



Midwest Regional Carbon Sequestration Partnership

The Midwest Regional Carbon Sequestration Partnership (MRCSP) was formed to assess the technical potential, economic viability, and public acceptability of carbon sequestration within its Region. The MRCSP Region consists of eight neighboring states: Indiana, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, and West Virginia. The Partnership includes over thirty organizations from the research community, energy industry, universities, non-government, and government organizations. The Region has a diverse range of CO₂ sources and many opportunities for geologic and terrestrial sequestration.

Potential locations for geologic sequestration in the MRCSP states include deep rock formations associated with broad sedimentary basins and arches that extend across most of the Region. Research and testing have established many promising geologic units for CO₂ sequestration including deep saline rock formations, depleted oil and gas reservoirs, organic shale layers, and coal beds. Geological surveys from the eight MRCSP states completed an assessment of the potential for geologic sequestration that indicates there is capacity to permanently contain hundreds of years of CO₂ emissions from the Region. Reports, data, and maps generated by the research were integrated into a geographic information system available for use on the MRCSP web site (www.mrcsp.org).

MRCSP Phase I research on terrestrial carbon sequestration focused on five dominant land-use types identified by the research team as offering the best opportunities for the Region. These land use categories included: traditional non-eroded cropland, eroded cropland, marginal lands, mineland areas, and wetlands. The specific objectives of the research were to quantify the carbon storage formation capacity of the major land use components and to identify land use and management options to achieve storage formation capacity such as improved agricultural practices, reforestation, and reclaiming mineland.



CO₂ pipeline from a gas processing plant in Michigan.



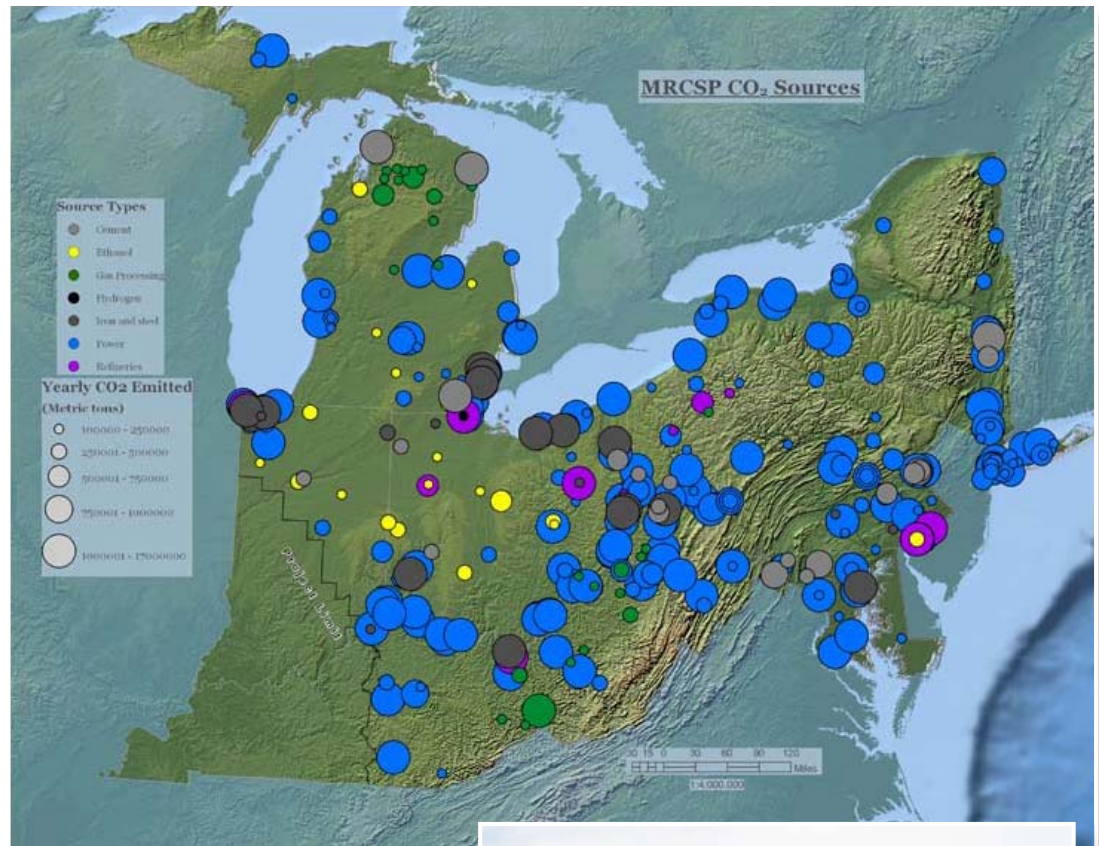
A Snapshot of the MRCSP Region

The MRCSP Region includes

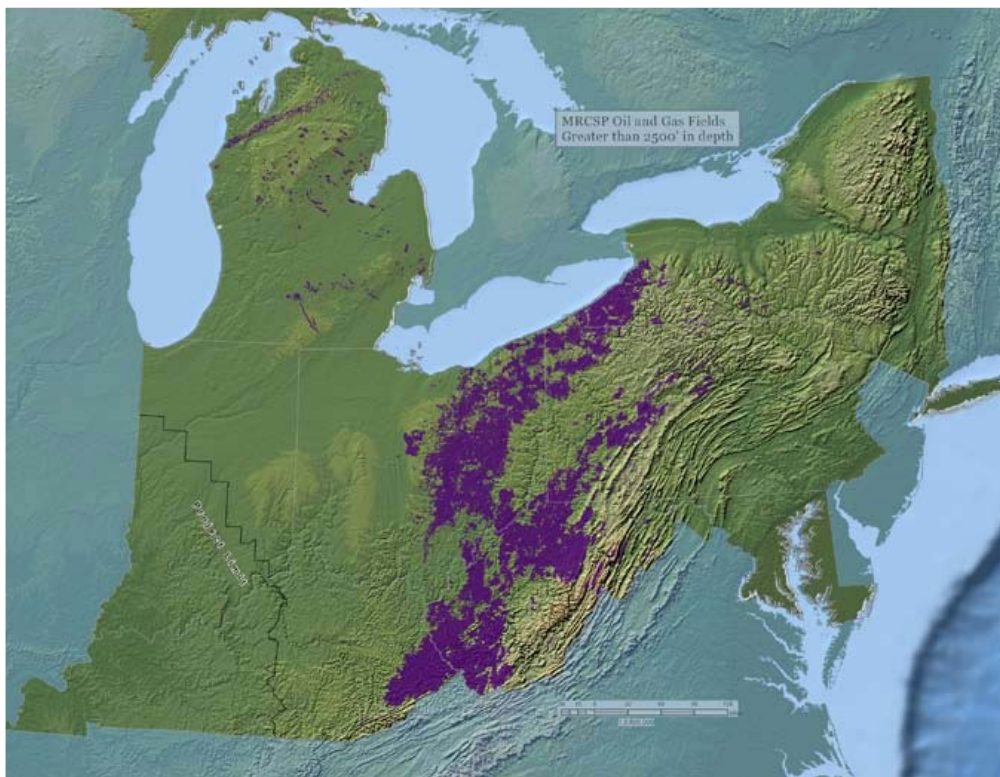
- 8 States: Indiana, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, and West Virginia
- Population: 71.3 million (nearly one quarter of U.S. population)
- Gross Regional Product: \$2,672 billion (one quarter U.S. economy)
- 21.5 percent of all electricity generated in the United States
- 77 percent of electricity generated in the Region is generated by coal
- 12 percent of nation's total CO₂ emissions

CO₂ Sources in the MRCSP Region

Due to its large and diverse economy, the MRCSP Region includes a large variety of sources of greenhouse gases. While distributed sources such as agriculture, transportation, and heating account for a large portion of CO₂ emissions in the MRCSP Region, over half of CO₂ emissions are linked to stationary sources. More than 680 million metric tons (750 million tons) of CO₂ are emitted each year from these large, fixed stationary sources including power plants, refineries, cement plants, and iron and steel plants. Emissions are highest along the Ohio River Valley and coastlines where many power plants and industries are located. In the MRCSP Region, 80 percent of CO₂ stationary source emissions are from electrical power plants.



Large CO ₂ Stationary Source Emissions (million metric tons CO ₂ /year)										
Category	MRCSP	MRCSP%	Northeastern Indiana	Eastern Kentucky	Maryland	Michigan	New York	Ohio	Pennsylvania	West Virginia
Power	553.8	80.90%	31.7	35.1	32	76.1	49.6	127.3	115.7	86.3
Iron and Steel	70.1	10.20%	26.2	2.4	4.5	12.3	0	17.5	3.3	4
Refineries	20	2.90%	3.9	2.1	0	0.7	0	5.5	7.6	0.1
Cement	14.2	2.10%	0.4	0	1.5	3.5	2	1.4	4.6	0.8
Gas Processing	21.7	3.20%	0	0.6	0	2.9	12.7	0.1	0.5	4.8
Ethanol	4.4	0.60%	1	0	0	0.9	0	2	0.5	0
Total	684.2	100	63.2	40.3	38	96.5	64.3	153.7	132.1	96.1



MRCSP: Oil and Gas Reservoirs

The MRCSP Region has many opportunities for CO₂ sequestration in oil and gas formations. Commercial exploration in the Region began in 1859 with the discovery of oil in a shallow well drilled by “Colonel” Edwin Drake in Titusville, Pennsylvania. Since then, the MRCSP Region has produced over 0.8 billion m³ (5 billion barrels) of oil and more than 1.4 trillion m³ (50 trillion ft³) of natural gas. In addition, the MRCSP Region includes four of the top seven, natural-gas storage states in the nation. Such large volumes of gas storage capacity (both natural and engineered) strongly suggest that CO₂ gas can be successfully managed in subsurface reservoirs within the Region. Finally, there is potential for value-added production of oil and natural gas associated with CO₂ sequestration. The oil and gas fields in the Region are most concentrated in the Appalachian and Michigan sedimentary basins. Research suggests that oil and gas fields have a potential CO₂ storage resource of 8,400 million metric tons (9,300 million tons) of CO₂. Much of this resource is intermixed with deep saline formations. In fact, it may be difficult to differentiate the two in many areas.

Oil and gas reservoirs cover large portions of the Appalachian basin with significant fields in Ohio, western New York, western Pennsylvania, western West Virginia, and eastern Kentucky. Key oil and gas formations in the Appalachian basin include Devonian Shales, “Clinton”/Medina/Tuscarora sandstones, the Oriskany Sandstone, and the Rose Run Sandstone. Within the Michigan basin, oil and natural gas reservoirs are concentrated along the Niagaran reef trend and Devonian Antrim Shales in the northwestern and southern margins of the basin. Enhanced oil recovery has only been applied to a relatively small percentage of fields in the Region. Studies have suggested that a large amount of oil and gas remains in place in many reservoirs. Thus, there is high potential for enhanced oil and gas production associated with CO₂ sequestration in the MRCSP Region.



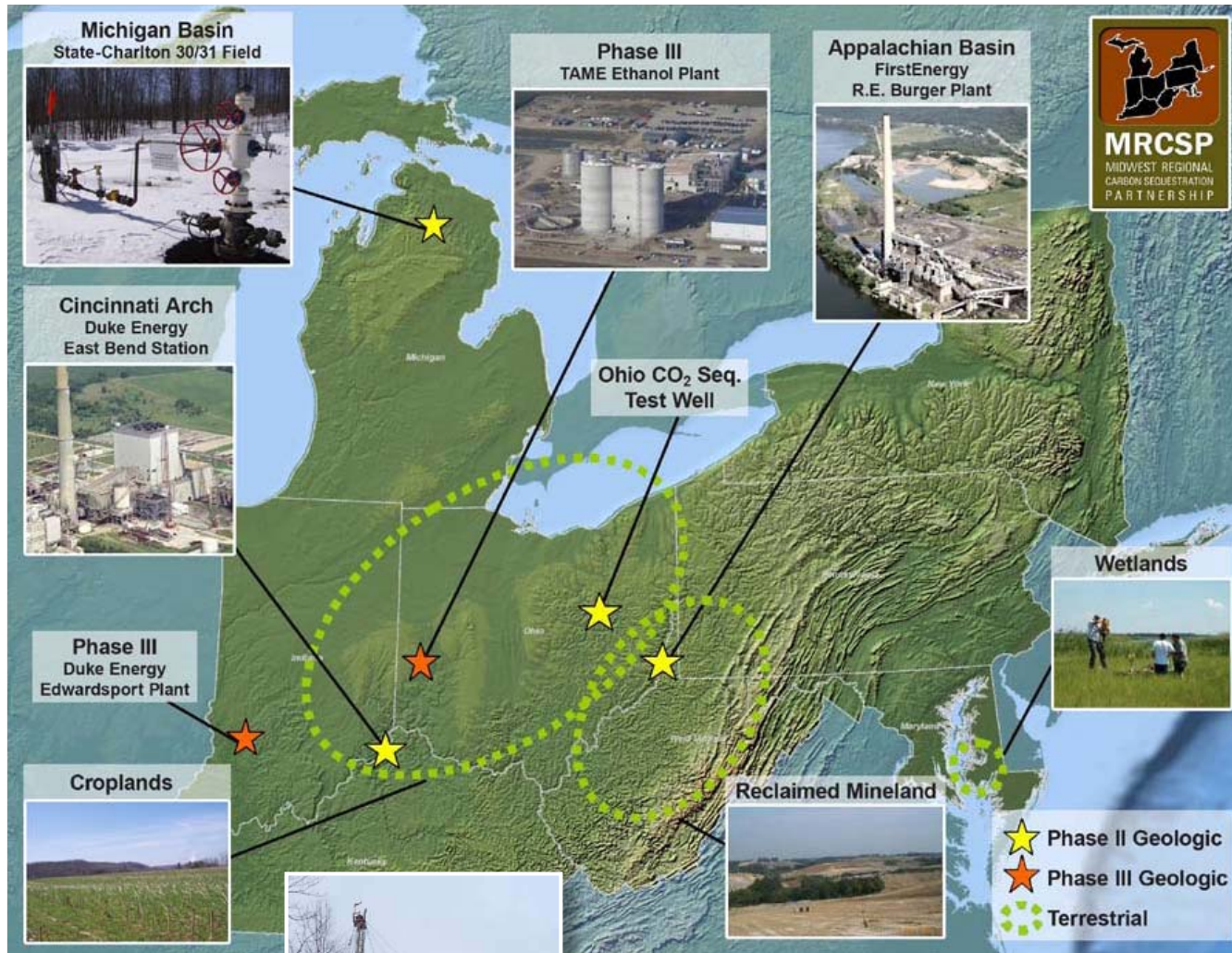
Grand Lake St. Mary's, circa 1890, one of the first sites for over water/off shore drilling in the United States. (Source: Ohio Division of Geological Survey). The MRCSP Region was the birthplace of the North American oil and gas industries.



Drilling operations at the Ohio CO₂ sequestration test well in Tuscarawas County, Ohio. Both CO₂ storage units and natural gas were discovered in this well.

Estimated Oil and Gas Reservoir CO ₂ Storage Resource			
State	# Fields	Area (acres)	Potential CO ₂ Storage Resource (million metric tons)
Northeastern Indiana	181	46,000	61
Eastern Kentucky	69	51,000	87
Michigan	1,348	3,500,000	457
New York	106	1,089,000	272
Ohio	1,807	3,609,000	3,405
Pennsylvania	948	1,129,000	2,806
West Virginia	232	761,000	1,423

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Appalachian Basin geologic test site.



Restored tidal marshes at Blackwater National Wildlife Refuge, Maryland.



Testing at restored tidal marshes at Blackwater National Wildlife Refuge, Maryland.

MRCSP Commercialization Opportunities

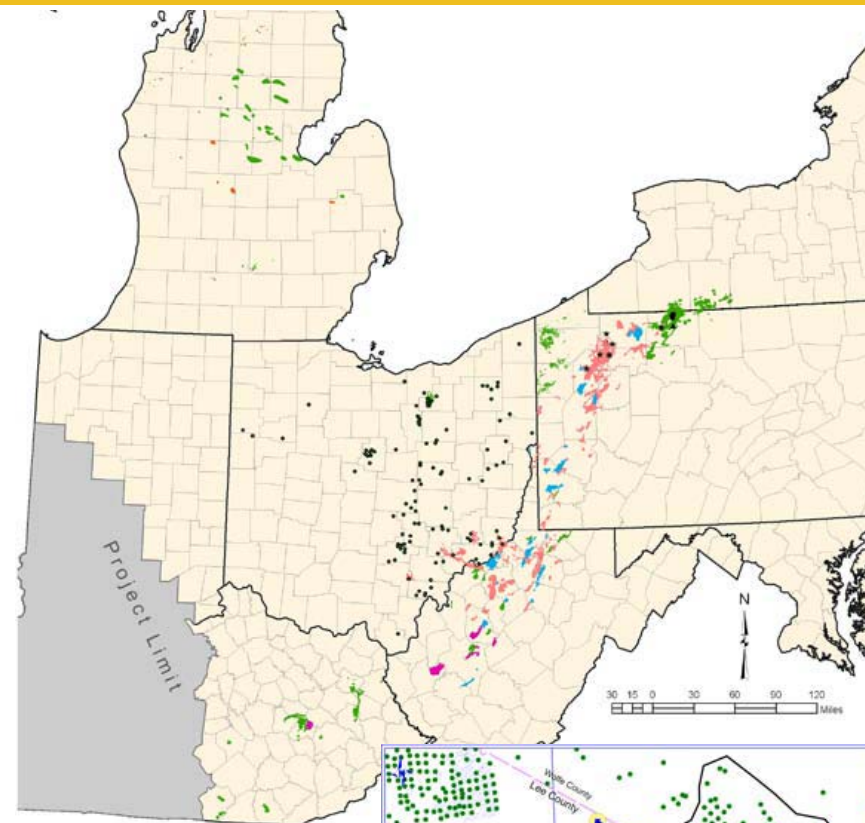
The MRCSP Region has many large anthropogenic CO₂ stationary sources that are in close proximity to the Region's geologic CO₂ storage formations, thus making them potential candidates for CO₂ capture and storage commercialization. These opportunities include ethanol plants, new coal-fired power plants, retrofitting existing coal-fired power plants, coal-to-liquid facilities, EOR ECBM, refineries, landfills, and gas processing facilities. Plans for a significant number of electric generating capacity developments are underway for the MRCSP Region, with the addition of over 10,000 MW of capacity predicted over the next decade. MRCSP analysis has also shown that there are a number of emerging technologies that show promise for improving the economics of CO₂ capture. The Region's industrial makeup has provided impetus for moving forward with CCS, and several projects are in various stages of development.

In addition to the DOE regional partnership, several field projects, state-level organizations and regulatory initiatives have been started to advance CCS:

- Integrated CCS demonstration with chilled ammonia capture technology with injection and monitoring in two saline formations at American Electric Power's Mountaineer Plant in West Virginia
- Kentucky Consortium for Carbon Sequestration
- Ohio CO₂ sequestration stratigraphic test well in Tuscarawas County, Ohio (no CO₂ injected)
- Pennsylvania Carbon Management Advisory Group
- The Midwestern Governors' Association Midwestern Regional Greenhouse Gas Reduction Accord (Michigan = member, Indiana and Ohio = observer)
- Regional Greenhouse Gas Initiative (Maryland and New York)

In the MRCSP states, dedicated CO₂ pipelines will be the primary means of transporting CO₂ from the stationary source to a suitable, long-term geologic storage site. While little CO₂ pipeline exists in the Region, an extensive natural gas distribution network is present, with an established technical and regulatory framework.

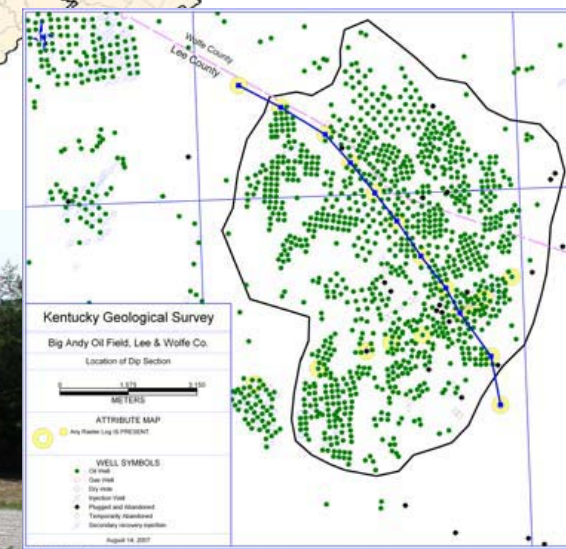
Many oil fields in the MRCSP Region are candidates for CO₂ miscible-flooding for EOR. Criteria in evaluating potential candidates for CO₂ miscible floods include depth, oil gravity, cumulative production, net pay thickness, and minimum miscibility pressure. Within the project area, ongoing CO₂ injection projects include the Niagaran reef reservoirs (Silurian) in the Dover field in Michigan and the Keefer Sandstone reservoir (Silurian) in the Big Andy field in Kentucky. Pilot CO₂ floods in the Big Injun and Berea Sandstone (Mississippian and Devonian) were conducted in the late 1970s and early 1980s in West Virginia. Some reservoirs in the Region have over 90 percent of the original oil remaining in place and large potential for additional production. There is also potential for enhanced coal bed methane recovery in portions of West Virginia, Pennsylvania, Kentucky, and Ohio.



Map showing historic EOR projects in MRCSP Region.



EOR CO₂ injection at Big Andy Field in Kentucky.



Map of Big Andy EOR Field in Kentucky.