Overview of the IEA GHG Weyburn-Midale CO₂ Monitoring and Storage Project

3rd CSLF Workshop on Capacity Building for Carbon Capture and Storage (CCS)

Al-Khobar, Saudi Arabia
26-30 January 2008

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Outline of this presentation

• Encana Weyburn and Apache Midale Commercial EOR Operations

• IEA GHG Weyburn CO$_2$ Monitoring and Storage Project: Overview and Results of Phase I (2000-2004)

• IEA GHG Weyburn-Midale CO$_2$ Monitoring and Storage Project: Final Phase (2007-2010)
Encana Weyburn and Apache Midale
Commercial EOR Operations
Location of the Weyburn-Midale CO₂ Project
Location of the Weyburn-Midale CO₂ Project
# Weyburn and Midale Oilfield Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Weyburn (EnCana)</th>
<th>Midale (Apache)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Size</strong></td>
<td>180 km²</td>
<td>104 km²</td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>1500 m</td>
<td>1500 m</td>
</tr>
<tr>
<td><strong>Gross Pay / Net Pay</strong></td>
<td>25 / 7.8 m</td>
<td>22 / 7.5 m</td>
</tr>
<tr>
<td><strong>Zone Porosity</strong></td>
<td>Marley Dolomite zone: 26% ; Vuggy Limestone zone: 15%</td>
<td></td>
</tr>
<tr>
<td><strong>Average Porosity</strong></td>
<td>17.2%</td>
<td>16.3%</td>
</tr>
<tr>
<td><strong>Zone Permeability</strong></td>
<td>Marley Dolomite zone: 10 mD ; Vuggy Limestone zone: 30 mD</td>
<td></td>
</tr>
<tr>
<td><strong>Average Water Saturation</strong></td>
<td>31.7%</td>
<td>16.3%</td>
</tr>
<tr>
<td><strong>Average Oil gravity</strong></td>
<td>29.3 API (880 kg/m³)</td>
<td>29.8 API (877 kg/m³)</td>
</tr>
<tr>
<td><strong>Minimum miscibility pressure</strong></td>
<td>14 - 16 MPa (2030 - 2320 psi)</td>
<td></td>
</tr>
<tr>
<td><strong>Original oil in place</strong></td>
<td>1.4 billion bbl</td>
<td>515 million bbl</td>
</tr>
<tr>
<td><strong>Oil recovery pre-EOR</strong></td>
<td>370 millions bbl (26.4% OOIP)</td>
<td>154 million bbl (25.4% OOIP)</td>
</tr>
<tr>
<td><strong>Number of injector wells</strong></td>
<td>n/a</td>
<td>60 – 70, incl. 10 CO₂</td>
</tr>
<tr>
<td><strong>Number of producing wells</strong></td>
<td>360 (in EOR area)</td>
<td>270 (total field)</td>
</tr>
</tbody>
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## Weyburn and Midale Operating Statistics

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<th><strong>Midale (Apache)</strong></th>
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<tbody>
<tr>
<td><strong>Start of CO₂ injection / duration</strong></td>
<td>2000 / 30 years</td>
<td>2005 /30 years</td>
</tr>
<tr>
<td><strong>Injection pressure</strong></td>
<td>10 - 11 MPa (1450 - 1600 psi)</td>
<td></td>
</tr>
<tr>
<td><strong>Injection of source CO₂</strong></td>
<td>6,500 t/d (125 MMscf/d)</td>
<td>1,300 t/d (25 MMscf/d)</td>
</tr>
<tr>
<td><strong>Recycle of CO₂ &amp; produced gas</strong></td>
<td>60 MMscf/d</td>
<td>6 – 8 MMscf/d</td>
</tr>
<tr>
<td><strong>Annual amount of source CO₂ injected</strong></td>
<td>2.4 million tonnes</td>
<td>474,000 tonnes</td>
</tr>
<tr>
<td><strong>Total amount source CO₂ injected to date</strong></td>
<td>9.5 million tonnes (Feb 2007)</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Incremental oil production</strong></td>
<td>18,000 b/d for EOR area</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>30,600 b/d for total unit</td>
<td></td>
</tr>
<tr>
<td><strong>Projected total incremental oil recovery due to CO₂</strong></td>
<td>155 million barrels</td>
<td>60 million barrels (17% OOIP)</td>
</tr>
<tr>
<td><strong>CO₂ utilization factor</strong></td>
<td>3 - 4 Mcf/b</td>
<td>2.3 Mcf/b</td>
</tr>
<tr>
<td><strong>Projected amount of CO₂ stored at project completion</strong></td>
<td>30+ million tonnes* (gross)</td>
<td>10+ million tonnes* (gross)</td>
</tr>
<tr>
<td></td>
<td>26+ million tonnes (net)</td>
<td>8.5+ million tonnes (net)</td>
</tr>
<tr>
<td><strong>Total capital cost of EOR project</strong></td>
<td>CAD$1 billion</td>
<td>CAD$95 million</td>
</tr>
</tbody>
</table>

*Equivalent to removing more than 8 million cars off the road for a year
EnCana’s Weyburn Unit Production Data

EnCana’s Weyburn Unit Production Data

Waterflood
Vertical Infills
Horizontal Infills

bopd (gross)
50,000
40,000
30,000
20,000
10,000
0


Date

EnCana Corporation
Apache’s Midale Unit Production Data

- Waterflood Wedge
- Primary Wedge
- EOR Phase Group #3
- EOR Phase Group #2
- EOR Phase Group #1

Oil Rate, bbl/d

Apache Canada
Dakota Gasification Company, Beulah, North Dakota, U.S.A.:

- Produces 13,000 tonnes/d of CO₂ as by-product of lignite coal gasification, of which 8,000 t/d is available for EOR
- CO₂ purity is 95% (less than 2% H₂S); trace mercaptans
- 5000 t/d contracted and transported through 320-km pipeline to Weyburn oilfield
- Pressure is 1000 psi (68 atm/6.9 MP/68.9 bar)
IEA GHG Weyburn CO2 Monitoring and Storage Project: Overview and Results of Phase I (2000-2004)
Objectives

- to **predict and verify** the ability of oil reservoirs to securely and economically contain CO$_2$ through a comprehensive analysis of various methodologies
- to **develop monitoring and modeling** methods to address the long-term migration and fate of CO$_2$

To address these objectives, Phase I was organized along 4 main “themes”, which comprised over 50 separate research subtasks:

1. Geological characterization of geosphere and biosphere
2. Prediction, monitoring and verification of CO$_2$ movements
3. CO$_2$ storage capacity and distribution predictions and the application of conformance control treatments
4. Long-term risk assessments of the storage site
**Phase I Partners**

**Government Sponsors**

$18 million

- Natural Resources Canada
- United States Dept. of Energy
- European Commission
- IEA GHG R&D Programme
- Saskatchewan Industry and Resources
- Alberta Energy Research Institute

**Industry Sponsors**

$22 million

- EnCana
- BP
- ChevronTexaco
- Dakota Gasification Co.
- RITE (Engineering Adv. Association of Japan)
- Nexen
- SaskPower
- Total
- TransAlta

**Research Organizations**

*In kind contributions*

- Saskatchewan Research Council (SRC)
- Alberta Research Council (ARC)
- Canadian Energy Research Institute (CERI)
- ECOMatters (ECOM)
- GEDCO Inc. (GEDCO)
- Geological Survey of Canada (GSC)
- Hampson Russell (HR)
- J.D. Mollard and Associates Ltd. (JDMA)
- Rakhit Petroleum Consulting Ltd. (RPCL)
- University of Regina (U of R)
- University of Saskatchewan (U of S)
- University of Alberta (U of A)
- University of Calgary (U of C)
- Colorado School of Mines, Golden, CO (CSM)
- Lawrence Berkeley National Laboratories, Berkeley, CA (LBNL)
- Monitor Scientific Corporation International, Denver, CO (MSCI)
- North Dakota Geological Survey (NDGS)
- British Geological Survey, Britain Bureau de Recherches Geologiques et Minieres, France (BRGM)
- Geological Survey of Denmark and Greenland (GEUS)
- Istituto Nazionale di Geofisica e Vulcanologia Quintessa Ltd. (INGV)
- Quintessa
Project Location and Study Areas

Source: Saskatchewan Geological Survey; University of Alberta
Tracking CO$_2$ Movement

Seismic Surveys (Baseline to 2004) – Phase 1a

Baseline - 2001

Baseline - 2002

Baseline - 2004
Geological “container” at Weyburn is very effective:
  - Primary carbonate and secondary shale seals are highly competent
  - There is hydraulic separation and no fluid flow between adjacent aquifers

Initial simulation results indicate that after 5000 years over 98% of the initial CO₂ in place will remain stored:
  - More sophisticated simulation work is required
  - Risk management practices need to be developed

After 5000 years, 27% of CO₂ moved outside EOR area, but remained within study area
IEA GHG Weyburn-Midale CO₂ Monitoring and Storage Project

The Final Phase
## Why pursue a Final Phase project?

### Issues to be Addressed

#### Technical
- Unfinished work (“gaps”) from Phase I
- Gaps identified by IPPC (Special Report on CCS, 2005)

#### Non-Technical / Policy

**Favourable regulatory regime**
- Site selection
- Operations
- Abandonment / post-abandonment
- Orphaned sites

**Public understanding and acceptance**

**Facilitating fiscal policy regime**
- Value placed on stored CO₂
- Credit trading mechanisms
- Financial / fiscal incentives

### Outcomes Sought

- Technical knowledge transferred to enable widespread deployment
- Solid technical basis established for policy development
- Storage security
- Risk management
- Long-term liability
- Verifiable GHG reductions
- Public health and safety
- License to operate
- Sources-to-sinks infrastructure
- Widespread use
- Deep GHG cuts
Final Phase Objectives

Best Practices Manual

- Will guide all aspects of future CO$_2$ EOR storage projects

[Integration]

Technical Components
(90% of budget)

1. Site Characterization / Selection
2. Wellbore Integrity
3. Monitoring and Verification
4. Risk Assessment

Non-Tech Components
(10% of budget)

1. Regulatory Issues
2. Public Communication and Outreach
3. Business Environment / Fiscal Policy
Final Phase: Partners to Date

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

**Industry Sponsors**
- Apache
- EnCana
- Chevron
- OMV Austria
- Aramco Services Co
- SaskPower
- Schlumberger
- Shell

**Research Organizations**
- Alberta Research Council (ARC)
- Canadian Light Source – Synchrotron
- ECOMatters (ECOM)
- Geological Survey of Canada (GSC)
- Permedia Group
- Saskatchewan Research Council (SRC)
- 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.
- Fugro Seismic Imaging
- Lawrence Livermore National Laboratories
- University of Bristol UK
- International Energy Agency
Final Phase – Technical Program

**Theme 1 – Geological Integrity (Site Selection)**

- develop firm protocols for site selection
- identify minimum data set required for successful site selection using full-cycle risk assessment
- integrate hydrogeological, geophysical, geological data sets to create complete picture of seal integrity
- further study leakage and storage integrity in natural analogues
- summarize impact of CO$_2$ on geochemical and geomechanical processes and regional reservoirs and seals

**Theme 2 – Wellbore Integrity**

- complete identifying essential parameters for well-bore integrity
- compile list of well remediation technologies that can be applied
- describe current well abandonment trends and how they may impact future abandonment requirements
- conduct cased-hole dynamic testing (look for pressures and mobile fluids that signal CO$_2$ migration out of the zone)
- document safe practices and effect on wellbore integrity and geomechanics
Final Phase – Technical Program

**Theme 3 – Storage Monitoring Methods**
- Characterize the accuracy of monitoring technologies for quantitative prediction of CO\textsubscript{2} location and volume
- determine if multi-year 4D seismic programs are an appropriate monitoring and verification requirement?
- determine CO\textsubscript{2} distribution through in-situ time-lapse well logging; spinner surveys; selective drilling, coring and logging of slim holes
- continue to explore passive seismic monitoring

**Theme 4 – Risk Assessment and Storage Mechanisms**
- complete full-field risk assessment from Phase 1
- determine risk levels for various storage optimization scenarios
- describe ultimate fate of CO\textsubscript{2}, the relative volumes in each storage/ trapping mechanism, the time needed for trapping, and factors affecting these mechanisms
- Study ways for stimulating and accelerating CO\textsubscript{2} mineral fixation at reservoir conditions
**Public Communications and Outreach**

- With stakeholders, develop a Communication Strategy based on the Weyburn-Midale experience and other major international CO$_2$ geological storage projects:
  - Identify and focus on issues of key interest to policy makers, regulators, investors and the local and national public
  - Communicate in the most appropriate manner the technical information from the Best Practices Manual and other relevant sources to these essentially non-technical audiences
  - Develop and/or participate in development of CCS educational materials
  - Launch the public communication process early
- Based on issues and feedback from stakeholders, revisit and revise the Best Practices Manual accordingly
Overall Status of the Final Phase

• Continued financial support by governments for the Final Phase is confirmed: NRCan, US DOE/NETL, Japan, Saskatchewan and Alberta

• Sponsorship from industry is enhanced to include new participants from different sectors

• Total funding (cash and in-kind) is expected to be in the order of $40 million, similar to that in Phase I

• Agreements with sponsors and research performers have been finalized or are currently being executed

• Budget envelopes (2007-2010) have been approved (90% technical; 10% policy)
Conclusions

- Based on preliminary Phase I results, the geological setting at Weyburn-Midale appears to be highly suitable for long-term CO$_2$ geological storage.
- The project has arguably developed the most complete, comprehensive, peer-reviewed data set in the world for CO$_2$ geological storage.
- An international team of high-quality researchers has been established and strong international leadership has been demonstrated by Canada, the USA and the EU through continued financial and managerial support.
- International credibility and recognition by the IEA GHG R&D Programme and the Carbon Sequestration Leadership Forum (CSLF) have been achieved.
- The final product – the Best Practices Manual - will serve as a practical technical guide for the design and implementation of EOR-type CO$_2$ storage, while accelerating the development of: (i) appropriate regulations for CO$_2$ storage; (ii) effective public consultation process; and (iii) public policy that provides effective incentives to ensure widespread deployment of long-term CCS.
Thank you for your attention!
Any Questions?

For more information, email
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How does CO₂ Enhanced Oil Recovery (EOR) work?