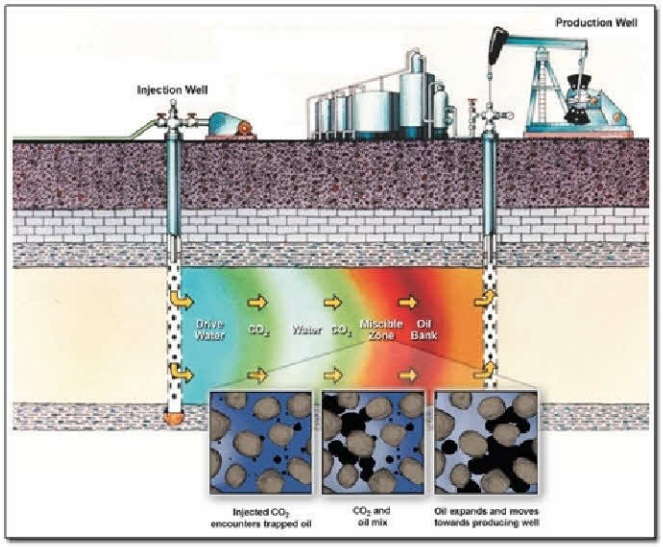
ENHANCED OIL RECOVERY

Clean Coal

Carbon Capture and Storage

Oil & Gas

- Methane Hydrate
- LNG
- Offshore Drilling
- Enhanced Oil Recovery
- Shale Gas



Cross-section illustrating how carbon dioxide and water can be used to flush residual oil from a subsurface rock formation between wells.

Crude oil development and production in U.S. oil reservoirs can include up to three distinct phases: primary, secondary, and tertiary (or enhanced) recovery. During primary recovery, the natural pressure of the reservoir or gravity drive oil into the wellbore, combined with artificial lift techniques (such as pumps) which bring the oil to the surface. But only about 10 percent of a reservoir's original oil in place is typically produced during primary recovery. Secondary recovery techniques extend a field's productive life generally by injecting water or gas to displace oil and drive it to a production wellbore, resulting in the recovery of 20 to 40 percent of the original oil in place.

However, with much of the easy-to-produce oil already recovered from U.S. oil fields, producers have attempted several tertiary, or enhanced oil recovery (EOR), techniques that offer prospects for ultimately producing 30 to 60 percent, or more, of the reservoir's original oil in place. Three major categories of EOR have been found to be commercially successful to varying degrees:

- **Thermal recovery**, which involves the introduction of heat such as the injection of steam to lower the viscosity, or thin, the heavy viscous oil, and improve its ability to flow through the reservoir. Thermal techniques account for over 40 percent of U.S. EOR production, primarily in California.
- **Gas injection**, which uses gases such as natural gas, nitrogen, or carbon dioxide that expand in a reservoir to push additional oil to a production wellbore, or other gases that dissolve in the oil to lower its viscosity and improves its flow rate. Gas injection accounts for nearly 60 percent of EOR production in the United States.
- **Chemical injection**, which can involve the use of long-chained molecules called polymers to increase the effectiveness of waterfloods, or the use of detergent-like surfactants to help lower the surface tension that often prevents oil droplets from moving through a reservoir. Chemical techniques account for about one percent of U.S. EOR production.
  Each of these techniques has been hampered by its relatively high cost and, in some cases, by the unpredictability of its effectiveness.

In the U.S., there are about 114 active commercial CO2 injection projects that together inject over 2 billion cubic feet of CO2 and produce over 280,000 BOPD (April 19, 2010, Oil and Gas Journal).

CO2 Injection Offers Considerable Potential Benefits

The EOR technique that is attracting the most new market interest is carbon dioxide (CO2)-EOR.

MORE INFORMATION

Primer on CO2-Enhanced Oil Recovery

Mobility and Conformance Control for CO2-EOR

First tried in 1972 in Scurry County, Texas, CO2 injection has been used successfully throughout the Permian Basin of West Texas and eastern New Mexico, and is now being pursued to a limited extent in Kansas, Mississippi, Wyoming, Oklahoma, Colorado, Utah, Montana, Alaska, and Pennsylvania.

Until recently, most of the CO2 used for EOR has come from naturally-occurring reservoirs. But new technologies are being developed to produce CO2 from industrial applications such as natural gas processing, fertilizer, ethanol, and hydrogen plants in locations where naturally occurring reservoirs are not available. One demonstration at the Dakota Gasification Company's plant in Beulah, North Dakota is producing CO2 and delivering it by a 204-mile pipeline to the Weyburn oil field in Saskatchewan, Canada. Encana, the field's operator, is injecting the CO2 to extend the field's productive life, hoping to add another 25 years and as much as 130 million barrels of oil that might otherwise have been abandoned.

Next Generation CO2 Enhanced Oil Recovery

DOE's R&D program is moving into new areas, researching novel techniques that could significantly improve the economic performance and expand the applicability of CO2 injection to a broader group of reservoirs; expanding the technique out of the Permian Basin of West Texas and Eastern New Mexico into basins much closer to the major sources of man-made CO2. Next generation CO2-EOR has the potential to produce over 60 billion barrels of oil, using new techniques including injection of much larger volumes of CO2, innovative flood design to deliver CO2 to un-swept areas of a reservoir, and improved mobility control of the injected CO2.

In September 2010 DOE competitively selected seven Next Generation CO2 EOR research projects. Four projects are developing techniques for mobility control of the injected CO2. Novel foams and gels have the potential to prevent the highly-mobile CO2from channeling through high-permeability areas of a reservoir, leaving un-swept, unproductive areas of the reservoir. The four projects are:

- **Improved Mobility Control in CO2 Enhanced Oil Recovery using SPI Gels** (Impact Technologies, LLC)
- **Engineered Nanoparticle-Stabilized CO2 Foams to Improve Volumetric Sweep of CO2 EOR Processes** (U. Texas - Austin)
- **Novel CO2 Foam Concepts and Injection Schemes for Improving CO2 Sweep Efficiency in Sandstone and Carbonate Hydrocarbon Formations** (U. Texas - Austin)
- **Nanoparticle-Stabilized CO2 Foam for CO2-EOR Application** (New Mexico Institute of Mining and Technology)

One project is investigating the potential for oil production by CO2 injection into the residual oil zone:

- **"Next Generation" CO2-EOR Technologies To Optimize The Residual Oil Zone CO2 Flood At The Goldsmith Landreth Unit**, Ector County, Texas (U. Texas – Permian Basin)

Two projects are developing simulation and modeling tools for CO2 EOR:

- **Real Time Semi-Autonomous Geophysical Data Acquisition and Processing System to Monitor Flood Performance** (Sky Research, Inc.)
- **CO2-EOR and Sequestration Planning Software** (NITEC LLC)