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Sequestration

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NETL

Carbon Sequestration through Enhanced Oil Recovery

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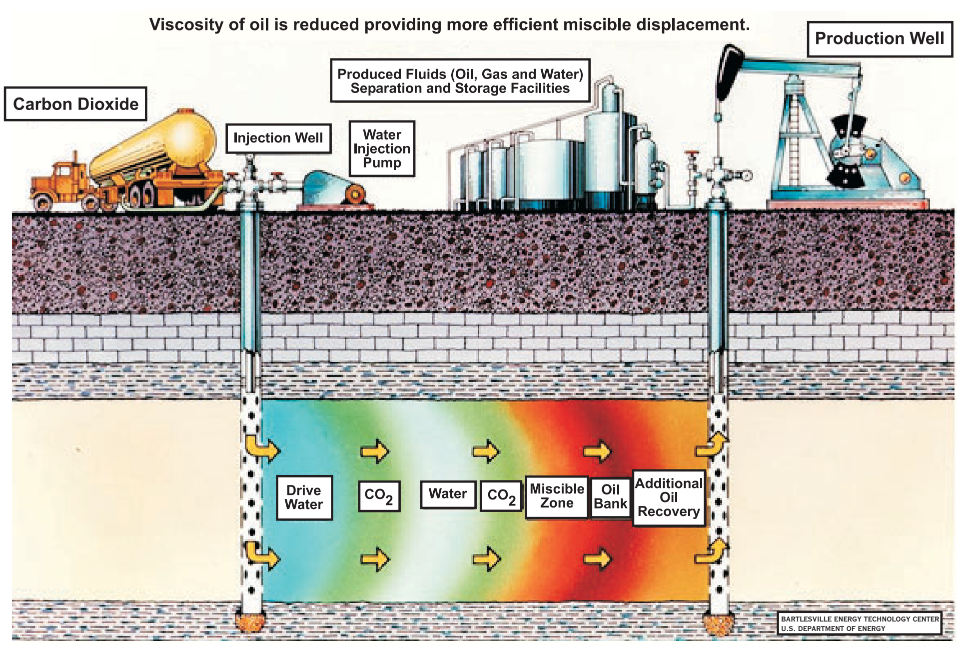
Description/Background

Enhanced Oil Recovery (EOR) refers to techniques that allow increased recovery of oil in depleted or high viscosity oil fields. In 2000, EOR projects produced a total of 780,000 barrels of oil per day (Moritis, 2000), almost 12 percent of the total U.S. production. One method of EOR, carbon dioxide flooding (CO_2 EOR), has the potential to not only increase the yield of depleted or high viscosity fields, but also to sequester carbon dioxide that would normally be released to the atmosphere. In general terms, carbon dioxide is flooded into an oilfield through a number of injection wells drilled around a producing well. Injected at a pressure equal to or above the minimum miscibility pressure (MMP), the CO_2 and oil mix and form a liquid that easily flows to the production well. Pumping can also be enhanced by flooding CO_2 at a pressure below the MMP, swelling the oil and reducing its viscosity.

CO_2 EOR has been used by the oil and gas industry for over 40 years, but only recently has its potential as a carbon sequestration method been realized and investigated. Although CO_2 EOR comprises only a small portion of



Schematic of CO_2 EOR

all EOR being performed in the U.S., maturing oil fields and narrow profit margins make this method of resource recovery increasingly attractive to industry. The U.S. has been a leader in developing and using technologies for CO_2 EOR; currently about 96% of EOR with CO_2 is preformed in the U.S. A simple schematic of the process is shown on the previous page.

Current CO_2 EOR Operations

Currently, over 8 megatons (Mt: 10^6 Tons) of CO_2 are used for EOR, accounting for 80 percent of all commercially used CO_2 in the U.S. (EIA 2002; DOE 1999). Of this total, about 10 percent (0.8 Mt) is anthropogenic in origin i.e., produced by human activities such as oil refining or fertilizer manufacturing. The rest is extracted from naturally occurring deposits. Up to three-quarters of CO_2 injected stays sequestered, amounting to about 0.6 Mt/year because EOR operator pay a premium price for CO_2 and standard practices recycle its use (Stevens, 2001). The amount of CO_2 that remains sequestered is highly dependent on whether the field is blown-down following any CO_2 operations. Further research and development in this area is expected to improve the storage rate to close to 100 percent. Estimates made by the International Energy Agency (IEA) show that depleted oil wells have the potential to sequester 130 gigatons of Carbon (Gt C: 10^9 Tons C) in total (IEA, 2003).

CO_2 Utilization and Potential in EOR Projects

United States	
Carbon Dioxide use for EOR	8 Mt/yr
• Naturally occurring	7.2 Mt/yr
• Anthropogenic	0.8 Mt/yr
Estimated CO_2 sequestered from EOR operations	0.6 Mt/yr
Worldwide	
Potential CO_2 EOR sequestration	130 Gt C
Total CO_2 accumulated in atmosphere	3-4 Gt C/yr

Benefits

CO_2 EOR is a promising method of sequestration for a number of reasons. First, the geologic structures that originally contained the oil and natural gas should be able to permanently contain the injected CO_2, provided the integrity of the structure is maintained. Because of seismic studies, the geologic structure and physical properties of many oil and gas fields are well understood. This, combined with the vast amount of industry experience with gas-injection EOR, provides a knowledge base from which to start researching the sequestration implications of CO_2 EOR. Another benefit of CO_2 EOR for sequestration purposes is the widespread distribution of depleted and operating oil and gas fields, making it likely that an oil field is near a CO_2 source. Finally, carbon sequestration from CO_2 EOR projects can create offsets resulting in trades in the emerging greenhouse gas market. In February 2002, CO2e.com announced its largest greenhouse gas (GHG) emission reduction trade to date—a transaction between Ontario Power Generation and Bluesource. The forward purchase of 6 million tCO_2 equivalent and option for an additional 3 million tonnes CO_2 equivalent resulted from geologic sequestration projects in Texas, Wyoming, and Mississippi, where CO_2 that would otherwise be vented by natural gas processing plants is used for enhanced oil recovery.

Industries Activities

CO_2 is specifically processed for 62 of the 66 projects utilizing CO_2 for EOR (Stevens, 2001). The CO_2 for these projects is mined from naturally occurring, high-pressure deposits that occur close enough to oil fields to make transmission economically feasible. The following projects, Weyburn and Rangely, are two projects that utilize anthropogenic CO_2 for EOR and additionally promote GHG reduction, since this CO_2 would otherwise be vented to the atmosphere.

Weyburn Project

In October 2000, EnCana began injecting CO_2 into a Williston Basin oilfield (Weyburn) in order to boost oil production. Overall, it is anticipated that some 20 Mt of CO_2 will be permanently sequestered over the lifespan of the project and contribute to the production of at least 122 million barrels of incremental oil from a field that has already produced 335 million barrels since its discovery in 1955. The gas is being supplied via a 205 mile pipeline stretching from the lignite-fueled Dakota Gasification Company Great Plains Synfuels plant site in North Dakota. At the plant, CO_2 is produced from a Rectisol unit in the gas cleanup train of the coal-fired plant. Sales of the CO_2 adds about $30 million of gross revenue to the gasification plant's cash flow each year (additional revenue results from the sale of CO_2; carbon sequestered through this project has not publicly been traded in the greenhouse gas market).

Researchers collected background information prior to the flooding of the field with CO_2, allowing for comparison of field characteristics before and after CO_2 injection and enhancing understanding of interactions and relationships between oil recovery and CO_2 storage.The IEA Weyburn CO_2 Monitoring and Storage Project is coordinated by 20 research organizations in the U.S., UK, France, Italy and Denmark, including the U.S. DOE/NETL Carbon Sequestration Program, and co-administered by the Petroleum Technology Research Centre, Natural Resources Canada, Saskatchewan Industry and Resources, the Saskatchewan Research Council, the University of Regina and IEA GHG. For more information, see The Weyburn Project: A Model for International Collaboration (posted at www.netl.doe.gov/coalpower/sequestration).

Rangely Project

Chevron's Rangely Weber field in Colorado is one of the largest geologic sequestration sites for anthropogenic CO_2. Carbon dioxide for this flood is purchased from the ExxonMobil LaBarge natural gas processing facility in Wyoming and then transported via pipeline to the field. The Rangely CO_2 flood is comprised of an array of 341 production wells and 209 injection wells and extends over an area of 61 km^2. CO_2 injection began at Rangely in 1986 and leakage of CO_2 via wellbores or through the reservoir cap is considered to be negligible. Foams, gels and other strategies are used to improve conformance and reduce premature CO_2 breakthrough. Monitoring wells are used to track movement of injectant within the reservoir, and reservoir simulations estimate ultimate CO_2 sequestration at the Rangely field. By the time the project is completed, an estimated total of 25 Mt (472 Bcf) of CO_2 will have been sequestered.

Summary of Anthropogenic CO2-EOR Projects in the U.S.

Plant Name	Plant Type	CO_2 Supply (t /day)	EOR Field	Operator	Start-up Date
Mitchell, Grey Ranch, Puckett and Terrel	Gas Processing	4.31	SACROC, TX	Pennzoil & Altura	1/1972
LaBarge	Gas Processing	2.58	Rangely, CO	Chevron	10/1986
Enid	Fertilizer	0.60	Purdy, OK	Anadarko	9/1982
Koch	Gas Processing	0.43	Paradis, LA	Texaco	2/1982
Great Plains Synfuels	Gas Processing	16.4	Weyburn, Saskatchewan	EnCana Energy	10/2000

Source: Stevens, 2001 and Moritis, 2002

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Conclusions

CO_2 EOR production will continue to be influenced by oil prices, technological improvements and the development of GHG trading markets, but the use of CO_2 EOR is expected to continue increasing under most future price scenarios. Higher oil prices enhance revenues and profitability. Technologies for improved flood monitoring reduce extraction costs and enhance profitability, stimulating investment and increased production. Emerging GHG markets may provide CO_2 EOR operators with further incentive to use this technique and ensure that CO_2 remains trapped underground. There are a few barriers to implementing CO_2 EOR as a means of sequestration, including:

- Incomplete understanding of reservoir processes
- High costs of capturing, processing, and transporting anthropogenic CO_2, particularly from power generation facilities
- Underdeveloped monitoring and verification technologies
- Unclear emissions trading protocols

These barriers are being addressed through the DOE's Carbon Sequestration Program. For more information about how the research program is specifically addressing CO_2-EOR, you can download The Carbon Sequestration Roadmap and Program Plan and Project Portfolio at www.netl.doe.gov/coalpower/sequestration.

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