
Highlight Carbon Sequestration Science Workshop

Time: May 22-24, 2001
Place: NETL-Pittsburgh
Initiator: Curt White
Organizer: Howard Herzog

Prepared by
H. P. Loh and Pat Le
Process Engineering Division
July 20, 2001



Speakers

| TOPIC | SPEAKER | AFFILIATION |
|-------------------------------|-------------------------|--|
| Overview | Howard Herzog | MIT |
| Capture technology | Harry Andus | Aube Energy and Environment |
| Economics | Howard Herzog | MIT |
| Geochemistry | Bill Gunter | Alberta Research Council |
| Oil and gas reservoirs | Vello Kuuskraa | Advanced Research International |
| Coal bed methane | Gunter, Kuuskraa | (above) |
| Aquifers | Bill Gunter | (above) |
| Ocean sequestration | Howard Herzog | MIT |
| Chemical absorption | Gary Rochelle | Univ. of Texas |
| Chemical conversion | Chunshan Song | Penn State |
| Public perception | David Keith | CMU |



Carbon Capture Cost Analysis

- Based on Economic Evaluation of Leading Technology Options for Sequestration of Carbon Dioxide
 - A master of science thesis (J. David, MIT, May 2000) supervised by Howard Herzog
 - Available at <http://sequestration.mit.edu/pdf/JeremyDavid.pdf>



Analysis Approach

- Analyzed 14 studies for three power cycles - IGCC (6), PC (4), and NGCC (4)
- All 14 study results are adjusted to a common economic basis:
 - Capacity Factor 75% (6570 hrs/yr)
 - Capital Charge Rate 15%/yr
 - Coal Price (LHV) \$1.24/MBtu
 - Natural Gas (LHV) \$2.93/MBtu
- Performance parameters of the same power cycle are averaged and used as the input for analysis of each power cycle



MEA Systems Today

- **Demonstrated, commercially mature**
- **Reasonable rates of absorption and stripping**
- **Energy use prohibitive**
- **Corrosion inhibitors to use carbon steel**
- **Cheap amine = Makeup costs acceptable**
 - Significant oxidative and thermal degradation
 - Pretreatment for SO₂ removal needed



MEA Process Conditions

| FEED GAS | FLUE GAS | NATURAL GAS |
|--|-----------------|--------------------|
| Pressure (atm) | 1 | 10-100 |
| Gas Rate (Mcfm) | 1-3 | 0.001-0.1 |
| CO₂ Partial Pressure (atm) | 0.1 | 1-10 |
| Oxygen (%) | 0.02-0.1 | 0-0.01 |
| Energy/Capital Cost | 1 | 0.1 |



MEA Systems for Flue Gas

- **Monoethanolamine**
 - Fluor Daniel
 - ABB Lummus
 - Praxair
- **Hindered amines**
 - Mitsubishi



Geological Storage

- Depleted oil and gas reservoirs
- EOR recovery
- Depleted coal bed methane (CBM) reservoirs
- Enhanced CBM (ECBM) recovery
- Deep aquifers



CO₂-EOR

- **Production technology is mature**
- **Focused on monitoring and maximizing CO₂ uptake**
- **Proposed commercial projects**
 - Weyburn project, Saskatchewan
 - BP project, Alaska North Slope



CO₂-EOR

Expertise Required

- **Geology: location of storage reservoirs**
- **Hydrogeology - movement of fluids**
- **Geotechnical - movement of solids**
- **Geochemical - mass transfer and fluid-rock interaction**



CO₂-EOR Industry Activity

- **Considerable value-added CO₂ sequestration is already underway in U.S. Oil fields**
- **Off-the-shelf oil field technology can be adapted for CO₂ sequestration**
- **Several EOR projects in Texas, Colorado, Oklahoma, Wyoming, and Saskatchewan**



CO₂-EOR Economics (Shell Projects)

- **Capital costs - \$0.8/Bbl**
- **O&M - \$2.70/Bbl**
- **CO₂ purchase: 5Mcf/Bbl @ \$0.65/Mcf**
- **Shell concludes that a conventional CO₂ EOR project would be economic at \$18 per barrel of oil**



CO₂-EOR

Unknown and Barriers

- **How much CO₂ is actually being sequestered?**
- **What is the long-term security/safety of sequestered CO₂?**
- **What is the long-term effect on the reservoirs of CO₂?**
- **What is the added cost of sequestration in ongoing EOR projects?**



Enhanced Coal Bed Methane (ECBM)

- **Technology is immature**
- **Require basic research and technical demonstration**
- **Value added - recovery of CH₄**
- **Demonstration projects**
 - San Juan Basin, New Mexico
 - Fenn-Big Valley, Alberta



ECBM

Screening Criteria

- Homogeneity
- Simple structure
- Permeability > 1 milli-darcey
- Depth 300-1,500 meters



ECBM Pilots

| | | |
|---|---|---|
| Burlington Resources Allison Unit | BP Tiffany Unit | Alberta Research Council |
| San Juan Basin | San Juan Basin | Alberta Basin |
| <ul style="list-style-type: none">• 4 injectors• 9 producers,• 3 Mcfd injected• 5 years of injection history | <ul style="list-style-type: none">• 12 injectors• 34 producers• Mid-2001• ARI/BP/DOE joint monitoring projects | <ul style="list-style-type: none">• Single-well short-term test completed• plan 5-spot once funding in place |



Representative Perception of Environmental NGO on Sequestration

- Oceanic sequestration a non-starter
- Energy penalty matters
- Sources of CO₂ matters (fossil vs biomass)
- Must not be an excuse for delay
- Must not be an excuse for reduced effort on biomass
- Might support if technologies could accelerate action on mitigation

– *Based on interviews conducted by David Keith (CMU)*

