INTERNATIONAL TEST CENTRE FOR CO₂ CAPTURE (ITC)
University of Regina, CANADA

“Update on Activities”

Presented at IEA GHG 11ᵗʰ International Post-Combustion CO₂ Capture Network

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www.co2-research.ca
INTERNATIONAL TEST CENTRE FOR CO₂ CAPTURE (ITC)
University of Regina, CANADA

- Located in Regina Innovation Research Park, Regina, Saskatchewan, CANADA
- Adjacent to University of Regina campus and other research centres
REGINA, SASKATCHEWAN, CANADA
Regina, Saskatchewan, CANADA
Why use reactive solvents for CO$_2$ capture (Post-combustion capture)?

→ Theoretical issue
  - Mass transfer of CO$_2$ in liquid is 10 to 100 times faster

→ Proven technology
  - Use in gas processing

→ Available today!

→ Cost ~ $25 to $50 per ton of CO$_2$ (depending on situation and location)
  - CO$_2$ for EOR ~ $20 to $100 per ton of CO$_2$
  - CO$_2$ trading ~ $15 to $35 per ton of CO$_2$
Flexibility of Post-combustion Capture

FLUE GAS FROM AN EXISTING COAL FIRED POWER PLANT

COAL

COGENERATION POWER PLANT

CO2 Capture Using Reactive Solvents

PRE-CONDITIONING PROCESS
- PARTICULATE REMOVAL
- SO\textsubscript{x} REMOVAL
- COOLING
- PRESSURIZATION

CLEAN FLUE GAS

POST CONDITIONING PROCESS
- COMPRESSION
- DEHYDRATION

CQ PRODUCT

ELECTRICITY FOR SALE

ELECTRICITY

STEAM

SHAFT WORK

COAL
ITC History

- ITC was established in 1999 and is housed in a dedicated GHG research building. *(GHG research group was established in 1991)*

  *ITC’s goal is to develop effective and economic solutions for large-scale GHG reduction*

- Our current major focus is to provide technologies to aid industry in GHG reduction
Climate Change Research at U of R

- One of U of R’s major research strengths is Climate Change research.
- Developed research excellence in:
  - Prairie Adaptation Research Collaborative (PARC)
    - [www.parc.ca](http://www.parc.ca)
  - Petroleum Technology Research Centre (PTRC)
    - [www.ptrc.ca](http://www.ptrc.ca)
  - IEA Weyburn Monitoring Program for CO2 EOR & Storage
    - [www.ptrc.ca](http://www.ptrc.ca)
  - ITC – CO2 capture Development Program
    - [www.co2-research.ca](http://www.co2-research.ca)
  - Hydrogen & Bio-fuel Research Program ([www.htcenergy.ca](http://www.htcenergy.ca))
Why Saskatchewan: Williston Basin

Weyburn Field
Weyburn Unit Stats - EnCana

Field size
• 70 square miles

Original oil in place:
• 1.4 billion barrels

Oil recovery (pre-CO$_2$-EOR):
• 370 million barrels

Projected CO$_2$ IOR:
• 155 million barrels

Projected CO$_2$ stored:
• 30+ million tonnes*  
  (gross)
• 26+ million tonnes (net)

*equivalent to removing over 6 million cars off the road for a year
Midale Unit Stats - Apache

Field size
- 40 square miles

Original oil in place:
- 515 million barrels

Oil recovery (pre-CO₂-EOR):
- 154 million barrels

Projected CO₂ IOR:
- 67 million barrels

Projected CO₂ stored:
- 10+ million tonnes* (gross)
- 8.5+ million tonnes (net)

*equivalent to removing over 2 million cars off the road for a year
ITC: Partnerships Across Sectors

**OIL & GAS**
- EnCana Corp.
- *Saudi ARAMCO*

**ENERGY & UTILITIES**
- SaskPower
- *E – ON, UK*
- HTC Purenergy
- RWE Power

**ENGINEERING**
- *B & W, USA **
- NG Neill & Gunter

**RESEARCH INSTITUTIONS**
- Alberta Energy Research Council
- RITE Japan
- Alberta Research Council

**ACADEMIA**
- *U of Regina*
- U. of Waterloo
- UBC

**GOVERNMENTS**
- Natural Resources Canada
- Government of Saskatchewan

**GOVERNMENT AGENCIES**
- Western Economic Diversification Canada
- National Science and Engineering Research Council of Canada
- Canadian Foundation for Innovation
Facilities
**Testing Facilities**

**Technology Demonstration Pilot Plant:**
(\(CO_2\) capture pilot unit at Boundary Dam Power Station near Estevan)

**Multi-Purpose Technology Development Pilot Plants:**
(at University of Regina)

**Research Facilities:**
(at University of Regina)

**U of R Research Facilities**
(Absorption units / reactors)

**Boundary Dam Semi-commercial testing**
(20-m H×18 in. ID)

**U of R Technology development**
(10-m H×12 in. ID)
(10-m H×18 in. ID)
Multi-purpose Technology Development Pilot Plant
Technology Demonstration Plant (Boundary Dam)

- Test the technical and economic feasibility of developed technologies.
- Evaluate process integration with overall system.
- Evaluate economic feasibility of various chemicals and components proposed after laboratory and pilot-plant studies.
Boundry Dam Unit

- Coal-fired flue gas
- Capacity - 4 - 8 ton / day of CO₂ (99% +)
- Flue gas flow rate - 500,000 scf / day
- ID = 18”
- Height = 20 m
ITC Investments

→ Over 20 million funding has been invested in ITC's research infrastructures

- $5.2 million pre-commercial scale demonstration plant at Boundary Dam
- $3.3 million Multi-purpose Technology Development Plant at the U of R
- $1.2 million bench scale facilities at the U of R
- $4.5 million analytical and computer facility from Canada Foundation for Innovations (CFI)
- $5 million from NSERC general grants over the past 10 years
Scope of Research

- **Fundamental**
  - Solvent development, solvent stability studies, membranes development, etc.

- **Bench**
  - Solvent & membrane testing, etc.

- **Pilot**
  - Technology testing on pilot scale capture plant

- **Demonstration**
  - Technology testing on pre-commercial field demonstration plant
Research Facilities
Bench Testing Facility

4” scale CO₂ capture unit

Bench scale CO₂ test equipment
State of the art research facilities

Phase analysis of catalyst using the Bruker XRD

using the JEOL SEM and EDAX EDS
Characterization of CO$_2$ scrubbing solvents using the Oxford/Varian LC-NMR system

Characterization of CO$_2$ scrubbing solvents using the Bruker FTIR with the ATR accessory
Characterization of catalyst porosity using the Micromeritics Surface Area Analyser

HPLC-MS (High Performance Liquid Chromatography Mass Spectrometer)
TGA-DSC (Thermo Gravimetric Analyzer – Differential Scanning Calorimeter)

ICP-MS (Inductively Coupled Plasma – Mass Spectrometer)
Our Ultimate Goals
1. Increase mass transfer of packing by 4 times

2. Increase the solvent separation capacity by 4 times
Base Case

Improved packing and solvent - Combine effect?

R & D

???
What do we have?

Inventory of U of R Intellectual Property (IP)
CO2 Capture & Storage Research

- **Process and Compounds for Removing Carbon Dioxide from Gas Mixtures** (UILO Ref #5403) US Provisional Patent
- **Process Integration – Method for Capturing CO2 from Gas Stream** (UILO Ref #5701) US Provisional Patent
- **Chemical Additives To Inhibit Oxygen And Sulfur Dioxide Induced Degradation Of Amine Solvents During CO2 Capture From Flue Gas Streams** (UILO Ref #5710) US Provisional Patent
- **Comprehensive Data and Industrial operations info (Pilot Plants)**
- **Know-how, Trade Secrets developed at UoF Process Engineering Lab**
Some selected results from ITC Activities
Issues Related to CO2 Capture

- To reduce CapExp and OpExp
  - Flue gas requires pre-treatment
  - Solvent losses due to degradation
  - High steam consumption
- Parasitic load
- Etc.
Approach to Cost Reduction

- **Operating Cost Reduction**
  - Optimize Process configuration
  - Reduce energy for solvent regeneration
  - Improve solvents and formulations of solvents
  - Minimize solvent circulation rates
  - Minimize corrosion & improve solvent stability
  - Optimize and improve operation strategy
  - Improve integration with power plant

- **Capital Cost Reduction**
  - Reduce size of capture plant
Boundary Dam CO$_2$ Capture Semi-Commercial Demonstration Plant and U of R’s Technology Development Plant

Test Results
CO₂ Pilot Plants Process Flow Diagram at Boundary Dam and U of Regina
Regina Solvents (RS Series)

Regina Solvent Degradation Study

Boundary Dam CO₂ Capture Pilot Plant Test Results.
Loading Tests of RS series at BDPS

BDPS Loading Results

- BTU/lb-mole
- Lean Amine
- Rich Amine
Process Integration Results

Heat Duty

![Heat Duty Chart]

- **BTU/lb-mole**
- **Figure 1**, **Figure 2**, **Figure 3**, **Figure 4**, **Figure 5**, **Figure 6**, **Figure 7**
- **MEA** and **Formulated**
- **Other Solvents**
Process Integration Results

Steaming Consumption

kg steam/kg CO2

Figure 1  Figure 2  Figure 3  Figure 4  Figure 5  Figure 6  Figure 7

Other Solvents

MEA  Formulated
COMPARISON OF DIFFERENT SOLVENTS

Amine Circulation Rate (MEA vs RS)

![Graph showing comparison of Amine Circulation Rate (MEA vs RS) with different CO2 concentrations.](image)
Steam Requirements

![Steam Requirement Chart]

- **4% CO₂**
  - MEA
  - External
  - RS-1

- **8% CO₂**
  - MEA
  - External
  - RS-1
Steam Duty

Steam Duty (kg steam/kg CO₂)

- MEA
- External
- RS-1

4% CO₂

8% CO₂

ITC

University of Regina
CO₂ Loading Profile in Absorber (4% CO₂) with RS-1
Experimental Results - Regina Plant

CO₂ Profile in Absorber (4% CO₂) with RS-1
Temperature Profile in Absorber (4% CO₂) with RS-1
Optimized Runs

CO₂ Profile in Absorber (4% CO₂) with RS-1

![Graph showing CO₂ profile](image-url)
Temperature Profile in Absorber (4% CO$_2$) with RS-1
ITC Involvements in Pilot and Commercial Projects

- With HTC & SVM – process optimization of a commercial plant (700 tones per day)

- With Bechtel (USA) and HTC Purenergy (Canada) for Government of Norway: Technology and Economic evaluations for CO2 capture from 500 MW NGCC Power Plant.

- With HTC/Bechtel - FEED Study for the Amine Plant of the European CO$_2$ Test Center, Mongostad, Norway
CO₂ Capture Plant
Kårstø, Norway
HTC & SVM and ITC Engagement to Reduce Steam Consumption and to Enhance CO2 Production

Plant Design Capacity 800 TPD, two trains
Absorption Column, 14 ft-6 in ID x high 119 ft
CCS Purenergy™ 1000

- Modular Design™
- Columns 12 ft dia
- 1000 TPD + -
- 1.45 kg Steam/kg CO2
- 37.7 kWh/ tonne CO2
- 0.224 kg solvent loss/ tonne CO2
### Example: Comparative Production Cost

**Coal Power Plant and NGCC Power Plant**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coal Power Plant</th>
<th>NGCC Power Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CO_2$ Production Capacity, TPD</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>$CO_2$ recovery, %</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>$CO_2$ in flue gas, mol%</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Number of trains</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Flue gas rate, mm/scfd</td>
<td>528</td>
<td>920</td>
</tr>
<tr>
<td>Absorber diameter, m</td>
<td>10 (one)</td>
<td>12 (two)</td>
</tr>
<tr>
<td>Regenerator diameter, m</td>
<td>6 (one)</td>
<td>6 (two)</td>
</tr>
<tr>
<td>Capital Cost, million US$</td>
<td>165</td>
<td>230</td>
</tr>
<tr>
<td>Operating cost, million US$</td>
<td>25</td>
<td>51</td>
</tr>
<tr>
<td>Production cost, US$/ton</td>
<td>33 +- 6</td>
<td>53 +- 10</td>
</tr>
</tbody>
</table>
Thank you
Key literatures in the research area

- Kohl A. L. and Riesenfeld F. C., *Gas Purification*,
- Proceedings of GHGT 6 (Australia), 7 (Japan) and 8 (Norway)
- and many others