Future Market Drivers for CO2 Compression Equipment

Workshop on Future CO2 Compression Systems

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Key Driver

Carbon Capture and Storage (CCS)
Focus on Lowering CO₂ Emissions

• We Should Use and Develop!
  • Clean and Renewable Energy Sources
    • Wind
    • Solar
    • Nuclear
    • New Technologies (Tide / Wave ...)
  • Energy Efficiencies
    • Transportation – Improved Miles Per Gallon
    • Construction Methodology – Lower Energy Usage
      • HVAC / Lighting / Automation / Other Efficiencies

• But-Hydrocarbons are important to our economy TODAY and will be for some time in the Future!
Where Our Energy Comes From!

U.S. Primary Energy Consumption by Source and Sector, 2007
(Quadrillion Btu)

85% Hydrocarbons

<table>
<thead>
<tr>
<th>Source</th>
<th>Percent of Source</th>
<th>Percent of Sector</th>
<th>Sector</th>
<th>Btu</th>
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<tr>
<td>Petroleum</td>
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<td>Industrial</td>
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<tr>
<td>Coal</td>
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<td>Residential and Commercial</td>
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<tr>
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<td>Electric Power</td>
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<tr>
<td>Nuclear Power</td>
<td>8.4</td>
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</tbody>
</table>

101.4 quadrillion BTUs

Source: US Department of Energy, Energy Information Administration (DOE/EIA)
http://www.eia.doe.gov/basics/energybasics101.html From Perot Charts
Lowering CO$_2$ Emissions

• If we want to significantly lower CO$_2$ emissions in the short term, CCS is a key component to the equation!

• CCS Options
  • Near Term Solution - EOR is **Now!!**
    • The U. S. needs the Oil!
    • Need to resolve issues relating to Liability & Pore Space
  • Long Term Solution - CCS
    • Depleted Hydrocarbon Reservoirs
    • Saline Aquifers (Issues: Liability & Pore Space Ownership)
Why Promote CO$_2$ in EOR?

• Infrastructure development
  – Existing 3,500 miles of CO$_2$ pipelines was built for EOR
  – Sunk assets will lower delivery cost and risk for CCS (depleted O&G reservoirs and aquifers)

• Environmental additionality

• Acceleration of CCS due to liability management, technology acceptance and economics as related to EOR
What To Do?

• Provide Incentives for CCS Today
  • Federal / State / Industry
• EOR with CO$_2$ (anthropogenic) Leads
  • Lowers CO$_2$ emissions
  • Stores CO$_2$ in known geologic traps
  • Pays for pipeline infrastructure for future geological sequestration in non-hydrocarbon reservoirs
  • EOR with CO$_2$ does not create incremental Bbls
  • Maximizes the use of America’s resources
  • Lowers Oil Imports
• Deep Saline Aquifers Follow
  • As Issues are resolved
What Do We Need to Happen?

• Reasonable Rules and Regulations
  • CO$_2$ (anthropogenic) used for EOR should count as CCS
  • Proper characterization of CO$_2$
    • It is a commodity for EOR!
    • Pollutant – No (EPA ?)
    • Hazardous Waste – No (EPA ?)
  • States should take the long term liability for storage – After proper injection and P&A
  • Clarification of pore space ownership
    • Storage Only
    • During EOR (mineral extraction) and After EOR (storage)

• Be proactive in sighting new facilities which can economically capture the CO$_2$, such as gasification projects
Carbon Infrastructure: Today and Tomorrow
Overview of CO₂ Infrastructure in USA

CO₂ - Sources / Pipelines
- Natural
- Anthropogenic
- Pipeline

Proved Oil Reserves (Billion Bbls) - EIA Data

North Dakota
Wyoming
Colorado
Oklahoma
Louisiana
Mississippi
New Mexico
McElmo Dome
Sheep Mountain
St. John Dome
Permian Basin
Bravo Dome
LaVeta
Coffeyville
Ammonia Plant
Jackson Dome

Coal Gasification

XX Proved Oil Reserves (Billion Bbls) - EIA Data

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Anthropogenic Sources of CO2

- **High Purity**
  - Gas Processing
  - Fertilizer
  - Ethanol
  - Hydrogen
  - Gasification

- **Low Purity**
  - Electrical Generation
    - Coal – 12% to 15%
    - Gas – 3% to 5%
  - Cement – 12% - 15%
High Purity Sources

- Generally 95%+ CO2 – No Separation Cost
- Generally Low Pressure – High Cost to Compress
- Location to Sink – Aquifer or EOR
  - For EOR, need 25 to 50 MMcf/d + to lay pipeline 50 miles; as volume goes up so does distance for economic transport
  - For Saline Aquifer, long distances may be uneconomic
- What does that mean
  - Cost to Compress and Transport about 50 MMcf/d for 50 miles will cost $1.30 to $1.75/ Mcf or $32.50 to $33.70 /metric ton
  - Note: (These cost can vary significantly depending upon such things as power cost at certain locations, terrain to construct pipelines and many other factors.)
Low Purity Sources

- Generally less than 15% CO2
  - Significant Separation Cost
  - Current Technology – Amine (Too Energy Intensive)
  - New Technology’s – Chilled Ammonia? / Other
    Most likely 3-5+ Years Out
- Generally Low Pressure – High Cost to Compress
- Location to Sink – Critical for Aquifer or EOR
Low Purity Sources

- For EOR, need 25 - 50 MMcf/d to lay 50 miles pipeline; as volume goes up so does distance
- For Saline Aquifer, longer distance is extra cost

What does that mean

- Cost to Capture, Compress and Transport about 50 MMcf/d for 50 miles will cost $2.85 to $4.00/ Mcf or $55.00 to $77.00/metric ton

Note: (These cost can vary significantly depending upon such things as local power cost, terrain to construct pipelines and many other factors.)
### Capture & Compression Costs for CO2a

Recent Studies for CO2a Capture and Compression

<table>
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<tr>
<th>Process</th>
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<th>SCPC</th>
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<td>DOE (Trimeric)*</td>
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<td></td>
<td>$67</td>
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</tbody>
</table>

* 2007 Study

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[Blue Source] | A Leading Climate Change Portfolio
Challenges

- Hydrocarbon Reservoirs
  - EOR requires High Purity CO₂ – 95% +
  - Need Significant Quantity > 25 MMcf/d / 1,300 metric tons/day
  - Needs to be relatively close to source – 1 to 2 miles for each 1 MMSCF/D
  - DOE Target of $20/tonne for CO2a Capture
  - Cost Target for Capture & Compression (C&C) CO2a ~$25-$30/tonne ($1.30-$1.55/MSCF)
Challenges

• Issues Emerging from Pending State Laws

  – CO2-EOR May Not Be Storage

  – Pore Space is Being Clarified “but”
    May Inhibit Oil & gas Operations in Storage Facilities

  – States Are Not Yet Willing to Accept Liability for Long Term Storage
Conclusions

- For Non EOR Sequestration to Commence, US Industry Needs Visibility On
  - Value of Emission Reduction Credit
  - Regulations – Federal and State
    - Early Action Might be Penalized
    - Economic - Benefit or Cost?
  - Pore Space Ownership
  - Liability Issue
  - Cost for C&C of CO2a Needs to be Decreased
Conclusions

- EOR Can and Is Happening Today

  - U. S. Infrastructure Backbone Can Be Built on the Back of Oil
  - High Purity Anthropogenic CO2 Sources Can Lead the Way
  - Infrastructure Starts Out Regionally
Questions!!