# INTERNATIONAL TEST CENTRE FOR $CO_2$ CAPTURE (ITC)
# University of Regina, CANADA

## "Update on Activities"

## Presented at IEA GHG 11th International Post-Combustion $CO_2$ Capture Network

**20th – 21st May, 2008**
**Vienna, Austria**

**www.co2-research.ca**

*Contact: Dr. Paitoon (P.T.) Tontiwachwuthikul*
*E-mail: paitoon@uregina.ca*
*Dr. Malcolm Wilson*
*E-mail: malcolm.wilson@uregina.ca*
*Tel: +1(306) 585-4160*

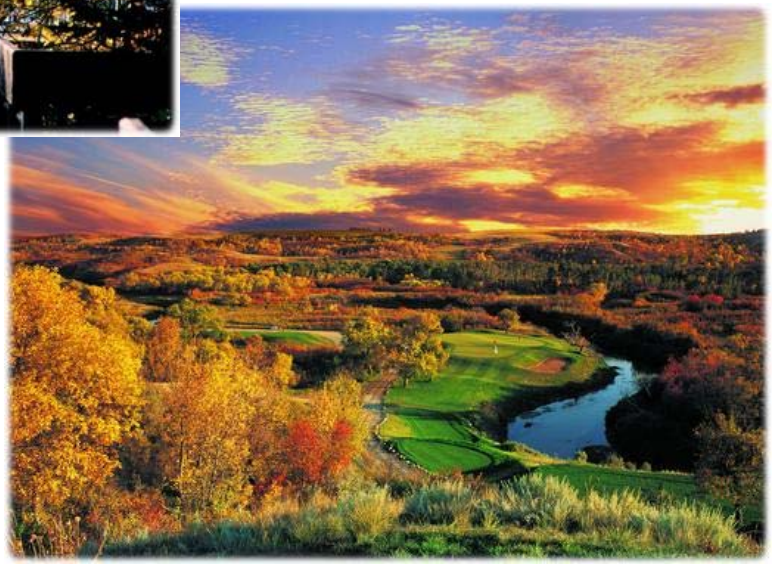
# *INTERNATIONAL TEST CENTRE FOR $CO_2$ CAPTURE (ITC)*
## *University of Regina, CANADA*



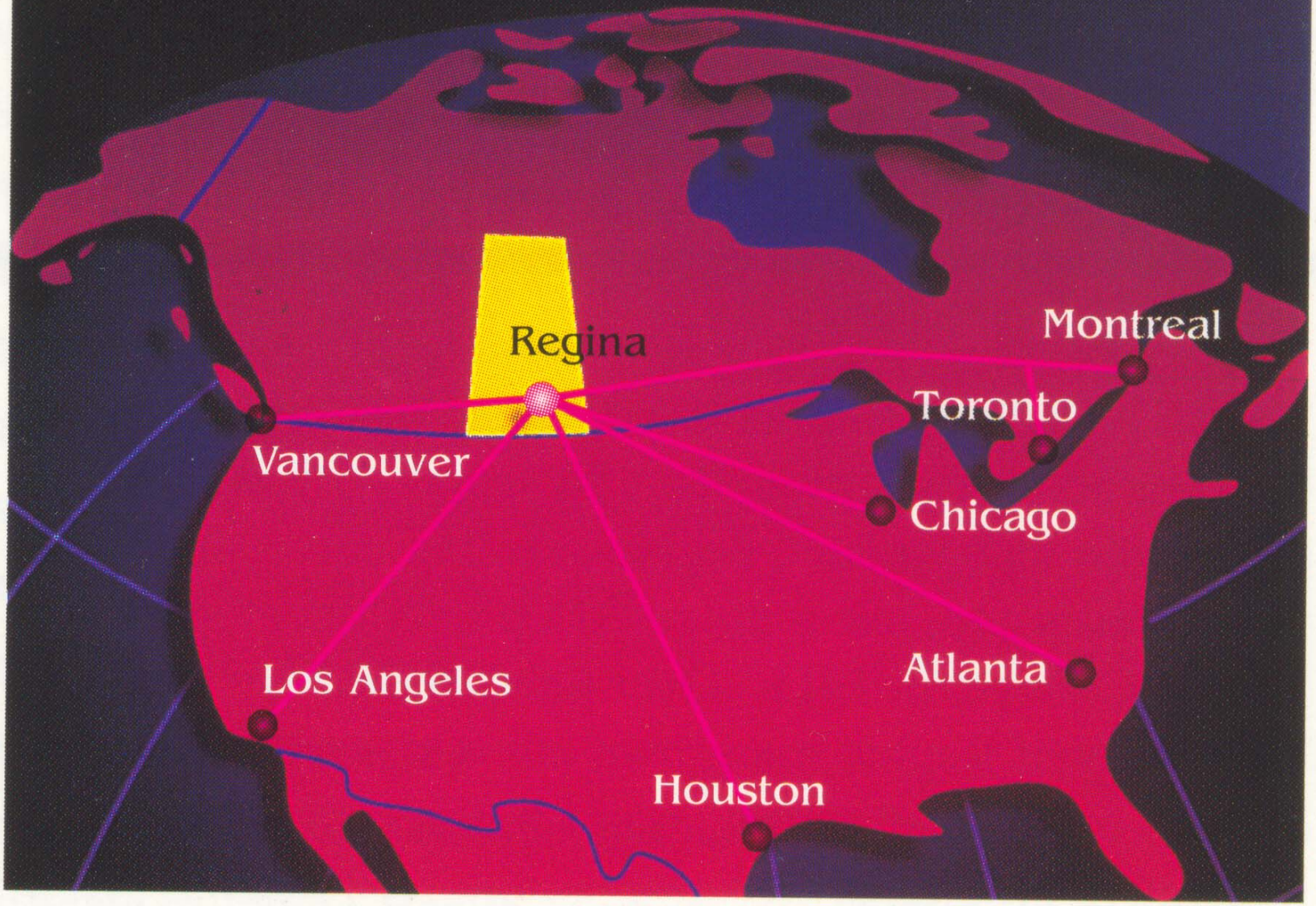
- ***Located in Regina Innovation Research Park, Regina, Saskatchewan, CANADA***
- ***Adjacent to University of Regina campus and other research centres***

[redacted]

# REGINA, SASKATCHEWAN, CANADA



# Regina, Saskatchewan, CANADA

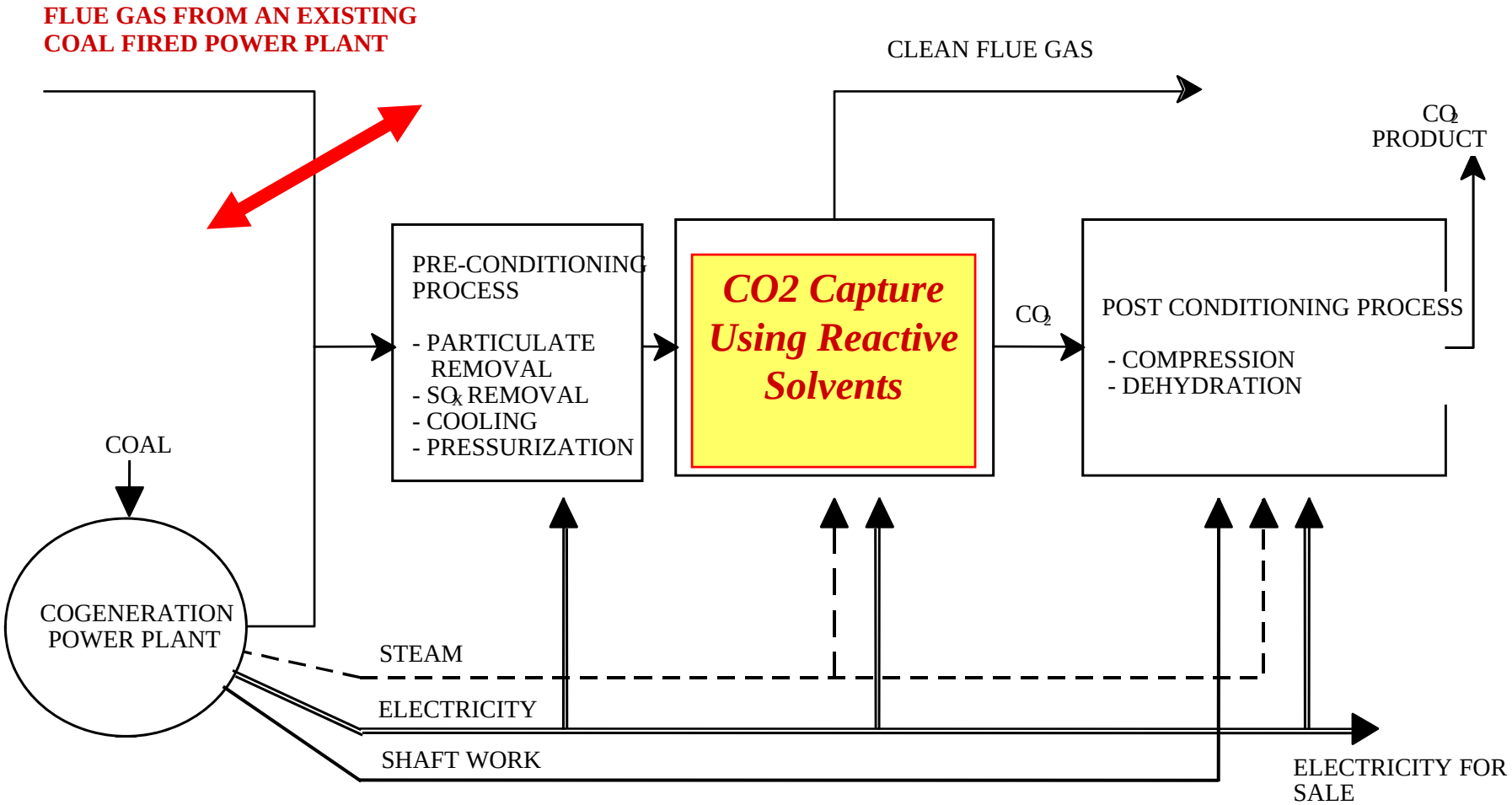


# Why use reactive solvents for $CO_2$ capture (Post-combustion capture) ?

- Theoretical issue
  - Mass transfer of $CO_2$ in liquid is 10 to 100 times faster
- Proven technology
  - Use in gas processing
- <u>Available today !</u>
- 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 $CO_2$

[redacted]

# Flexibility of Post-combustion Capture

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# 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

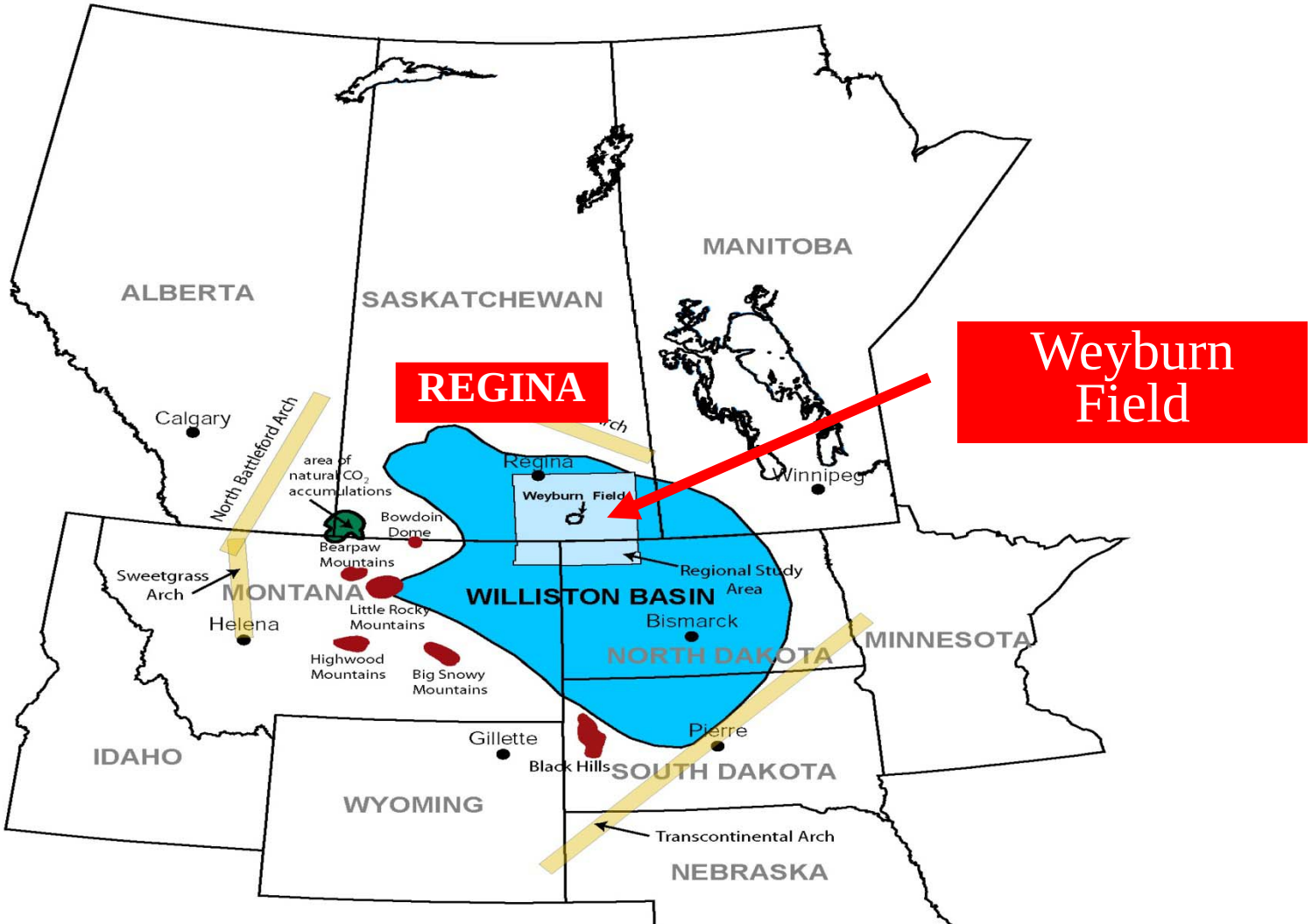
[redacted]

# 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**
  - Petroleum Technology Research Centre (PTRC)
    - **www.ptrc.ca**
  - IEA Weyburn Monitoring Program for CO2 EOR & Storage
    - **www.ptrc.a**
  - ITC – CO2 capture Development Program
    - **www.co2-research.ca**
  - Hydrogen & Bio-fuel Research Program **(www.htcenergy.ca)**

[redacted]

# Why Saskatchewan: Williston Basin



# 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*

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ptrc Petroleum Technology Research Centre

# Midale Unit Stats - *Apache*

**Field size**

- **40 square miles**

**Original oil in place:**

- **515 million barrels**

**Oil recovery (pre-$CO_2$-EOR):**

- **154 million barrels**

**Projected $CO_2$ IOR:**

- **67 million barrels**

**Projected $CO_2$ stored:**

- **10+ million tonnes* (gross)**
- **8.5+ million tonnes (net)**

**equivalent to removing*

***over 2 million cars***

*off the road for a year*

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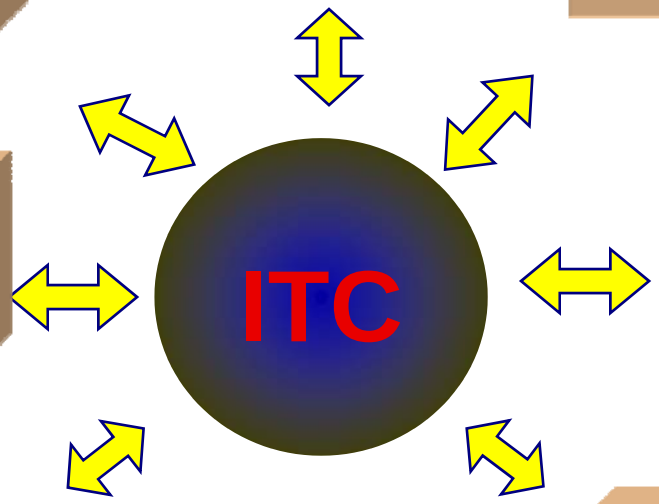
# ITC: Partnerships Across Sectors

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

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

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




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

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

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

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

# Facilities

[redacted]

# ITC Unique Features

## *Testing Facilities*

**Technology Demonstration Pilot Plant:**

(*$CO_2$ capture pilot unit at Boundary Dam Power Station near Estevan*)

**Multi-Purpose Technology Development Pilot Plants:**

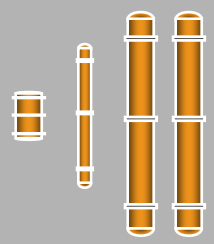
(*at University of Regina*)

**Research Facilities:**

(*at University of Regina*)

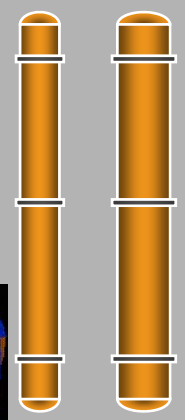
**U of R**
**Research Facilities**

(Absorption units / reactors)



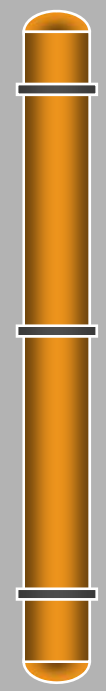
**U of R**
**Technology development**

(10-m H×12 in. ID)
(10-m H×18 in. ID)

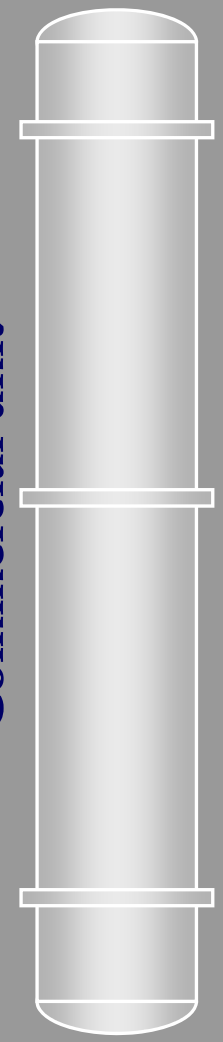


**Boundary Dam**
**Semi-commercial testing**

(20-m H×18 in. ID)



**Commercial unit**



[redacted]

# Multi-purpose Technology Development Pilot Plant

[redacted]

# 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.

[redacted]

# Boundry Dam Unit

- Coal-fired flue gas
- Capacity - 4 - 8 ton / day of $CO_2$ (99% +)
- Flue gas flow rate - 500,000 scf / day
- ID = 18”
- Height = 20 m


[redacted]

# ITC Investments

- Over 20 million funding has been invested in ITC' 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*

[redacted]

# Scope of Research

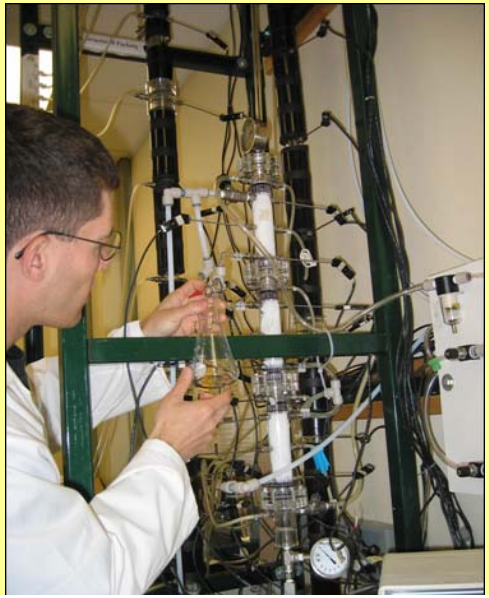
- Fundamental
  - Solvent development, solvent stability studies, membranes development, etc.
- Bench
  - Solvent & membrane testing, etc.
- Pilot
  - Technology testing on pilot scale capture plant
- Demonstration
  - Technology testing on pre-commercial field demonstration plant

[redacted]

# Research Facilities


# Bench Testing Facility

4” scale $CO_2$ capture unit



Bench scale $CO_2$ test equipment

# State of the art research facilities

Phase analysis of catalyst using the Bruker XRD

using the JEOL SEM and EDAX EDS

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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

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Characterization of catalyst porosity using the Micromeritics Surface Area Analyser

HPLC-MS (High Performance Liquid Chromatography Mass Spectrometer)

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TGA-DSC (Thermo Gravimetric Analyzer – Differential Scanning Calorimeter)

ICP-MS (Inductively Coupled Plasma – Mass Spectrometer)

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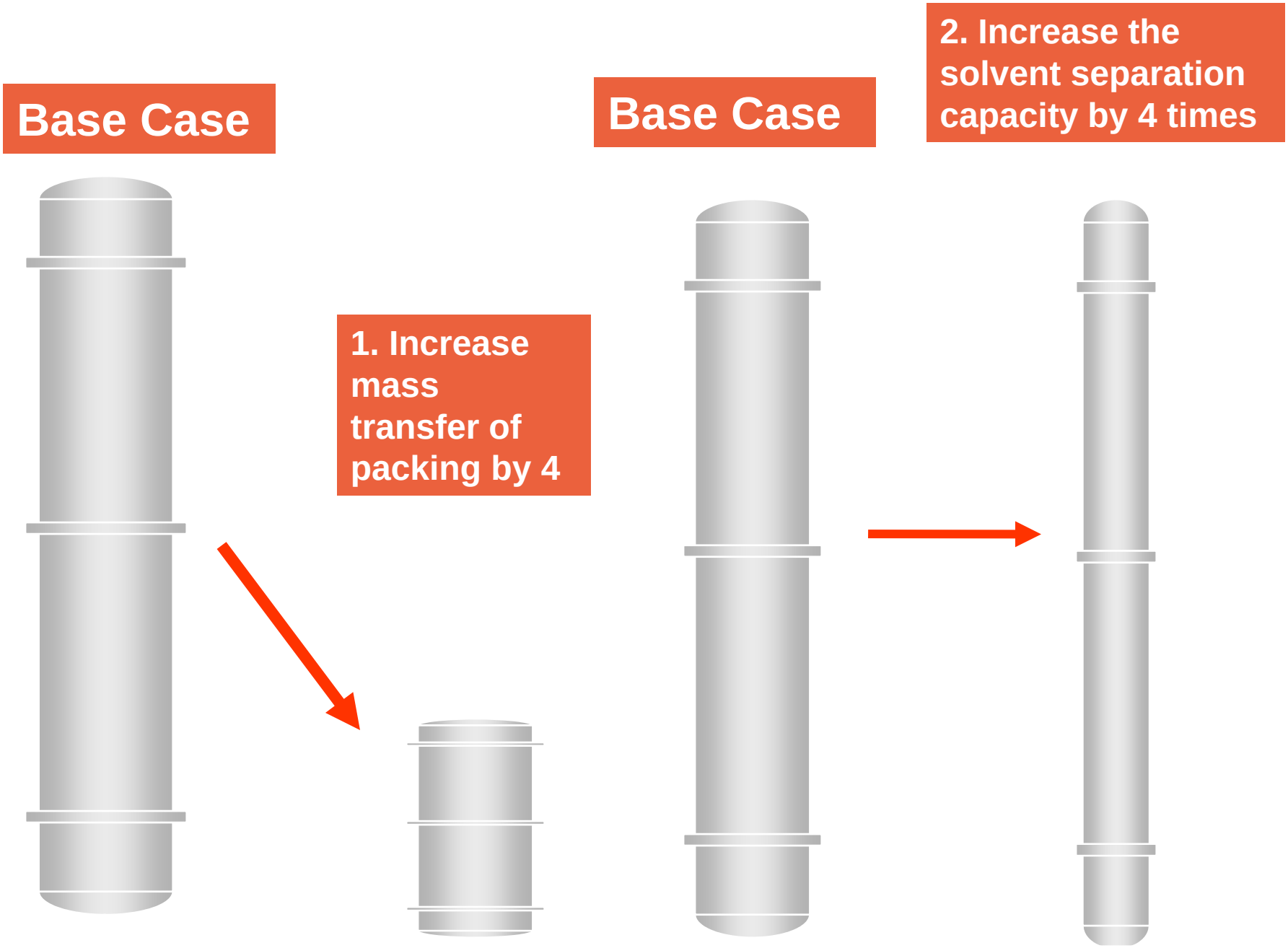
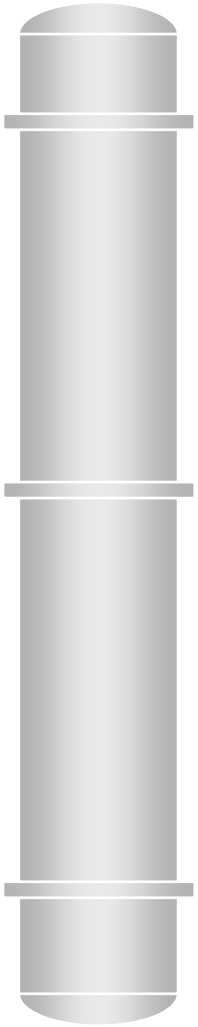
# Our Ultimate Goals

[redacted]

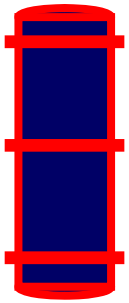

Base Case
1. Increase mass transfer of packing by 4
Base Case
2. Increase the solvent separation capacity by 4 times

Base Case



R & D

Improved packing and solvent - Combine effect ?



???

# 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 C02 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 UofR Process Engineering Lab***

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# Some selected results from ITC Activities

[redacted]

# 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.*

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# 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

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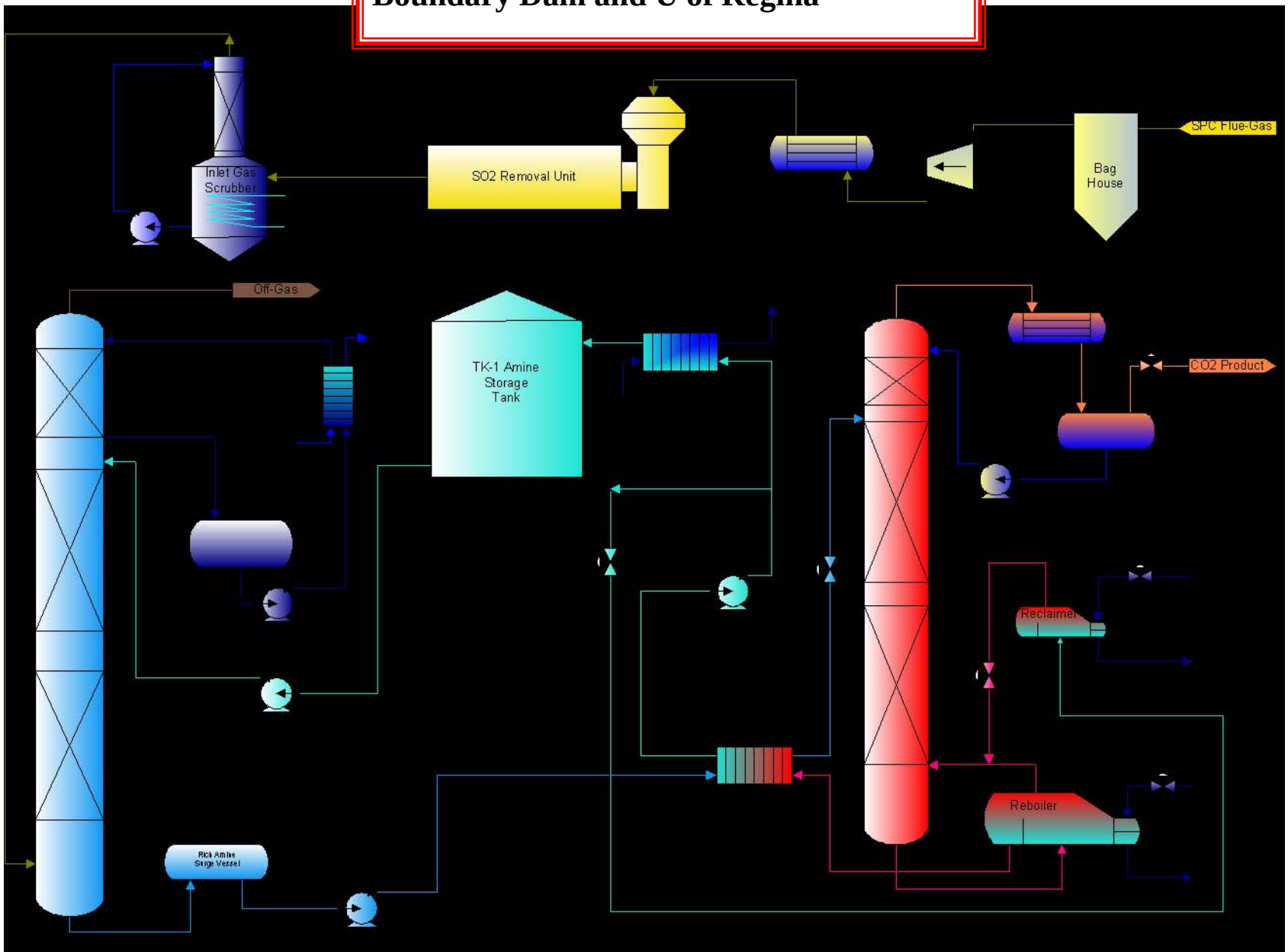
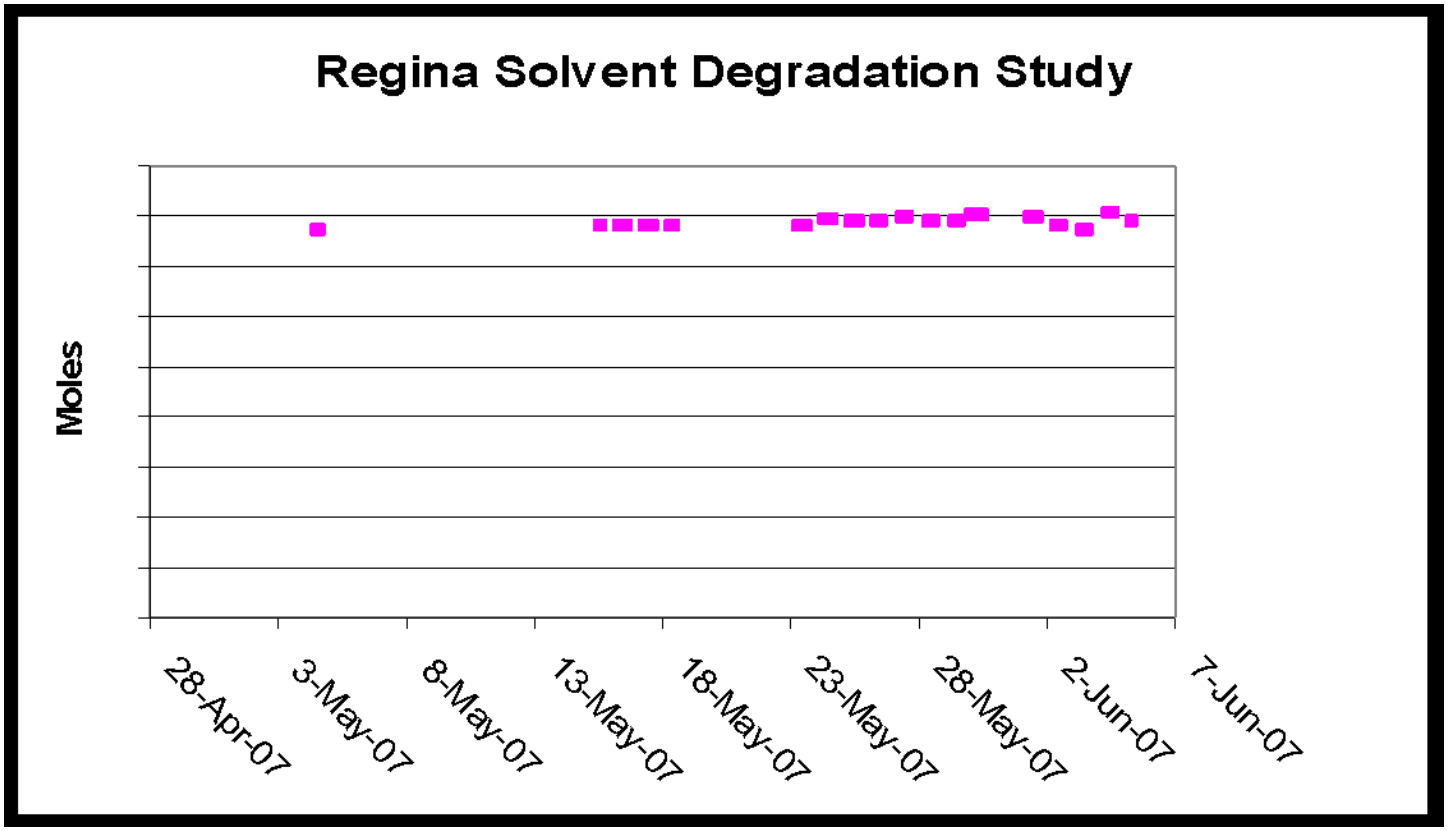
# $CO_2$ Pilot Plants Process Flow Diagram at Boundary Dam and U of Regina



# Regina Solvents (RS Series)




**Boundary Dam $CO_2$ Capture Pilot Plant Test Results.**

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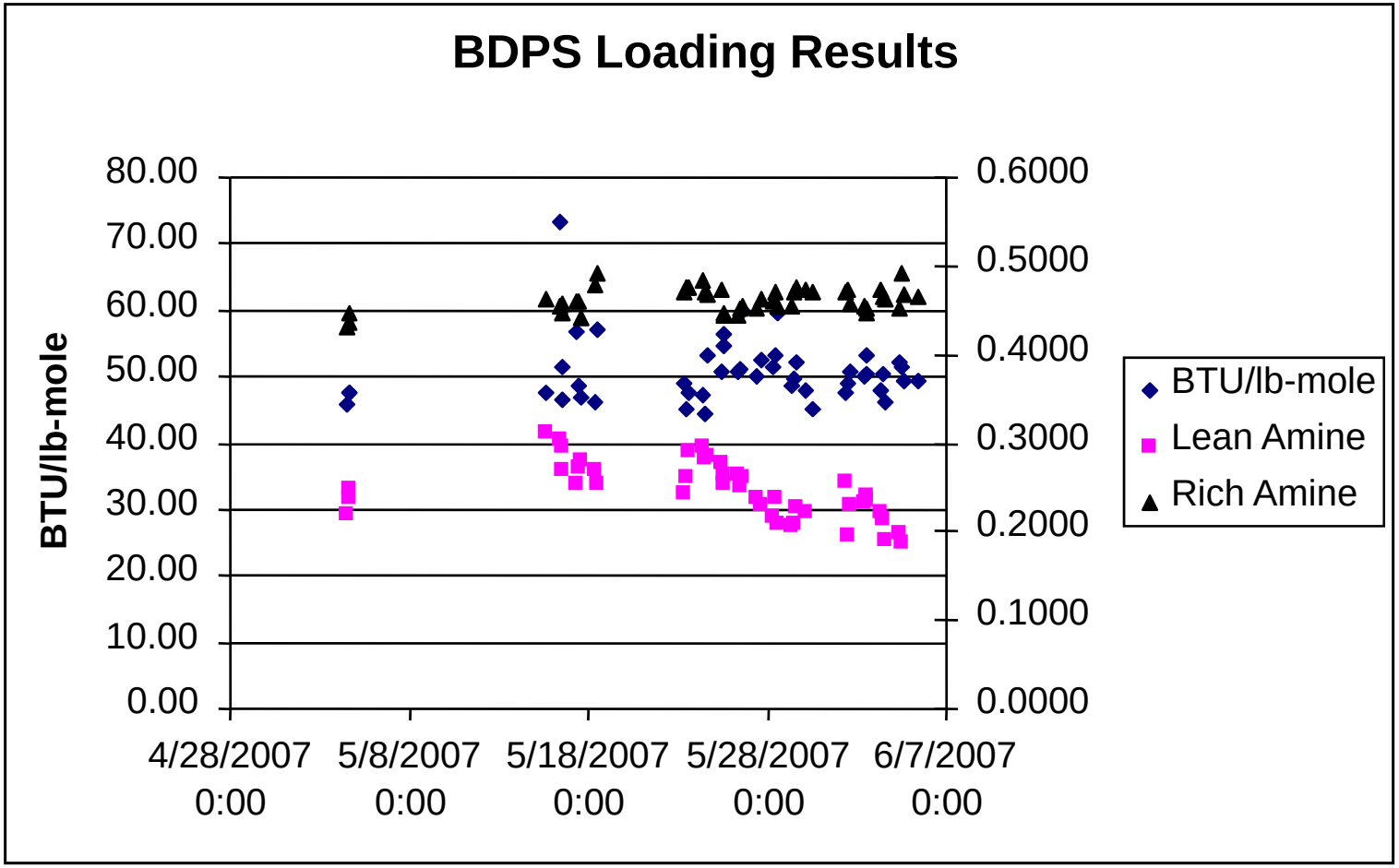
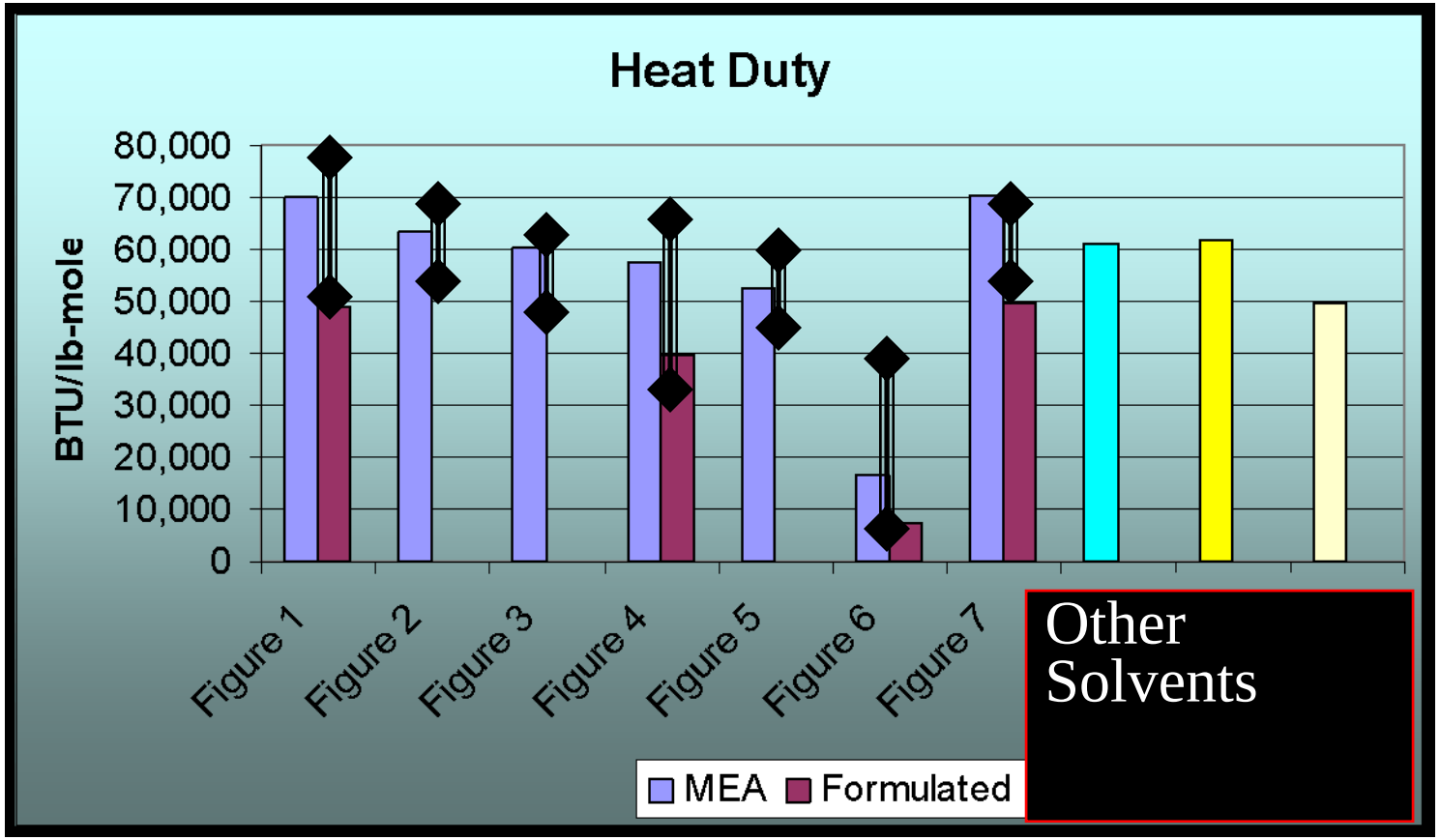
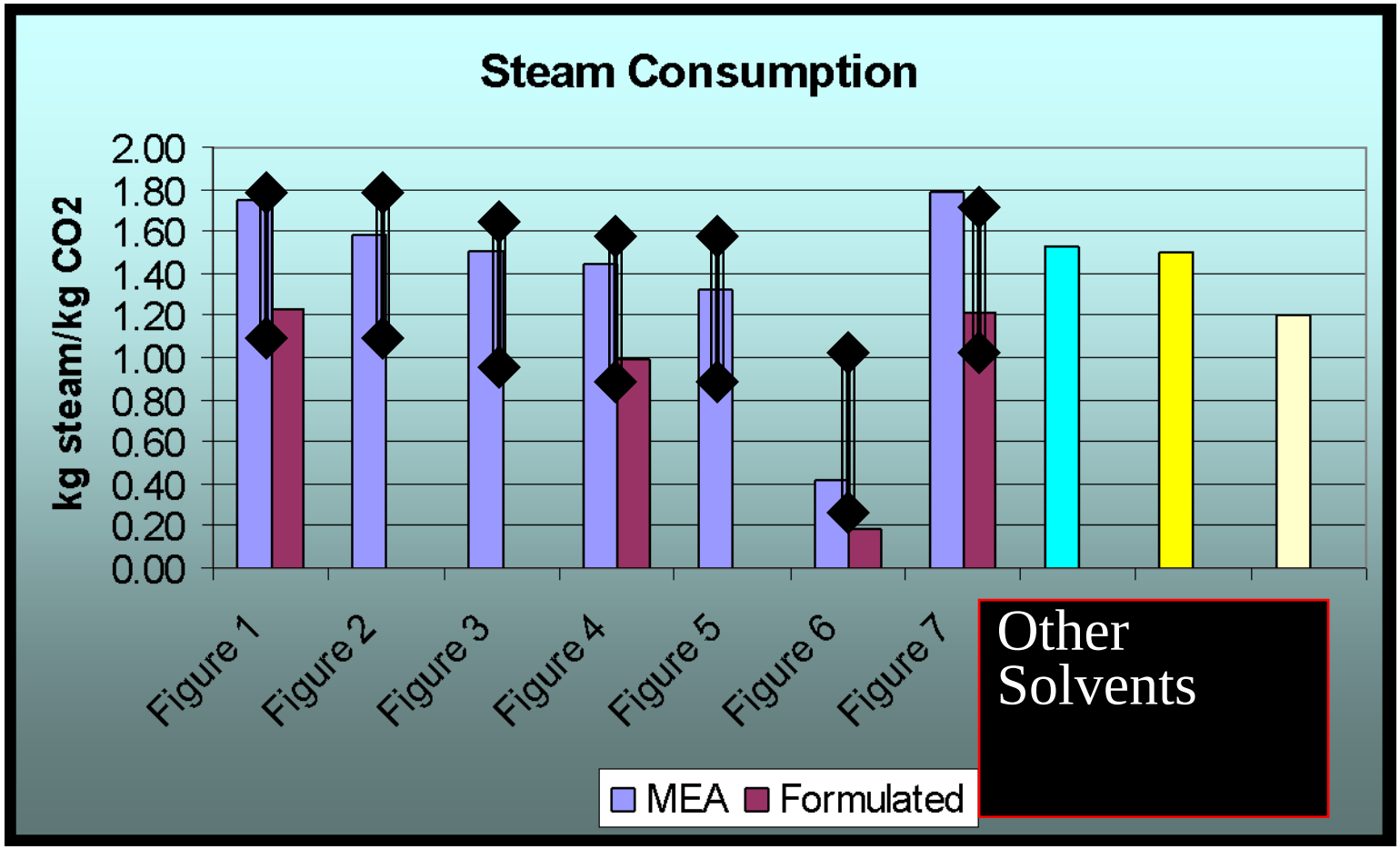
# Loading Tests of RS series at BDPS



# Process Integration Results

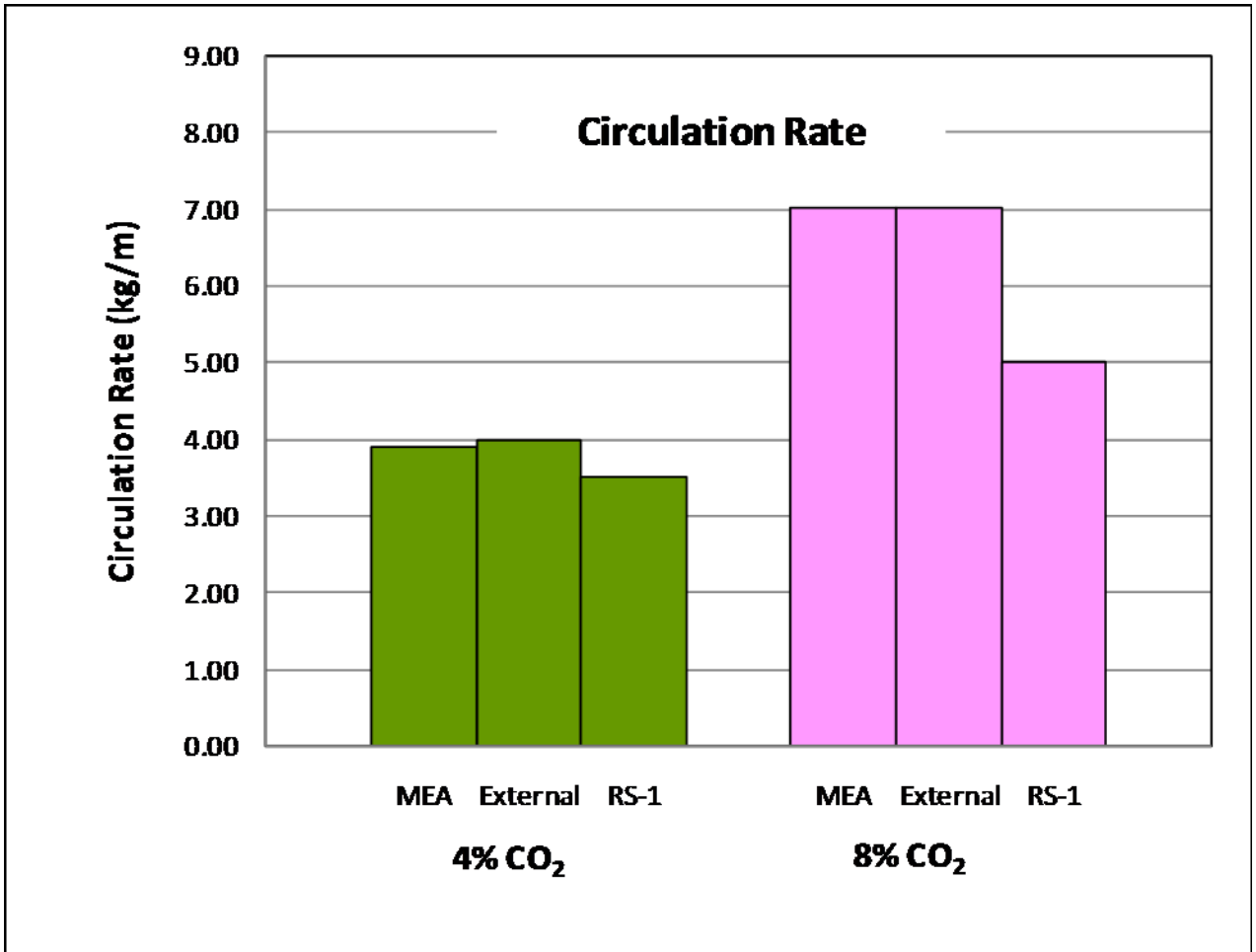


# Process Integration Results



# COMPARISON OF DIFFERENT SOLVENTS

## Amine Circulation Rate (MEA vs RS)

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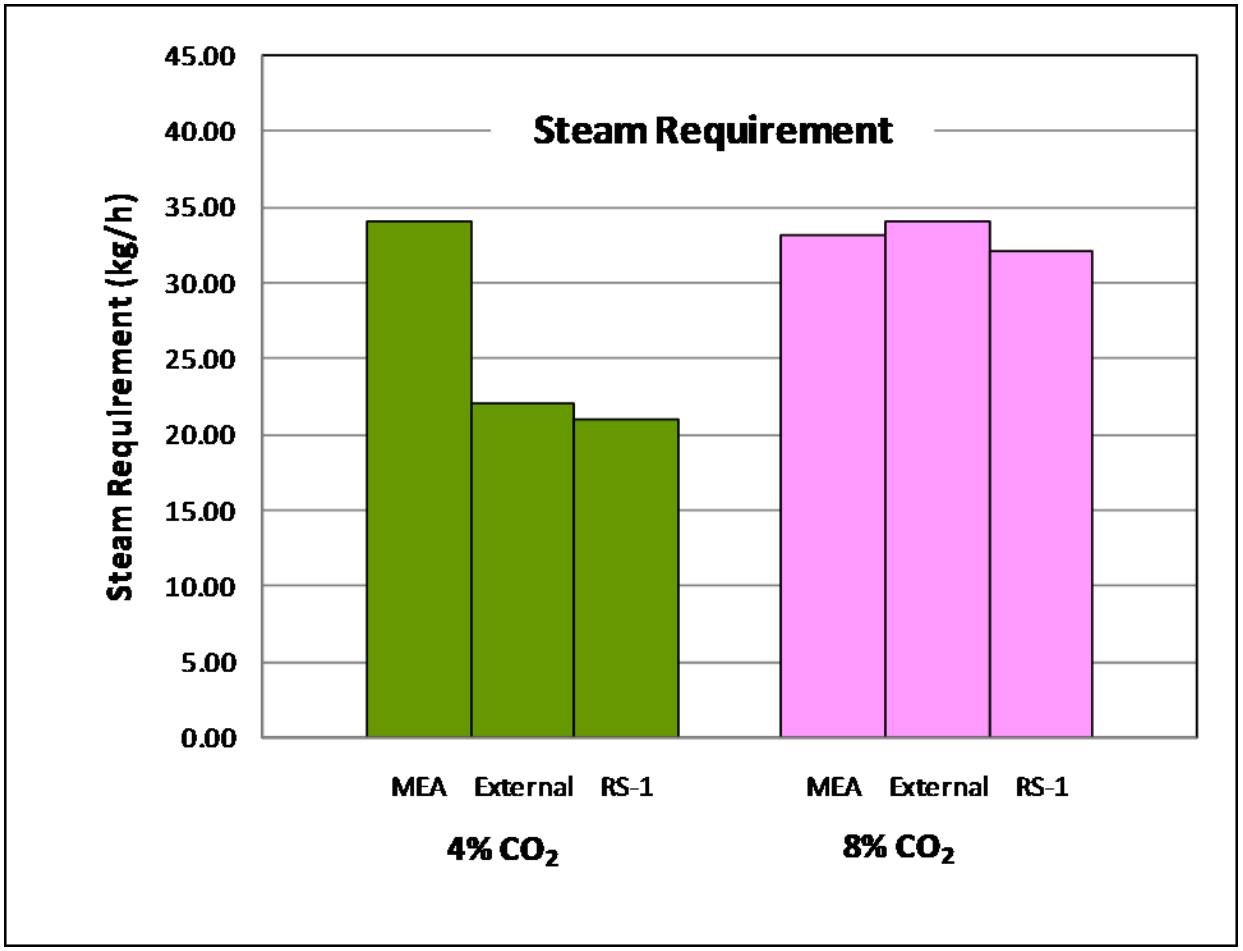
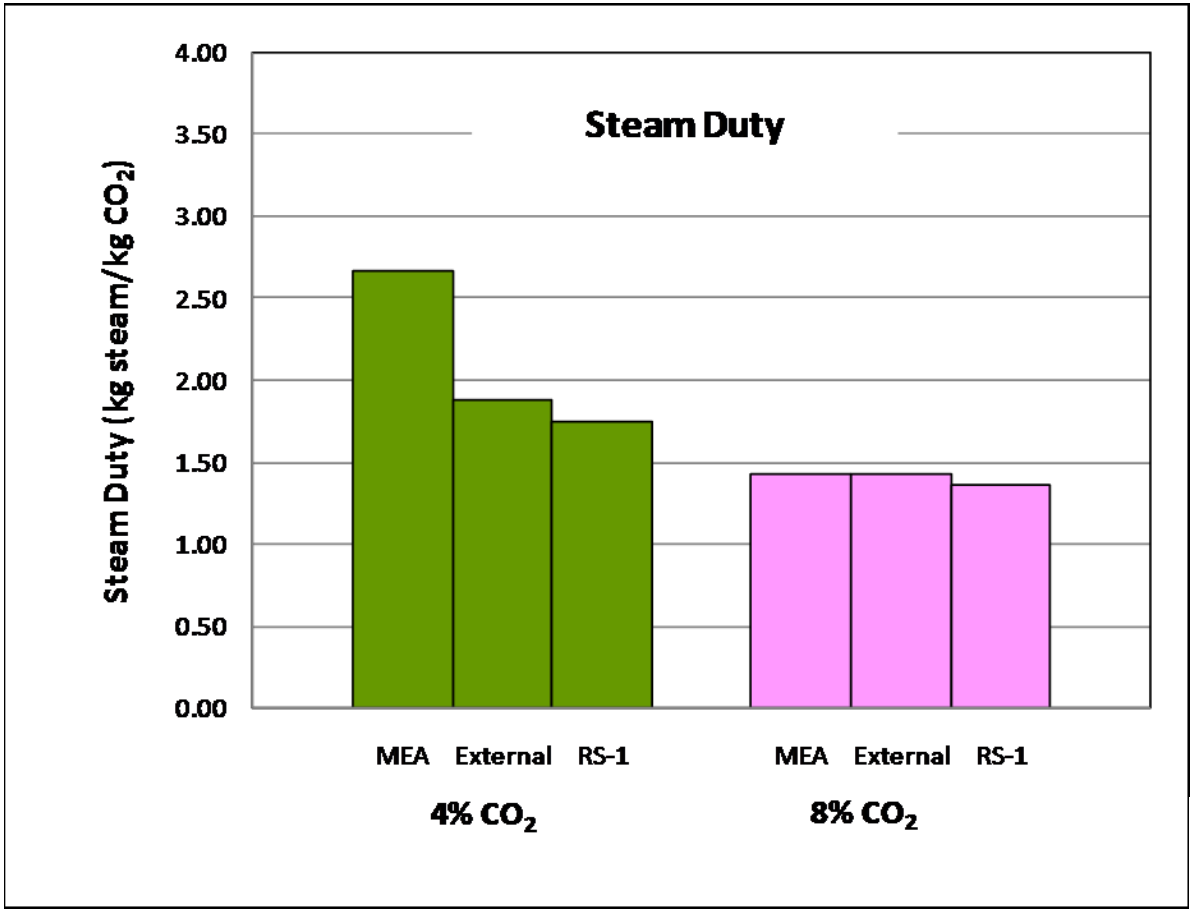
# Steam Requirements



# Steam Duty

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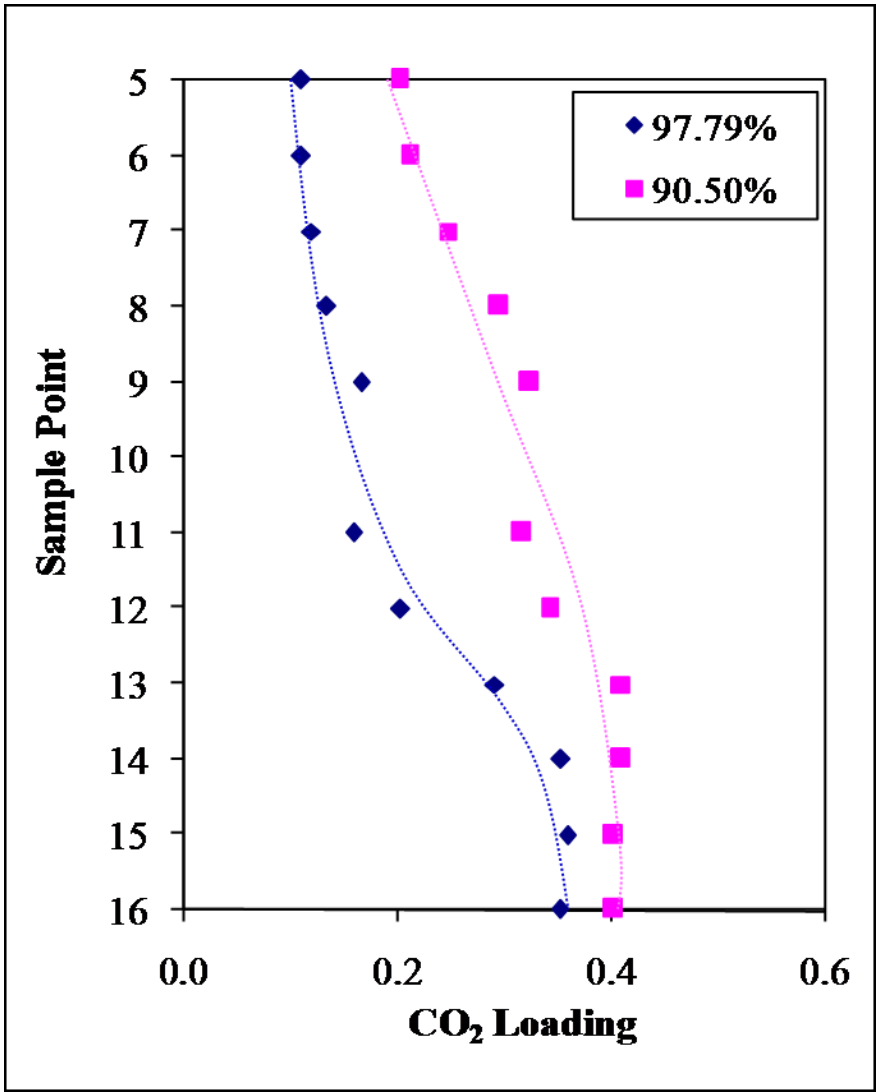
# $CO_2$ Loading Profile in Absorber (4% $CO_2$) with RS-1

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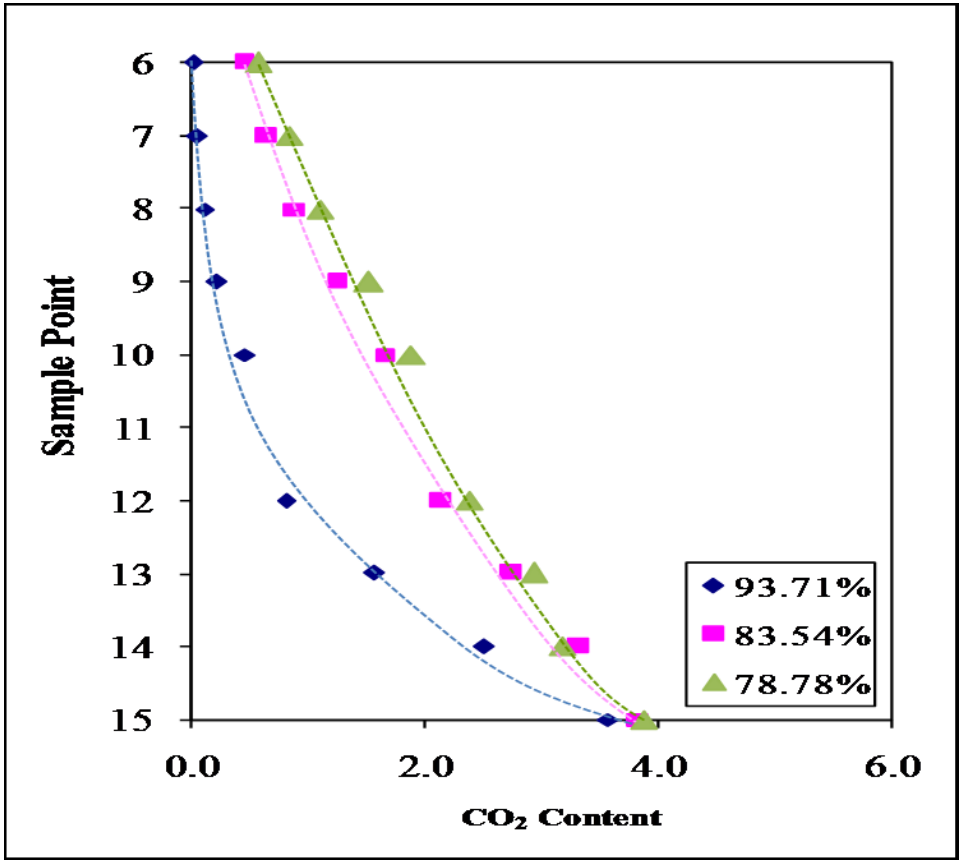
# Experimental Results-Regina Plant
## $CO_2$ Profile in Absorber (4% $CO_2$) with RS-1

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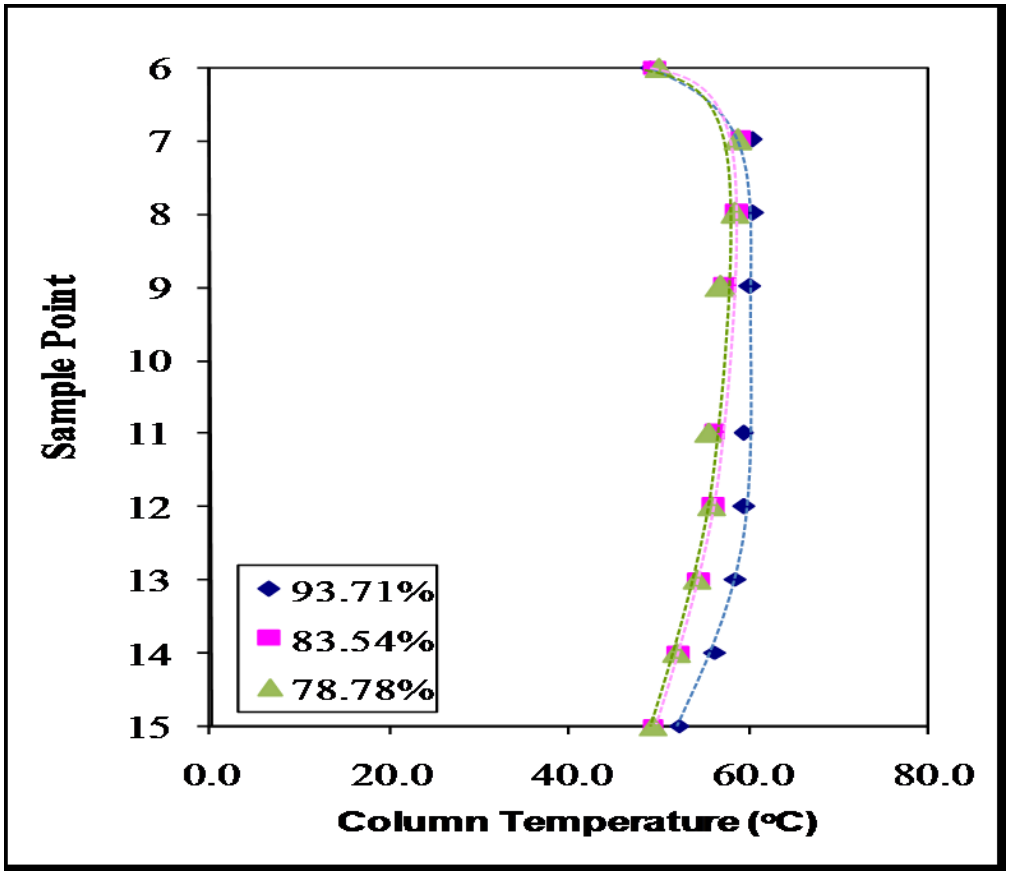
# Temperature Profile in Absorber (4% $CO_2$) with RS-1

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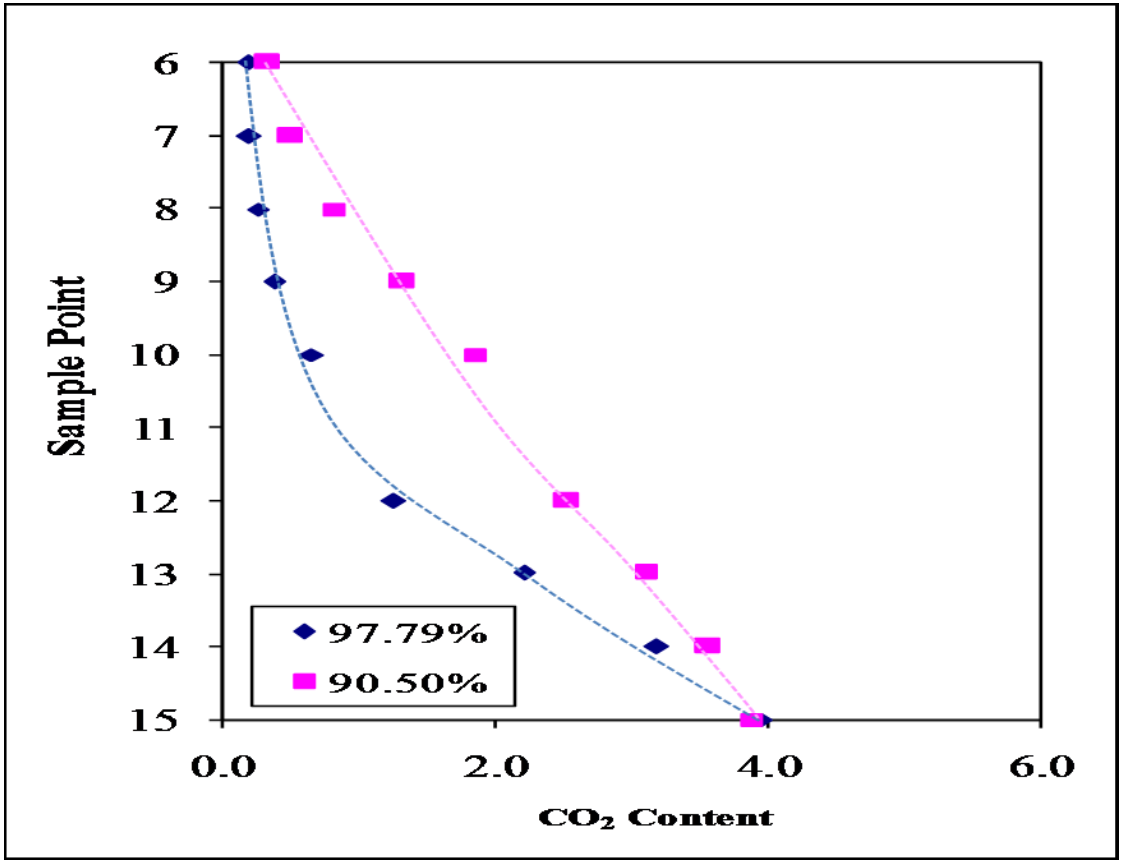
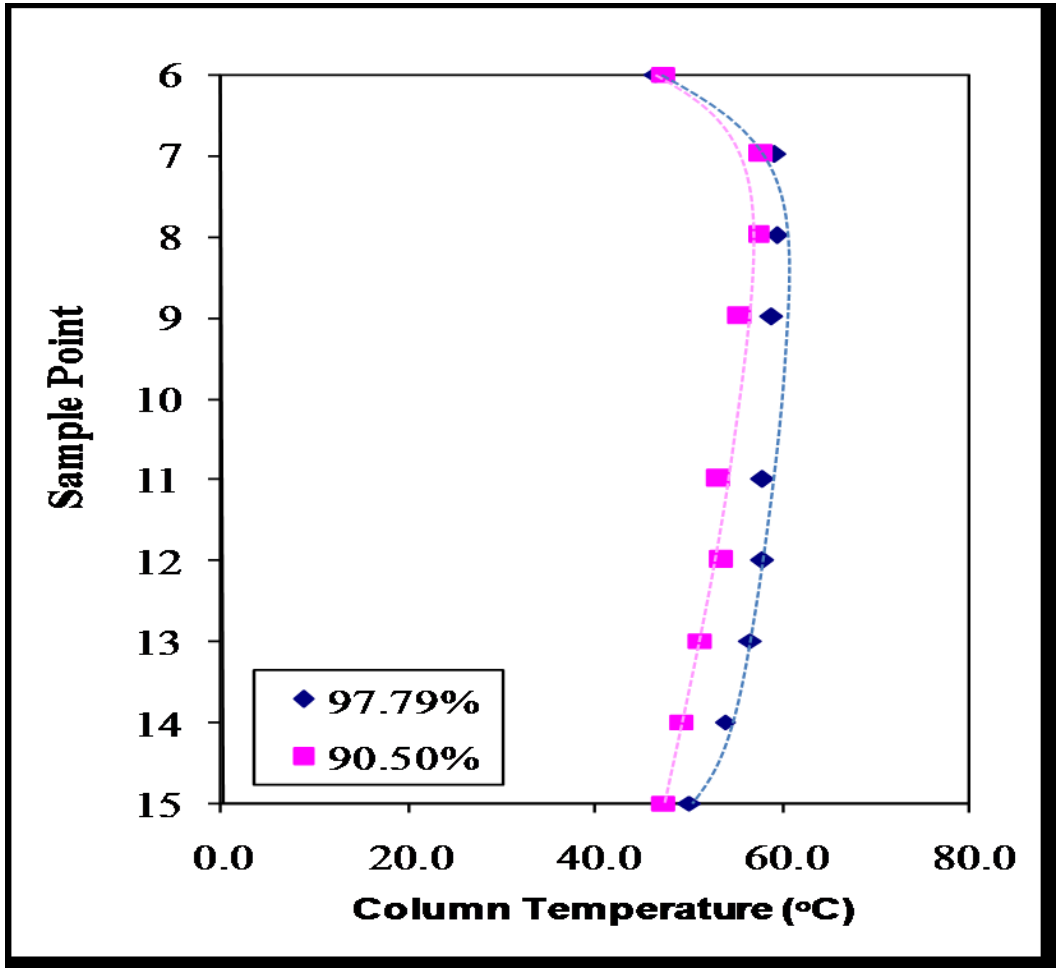
# Optimized Runs
# $CO_2$ Profile in Absorber (4% $CO_2$) with RS-1



# Temperature Profile in Absorber (4% $CO_2$) with RS-1

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# 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*

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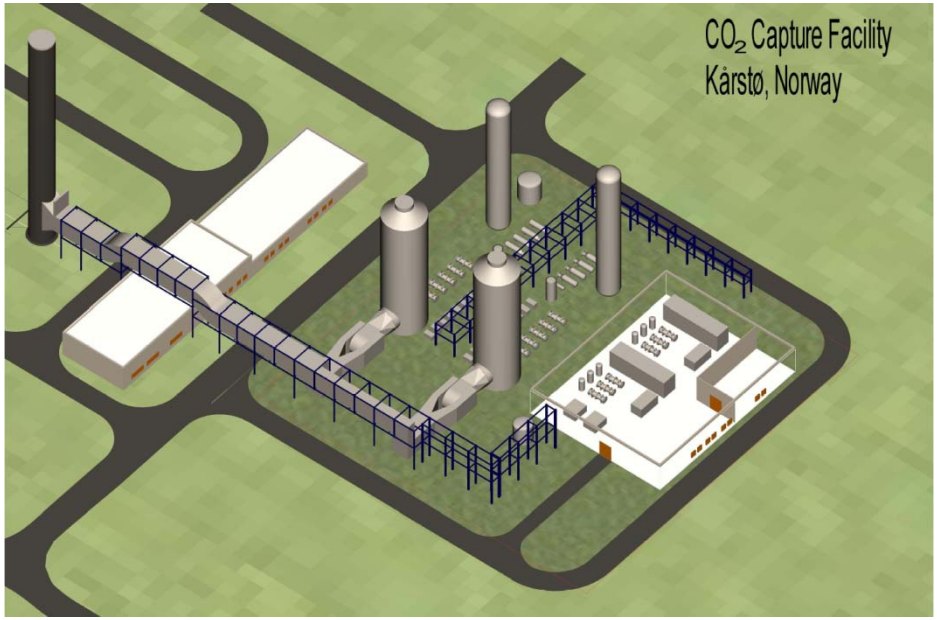
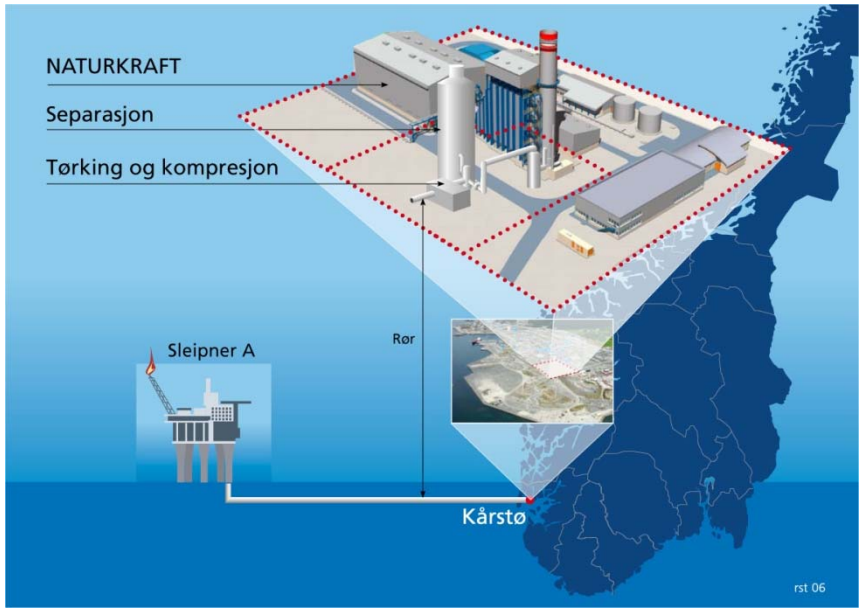
# $CO_2$ Capture Plant Kårstø, Norway




HTC PURENERGY CARBON CLEAR SOLUTIONS

ITC

BECHTEL

# 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

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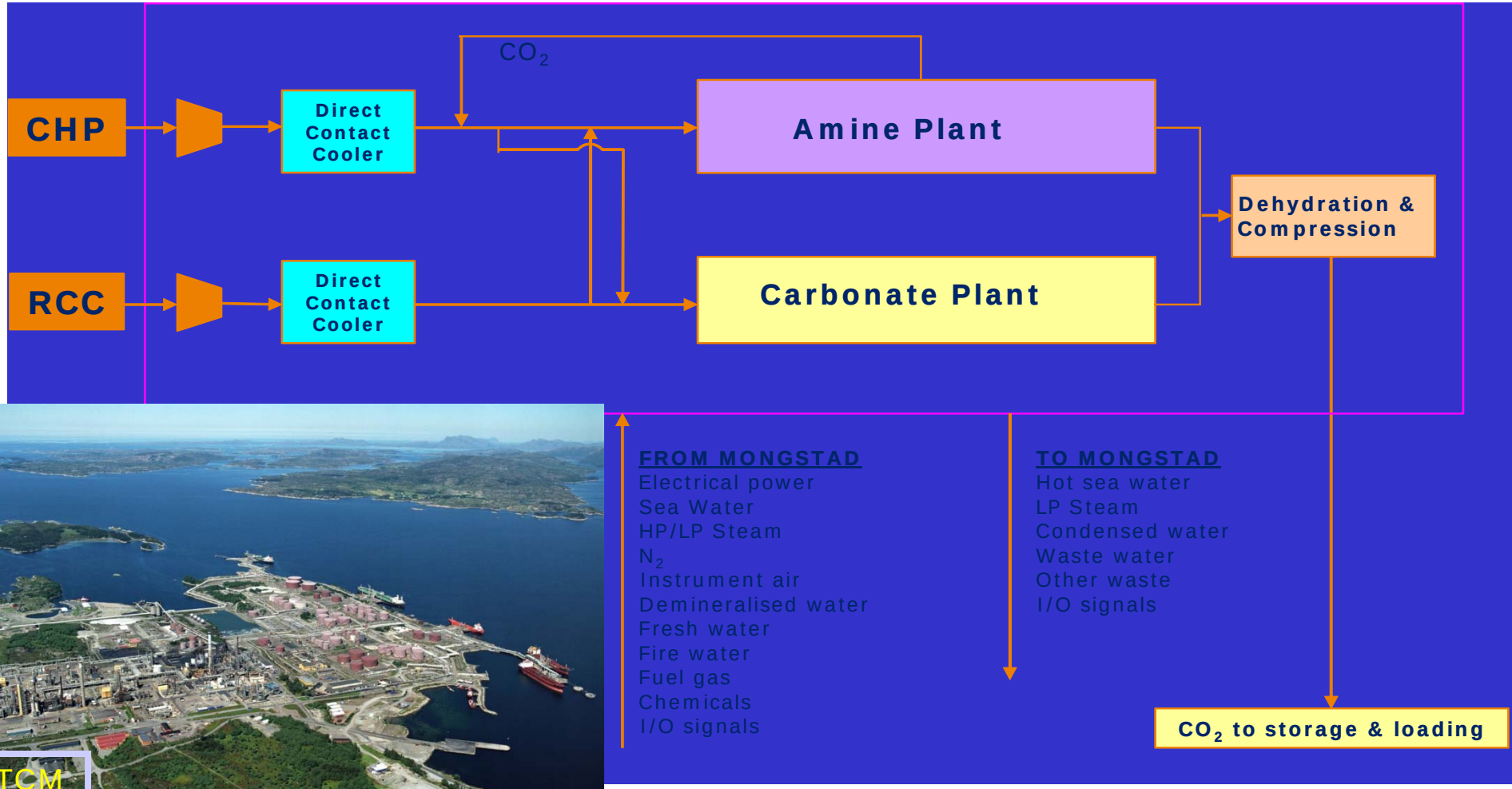
## HTC & SVM and ITC

# ITC/HTC/Bechtel FEED Study for the Amine Plant of the European $CO_2$ Test Center, Mongostad, Norway




# 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***

# PURENERGY CCS Series

# (500, 1000, 1500)

# Example: Comparative Production Cost
## Coal Power Plant and NGCC Power Plant

| Parameter | Coal Power Plant | NGCC Power Plant |
|---|---|---|
| $CO_2$ Production Capacity, TPD | 3000 | 3000 |
| $CO_2$ recovery, % | 90 | 90 |
| $CO_2$ in flue gas, mol% | 12 | 4 |
| Number of trains | 1 | 2 |
| Flue gas rate, mmscfd | 528 | 920 |
| Absorber diameter, m | 10 (one) | 12 (two) |
| Regenerator diameter, m | 6 (one) | 6 (two) |
| Capital Cost, million US$ | 165 | 230 |
| Operating cost, million US$ | 25 | 51 |
| Production cost, US$/ton | 33 +- 6 | 53 +- 10 |


# Thank you

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# Key literatures in the research area

- Astarita G., "Mass Transfer with Chemical Reaction", Elsevier Publishing Co., New York, 1967.
- Danckwerts P. V., "Gas Liquid Reactions", McGraw Hill, New York 1970.
- Kohl A. L. and Riesenfeld F. C., "Gas Purification",
- Proceedings of GHGT 6 (Australia), 7 (Japan) and 8 (Norway)
- Special Issue on “Carbon Dioxide Capture” in Industrial & Engineering Chemistry Research (Special Issue Editors: R. Idem and P. Tontiwachwuthikul) , Vol. 45, April 2006.
- and many others