The Weyburn Oil Field – A Model for Value-Added Direct CO_2 Sequestration

Carbon dioxide (CO_2) has been used safely and effectively for the past 30 years to help increase the production of oil and natural gas from underground formations.[1] This practice, called CO_2 enhanced oil recovery (EOR) or CO_2 flooding, can be modified to result in the permanent storage of CO_2 in underground formations.[2] Storing CO_2 underground, referred to as geologic CO_2 sequestration, is one of several ways to control atmospheric emissions of CO_2 from human activities. Combining CO_2 flooding and CO_2 sequestration is an example of value-added sequestration. The Weyburn oil field in southern Saskatchewan is a real-world laboratory for an international effort to determine criteria for developing, assessing, and implementing safe and effective value-added direct sequestration in depleted oil fields. The results indicate that direct value-added CO_2 sequestration can be safe and effective given the right combination of site characterization, site monitoring, geologic conditions, and site operations. The Weyburn project is one of the sequestration activities involving members of the Plains CO_2 Reduction (PCOR) Partnership.

The Great Plains Synfuels Plant (Dakota Gasification Company) in Beulah, North Dakota, generates the CO_2 used in EOR operations in the Weyburn, Saskatchewan, oil field.[2]

What Is the Role of CO_2 in the Weyburn Oil Field?

The Weyburn oil field had original oil in place of 1.4 billion barrels. It has produced 356 million barrels of oil since its discovery in 1954.[1,2] In the late 1990s, oil production had decreased to the point that the oil field was being considered for abandonment even though operators knew that additional oil remained in the production zones. In 2000, EnCana Resources initiated a CO_2 flood program designed to recover an estimated 130 million barrels of this additional, or "incremental," oil. This action is expected to extend the life of the oil field until 2025 and bring significant economic benefits to the region. Over the life of the CO_2 flood, about 20 million metric tons of CO_2 will be sequestered in the production zones, which is equivalent to the annual CO_2 output of 3.8 million passenger vehicles.[3]

What Is Value-Added Sequestration?

- "Value-added" means that the economic value of a product or process has been increased through changes in practices or processing.
- Operations that use CO_2 to help produce oil or natural gas and then put the CO_2 into permanent storage generate an additional economic return so they are said to be value-added when compared to operations that simply capture and store the CO_2.
- The economic return in value-added sequestration provides a near-term incentive to undertake sequestration activities.

Where Does the CO_2 Come From for Weyburn?

The CO_2 for the Weyburn CO_2 flood and sequestration activities comes from the Great Plains Synfuels Plant owned by the Dakota Gasification Company in Beulah, North Dakota. Each year, the Synfuels Plant converts about 6 million tons of lignite coal to 54 billion cubic feet of synthetic natural gas.[4] The coal gasification process produces nearly pure streams of several by-products, including CO_2. A portion of this CO_2 is transported 320 km (200 mi) by pipeline from the Synfuels Plant north to the Weyburn oil field for use in CO_2 flooding and sequestration.[2]

CO_2 Flooding at Weyburn

CO_2 is pumped into the production formation through an injection well. Once in the production zone, the CO_2 dissolves in the oil, reducing the oil viscosity and making the oil flow

more easily to the production well. The CO_2 also causes the oil to swell, helping to mobilize the oil trapped in the pores in the rock and forcing it into channels where it can move through the rock. Much of the CO_2 remains in the production zone dissolved in oil that cannot be moved or as liquid CO_2 in the rock. The CO_2 that comes to the surface with the produced oil is separated, recompressed, and injected back into the reservoir to begin the process again.[5]

What About CO_2 Sequestration at Weyburn?

Ultimately, the CO_2 flooding could result in sequestering 20 million metric tons of CO_2 in the Weyburn oil field.[2] The Weyburn site is a field laboratory for a multiyear, international sequestration research effort called the International Energy Agency (IEA) Greenhouse Gas R&D Programme Weyburn CO_2 Monitoring and Storage Project.[6] Begun in 1999 and now in its second phase, the multiyear effort is assessing economics, long-term fate, and security of CO_2 storage in geologic formations. The project is coordinated by the Petroleum Technology Research Centre located in Regina, Saskatchewan.

Who Is Participating in the IEA Weyburn CO_2 Sequestration Assessment?[6]

Industry Partners

EnCana Resources
SaskPower
Nexen Canada Ltd.
Dakota Gasification Company
BP
TransAlta Utilities
ENAA Japan
TotalFina Elf
Chevron Texaco

Government Partners

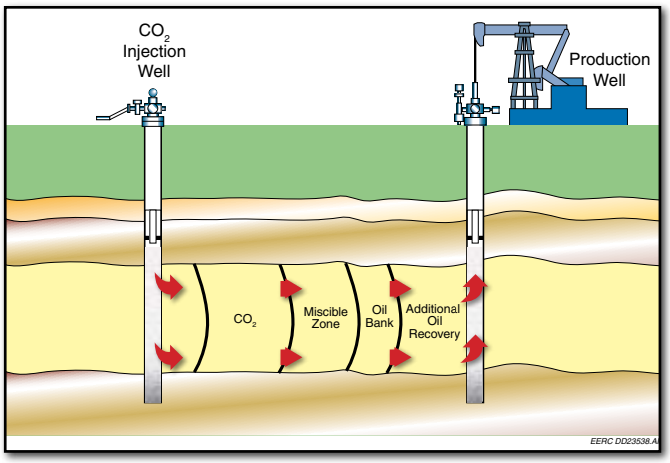
IEA, Greenhouse Gas R&D Programme
U.S. Department of Energy
Natural Resources Canada
Saskatchewan Industry & Resources
Alberta Energy Research Institute
European Community

What Are the Results So Far at Weyburn?

The research at Weyburn has confirmed the importance of impervious caprock (seal on top of reservoir that holds in oil and will hold in CO_2), having detailed knowledge of the site, and the geologic stability of the site (lack of earthquakes and faulting).[8] The field test at Weyburn has also confirmed that existing oil field practices are, in large part, appropriate for ensuring safe CO_2 injection and guarding against the escape of stored CO_2 (given appropriate characteristics).

What Does Weyburn Mean to CO_2 Sequestration in This Region? Worldwide?

The Weyburn project is the most extensive study of geologic CO_2 sequestration in the world, and its findings can be widely applied in planning and implementing CO_2 sequestration. The findings at Weyburn confirm that CO_2 sequestration can be done



CO_2 is injected into the oil-producing formations in the Weyburn oil field to improve oil production and to sequester CO_2.[8]

safely for humans and the environment at sites with characteristics like those at Weyburn. Weyburn also shows that sequestration can add value to conventional CO_2 flood operations.

Is Weyburn the Answer to Controlling CO_2?

The 20 million metric tons of CO_2 that will eventually be stored at Weyburn is about 0.3%[9] of the annual CO_2 output from fossil energy use in the United States and Canada and about 2.4%[10] of the annual output from the PCOR Partnership region. The sequestration projects that will build on the Weyburn experience will be a key part of a larger picture of CO_2 control that includes low-CO_2-emission power plants, greater use of renewable fuels, increased efficiency for power systems, and energy conservation.

References and Notes

1. Benson, S.M., Hepple, R., Apps, J., Tsang, C.F., and Lippmann, M., 2004, Lessons learned from natural and industrial analogues for storage of carbon dioxide in deep geological formations: E.O. Lawrence Berkeley National Laboratory Report 1170. **2.** www.pttc.org/tech_sum/ts_v11n1/statev11no1.htm. **3.** 20 million metric tons of CO_2 sequestered divided by 5.32 metric tons of CO_2 per passenger vehicle per year; passenger vehicle CO_2 output calculated using average output for Daimler-Chrysler, Ford, and GM passenger vehicles for 2002 (1.0289 lb per mile) from Figure 7 at http://earthtrends.wri.org/features/view_feature.cfm?theme=3&fid=53 and average annual residential vehicle mileage (11,400 miles) for 1994 from www.eia.doe.gov/emeu/rtecs/Chapter3.html. **4.** www.dakotagas.com/. **5.** www.ieagreen.org.uk/glossies/weyburn.pdf. **6.** www.netl.doe.gov/publications/carbon_seq/mediarelease/mr-101102.pdf. **7.** Kovscek, A.R., 2002, Screening criteria for CO_2 storage in oil reservoirs: Petroleum Science and Technology, v. 20, nos. 7 and 8, p. 841–866. **8.** Davison, J., Freund, P., and Smith, A., 2001, Putting Carbon Back in the Ground, IEA Greenhouse Gas R&D Programme at www.ieagreen.org.uk/putcback.pdf. **9.** 20 million metric tons of CO_2 (equivalent to 22.05 million tons) sequestered at Weyburn divided by 6937.47 million tons of CO_2 generated in 2000 in the United States and Canada from http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf. **10.** 20 million metric tons of CO_2 (equivalent to 22.05 million tons) sequestered at Weyburn divided by 6937.47 million tons of CO_2 generated in 2000 in the United States and Canada from http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJQ6G/$File/2003-final-inventory.pdf.

The Plains CO_2 Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of sequestering CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership is managed by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:

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Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

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