

CO₂-Enhanced Oil Recovery Pilot Projects

Name: Two types of enhanced oil recovery projects conducted:

1. Flood pattern project (Sugar Creek Field, Hopkins County)
2. Single well cyclic project (Euterpe Field, Henderson County)

Background:

- CO₂-enhanced oil recovery demonstrated technology in parts of the United States
- Little history in Kentucky
- Potential enhanced oil recovery resource in Illinois Basin (includes western Kentucky) is 860-1,300 million barrels
- Possible bridge technology for saline storage

Goals:

- Analyze CO₂-enhanced oil recovery potential in Kentucky with appropriate field demonstrations
- Identify impediments to CO₂-enhanced oil recovery deployment in Kentucky
- Develop expertise to track fate of CO₂ in the subsurface

Costs: Approximately \$1 million total for Sugar Creek and \$200,000 for Euterpe

Funding Sources:

- Incentives for Energy Independence Act 2007 (\$300,000 for Sugar Creek, \$200,000 for Euterpe)
- Midwest Geologic Sequestration Consortium (\$170,000 match for Sugar Creek)
- In-kind contributions of wellbore and field infrastructure (Sugar Creek–Gallagher Drilling, Euterpe–Basin Petroleum)

How CO₂-enhanced oil recovery works:

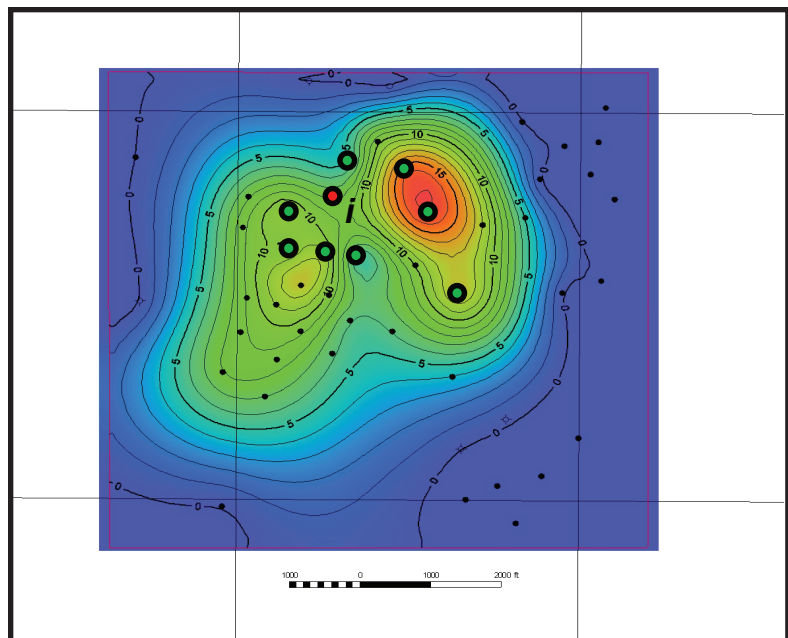
CO₂ injected into an oil reservoir can change oil properties and increase pressure in the reservoir. The best results are when CO₂ dissolves into the oil in the reservoir, which is called “miscibility.”

Sugar Creek Pilot:

- Field discovered in 1963
- Reservoir is Mississippian Jackson Sandstone
- Average reservoir depth is 1,870 ft below ground surface
- Approximately 33 percent (895,575 barrels) of original oil in place (2.7 million barrels) produced before CO₂ pilot

Sugar Creek CO₂ Injection and Monitoring Program:

- Implemented as pattern flood where CO₂ injected into central well surrounded by 6 to 8 producers (see map below)
- Continuous injection from 05/2009 to 05/2010 at 20 to 30 tons CO₂ per day
- Total injected CO₂ equals 7,268 tons
- Full suite of geochemical and pressure monitoring before, during, and one year after CO₂ injection



Thickness of Jackson Sandstone oil reservoir at Sugar Creek Field. Red dot represents the injection well and green dots the production wells. Lobate pattern represents some of the heterogeneity in the reservoir.

Sugar Creek Results:

- Over period of CO₂ injection, 9,900 barrels of additional oil recovered; 6,700 barrels of improved oil recovery, of which 3,200 barrels attributed to CO₂ enhanced oil recovery
- Thus, 66 percent of additional oil can be attributed to well workovers (remediation)
- 84 percent of CO₂ remained in reservoir more than 1 year after injection
- Reservoir modeling for continuous injection for 5 years through a single well shows recovery of 3.7 to 5.9 percent of original oil in place
- Brine and gas geochemistry are very effective at tracing CO₂ movement in reservoir

Euterpe Pilot:

- Field discovered 1928; most field development in 1950's and 1960's
- Reservoir is Mississippian Cypress Sandstone
- Average reservoir depth is 1,860 ft below ground surface
- 30% (770,000 barrels) of original oil in place (2.6 million barrels) produced before CO₂ pilot

Euterpe CO₂ Injection Program:

- Implemented as single-well cyclic injection project where CO₂ was injected into single well; the CO₂ was allowed to soak into the reservoir for 3 to 4 weeks, and the well was returned to production
- Injection well was tested for leaks and mechanical integrity before injection
- Perforations cleaned and pre-CO₂ injection rates established at 0.9 barrels oil per day and 20 barrels of water per day
- Two rounds of CO₂ injection:
 1. 10/25/2010 Injected 20 tons in 6 hours, shut-in for approximately 4 weeks
 2. 01/22-01/24/2011 Injected 60 tons in 3 days, shut-in for approximately 3 weeks
- Total injected CO₂ equals 80 tons

Euterpe Results:

- After first injection and soak period, oil rate increased to 2.7 barrels of oil per day
- The increase represents a 200 percent increase over the 5 weeks of monitoring
- Significant increase reflects influence of cleaning perforations and CO₂ injection
- After second injection, observed similar increased oil production
- Unable to document longer-term response because of well mechanical problems and subsequent project termination



Liquid CO₂ being off-loaded from tanker truck (20 ton capacity) into injection pump where CO₂ was pressurized to 850 to 1,350 psi as it was injected into the Euterpe test well. Transfer lines are white due to frost as the CO₂ in the lines was very cold (-109°F).

Critical Findings and Recommendations:

- Immiscibility between CO₂ and oil will be the prevailing condition in most Kentucky reservoirs (approximately 90 percent) and limit CO₂-enhanced oil recovery effectiveness
- Despite this, single-well cyclic projects such as Euterpe, might be economic where reservoir pressure is not too depleted and oil saturation is high
- Good wellbore infrastructure and use of corrosion inhibitors are needed to avoid mechanical problems with CO₂
- Wellbore workovers 9 to 12 months ahead of CO₂ injection will ensure establishment of accurate reinjection production rates