# $CO_2$ Capture, Utilization, and Storage – Enabling Technology for Coal

**North Dakota Legislative Council**
**Energy Development and Transmission Committee Meeting**

**August 28, 2012**

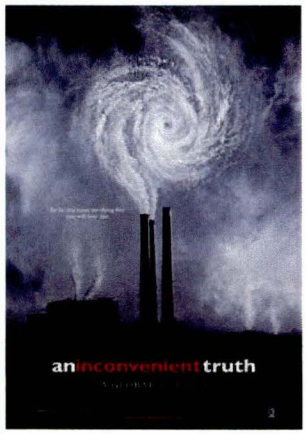
**John Harju**
**Associate Director for Research**

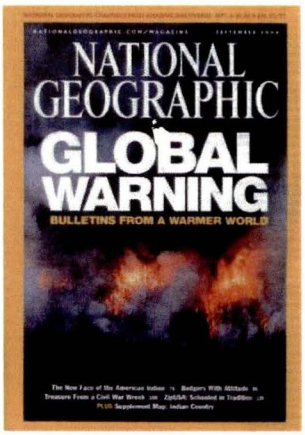
EERC

Energy & Environmental Research Center (EERC)…



## Climate Change ?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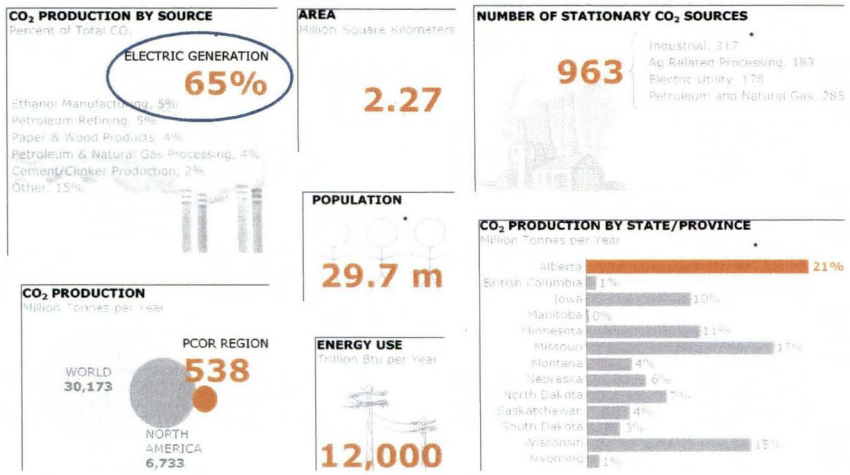
# PCOR Partnership Regional Profile




*These percentages represent only the portion of the states/provinces that are in the PCOR Partnership region.

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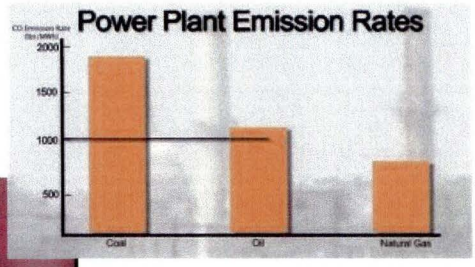
# New EPA GHG Rules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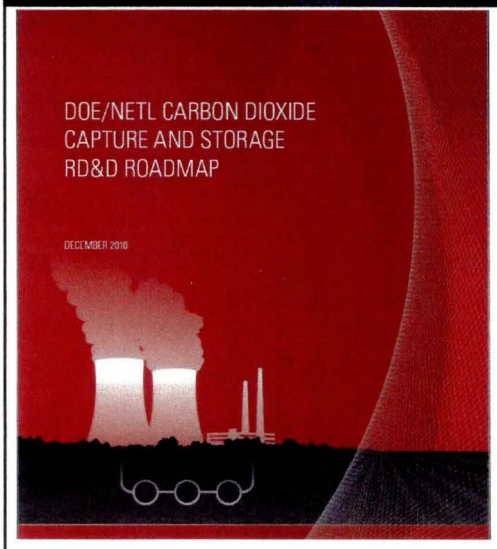
# DOE NETL Program Goals




U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) technology goal: "To develop, by 2020, fossil fuel conversion systems that offer 90% $CO_2$ capture with 99% storage permanence at less than a 10%–35% increase in the cost of energy services."

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# A Growing Partnership


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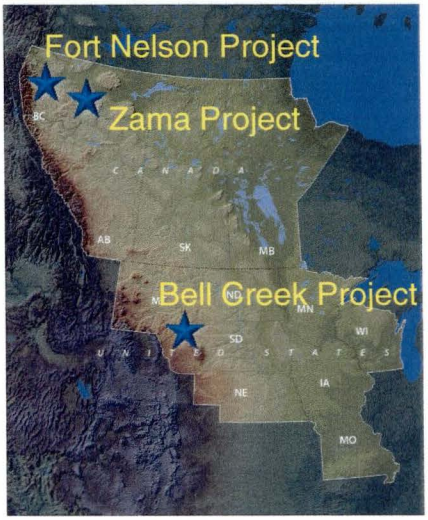
## Plains $CO_2$ Reduction Partnership (PCOR) Commercial-Scale Demonstration Phase

- Two 1-million-ton/year-or-greater-scale demonstrations
  - Saline
  - Enhanced oil recovery (EOR)
- Ongoing and effective public outreach
- Continuing regional characterization
- Continued involvement in other carbon dioxide ($CO_2$) storage projects in the region.
- Continued involvement in carbon capture and storage (CCS) and $CO_2$ EOR regulations

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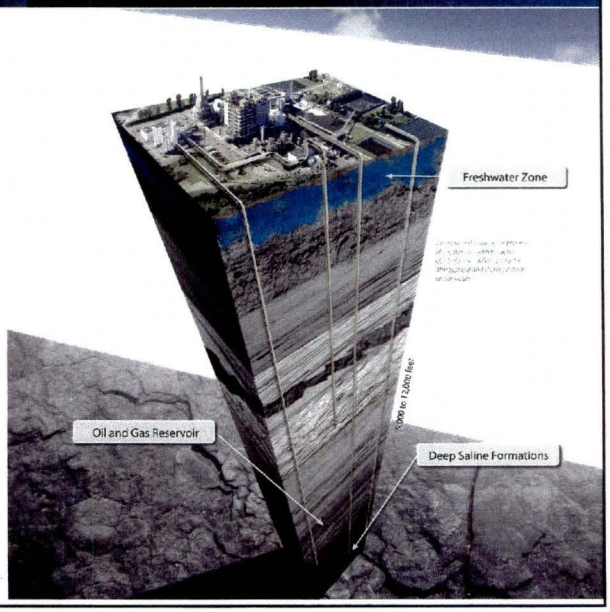
## CCS or CCUS?

- Saline Formations
- Oil and Gas fields:
  - Storage in association with $CO_2$-based enhanced oil recovery.
  - Storage in depleted oil and gas fields.

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# Fort Nelson Organizational Chart

Commercial Partners

Regulatory Partners

BC Oil & Gas COMMISSION

BRITISH COLUMBIA
The Best Place on Earth
Ministry of Energy, Mines and Petroleum Resources

Natural Resources Canada

NETL

EERC
PCOR Partnership
Fort Nelson Demonstration

Research Partners

Spectra Energy

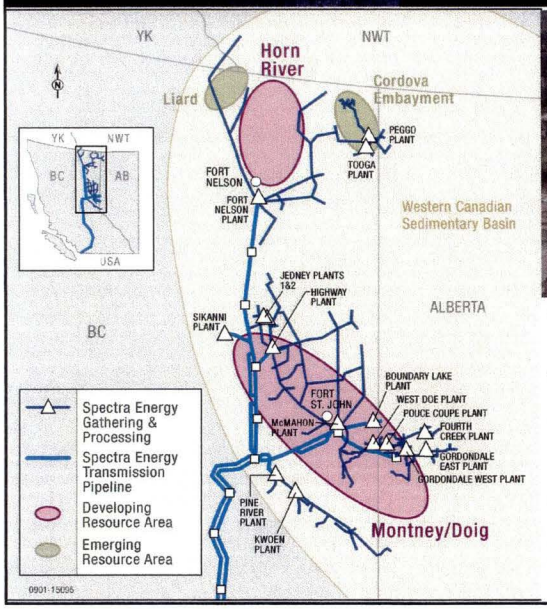
CMG
COMPUTER MODELLING GROUP LTD.

Schlumberger
Carbon Services

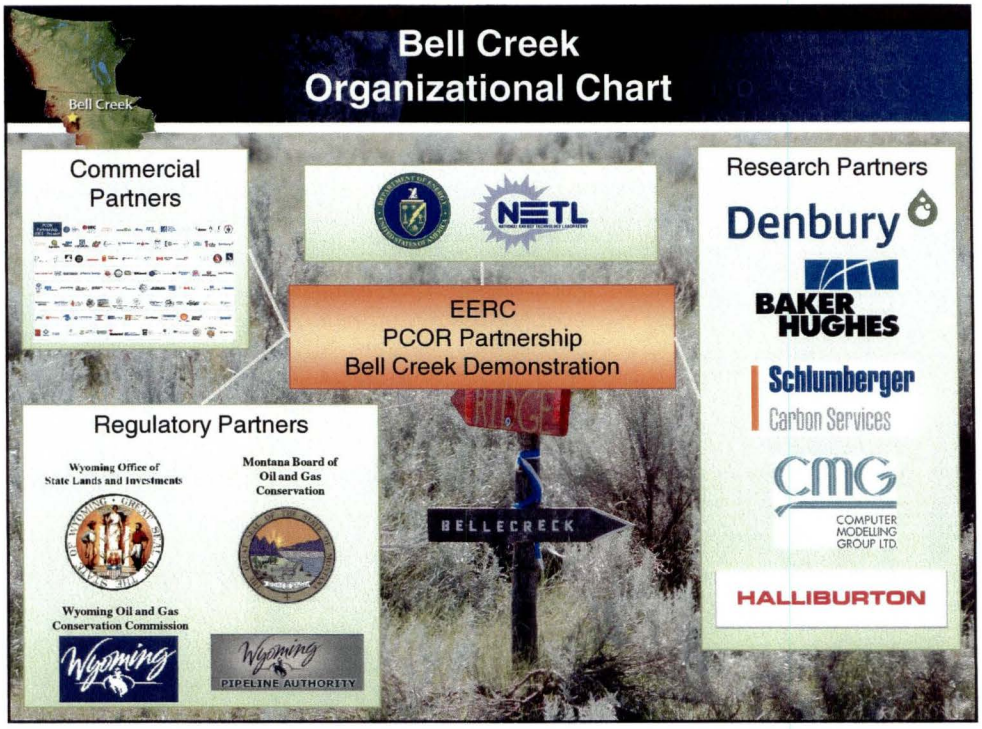
RPS Energy

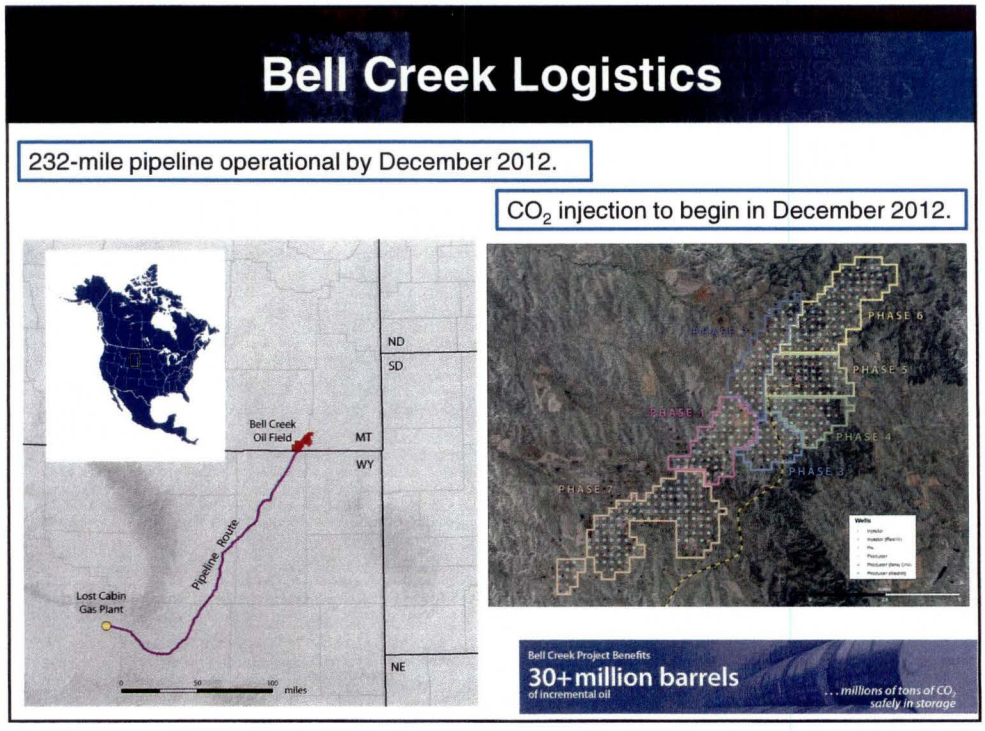
Alberta Innovates Technology Futures

# Fort Nelson Gas Plant

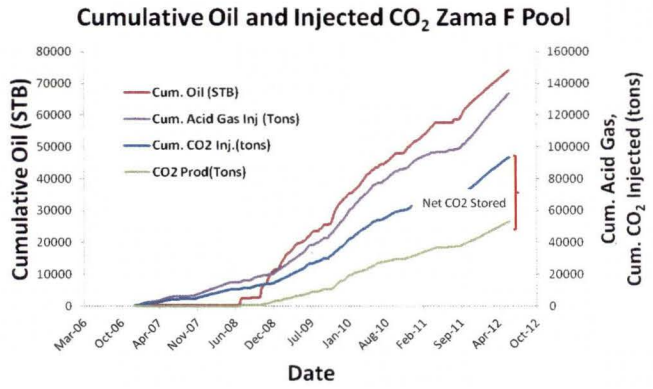



- 1 Bcf/d raw gas-processing capacity – largest facility of its kind in North America.
- Spectra Energy gathering and processing assets are strategically positioned in the growing Horn River Basin, processing both conventional and unconventional shale gas resources.
- The Fort Nelson CCS project is a potential solution to mitigate $CO_2$ emissions as shale gas production grows.


Bell Creek
Bell Creek
Organizational Chart
Commercial Partners
NETL
EERC
PCOR Partnership
Bell Creek Demonstration
Research Partners
Denbury
BAKER HUGHES
Schlumberger
Carbon Services
CMG
COMPUTER MODELLING GROUP LTD.
HALLIBURTON
Regulatory Partners
Wyoming Office of State Lands and Investments
Montana Board of Oil and Gas Conservation
Wyoming Oil and Gas Conservation Commission
Wyoming
PIPELINE AUTHORITY
BELLECREEK


Bell Creek Logistics
232-mile pipeline operational by December 2012.
$CO_2$ injection to begin in December 2012.
ND
SD
MT
WY
NE
Bell Creek Oil Field
Pipeline Route
Lost Cabin Gas Plant
miles
PHASE 6
PHASE 5
PHASE 4
PHASE 3
PHASE 2
PHASE 1
PHASE 7
Bell Creek Project Benefits
30+million barrels
of incremental oil
...millions of tons of $CO_2$ safely in storage

## Zama Project Update – Cumulative Injection and Production through May 28, 2012




- Acid gas injected: 133,550 tons
  - $CO_2$: 93,485 tons
- Oil produced (bbl): 74,202 bbl
- Net $CO_2$ stored: 40,357 tons

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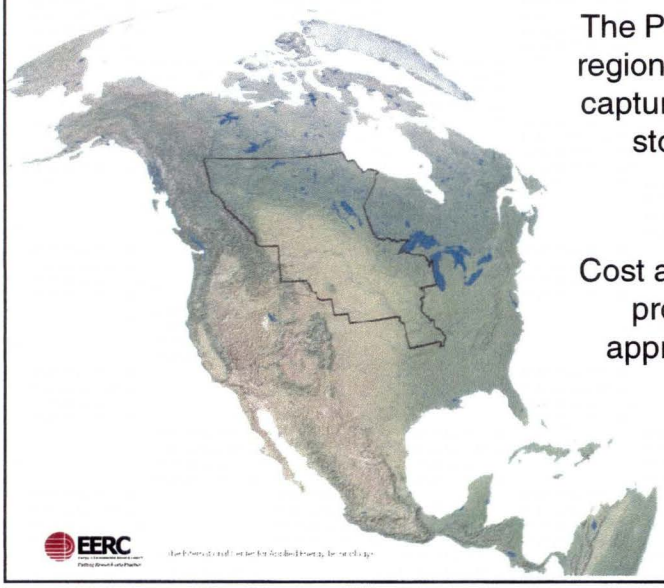
## Bringing it Together



The PCOR Partnership region has huge carbon capture, utilization, and storage (CCUS) potential!

Cost and quality of $CO_2$ produced needs to approach levels viable to end users

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# PCO$_2$C Sponsors

HITACHI Inspire the Next
MIDWEST GENERATION
TransAlta
SaskPower
PUGET SOUND ENERGY
C-QUEST
Nebraska Public Power District
ppl
HUNTSMAN
Portland General Electric
Industrial Commission of North Dakota Lignite Research, Development and Marketing Program
metso power
Constellation Energy
BAKER HUGHES
AVISTA
PACIFICORP
NorthWestern Energy
ATCO Power
GE
BLACK & VEATCH
bp
Chevron
ConocoPhillips
eni
minnesota power
PETROBRAS
SUNCOR ENERGY
LIGNITE Energy COUNCIL
State of Wyoming Clean Coal Technology Fund

# $CO_2$ Capture Technology Status

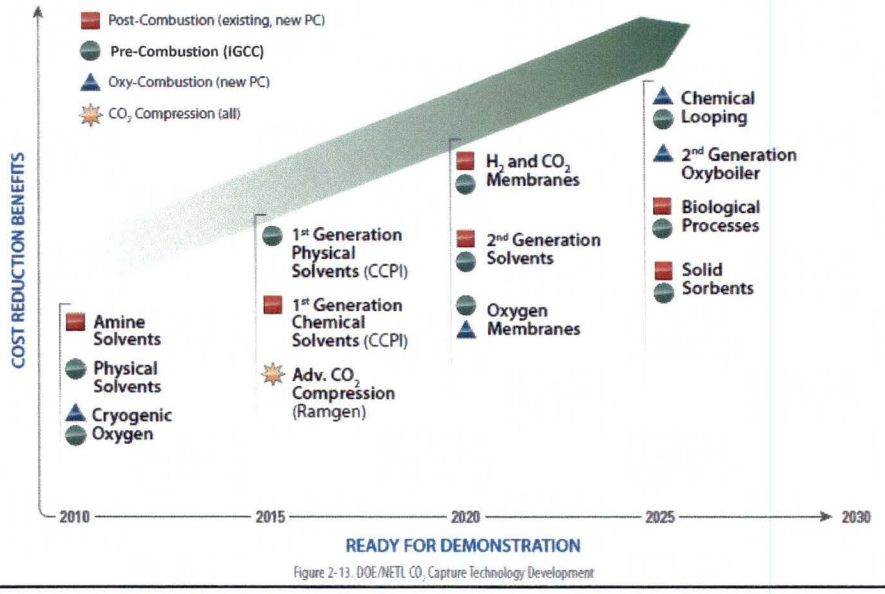
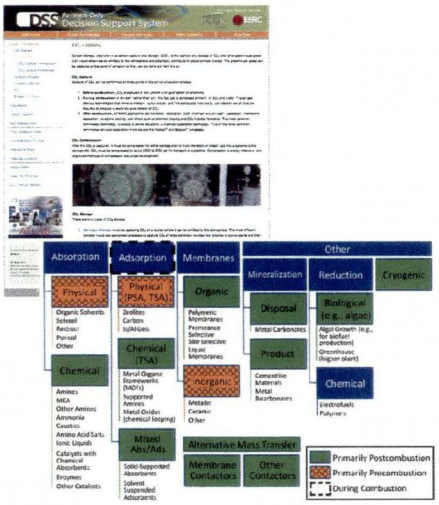



Figure 2-13. DOE/NETL $CO_2$ Capture Technology Development

# Interactive $CO_2$ Capture Technology Summary




The $CO_2$ capture technology document is being adapted for inclusion on the PCOR Partnership Partners-Only Decision Support System. **Interactive features** will allow the user to access:

- Summaries of the three capture platforms (pre-, during, and postcombustion)
- Summaries of the various technology types (adsorption, absorption, membrane, cryogenic, etc.)
- Specific technology information
  - Description
  - Development status
  - Developer name(s)
  - Process schematic
  - References

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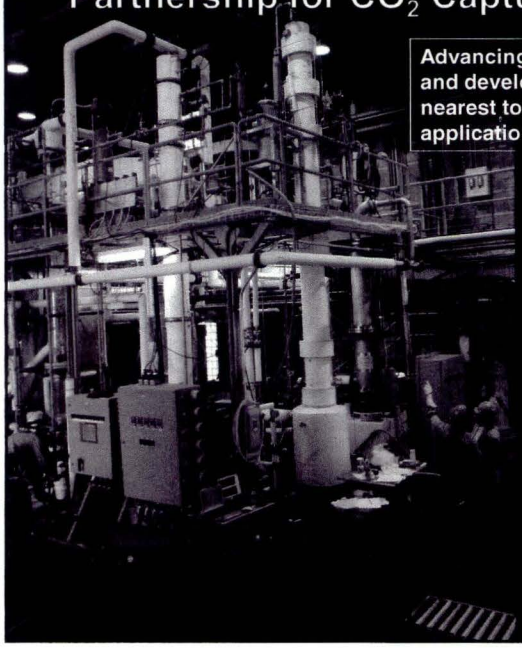
# Partnership for $CO_2$ Capture (PCO$_2$C) Summary



**Advancing the state of $CO_2$ capture by evaluating and developing those technologies that are nearest to commercial viability for utility applications.**

- Multiple-phase program.
- Includes funding from private sector sponsors (27), the North Dakota Industrial Commission, and DOE NETL.
- Identify technology challenges and develop strategies for cost-effective and efficient implementation at the power utility scale.

# Summary of $CO_2$ Capture Technologies

Technologies Under Evaluation

- Solvents
  - Monoethanolamine (MEA) – Phase 1
  - Hitachi H3-1 – Phases 1 and 2
  - Methyldiethanolamine (MDEA)–piperazine – Phase 1
  - Cansolv – Phase 2
  - Huntsman – Phase 2
  - ION Engineering – Phase 2
- Oxycombustion – Phases 1 and 2
- Solid Sorbents – Phase 2
  - NETL
- Other
  - C-Quest (slurry based) – Phase 2
- Solvent additives
  - Baker Hughes – Phase 1
  - Huntsman – Phases 1 and 2
  - Advanced solvent contactor (NSG)

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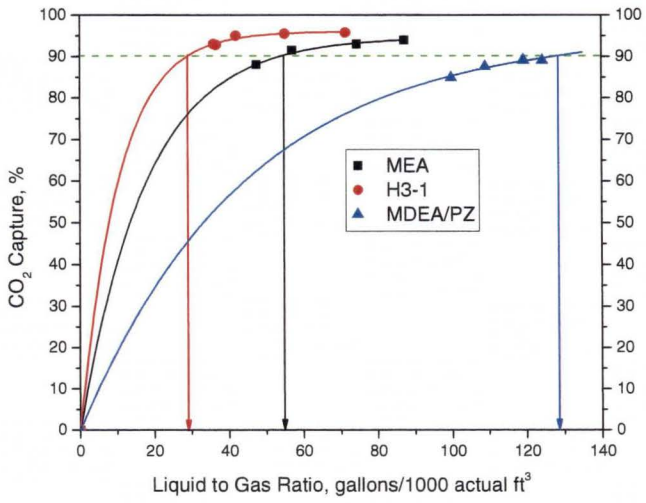
# $CO_2$ Capture vs. Liquid-to-Gas Ratio

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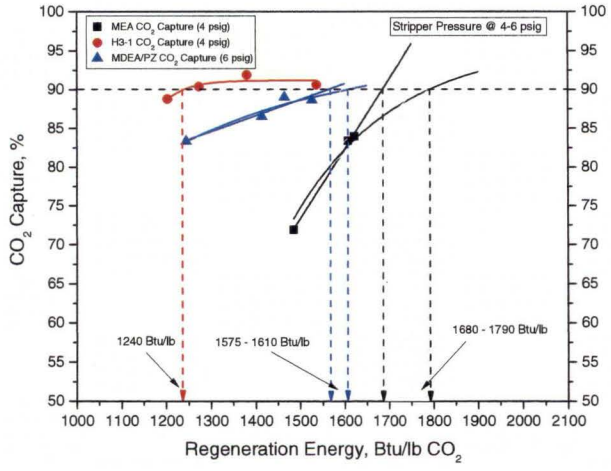
# $CO_2$ Capture vs. Regeneration Energy

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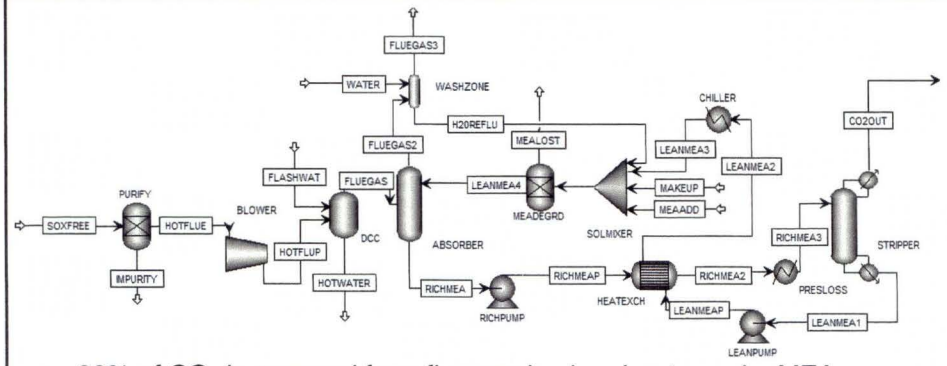
# 500-MW Aspen Plus® Model for $CO_2$ Capture




- 90% of $CO_2$ is removed from flue gas in absorber tower by MEA solvent.
- MEA losses from degradation are estimated from pilot-scale data.
- Wash zone minimizes MEA evaporation losses in absorber tower.

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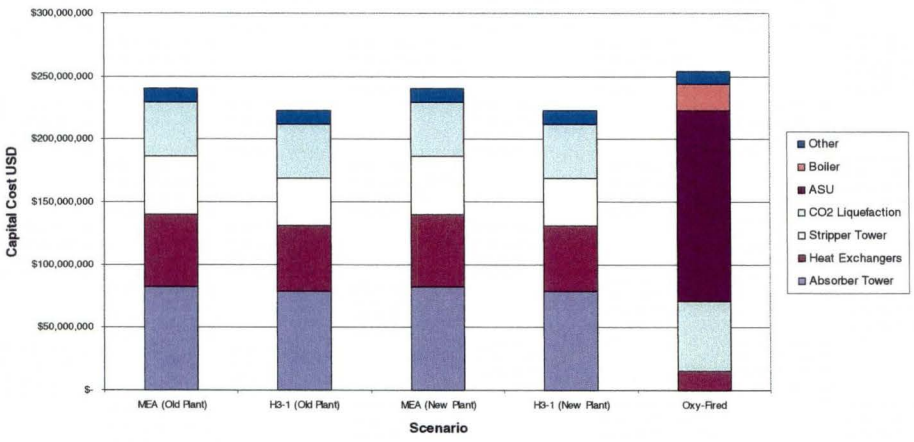
# Capital Cost Comparison

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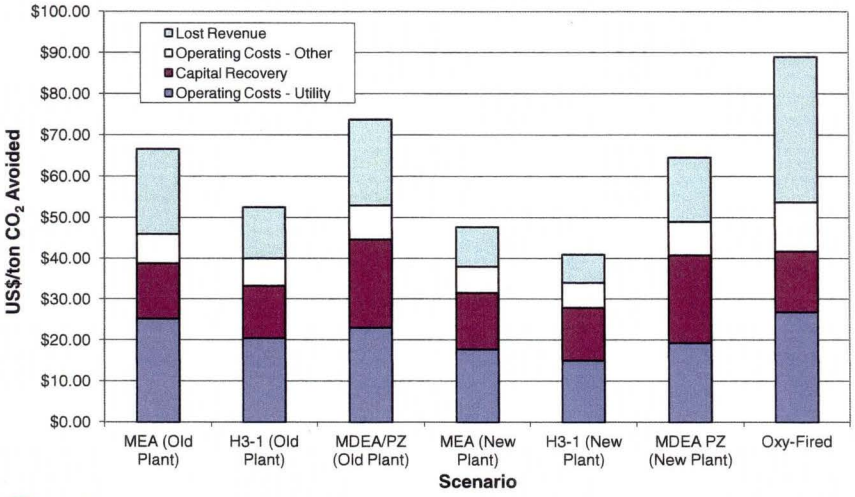
# Cost of $CO_2$ Avoided

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# Development Focus Areas for $CO_2$ Capture Implementation in Coal-Fired Power Plants

- Scale-up
- Energy penalty
  - 20% to 30% less power output
- Cost
  - Current costs are $40 to $80 per ton of $CO_2$ (80% increase in cost of electricity [ICOE]).
  - Very capital intensive ($1500 to $2000/kW).
- Contaminants
- Resource availability and sector readiness
  - Supply of solvents or sorbents will be limited.
  - Manufacture of air separation units (ASUs) and other large equipment will be a handcuff to implementation.
- Regulatory framework
  - Lots of unknowns and liability issues.

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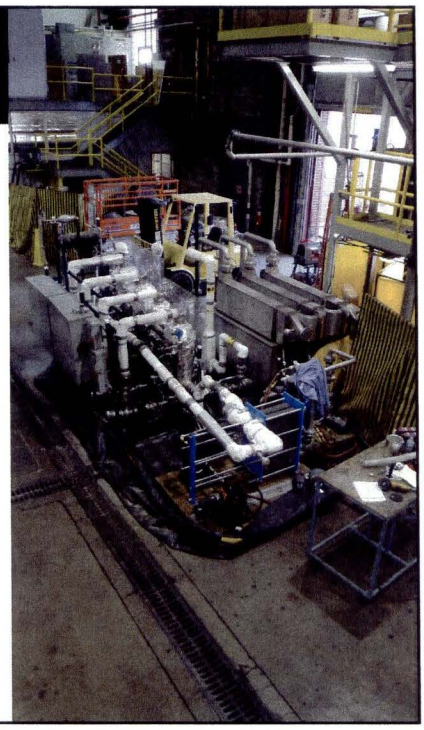
# Evaluation of Novel Technologies for $CO_2$ Capture

- Neumann Systems Group's (NSG's) NeuStream-C™ system.
- Pilot-scale evaluation to determine the performance and economics of the NeuStream-C system.
- The end result of the program is focused on the development of lower-cost and more effective capture technologies and their integration into a total system that provides substantial economic and environmental benefits.



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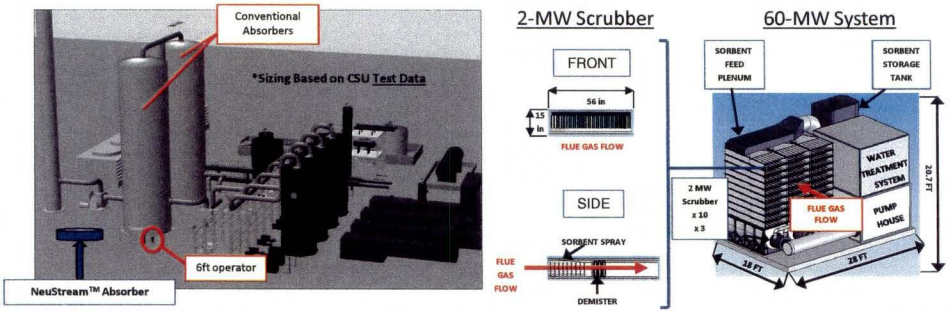
# *NeuStream* Capture and Processing Systems




**Up to 90% Smaller** **Modular Design**

**Up to 50% Lower CapEx**
**Up to 40% Lower OpEx**

**Through NSG Mechanical Advancement**
**Useful with Variety of Chemistries**

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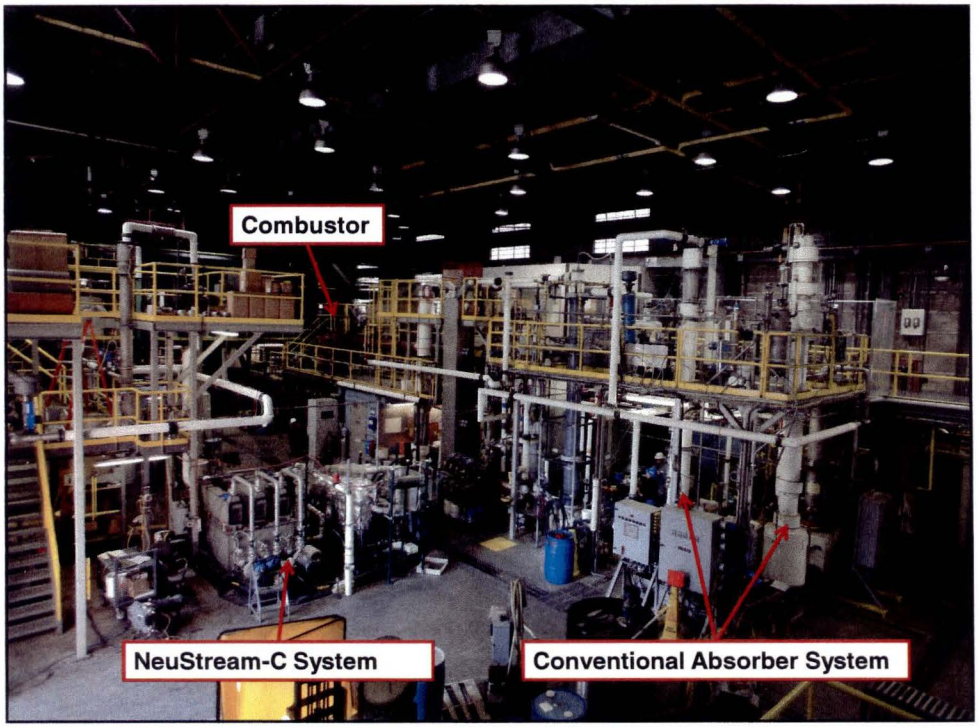
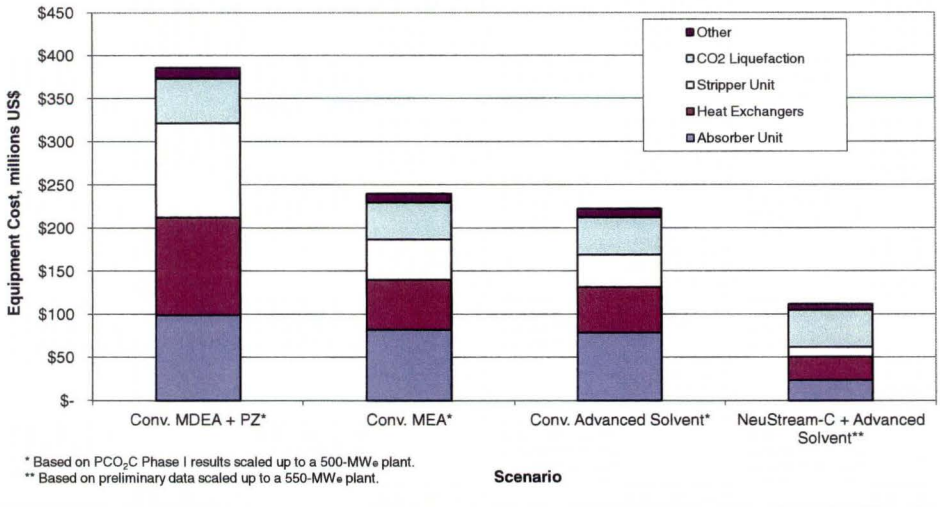
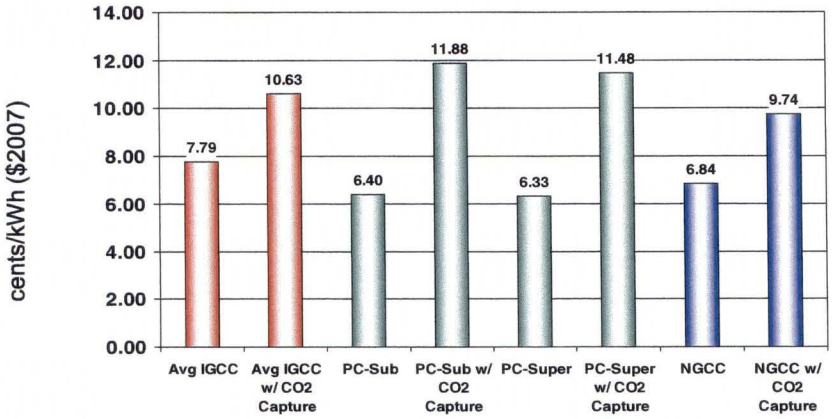



# Capital Cost Comparison




* Based on $PCO_2C$ Phase I results scaled up to a 500-$MW_e$ plant.
** Based on preliminary data scaled up to a 550-$MW_e$ plant.

# Or, Coal Gasification Systems?

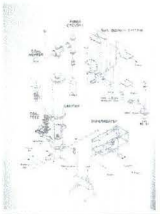



January 2007 Dollars, Coal cost $1.80/10$^6$Btu. Gas cost $6.75/10$^6$Btu

Cost and Performance Baseline for Fossil Energy Plants
*Final Results*
*May 15, 2007; Revised August 2007*
National Energy Technology Laboratory, accessed Aug 2009

# Demonstration of Pilot-Scale Systems for Gasification and Precombustion $CO_2$ Capture

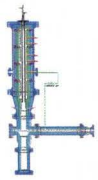
**Chronology of Gasification Research, Development, and Demonstration (RD&D) at the EERC**



**Transport Reactor Development Unit**

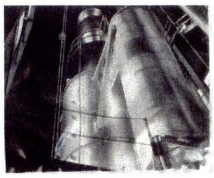
**Catalytic Gasification/SOFC**

**Entrained-Flow Gasifier**

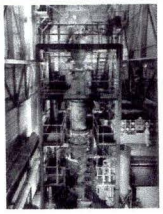


Year 1945 1955 1965 1975 1985 1995 2005

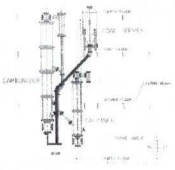
**Annular Externally Heated Retort**



**Slagging Fixed-Bed Gasifier**



**Mild Gasification**



**Biomass Microgasifier**

# Great Plains Synfuels Plant

Figure from Basin Electric Power Cooperative Web Site – www.basinelectric.com/Energy_Resources/Gas/index.html

**Current Commercial Example**

- Producing natural gas (over 54 billion standard cubic feet/year) from coal since 1984.
- Produces a number of by-products, including $CO_2$ (40 billion standard cubic feet/year) that is piped to Saskatchewan and sold for EOR.
- New system would take advantage of technology advancements and separate out hydrogen product.

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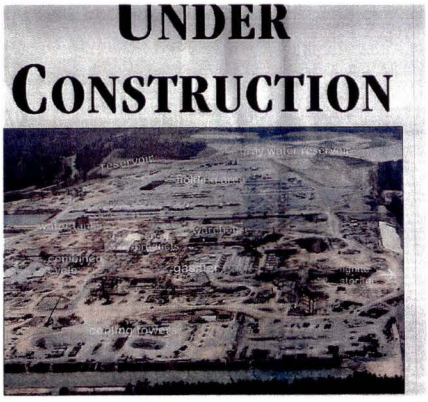
# Kemper County, Mississippi IGCC

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