 EOR, oil reservoirs offer the most potential for economic offset to the costs associated with carbon sequestration in the Illinois Basin. To assess this potential, a Basin-wide EOR estimate was made based on a new understanding of the OOIP in the Basin, the CO_2 stored volume, the assessed EOR resource, the geographical distribution of EOR potential, and the type of recovery mechanism (miscible vs. immiscible). The resource target for EOR is 137–207 million cubic meters (m^3)—860–1,300 million barrels (bbls)—recoverable with consequent sequestered volume of 140–440 million metric tons (154–485 million tons) of CO_2.

With cumulative oil production for the Basin of about 0.67 billion m^3 (4.2 billion bbls), nearly 1.5 billion m^3 (10 billion bbls) of resources remain, primarily as unrecovered resources in known fields. To assess the recovery potential of a part of this resource and the concurrent stored CO_2 volumes, reservoir modeling and compositional reservoir simulation were carried out. Parts of nine fields were used to create generic geologic models for the most prolific reservoirs in the Basin, the Aux Vases and Cypress Sandstones and the Ste. Genevieve Limestone. These models incorporated data from >1,000 total wells, 120 wells with core, >2,000 core sample points, 12,000 field acres, and 20 flow zones. Structure and isopach maps were developed from well logs, whereas porosity and permeability distributions were developed geostatistically from core analysis data for the reservoir simulator. Processes simulated were miscible and immiscible flooding, based on reservoir pressure and temperature, and both continuous and water-alternating-gas CO_2 injection.

Well drilling in the Illinois Basin.



Model showing porosity in the Aux Vases Sandstone.

Potential CO_2 Capacity	Estimated EOR*
140–440 million metric tons (154–485 million tons)	137 million–200 million m^3 (860 million–1,300 million barrels)

* The EOR volume was estimated based on a series of oil recovery factors for specific geologic units and miscibility type that were applied to the OOIP as assessed per oil field.

MGSC: Illinois Basin Unmineable Coal Seams

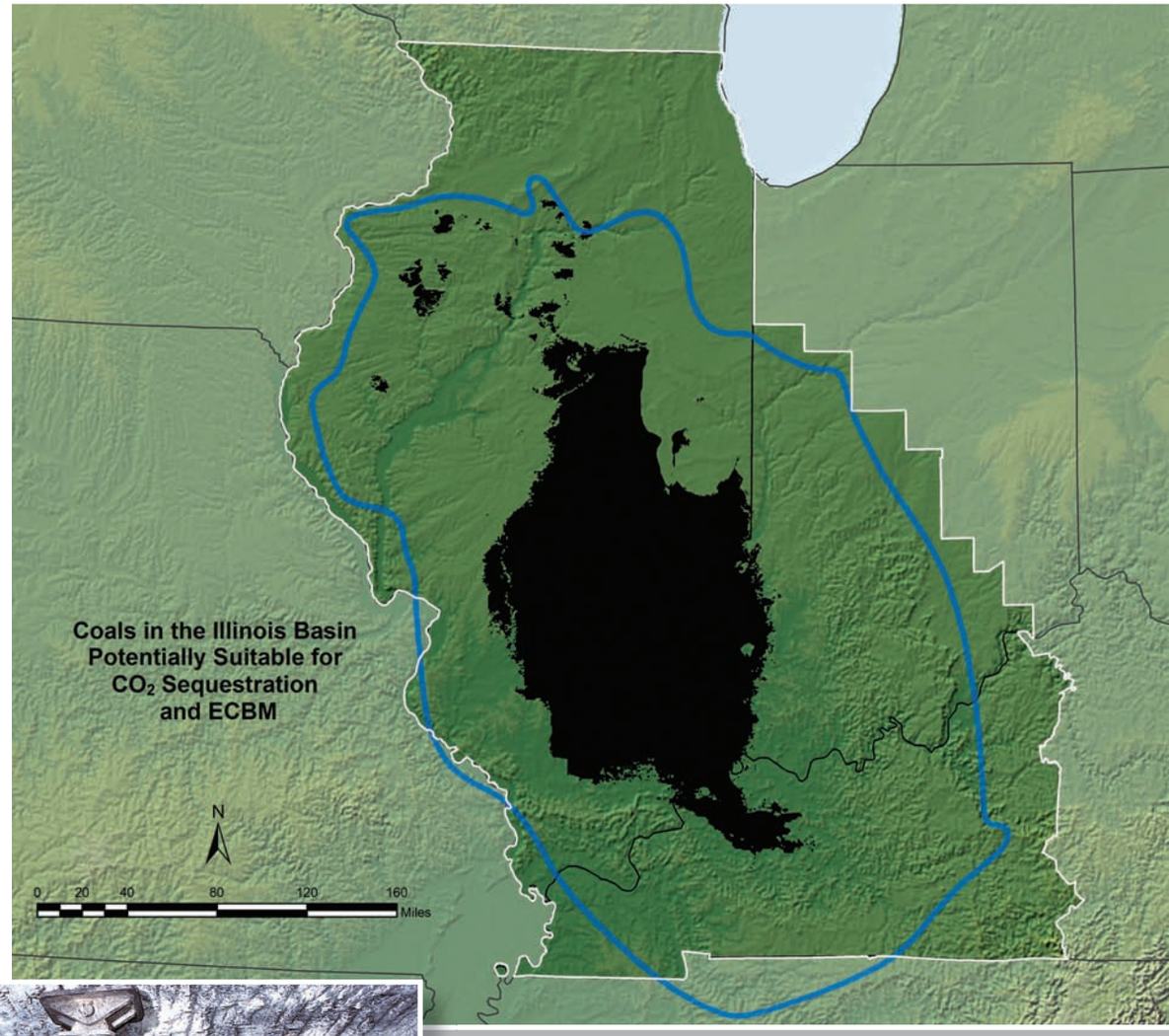
The Illinois Basin includes substantial coal resources, totaling 258 billion remaining metric tons (284 billion tons). Extraction techniques range from surface mining to room-and-pillar and longwall subsurface methods, with most mining occurring around the margins of the Basin. Most of the Basin's remaining coal resources are moderate to high in sulfur content. Consequently, market share has been lost to low-sulfur, western coal from the Powder River Basin, and Illinois coal production has declined by half since 1990. The opportunity to sequester CO_2 in coals currently considered to be unmineable is based on both technical and economic considerations and could be supported by production of coalbed methane (CH_4) displaced from these coals.

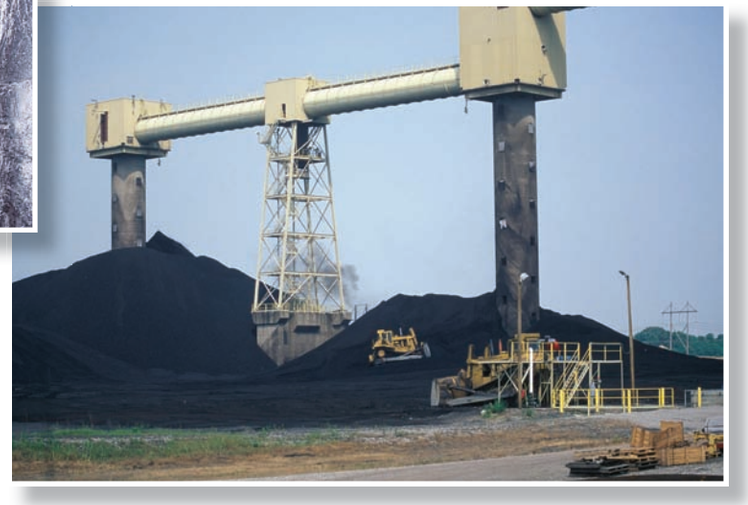
With respect to defining unmineable coal, no consideration is given to coals at depths <152 m (<500 ft). Coals from 152–305 m (500–1,000 ft) in depth and from 0.48–1.1 m (1.5–3.5 ft) thickness are considered sequestration targets. A seam <1.1 m (<3.5 ft) in thickness is currently not mineable with existing equipment. It would be costly to develop new equipment compared to mining seams of greater thickness, which remain an abundant part of the resource base. Below 305 m (1,000 ft) in depth, all seams >1.1 m (>1.5 ft) in thickness are sequestration targets.

Key characteristics of seven coals were mapped throughout the Illinois Basin, including thickness, depth, elevation, moisture content, ash content, heating value, temperature, and expected reservoir pressure. Most data were available for the Herrin and Springfield coals, the major coal seams in the Basin. Gas contents for Illinois Basin coals are in the range of 3.12–4.68 m^3/metric ton (100–150 standard cubic feet [scf]/ton) for the better samples; CO_2 adsorption capacity can range from 14.1–21.9 m^3/metric ton (450–700 scf/ton) at 2,068 kilopascals (300 psi).

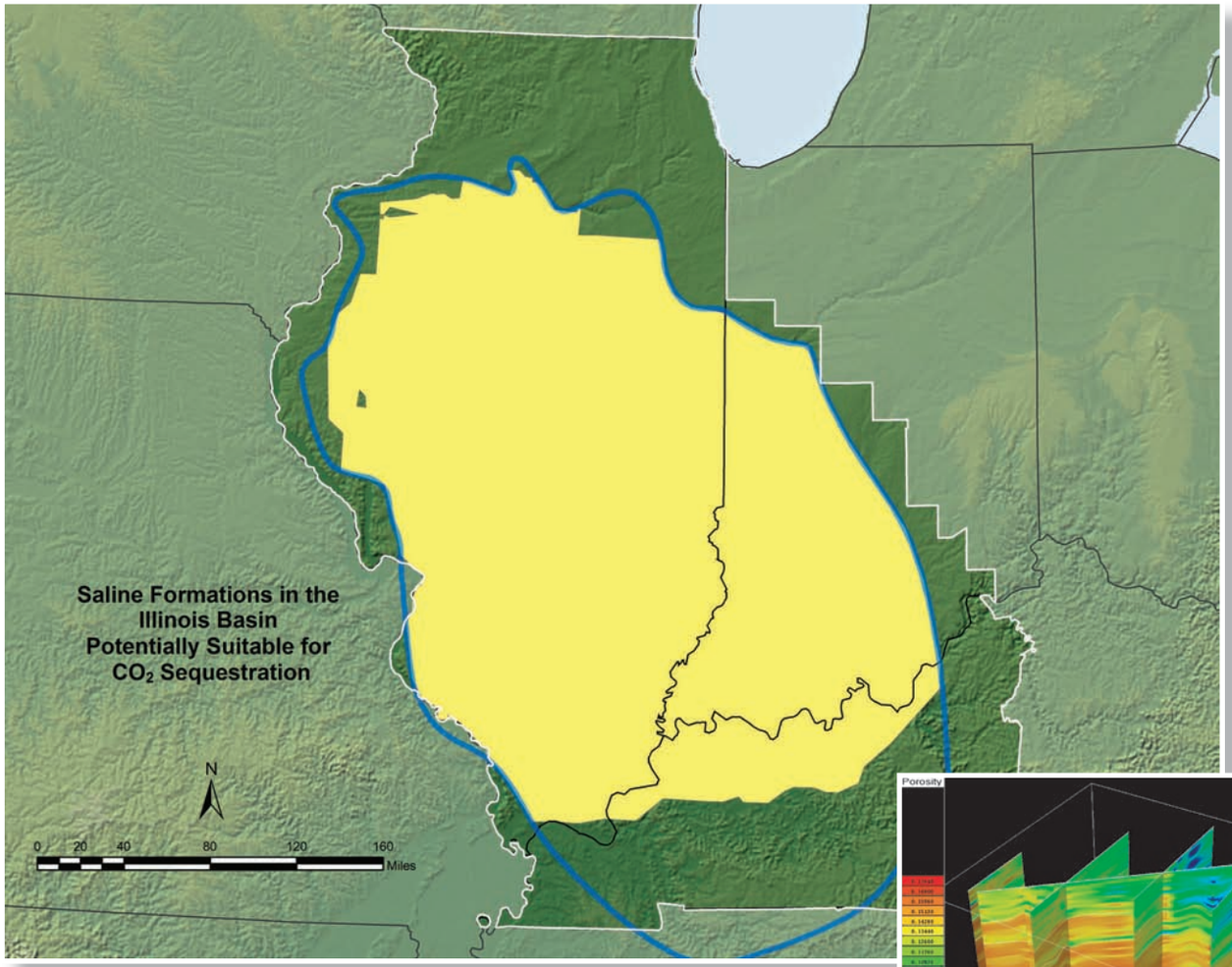
Potential CO_2 Capacity	Estimated ECBM*
2.3–3.3 billion metric tons	0.08–0.31 trillion m^3
(2.5–3.6 billion tons)	(3.0–10.9 trillion scf)

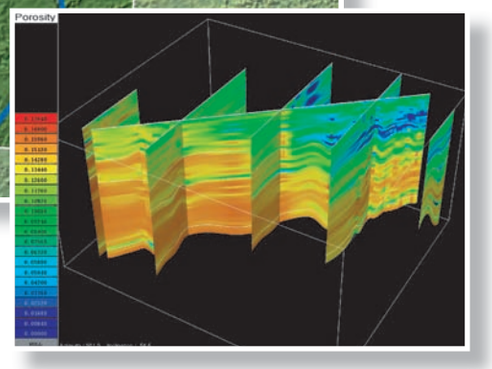
* ECBM was estimated based on a methane recovery factor that was applied to the original gas-in-place volume per coal seam for unmineable coal areas as described above.





Coal mining in the Illinois Basin.





Model showing potential post-injection CO_2 migration in the Mt. Simon Sandstone.

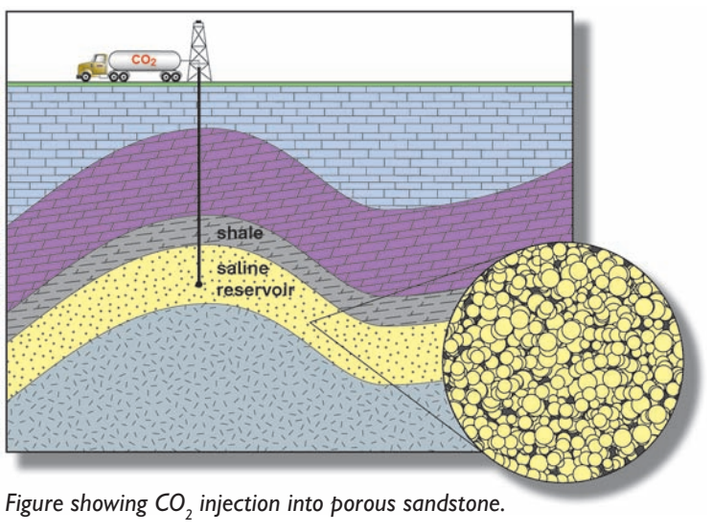
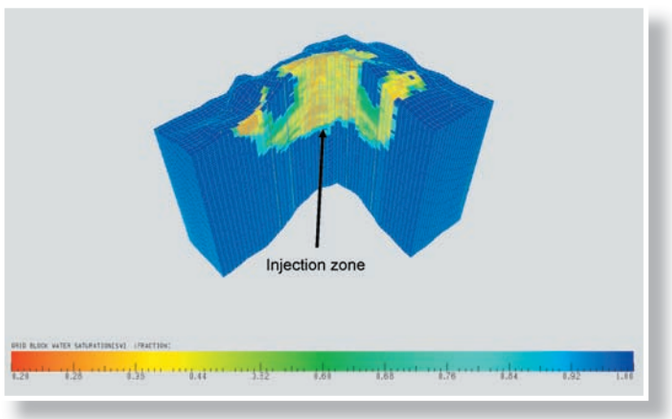


Figure showing CO_2 injection into porous sandstone.



Model showing porosity in the Mt. Simon Sandstone.

MGSC: Illinois Basin Deep Saline Formations

Two major saltwater-filled, or saline, reservoirs in the Illinois Basin were studied for CO_2 storage potential: the Ordovician St. Peter Sandstone and the Cambrian Mt. Simon Sandstone. The St. Peter Sandstone is a widespread, porous, and permeable quartz sandstone that is generally fine-grained with good lateral continuity. Seals above the St. Peter include several hundred feet of dense limestone and dolostone overlain by 45.7–76.2 m (150–250 ft) of Maquoketa Shale.

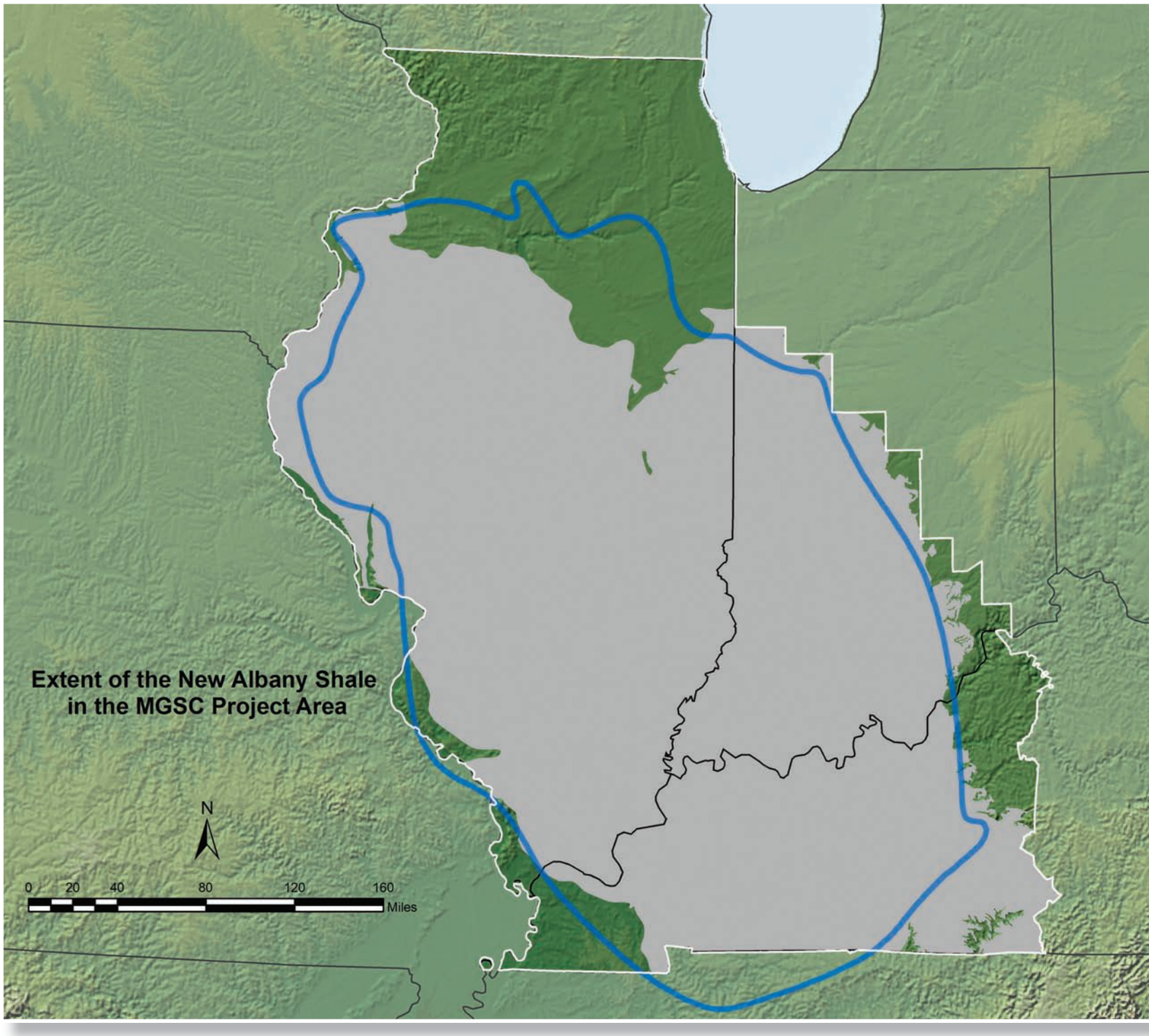
The Mt. Simon Sandstone is commonly used for natural gas storage in the Illinois Basin and has fair to good permeability and porosity. The major seal for the Mt. Simon is the Eau Claire Formation which averages 102–305 m (400–1,000 ft) in thickness. The strata overlying the Eau Claire Strata contain impermeable limestone, dolomite, and shale intervals. The depth of the Mt. Simon ranges from approximately 610–4,267 m (approx. 2,000–14,000 ft) below the surface. In the southern half of the Basin the reservoir is brine-filled, and no oil or natural gas resources have been discovered in this unit. At its greatest thickness in the Illinois Basin, the Mt. Simon is over 793 m (2,600 ft) thick. The Mt. Simon does not outcrop in Illinois, but correlative units are exposed in southern Wisconsin, southeastern Minnesota, and Missouri. The Mt. Simon exists in the subsurface throughout much of Indiana, Iowa, Michigan, and Ohio. In the southern region of the Basin, the potential CO_2 reservoir facies are either very deep or are absent in the paleotopography.

Depths less than 762 m (2,500 ft) for the St. Peter and Mt. Simon Sandstones were not considered as sequestration targets due to anticipated lower salinity and potentially potable water resources in these areas.

Reservoir	Potential CO_2 Capacity
St. Peter Sandstone	1.6–6.4 billion metric tons (1.8–7.0 billion tons)
Mt. Simon Sandstone	27–109 billion metric tons (30–120 billion tons)
Total	**29–115 billion metric tons (32–127 billion tons)**

MGSC: Illinois Basin Organic-Rich Shales

Organic-rich shales in the Illinois Basin will be assessed from two perspectives. The Devonian New Albany Shale in the Illinois Basin is commercially productive of natural gas in the same manner as deep coal seams. It is stratigraphically equivalent to the Antrim Shale in the Michigan Basin and the Ohio Shale in the Appalachian Basin, a shale gas play that currently supports over 25,000 producing wells in those basins. The New Albany is producing gas in Indiana and Kentucky, and samples from these localities are currently being tested for their CO_2 adsorption capacity. Organic carbon content of the shale is directly related to the CO_2 adsorption capacity. Injection of CO_2 into the organic shales may result in adsorption of CO_2 and possibly the enhanced production of CH_4, just as in coal beds. Adsorption isotherm data and geophysical logs will be used to estimate and identify areas of the Basin with sequestration potential in the shale. Because of its CO_2 adsorption potential, the New Albany may also act as a secondary seal for sequestration in any deeper saline reservoirs, like the St. Peter and Mt. Simon Sandstones.



Regional Shale Outcrop

Aerial view showing no-till farming in the Illinois Basin.

MGSC: Illinois Basin Terrestrial Opportunities

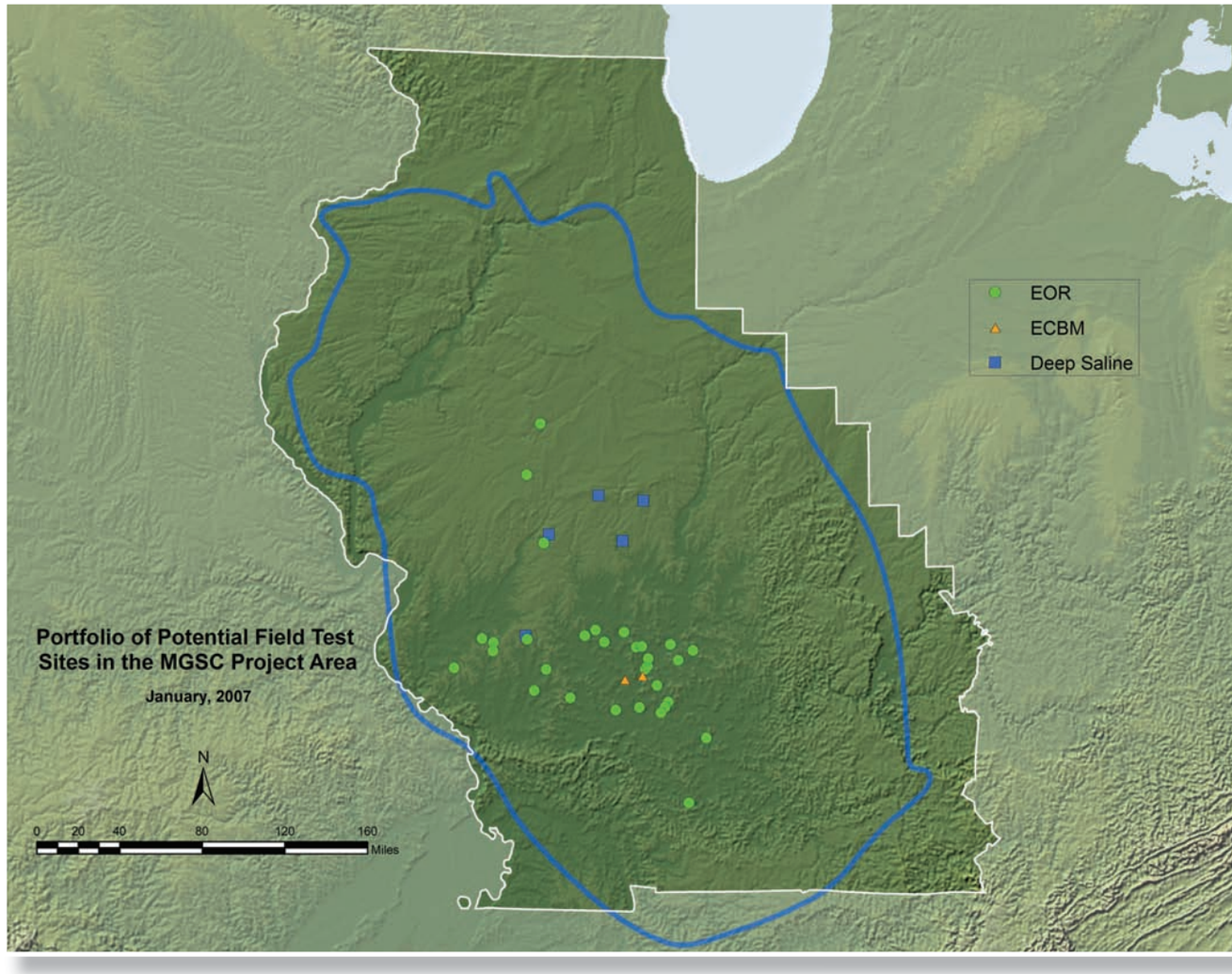
A number of universities and other groups in the Illinois Basin are actively researching many terrestrial sequestration techniques. The Illinois Basin is an area rich in agricultural resources with many terrestrial sequestration opportunities currently under assessment. Approximately 33.1 percent of all grain fields in Illinois were planted using no-till methods in 2006, an increase of 3.9 percent from 2004. Long-term studies of tillage impacts on erosion, soil fertility, and organic matter storage are being conducted at the University of Illinois. Remote sensing techniques are being employed to research soybean uptake of CO_2. Ongoing research is being conducted by the Illinois State Geologic Survey on wetlands restoration and mitigation throughout the Illinois Basin.

Scientists testing response in soybeans from CO_2 release.

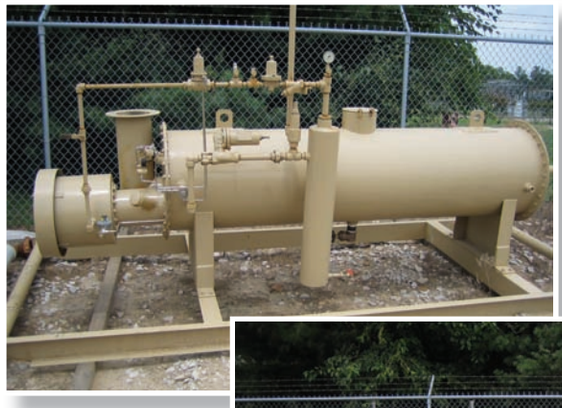
MGSC Field Tests

The MGSC, along with its industry partners, is conducting a series of six field validation tests in the Illinois Basin to assess the potential for CO_2 storage in oil reservoirs, coal seams, and deep saline water-bearing formations. Added-value benefits for oil reservoirs and coal beds are the potential for EOR and ECBM production, respectively. While the deep saline test has no enhanced production potential, it is expected to utilize the geologic formations with the largest CO_2 storage capacity in the test area.

The MGSC effort focuses on a series of field tests, beginning with a one-well, inject/soak/produce oil reservoir test and culminating with drilling to a deep saline reservoir and injecting supercritical CO_2. Between these end members, an ECBM test and mature oil field tests will involve well conversion(s) and drilling of one or more new injection wells to evaluate pattern flooding. Test sites will incorporate miscible and immiscible flooding and assess Illinois Basin sandstone and carbonate reservoirs to provide both comparison and contrast to Permian Basin (West Texas) experience, which is dominated by miscible carbonate floods. As a result of initial characterization work, some 31 oil field sites, several possible ECBM sites, and five saline reservoir sites have been identified as possible test sites.



Preparing for Pilot field test at Loudon Field, Illinois.



Equipment showing skid and line heater.