A Decade of CCUS and Associated Research at the Weyburn and Midale Oilfields, Saskatchewan, Canada

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Petroleum Technology Research Centre

- Non-Profit Research & Development
- Collaborative partnership with Industry, Government and Research Organizations
- Committed to reducing environmental impacts of oil production
  - STEPS (EOR Centre of Excellence)
- Research associated with CO₂ management
  - IEAGHG Weyburn –Midale CO₂ Monitoring & Storage Project
  - Aquistore
Main Areas of Current CCUS Development in Canada
## Current Government Funding of CCS Projects: Alberta and Saskatchewan

<table>
<thead>
<tr>
<th>Project</th>
<th>Federal</th>
<th>Provincial</th>
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<tbody>
<tr>
<td>Quest Project</td>
<td>120 MM</td>
<td>745 MM</td>
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<tr>
<td>Swan Hills</td>
<td>----</td>
<td>285 MM</td>
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<tr>
<td>Enhance (ACTL)</td>
<td>63 MM</td>
<td>495 MM</td>
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<tr>
<td>Boundary Dam</td>
<td>240 MM</td>
<td></td>
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<tr>
<td>Aquistore</td>
<td>14 MM*</td>
<td>5 MM</td>
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<tr>
<td>Weyburn-Midale</td>
<td>+15 MM**</td>
<td>3.5 MM</td>
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* 5 million from Sustainable Development Technology Canada (stand-alone federally funded agency) and 9 million ECOeti

**Includes NRCan and USDOE (Canada and USA)
IEAGHG Weyburn-Midale CO₂ Monitoring & Storage Project (WMP) 2000 to 2012

- Commercial EOR operations in Weyburn and Midale oilfields utilise anthropogenic CO₂
- Over 20Mt of CO₂ injected and stored since 2000
- WMP has used these sites to study technical aspects of CO₂ geological storage
Regional GeoScience Framework Area of Investigation:

- >30,000 wells in study area
- 11,121 drill stem tests
- 6,292 wells with digital core analyses
- 9,207 formation water chemistry samples
Midale Field CO2-EOR
Best Practice Manual

Introduction
- Purpose, scope, context, background, ...

Characterization
- Regional geology
- Regional hydrogeology
- Containment characterization
- Geomechanical characterization
- Geochemical characterization

Performance predictions
- CO₂ migration
- Capacity and mass partitioning
- Containment

Geochemical monitoring
- Groundwater
- Soil gas
- Reservoir fluids
- Reservoir/caprock core

Geophysical monitoring
- Geophysical char. of rock-fluid system
- Feasibility studies
- Downhole monitoring methods
- 3D seismic methods

HM and performance validation
- Prediction/measurement comparison
- Revision of Geologic Models

Well integrity
- Integrity assessment
- Design considerations
- Remediation and conversion
- Abandonment considerations
- Integrity monitoring and field testing

Risk assessment

Community outreach
Revised Model

Was improved with:

1. More detailed aquitard characterization
2. Larger area
3. More accurate subcrop mapping
4. Increased well density (800 in area)
Natural Analogue Study
3D Time-Lapse Seismic: CO₂ Distribution

Monitoring regional subsurface distribution of CO₂:
• Verifying storage conformance
• A primary input for updating reservoir models
• Optimal resolving capability
• Sensitive to low CO₂ saturations
• Data repeatability is fundamental
Inversion of prestack seismic data:

- Semi-quantitative CO\textsubscript{2} saturation and P changes
- Results are model-based
- Characterization of reservoir rock physics is essential
- Monitoring survey design is important as “long offset” data are required
Seal Integrity: Fracture Mapping

Seismic anisotropy as a proxy for vertical fracturing:
- Means of identifying potential fracture zones regionally
- Scale of individual fractures and hydraulic conductivity is not resolved
- “Fracture zones” may warrant subsequent attention
Passive Seismic Monitoring

Documentation of time, magnitude and location of seismicity:
- Public assurance
- Integrity of the sealing units
- Injection control
Soil gas monitoring: Overview

Research Providers
- Dave Jones et al. (BGS)
- Dave Risk et al. (StFX)

Measurements
- CO₂, O₂, N₂ conc.
- CH₄, C₂H₆, C₂H₄ conc.
- Rn, He conc.
- CO₂ flux
- C isotopes

Methods
- Single-depth (BGS), depth-profile (StFX) CO₂
- CO₂ flux (BGS)
- Continuous CO₂ (BGS), CO₂ flux (StFX)
- δ¹³CO₂, ¹⁴CO₂
Soil Gas Monitoring Data

soil gas CO$_2$ - October, 2011

CO$_2$ soil gas concentration (%)
Carbon Isotopes

Scatter plot of $^{13}\text{C}$ on CO$_2$ with $^{14}\text{C}$ on CO$_2$
- Control, Investigation (Event 1 and Event 2)
and Injection Gas samples

- Control Site (Event 1)
- Control Site (Event 2)
- Investigation Site (Event 1)
- Investigation Site (Event 2)
- Injection (DGC)
- Injection (Recycle)
- Literature control site 1
- Literature control site 2
- Teapot Dome oil field
- Rangely CO2-EOR
Well Integrity: Field Testing Program

Modified coring tool:
→ Direct confirmation of cement
Pressure transient test confirms cement effectiveness.
RA and Geological Storage of CO$_2$

104% Increase

And for just the final? year of each Phase:
2004 – 4 and 2011 – 57

670% Increase

1,325% Increase
Process: Geosphere & Biosphere Risk

Geosphere Risk Assessment

Technical Inputs
- Wellbore integrity research
- Characterisation of reservoir characteristics & transport of CO₂
- Seismicity of area
- Characterisation of CO₂ reactions in reservoir
- Monitoring techniques & effectiveness

Outputs
- CO₂ risk events (initiating event & pathway) & ranking
- Mass of CO₂ released if event occurs
- Likelihood of each event occurring & releasing CO₂

Other Technical Inputs
- Characterisation of aquifers
- Characterisation of surface water
- Characterisation of soils / sediments
- Behaviour of CO₂ in soils, sediments, groundwater, surface water
- Receptors in environment
- Toxicology (animal, plant, human)

Outputs
- Risks to biosphere assets (ranking & severity)

Stakeholder Engagement
- Stakeholder Values
- Building Capacity to Engage
- Acceptability of Risks

Mitigation Measures
Containment Risk Profile

The storage will retain most of the CO₂ injected

Weyburn - Containment risk profile

No further work would be required to demonstrate containment acceptability.
Boundary Dam Near Estevan Saskatchewan
PRTC Aquistore Project Location

Ground level view towards Boundary Dam Power Station with drilling rig in foreground

Well location remains largely free of water during the 1:500 year flood in Saskatchewan 2011
Subsurface Model
Thanks for your attention