The IEA GHG Weyburn-Midale CO₂ Monitoring and Storage Project: An Update on the Final Phase

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Outline

Overview
- Partners
- Project History
- Field Location and Statistics

Project Progress of the Final Phase

Final Objectives by 2011
What is the PTRC?

Mission: To develop world-leading enhanced oil recovery and CO₂ storage technologies that ensure sustainable and environmentally-sensitive development of Canada’s energy resources.

• PTRC is a non-profit R&D corporation
• PTRC manages EOR research and delivers basic and applied research results to its partners for field application, including the IEA GHG Weyburn-Midale CO₂ Monitoring and Storage Project (2000-2011)
• Partnered with, funded by, and liaison to: government, industry and researchers
• Founded in 1998 by
  • NRCan (Federal Gov’t)
  • SER (Provincial Gov’t)
  • SRC (Research Organization)
  • UofR (Research Organization)

Petroleum Technology Research Centre
Regina, Saskatchewan, Canada

“Enhanced Oil Recovery technology with a bigger impact and a smaller footprint.”
“The Weyburn-Midale Project will provide policymakers, the energy industry and the general public with reliable information about industrial carbon sequestration and enhanced oil recovery.”

• Samuel Bodman, Former Secretary of Energy, USA
World’s Largest Monitored CO₂ Geological Storage Site

IEA WMP is a research program in 2 Phases

• $80 million funding including in-kind support
• Currently in Final Phase

Research Focused on

• Geological Integrity
• Wellbore Integrity
• Seismic monitoring
• Geochemical monitoring
• Risk Management
• Over 30 projects in progress

Non-technical issues

• Communication
• Policy
Final Phase: Partners to Date

Industry Sponsors
- Apache
- EnCana
- Chevron
- OMV Austria
- Saudi Aramco
- SaskPower
- Schlumberger
- Shell
- DGC
- Nexen

$40 Million

Government Sponsors
- Natural Resources Canada
- United States Dept. of Energy-National Energy Technology Lab
- IEA GHG R&D Programme
- Saskatchewan Ministry of Energy and Resources
- Alberta Energy Research Institute
- RITE (Research Institute of Innovative Technology for the Earth – Japan)

Research Organizations
- Alberta Research Council (ARC)
- Canadian Light Source – Synchrotron
- ECOMatters (ECOM)
- Geological Survey of Canada (GSC)
- Permedia Group
- Saskatchewan Research Council (SRC)
- Canada Capital Energy Corp.
- T.L. Watson & Associates
- University of Regina (U of R)
- University of Sask. (U of S)
- University of Alberta (U of A)
- University of Calgary (U of C)
- URS Canada Inc.
- Saskatchewan Geological Survey
- Fugro Seismic Imaging
- Lawrence Livermore National Laboratories
- Bluewave Resources
- University of Bristol UK
- IEA GHG R&D Programme
Weyburn-Midale: Where is the CO$_2$ from? Where is it stored?

Geoscience Framework Study Area 100,000 km$^3$

Geological Survey of Canada

Courtesy © Geological Survey of Canada
The Source of CO₂

Great Plains Synfuels Plant – Beulah, North Dakota

• 250 mmscfd CO₂ by-product of coal (lignite) gasification
  • approx. 8000 tonnes/day suitable for EOR

• CO₂ capture facility installed by Great Plains

• CO₂ purity 95% (less than 2% H₂S)
  • trace mercaptans (provide basis for leak detection at surface facilities)

• 320 km pipeline (14 in & 12 in) built & operated by Great Plains

• Compressed CO₂ delivered to custody transfer location in Weyburn

• EnCana and Apache take delivery at the field gate
# Weyburn & Midale Statistics

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<thead>
<tr>
<th></th>
<th>Weyburn (EnCana)</th>
<th>Midale (Apache)</th>
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</thead>
<tbody>
<tr>
<td><strong>Field Size</strong></td>
<td>70 square miles</td>
<td>40 square miles</td>
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<tr>
<td><strong>Original oil in place</strong></td>
<td>1.4 billion barrels</td>
<td>515 million barrels</td>
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<tr>
<td><strong>Oil recovery</strong></td>
<td>370 millions barrels</td>
<td>154 million barrels</td>
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<td>(pre-CO2-EOR)</td>
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<td><strong>Projected CO₂ IOR</strong></td>
<td>155 million barrels</td>
<td>67 million barrels</td>
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<tr>
<td><strong>Projected CO₂ stored</strong></td>
<td>30+ million tonnes* (gross)</td>
<td>10+ million tonnes* (gross)</td>
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<tr>
<td></td>
<td>26+ million tonnes (net)</td>
<td>8.5+ million tonnes (net)</td>
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</table>

*equivalent to removing more than 8 million cars off the road for a year
CO₂ Injection 2000 vs. 2009

Initial CO₂ injection at Weyburn Sept. 2000:
~5,000 tonnes/day or 95 MMSCF

Dec 2008, Weyburn:
~6,550 tonnes/d
(+ 5,500 tonnes/day recycle)

Dec 2008, Midale:
~1,500 tonnes/d

Total Stored (as of January 1, 2009)
Weyburn:
• 13 MT stored
Midale:
• 1.6 MT stored
Oil Production and CO₂ Stored at Weyburn

- At Weyburn-Midale: 14.6 million tonnes of anthropogenic CO₂ stored to-date
- Annual Injection 1.75 million tonnes at Weyburn alone
- 40 million tonnes will be stored by 2035 in Weyburn-Midale fields
- Excellent EOR response: >20,000 incremental bbl/day

CO₂ stored equivalent to removing more than 8 million cars off the road for a year
Phase I Project Organization

Organized into 4 themes:

• Theme 1: Geological Characterization of the Geosphere and Biosphere
• Theme 2: Prediction, Monitoring, and Verification of CO₂ movements
• Theme 3: CO₂ Storage Capacity and Distribution Predictions and the Application of Economic Limits
• Theme 4: Long Term Risk Assessments of the Storage Site
Final Phase: Research Program

*Non-Technical Components*

- Regulatory
- Public Communications
- Fiscal Policy

*Technical Components*

- Geological Integrity
- Wellbore Integrity
- Storage Monitoring Methods (Geophysics & Geochemistry)
- Risk Assessment
Study Region - Geoscience

Alberta

Montana

North Dakota

Williston Basin

Saskatchewan

Manitoba

South Dakota

Wyoming

System Model
(10 km beyond EOR)

Regional Study
(200 x 200 km)
Geological/Hydrogeological Model

- 10 km beyond CO₂ flood limits
- Geological architecture of system
- Properties of system:
  - lithology
  - hydrogeological characteristics
  - hydrochemistry
  - poro/perm
  - faults
GEOSCIENCE FRAMEWORK
200 x 200 km
- Stratigraphic framework
- Hydrostratigraphic framework
- Tectonic framework

Geological Model
10 km beyond CO₂ flood
Theme 1

CO₂ Storage capacity and distribution
History matching
Theme 3

System Model

Risk Assessment

Prediction & Monitoring
4D Seismic Geochemical
Theme 2

Features, Events, Processes
Numerical modeling
Theme 4
Theme 1: Final Phase Study Area(s)

- projects related to: improved geological model, hydraulic properties of aquitards, fault characterization
Theme 2: Wellbore Integrity

Projects related to: wellbore databases, knowledge synthesis, wellbore modelling
Theme 2: Wellbore Integrity

Well Integrity Modeling

• Numerical Simulation of Wellbore Systems

Wellbore Stability for CO₂ Storage Sampling

• Downhole Cement Sampling, Testing & Logging

• Overall Objective: Assess conditions of casing/cement formations in a typical well.

Legend
Cement core recovery
Pressure test cement sheath
Fluid / gas sample

Recovery Summary
• 6 Cement cores
• 6 Cement pressure tests
• 2 Fluid samples

Courtesy: Christopher and Crow, Carbon Capture Project, March 2007
Theme 3: Storage Monitoring Techniques

- 4D, 3C surface seismic
- 4D, 9C surface seismic
- 3D, 3C vertical seismic profile (VSP)
- Cross-well seismic
- Geochemical sampling analysis
- Tracer injection monitoring
- Conventional production data analysis
- Passive seismic
- Soil Gas Survey
Microseismicity Summary (03-08)

**Microseismicity is low**: 175 microseisms near the reservoir; 148 locatable.

M=–3 to –1 (energy-equivalent of **30 mg-30gm of TNT**).

Very **sporadic**; clustered temporally and spatially.

Associated with changes in **injection rates** or temporary **well shut-downs**.

**Tentative correlation of locations with CO₂ distribution** from time-lapse seismic.
Theme 3: Geophysical Monitoring

Including Time Lapse Seismic & Geochemical Mass-Balance

- Measured Seismic Volume at Time 1
- Geochemical Mass-Balance
- Reservoir Simulation at Time 1
- Reservoir Simulation at Time 2
- Lab Measurements
- Well Data
- Core Data
- Production Data
- Measured Seismic Difference

“History Matching”

IMPROVED Production Forecasts, Facilities Planning, Recovery Strategies

Geochemical Signature Distribution

Reservoir Modeling and Flow Simulation
Theme 3: Monitoring Methods (Geochemical)

Shallow Groundwater Sampling
Hydrocarbon Fluid Sampling
Soil Gas Sampling
Geochemical Fluid Sampling

• Geochemical Monitoring of Gas-Fluid-Rock Reactions in the EnCana Weyburn Reservoir

Reactive Transport Modeling of CO₂ - flood EOR and sequestration at Weyburn

• This task has been completed by ARC

CO₂ Brine-Rock Interactions


Pore-Scale Mineral Alteration Studies

• Micron Scale Reservoir Matrix Analysis
Theme 4: Risk Assessment

Application and comparison of different quantitative RA methods:

- Bow-Tie Method
- RISQUE (URS) Method
- Percolation-Invasion Methods (Permedia)
Non-technical Themes

Public Communications and Outreach:

• Establishment of Expert Advisory Panel to plan public communications on CCS.
• CCS public general knowledge website being established
• Trade show booth and IEA publications to increase public awareness of CCS
• Media kits in preparation

Regulatory Issues:

• Survey (report) completed on regulatory progress, approaches and laws about CCS in several jurisdictions, globally
Conclusions

• Geological container at Weyburn is suitable for long-term storage of CO$_2$

• Effective trapping setting:
  • primary seals are highly competent and thick shales above the reservoir serve as secondary barriers

• Risk Assessment using Geological Model indicates no seepage to surface over 5000 years

• Dec 2008: ~ 14 Mtonnes stored…
Conclusions: Final Phase Objectives

Best Practices Manual

Transition of CO₂-EOR Operations to CO₂-storage

Pre-injection, Operations, Post-injection, Closure

Technical Components
- Site Characterization
- Monitoring & Verification
- Wellbore Integrity
- Risk Management

Policy Components
- Regulatory Issues
- Public Communications & Outreach
- Fiscal Policy Issues