AN UPDATE: U.S. CO$_2$ EOR STATUS

Steve Melzer

Melzer CO$_2$nsulting

Casper, WY

July 11 & 12, 2012
CO\textsubscript{2} EOR Progress:

Let’s Examine Several Fronts

1. Overall U.S. Status
2. Regional EOR & \textit{Supply} Status
   - Wyoming/Rockies
   - Permian Basin
   - Gulf Coast
3. EOR and CO\textsubscript{2} Storage
4. Newsworthy Announcements/Events
5. Technical Advances/Challenges
6. Reservoir Target Expansions

\textit{and Finally}.............

7. Can I Really Make a Career in Oil/Gas?
Overall U.S. EOR Status

and Univ Tx of the Permian Basin’s Petroleum Industry Alliance
A CO$_2$ EOR Progress Report

“EOR Continues its Climb up the Hill”
CO₂ EOR PROJECT GROWTH*

GROWTH OF WW, U.S. and PERMIAN BASIN CO₂ EOR PROJECTS
1992 - 2012

- Worldwide Projects
- U.S. Projects
- Permian Basin Projects

8 projects/yr

* Oil & Gas Journal 4/2/12 & UTPB Petroleum Industry Alliance
CO₂ EOR Production Growth*

WW, U.S., & PB CO₂ EOR PRODUCTION
1986 - 2012

* Ref: O&GJ Biennial EOR Editions & UTPB Petr Industry Alliance

Melzer Consulting
# The CO₂ Suppliers, Transportation and EOR Companies

## Significant CO₂ Suppliers/Transporters

<table>
<thead>
<tr>
<th>Suppliers/Transporters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denbury Resources (Jackson***)&lt;br&gt;KinderMorgan (McElmo*, Doe Canyon*, Bravo*)&lt;br&gt;ExxonMobil (McElmo*, Sheep Mtn*, LaBarge**)&lt;br&gt;Occidental (Bravo*, Sheep Mtn*)&lt;br&gt;Dakota Gasification (N. Dak)</td>
</tr>
<tr>
<td>SandRidge/Oxy (Val Verde*)&lt;br&gt;CVR Partners: Coffeyville (under construction)&lt;br&gt;Chaparral Energy (Ok)&lt;br&gt;Chevron (McElmo*)&lt;br&gt;Core Energy (MI)</td>
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* Permian Basin, ** Wyoming, *** Mississippi, Gulf Coast (Tx, La), Wy/Mt (coming)

## CO₂ Flood Operators

(as of Jan '10)

<table>
<thead>
<tr>
<th>Operators</th>
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<tbody>
<tr>
<td>Anadarko (5)</td>
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<td>Apache Corp.(4)</td>
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<td>Chevron (7)</td>
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<td>George R. Brown Partnership (1)</td>
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<td>XTO Energy (4)</td>
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Regional EOR and CO$_2$ Supply Status
U.S. CO₂ Supply ( Capacities )

for the Big Three + ND Regions

- Wyoming/Rockies
  - Established 160 mmcfpd in 1986 (Shute Creek Plant)
  - Expansion to 240 mmcfpd in 2011 (Shute Creek Expansion)

- Permian Basin
  - Original ~100 mmcfpd in the 1970’s (Val Verde Nat’l Gas Plants)
  - Mid-80’s an Incremental 1 bcfpd (McElmo, Bravo Domes & Sheep Mtn)
  - Source Expansions at McElmo in early 2000’s
  - 2009 Expansion of McElmo Dome + Addition of Doe Canyon and Pump Stations on Cortex Pipeline - to 1.3 bcfpd

- Gulf Coast
  - Development of Jackson Dome in the 1980’s - to 100 mmcfpd
  - Expansions at Jackson in early 2000’s - to 400 mmcfpd
  - Additional Drilling at Jackson Dome in late 2000’s - to 1 bcfpd

- Dakota Gasification - 160 mmcfpd

TOTAL U.S. CO₂ SOURCE CAPACITY Dec 2011 = 3.2 bcfpd
U.S. CO₂ Sources

as of Dec 2011 and Ranked by Size of Source

Late 4th Q '11 CO₂ Sourcing for EOR

CO₂ Volumes in mmcfpd

- Permian Basin
- Gulf Coast
- Wyoming/Rockies
- Other

Melzer Consulting
In Three Years the CO₂ Supply Grew by 40% (from 2.3 bcfpd to 3.2 bcfpd)
EOR and CO$_2$ Storage
A Myth That You May Hear

- \( \text{CO}_2 \) stores only about half of the injected \( \text{CO}_2 \).

What that implies is that half the \( \text{CO}_2 \) is vented (which is quite obviously not the case).

The problem stems from the way we define retention:
- In the definition, we use total injected volumes (which includes the recycle) in the denominator instead of only the purchased volumes.
- So, ultimately, with roughly an equal volume of recycle as purchased volumes, the retained (stored) \( \text{CO}_2 \) amount appears to be 50%.
- If we would have used just the purchased volume, the ‘retained’ volumes would be close to unity.

The two following examples are illustrative.
CO₂ Balance

\[ CO₂_{prod} = 715,736,915 \text{ Mcf} \quad (40.9 \text{ MM tons} = 37.2 \text{ MM MT}) \]
\[ CO₂_{inj} = 705,312,883 \text{ Mcf} \quad (40.3 \text{ MM tons} = 36.6 \text{ MM MT}) \]

Total emission contribution \(~600,000 \text{ tons}\)
Reduction in emissions \(~98.5\%\) (compared to ‘conventional’ recovery of same volume of oil)
A Recently Reported Very Large (Oxy) Case History

An Example of Reported CO$_2$ Losses During CO$_2$ EOR in a Very Large Permian Basin Case History

Reference: Docket Number (08-AFC-8A) Amended Application For Certification
Hydrogen Energy California Power Plant Licensing Case
Amended Application For Certification


Other Pertinent Data from Reference: Hydrogen Energy California Power Plant Licensing Case

Docket Number: 08-AFC-8A
(Amended Application For Certification)

http://www.energy.ca.gov/sitingcases/hydrogen_energy/
CO₂ EOR/Storage Statistics:
Oxy Case History

- Total CO₂ Purchased Amount = 115 million MT*
- Total CO₂ Injected Amount = 252 million MT
- Total CO₂ Recycled Amount = 137 million MT
- Operating & Fugitive Losses = 0.3%
- Percent Sequestered = 99.7%

Data are illustrative of a large field in operation for 25 years. Each field is unique and ratios will vary by field and over time. Information predates EPA GHG reporting rule.

* Note that this is a very large EOR project: Equals a Cumulative 2.2 Trillion ft³ of Purchased CO₂
Newsworthy
Announcements/Events
(or...a look into the future)
The Single Most Important Limiter for EOR Growth
Making CO₂ Capture Affordable for EOR Projects

Background

- Lots of Cost Challenges for Capturing Industrial CO₂
- Oil Price has Helped Greatly with EOR Industry’s Ability to Pay More for the CO₂
- Industry is Slowly Dispelling the Myth that EOR Targets are Small and Insignificant Compared to CO₂ Capture Volumes, e.g., EOR technology, ROZs, higher oil prices
## CO₂ Supply

### (the Leading Indicator of EOR Growth)

**Rockies**
- Lost Cabin and GreenCore Pipeline (Wy/Mt) – Capture and PL under Construction: 50
- DKRW Coal Gasification (Wy) – In Financing: 230
- Riley Ridge (Wy) – Plant w/o CO₂ Capture Currently Under Construction: 130

**Permian Basin**
- Century Plant (Ph 1&2) – Ph 1 Complete, 2 under construction: ?
- Texas Clean Energy Project – Air Permit Approved, In Financing: 125
- Tenaska Trailblazer Project – Air Permit Approved, On hold: 250
- St. Johns Dome – Under Study: 350
- McElmo Dome – Upgrade AFE’d: 100
- Doe Canyon – Upgrade AFE’d: 100

**Gulf Coast**
- Faustina Petroleum Coke Gasification Project (La) – Under Construction: 100
- Air Products Port Arthur Hydrogen Generation Plant (Tx) – Nearing Completion: 100
- NRG W.A. Parish Plant (Tx) – Post Combustion Capture (status uncertain): 50
- Southern Company’s Kemper County Capture Project (Al) – Under construction: 100
- Leucadia Methanol Plant (La) – permitted: 100

**MidContinent**
- Coffeyville Gasification Project (Ks) – Capture Under Construction: 50

**Other**
- Hydrogen Energy California (Ca) – Permitting: 100
- Indiana Gasification, LLC (In) – Permitting: 275

**Total Incremental CO₂ =** 2010

(63%)
# CO₂ EOR

*(Follows the Available CO₂ Supplies)*

- **Rockies**
  - Grieve
  - Bell Creek (Mt)
  - Cedar Creek Anticline (Mt/SD)
- **Permian Basin**
  - Seminole ROZ Expansions
  - West and East Seminole
  - Goldsmith Expansion
  - Means ROZ
  - South Hobbs (NM)
  - George Allen
  - Greenfield ROZs
  - Etc.
- **Gulf Coast**
  - Hastings Expansions (Tx)
  - Citronelle (Al)
  - Conroe (Tx)
- **MidContinent**
  - Burbank (Ok)
- **Other**
  - Elk Hills (Ca)
  - Ventura (Ca)

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<th>Next 2 Yrs</th>
<th>2-5 Yrs</th>
<th>5+ Yrs</th>
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<td>South Hobbs</td>
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<td>George Allen</td>
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<td>Greenfield ROZs</td>
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<td>Etc.</td>
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<td>Hastings</td>
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<td>Conroe</td>
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<td>Burbank</td>
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<td>Elk Hills</td>
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<tr>
<td>Ventura</td>
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Other Potentially Significant Initiatives/Events/Announcements

• DOE and CCUS

• National Coal Council’s Recent Report

• NEO RI’s Work

• Indiana Department of Environmental Management (IDEM) issuance of a final PSD/Title V permit for Indiana Gasification Project
Technical Advances/Challenges

(Let’s Get Geeky for a Bit)
EOR Project Observations

• If Scaling Tendencies, Asphaltene and/or Parafin Problems are Noted in a Project during Primary or Secondary Phases of Production, CO₂ Phase will Most Often Demonstrate Accelerated Rates and Tendencies.

• Some Projects Display Significant Losses in Injectivity During the WAG Cycle and Some (generally smaller) Injectivity Losses upon Re-injection of CO₂ while Other Projects Do Not

• Blowdown Phase of CO₂ Can be Quite Unsuccessful
Reservoir Target Expansions
Permian Basin and Wyoming (Big Horn) ROZ Studies

- Many Basins in the World Possess Multiple Stages of Tectonics
- If a Basin has a Post Oil Entrapment Stage, Water Can Encroach Upon an Oil Reservoir and Sweep the Mobile Oil Out
  - A Residual Oil Zone (ROZ) Will be left Behind (We Call these “Naturally Waterflooded” Reservoirs)
- If the Residual Oil Saturation Left Behind is Sufficient (>20-25%), EOR Processes Will Work There Just Like they Have Worked in Man’s Water Floods
- Some Basins Possess Huge Amounts of Oil in the ROZs
  - Permian Basin San Andres Appears to have in Excess of 100 billion barrels in Place in the ROZs
  - Big Horn Basin Also Has a Huge Target Resource of Oil in Place
Unconventional* Reservoir Framework

The Industry’s ‘Lookback’

HC Maturation & Generation >> Original Entrapment >> Tectonic >> Modern Entrapment Readjustment

Source Rocks

Original Entrapments

Conventional Oil, Gas, and Heavy Oil Reservoirs

Shale O/G Accumulations

* Reservoirs Not Part of Modern, Conventional Entrapments
MIDDLE SAN ANDRES PALEOGEOGRAPHY
with Location of Industry Documented ROZ Zones/Fields*

- VACUUM FIELD
- Guadalupe Mountains
- Shelf Margin “reef”
- New Mexico
- Texas
- Delaware Basin
- Open Marine
- Restricted Carbonate Shelf
- WASSON FIELD (3)
- HANFORD FIELD
- SEMINOLE FIELD (4)
- MEANS FIELD
- GOLDSMITH FIELD
- Midland Basin
- Midland
- Hobbs
- Central Basin Platform
- Marathon Overthrust Belt
- Marathon

* Adapted from Sagnak (2006), Chevron Presentation at the 12/06 CO₂ Flooding Conference
# The List of On-going ROZ CO₂ EOR Projects

(All Brownfields in the Permian Basin)

## ON-GOING AND PLANNED ROZ CO₂ EOR PROJECTS

IN THE PERMIAN BASIN REGION OF THE U.S.

<table>
<thead>
<tr>
<th>Type and operator</th>
<th>Field</th>
<th>State</th>
<th>County</th>
<th>Top MPZ Depth, (ft)</th>
<th>Pay zone</th>
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<tr>
<td><strong>Active CO₂ miscible</strong></td>
<td></td>
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<tr>
<td>1. Chevron</td>
<td>Vacuum San Andres Grayburg Unit</td>
<td>NM</td>
<td>Lea Co.</td>
<td>4,550</td>
<td>San Andres</td>
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<tr>
<td>2. Fasken</td>
<td>Hanford</td>
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<td>5,500</td>
<td>San Andres</td>
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<tr>
<td>3. Hess</td>
<td>Seminole Unit-ROZ Phase 1</td>
<td>Tex.</td>
<td>Gaines</td>
<td>5,500</td>
<td>San Andres</td>
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<td>4. Hess</td>
<td>Seminole Unit-ROZ Phase 2</td>
<td>Tex.</td>
<td>Gaines</td>
<td>5,500</td>
<td>San Andres</td>
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<tr>
<td>5. Hess</td>
<td>Seminole Unit-ROZ Stage 1 Full Field Dev</td>
<td>Tex.</td>
<td>Gaines</td>
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<td>San Andres</td>
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<td>6. Hess</td>
<td>Seminole Unit-ROZ Stage 2 Full Field Dev</td>
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<td>Gaines</td>
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<td>7. Legado</td>
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<td>Ector</td>
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<td>8. Occidental</td>
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<td>Yoakum</td>
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<td>9. Occidental</td>
<td>Wasson Denver Unit</td>
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<td>10. Occidental</td>
<td>Wasson ODC</td>
<td>Tex. &amp; Gaines</td>
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<td>11. XTO/ExxonMobil</td>
<td>Means</td>
<td>Tex.</td>
<td>Andrews</td>
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<td>San Andres</td>
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</table>

Rumored Additions:
- Conoco at East Vacuum (2012)
- Chevron at Central Vacuum (2012)
- XTO at CA Goldsmith (2013?)
- Tabula Rasa at E. Seminole and Lindoss (2013)
- A Greenfield ROZ (Operator wants to remain Confidential)
EXTENDING EOR BELOW THE OIL/WATER CONTACT

Seminole Field

Main Pay Zone (MPZ):
- Gross Thickness: 160’
- Net Thickness: 126’
- Porosity: 12%
- Permeability Range: 0.8-120 md
- OOIP: 1 billion stbo
- Oil Saturation: 0.84

Residual Oil Zone (ROZ):
- Gross Thickness: 246’
- Net Thickness: 197’
- Porosity: 12.6%
- Permeability Range: 0.5-270 md
- OOIP: 960 million stbo
- Oil Saturation: 0.32

Reference Slides are from the 2001 and 2008 CO₂ Flooding Conferences
A NEW FOURTH PHASE? ‘QUATERNARY’ OIL*

Total, Primary, Waterflood, Main Pay and ROZ CO₂ Performance
(the Concept of "Brownfield" Quaternary Oil)

* SHAPE OF THE CURVE WILL BE DICTATED BY THE AVAILABILITY OF AMPLE, AFFORDABLE CO₂
and the ROZ Production in Aggregate
Permian Basin ROZ Production Rollup

CO2 EOR OIL PRODUCED BELOW THE OIL/WATER CONTACT (PERMIAN BASIN)

- Project 1
- Project 3
- Project 4
- Project 2
- Aggregate PB ROZ

Now Exceeds 11,000 bopd!!
and Finally……

Can I Make a Career out of the U.S. Oil and Gas Business?
Hubbert Curve

Annual Oil Production
U.S. Lower 48

Oil Production in Billions of Barrels/Year


Woops....what happened?
Violating the Classic Hubbert Curve

Permian Basin Historical Production

Analysis Provided by Oxy Permian (2005)
Really Non-Classic “Hubbert Curve”

Texas RRC Districts Around Midland

Districts: 07C, 08C

Well Count

Pk of 1.0 MM bopd

0.6 MM bopd & headed ‘North’

Compliments of Drilling Info
EIA Violating the Hubbert Curve

Ref: EIA Annual Energy Outlook 2012, p. 95, Jun 2012
And the EIA Forecast*

It is Official: Hubbert’s Curve is Dead

* AEO2012 dtd 6/12
The End

Thanks Need to go to EORI and to Lon Whitman for his Expert Help on several of the Slides
The CO₂ Conference Week is Coming!

Be Part of the Conversation

We are seeing some really interesting things in the field.

Carbon Management Workshop, Houston – December 3 & 4
CO₂ Flood Field Trip, Midland – December 5
CO₂ Flooding Conference Theme Sessions - December 6 & 7

For More Information See www.CO2Conference.net
(Registration Begins after Labor Day)
Backup Slide
# Large Scale Power Plants w/ CCS Projects (North America)

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Leader</th>
<th>Feedstock</th>
<th>Size MW</th>
<th>Capture Process</th>
<th>CO2 Fate</th>
<th>Start-up</th>
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<td>TCEP</td>
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## Canada

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