North American CO$_2$ Status

Enhanced Oil Recovery Institute’s
3rd Annual CO$_2$ Conference
Casper, Wy

Tom Doll, State Oil & Gas Supervisor
Wyoming Oil and Gas Conservation Commission

Tracy Evans,
Denbury Resources

L. Stephen Melzer,
Melzer Consulting

June 2009
For Their Assistance, We Also Wish to Thank:

- Lon Whitman, EORI
- Bryan Hargrove, Trinity CO$_2$
- Stefan Bachu, Alberta Research Council
North American CO$_2$ Status

OUTLINE OF TALK

- CO$_2$ EOR Over The Past 2 Decades
- An Update On CO$_2$ Supply
- Areas Of Growth
- A Lead-in to the Rapidly Advancing Policy World
GROWTH OF WW and U.S. CO₂ EOR PROJECTS
1986 - 2008

- Worldwide Projects
- U.S. Projects

* Includes CO₂ only Miscible Floods (Source: OGJ 4/21/08 & APTA CO₂ School (Jan & Aug ‘08)
Worldwide and United States CO₂ EOR Production*

* Includes CO₂ Miscible & Immiscible Floods (Source: OGJ 4/21/08 & APTA CO₂ School (Jan & Aug ‘08)
New Developments in the Gulf Coast

RECENT GROWTH OF MISSISSIPPI CO2 PROJECTS & PRODUCTION  
1992 - 2008

EOR Production - Kbbls/day

Denbury Operates 12 Floods now

* Source: OGJ 4/21/08 & APTA CO2 School (Jan & Aug ’08)
Gulf Coast (MS) CO₂ EOR Production

Projected Yearly Growth Rate of 10-20% through 2015
Wyoming Crude Oil Production 1998 - 2007

Decline Leveled

Due to CO₂ EOR
Production History at EnCana’s Weyburn Unit
Saskatchewan, Canada

Current production at 35-year high

Source: Bachu, 2008 CO₂ Conference and EnCana Corporation
STATUS OF THE SUPPLY OF CO$_2$
U.S. CO₂ SALES FOR EOR

CO₂ Sales

Just reached 3 bcfpd

* Source: 2008, Hargrove, Melzer and Whitman, CO₂ Flooding Conference (Dec ’08)
NORTH AMERICAN CO$_2$ SOURCE DELIVERIES
FOR ENHANCED OIL RECOVERY (1$^{st}$ Q ’09)

Average Daily North American CO$_2$ Source
Deliveries for CO$_2$ EOR - 1st Q '09

- Underground: 83.0%
- Nat'l Gas Plants: 10.6%
- Coal Synfuels: 4.9%
- Ethylene: 0.1%
- Ethanol: 0.0%
- Refinery: 0.0%
- Ammonia (Fert): 1.4%

TOTAL CO$_2$ VOLUMES
NA = 3.05 bcfpd
PB = 1.8 bcfpd
(Both New Records)

* Source: APTA CO$_2$ School (Jan ’09) and Melzer Consulting
Wyoming CO$_2$ Supply

Wyoming CO2 Purchases - 2000 to 2007

YEAR

CO$_2$ Purchases - mmcf/month

2000 2001 2002 2003 2004 2005 2006 2007

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000

100 mmcfpd
Permian Basin CO₂ Supply
Suppliers At Maximum Capacity

• McElmo Dome/Doe Canyon Source Fields Limited by Cortez Line Capacity (but a recent upgrade incremented throughput by 200 mmcfpd)
  1.1-1.3 bcfpd
  REACHED 1.3 BCFPD IN JAN & FEB)
• Sheep Mountain on Decline (~2-4 years life left?)
  40 mmcfpd
• Bravo Work Underway but Expansions are Challenging
  250 mmcfpd
• West Bravo Now On-line
  110 mmcfpd
• South Permian by-product CO₂ is Currently Compression Limited*
  80 mmcfpd
• South Permian by-product CO₂ is Currently Compression Limited*
  1.6-1.8 bcfpd

* But about to change
Permian Basin CO₂ Supply

Average Daily CO₂ Purchases w/ Projections - Permian Basin

- Coal Plant Capture CO₂ Additions?
- Nat’l Gas By-product CO₂ Additions

Year

Ave. Daily CO₂ Purchase Vols - mmcfpd
Proposed CO₂ Backbone Pipelines in Alberta

ICON Project Proponents:
- Suncor, Husky, Nexen, Shell and Air Products
- CNRL, ConocoPhillips, Syncrude, Imperial Oil, Transalta, Sherritt and Agrium

Currently in negotiations with the federal and Alberta governments

Note: Weyburn pipeline: 328 km (204 mi), capacity of 5 Mt/yr

Source: Bachu, 2008 CO₂ Conference
But What About EOR Growth Potential?
…and then, Where Would the CO₂ Come From?
SALT CREEK AND MONELL FLOOD PERFORMANCE
12,000 BOPD (@ 40% Development)

SALT CREEK AND MONELL CO₂ FLOOD PERFORMANCE

- Monell Unit BOPD
- Salt Creek CO₂ Oil BOPD
- Total CO₂ Injection MMCFD

CAGR of 20%
Gulf Coast CO₂ EOR Growth Record*

Projected Yearly Growth Rate of 10-20% through 2015

Ref: Denbury Resources, Inc. June 2009 Corporate Presentation  www.denburyresources.com
U.S. Growth Potential
## So How Much U.S. CO₂ EOR Potential is Out There?

### Table 4: Technically Recoverable Resources from Applying State-of-the-Art CO₂ EOR Technology *

<table>
<thead>
<tr>
<th>Basin/Area</th>
<th>DATA BASE</th>
<th>NATIONAL</th>
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<tbody>
<tr>
<td></td>
<td>OOIP (B Bbls)</td>
<td>OOIP Favorable for CO₂-EOR (B Bbls)</td>
</tr>
<tr>
<td>1 Alaska</td>
<td>65.4</td>
<td>64.5</td>
</tr>
<tr>
<td>2 California</td>
<td>75.2</td>
<td>31.6</td>
</tr>
<tr>
<td>3 Gulf Coast (AL, FL, MS, LA)</td>
<td>26.4</td>
<td>20.2</td>
</tr>
<tr>
<td>4 Mid-Continent (OK, AR, KS, NE)</td>
<td>53.1</td>
<td>28</td>
</tr>
<tr>
<td>5 Illinois/Michigan</td>
<td>12.0</td>
<td>4.6</td>
</tr>
<tr>
<td>6 Permian (W TX, NM)</td>
<td>72.4</td>
<td>63.1</td>
</tr>
<tr>
<td>7 Rockies (CO, UT, WY)</td>
<td>23.7</td>
<td>18</td>
</tr>
<tr>
<td>8 Texas, East/Central</td>
<td>67.4</td>
<td>52.4</td>
</tr>
<tr>
<td>9 Williston (MT, ND, SD)</td>
<td>9.4</td>
<td>7.2</td>
</tr>
<tr>
<td>10 Louisiana Offshore</td>
<td>22.2</td>
<td>22.1</td>
</tr>
<tr>
<td>11 Appalachia (WV, OH, KY, PA)</td>
<td>10.6</td>
<td>7.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>437.8</strong></td>
<td><strong>319.1</strong></td>
</tr>
</tbody>
</table>

* “Storing CO₂ with Enhanced Oil Recovery,” DOE/NETL-402/1312/02-07-08 dtd Feb 7, 2008, Advanced Resources International
Regional CO₂ EOR Growth Potential

Distribution of Technically Recoverable CO₂ Reserves*
in billions of barrels

Total Recoverable: 87.1 billion bbls

- Alaska: 20%
- California: 12%
- Gulf Coast (AL,FL,MS,LA): 7%
- Mid-Continent (OK,AR,KS,NE): 8%
- Illinois/Michigan: 1%
- Permian (W TX,NM): 7%
- Rockies (CO,UT,WY): 14%
- Texas, East/Central: 5%
- Williston (MT, ND, SD): 21%
- Louisiana Offshore: 3%
- Appalachia (WV, OH, KY, PA): 2%

* "Storing CO₂ with Enhanced Oil Recovery," DOE/NETL-402/1312/02-07-08 dtd Feb 7, 2008, Advanced Resources International
WHAT ARE THE LIMITING FACTORS FOR FURTHER GROWTH OF CO₂ EOR?

• LACK OF AFFORDABLE CO₂
• LOCAL AVAILABILITY / TRANSPORTATION NETWORKS
• CONVERGENCE OF CARBON CAPTURE AND STORAGE GOALS WITH CO₂ EOR
• NEXT GENERATION TECHNOLOGIES
One Large Next Generation Technology is Already Here!

(if Time Permits)
Hess to Expand

CORP. ANNOUNCES $300 MILLION PROJECT PLANS

According to Petroten, the RO2 wells, into the RO2, and the three directly underneath, are the main pay zones and will be converted from production to carbon dioxide injection for future production. All of the oil in the field will be handled with carbon dioxide injection.

The first stage of the development will include the deepening of 47 existing wells.
GEOGRAPHICAL AND GEOLOGICAL SETTING OF THE WASSON AND SEMINOLE FIELDS

San Andres Producing Fields and Approximate mid-San Andres Paleogeography

SSAU MPZ & ROZ Crossection and Zonal Attributes

Main Pay Zone (MPZ):
- 160' thickness
- 126' net thickness
- 12% porosity
- 0.8-120 md permeability range
- 1 billion stbo OOIP
- 0.84 oil saturation

Residual Oil Zone (ROZ):
- 246' thickness
- 197' net thickness
- 12.6% porosity
- 0.5-270 md permeability range
- 0.4-1.1 billion stbo OOIP
- 0.32 oil saturation

Bush, J. (2001), The SSAU Residual Oil Zone (ROZ) CO₂ Flood, "Presentation Slides, CO₂ Flooding Conference, Midland, TX. Dec 2001 (www.utpb.edu/ceed)
Seminole Field Water Saturation Profile*

**Seminole San Andres Unit**

SSAU Structure Map & Cross Section

<table>
<thead>
<tr>
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<th>Net Thickness</th>
<th>Average Permeability</th>
<th>Initial Oil Saturation</th>
</tr>
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<tbody>
<tr>
<td>Main Pay Zone (MPZ):</td>
<td>126'</td>
<td>9 md</td>
<td>84%</td>
</tr>
<tr>
<td>Residual Oil Zone (ROZ):</td>
<td>213'</td>
<td>12 md</td>
<td>32%</td>
</tr>
</tbody>
</table>

* Source: Biagiotti (2008), Hess Corp., CO₂ Flooding Conference (Dec '08)
But Not All the Policy for this Growth is in Place

(\textit{CO}_2 \textit{Sourcing is Still Challenging})
A QUICK LEAD-IN FOR TOMORROW

• STATE POLICY ACTIONS
  – Wyoming
  – Texas
  – Louisiana
  – Others

• FEDERAL ACTIVITY
  – Draft EPA Rules on Sequestration
  – Draft GhG Source Reporting Rules
  – Senate Energy Bill
  – Waxman-Markey Climate Change Bill
  – Stimulus (ARRA) Funding
SUMMARY (1)

• CO₂ EOR Growth has been Steady for Two Decades and Rapidly Accelerating in the Past Few Years

• For 2007-8, CO₂ Supplies Were at Full Utilization in the Permian Basin, Wyoming, and Canada (and Mississippi Supplies were Rapidly Expanding)

• Until the Very Recent Months, EOR Production Growth was Reflective of Lack of Supply Growth (New Projects were also Limited as a Result)
SUMMARY (2)

- Mississippi Supplies Were Not Similarly Constrained and Showed Dramatic Growth: EOR Production Rising Quickly as a Result

- Wyoming CO$_2$ Production Continuing to Grow as Salt Creek and Monell Mature

- Sudden Collapse of Oil Prices in Last Half of ‘08 Curtailed Demand Somewhat but Lingering, Pent-up Project Demand is Filling Gaps; New Projects are Being Announced and Implemented
SUMMARY (3)

• Further CO₂ EOR Production Growth Expected, Both Within the Three Regions and Canada plus Louisiana and Texas Gulf Coast, Michigan, Montana, Oklahoma, and Possibly California and Kansas

• Next Generation Technologies are Coming (‘Quaternary’ Oil)

• Policy Actions are Everywhere (Driven by Storage Considerations)
QUESTIONS?
BACKUP SLIDES
Canadian CO₂ Conclusions

- CO₂ EOR has not been developed in Canada because of the high cost of CO₂ (there are 68 tertiary recovery projects using natural gas and solvents)
- Policies and incentives for reduction of greenhouse gas emissions will create the regulatory and economic framework for CO₂ capture and transportation
- CO₂ will be used for CO₂ EOR wherever and whenever possible
- Large emitters will use deep saline aquifers and depleted gas reservoirs for storage of surplus CO₂

Source: Bachu, 2008 CO₂ Conference
HOW BIG IS THE CO₂ EOR BUSINESS?


- Cum Permian Basin CO₂ EOR Oil
- Cum US CO₂ EOR Oil

Annual Production Rev Figures**
- U.S. $8.0 billion*
- PB $5.3 billion*
  - * @ $80/bbl

* Source: Oil & Gas Journal (Mar ’08) and CO₂ Flooding Conference (2007)

** Does not take into account the NGLs produced from the recycle volumes