The History and Development of CO₂ EOR in the Permian Basin with an Emphasis on Pipelines

The Wyoming Enhanced Oil Recovery Institute’s Joint Producers Meeting

“CO₂ in Wyoming”

Casper, Wyoming

L. Stephen Melzer

June 26, 2007
The History and Development of CO₂ EOR in the Permian Basin with an Emphasis on Pipelines

1) Historical Overview of PB CO₂ Projects and Production
2) The Stages of Development
3) The Historical Linkage between CO₂ and Oil Prices
4) CO₂ Project and Pipeline Evolution & Source-to-Sink Anchor Projects
5) Anthropogenic CO₂: The Vital Role of CO₂ Specifications and H₂S
6) Aggregation of Supply and Sinks and the Role of Competition
7) Ownership, Point-to-Point, and Open Access Issues
8) Facilitating the Pipelines – Government/Quasi Government and Commercial Facilitators
PERMIAN BASIN CO$_2$ PROJECT STARTS

YEARLY PROJECT STARTS

- Project Starts
- Cum Project Starts (Rt Scale)

YEAR


CUM PROJECT STARTS

0 10 20 30 40 50 60 70

Cluster #1:
Large & Reliable Supply

Cluster #2:
Economic Success

The Start:
North Cross and SACROC
RECENT GROWTH OF PERMIAN BASIN
CO$_2$ PROJECTS & PRODUCTION
1984 - 2006

- Projects
- PB Production (Rt Scale)
The Stages of Development

Six Phases of CO₂ EOR in the PB

I. Demonstration/Observational Phase
II. Commercial Deployment Phase
III. 1st Oil Price Crash ('86)
IV. Renewed Deployment
V. 2nd Oil Price Crash ('98)
VI. Source Limited Expansion

PERMIAN BASIN CO₂ PROJECT STARTS

YEARLY PROJECT STARTS

YEAR


Growth

2 4 6 8

Cumulative Project Starts

0 10 20 30 40 50 60 70

0 10 20 30 40 50 60 70
THE TWO BILLION DOLLAR PERMIAN BASIN CO₂ PIPELINE INFRASTRUCTURE*

* VALUED @ $40K / INCH-MILE

Chart Adapted From Havens, K., 2003 EOR Carbon Mgmt Workshop, Midland, Tx
The Three Billion Dollar
PERMIAN BASIN CO2 PLANT AND PIPELINE INFRASTRUCTURE

[Map of Permian Basin showing existing pipelines, gas plants, and fields, with labels for various locations such as Denver City Hub and McCamey Hub.]
The Historical Linkage Between CO$_2$ and Oil Prices
HISTORICAL OIL AND CO₂ PRICING
(PERMIAN BASIN)

WTI Posted Oil and Denver City CO₂ Prices - 1983-2006

- Average Yrly Price of WTI Crude Oil
- Average Yrly Price of New CO₂ @ Denver City (Rt Scale)

YEAR

CO₂ PRICES IN $/mcf

OIL PRICES IN $/bbl

Mar-07
CO₂ and Oil Price Sensitivities to Project ROR*

Slope ~ -2.4% per dime

Slope ~ 2.2% per dollar

For this (Old) Example at least: a dollar of Oil Price Increase ~ to a dime of CO₂ Price Decrease

- Internal Rates of Return Calculated Using KinderMorgan Spreadsheet Model for a Moderate-sized San Andres flood
CO$_2$ Pricing as a Function of Regional Flooding Maturity

**STAGE OF EOR DEVELOPMENT (Maturity)**

I. Mature Proven EOR Area & Reservoir: Ready for CO$_2$ Contracting

II. Mature Proven EOR Area & New Reservoir: Needs Pilot/Simulation Work

III. New EOR Area: Needs Pilot/Simulation – Success Risk Higher
CO₂ PRICING CONCEPTS (from Seller’s Viewpoint)

Example CO₂ Sales Algorithms
For Utilization in Contracts

- "Mature" EOR Area
- "Unproven" EOR Area
- "Unproven" EOR Reservoir

Oil Price vs. CO₂ Price

Area Risk "Premium"
Reservoir Risk "Premium"
PB CO₂ Project and Pipeline Evolution and Source-to-Sink Anchor Projects
PB CO₂ DEVELOPMENT HISTORY

*Adapted From Stout, J., 2003 EOR Carbon Mgmt Workshop, Midland, Tx

Colors
1970’s
1980’s
1990’s
2000’s
PERMIAN BASIN HISTORY

- VERY LARGE UNDERGROUND CO\textsubscript{2} SOURCES DEVELOPED BY FLOODERS (*INTEGRATED DEVELOPMENT*)
- SMALLER COMPANIES “PIGGY-BACKED” ON LARGE SOURCES AND PIPELINES PAID FOR BY ANCHOR PROJECTS (*WASSON, SEMINOLE, SLAUGHTER*)
- BIG SOURCES AND OVERSIZED PIPES LED TO CENTRAL BASIN AND CENTERLINE PIPELINES

THE PB ANALOGUE TO WYOMING BREAKS DOWN HERE
- WY SOURCES OWNED BY ENTITIES OTHER THAN FLOODERS
- “ANCHOR” PROJECTS MAY BE TOUGH TO FIND, THUS FLOODERS NEED TO AGGREGATE DEMAND
- SOURCES ARE SMALLER; NEED TO AGGREGATE SUPPLY
  - FOR SCALE
  - FOR RELIABILITY
- IN WY, THE COAL AND EOR PARTNERSHIP IS ASSURED!
PERMIAN BASIN CO₂ EOR PROJECTS

DISTRIBUTION OF SIZE OF CO₂ PURCHASES BY PROJECT

Distribution of Project CO₂ Purchases by Project*

Total Purchase Volumes = 1.4 bcfpd = 30 million tons per year

Project Plant CO₂ Output = 1 million tons per year


ANCHOR STATUS

Project No.

Melzer Consulting
ANTHROPOGENIC CO$_2$

THE VITAL ROLE OF CO$_2$ SPECIFICATIONS
AND H$_2$S
THE EVOLVING AND EXISTING FRAMEWORK
for CO₂ Pipeline Systems

**Type I**  Special, Single Use Pipelines
(Case-by-case Specifications for Carried Fluid Composition)

**Type II**  The North American Network i.e.,
Multiple Source and User Lines
(Strict Specified CO₂ Composition)

**Type III**  Hybrid Lines (Relaxed but Controlled CO₂ Composition)
TYPE I
SPECIAL, SINGLE USE “CO₂” PIPELINES

• Does Not Attempt to Commoditize CO₂
• Minimizes Processing Cost of CO₂
• Specification of Carrier (Injectate) Fluid Could Vary Widely
• Would Most Often be a Short Run Pipeline Connecting Single Source to Single Sinks or Sink Clusters
• Common Source-to-Sink Ownership

No Current (High Volume) Operational Models for Type I CO₂ Pipelines
Current CO₂ Pipeline Systems
i.e., Commodity CO₂ Lines

Types II and III
Type II
MULTIPLE SOURCE AND USER LINES (HIGH VALUE AND SPECIFIED CO₂ COMPOSITION)

- Designed to Connect Multiple Sources with Multiple Sinks
- Strict Specifications for CO₂
- Multiple Pipeline Interconnects
- Several Pipeline Models Exist Today that can/will Interconnect to Future Lines (Perhaps Evolving to a North American CO₂ Pipeline Network)
Type III
HYBRID (RELAXED SPEC) CO₂ PIPELINES

• Can Include Multiple Sources and Multiple Sinks
• Locally Sink-Defined Specifications for CO₂
• Commodity Pipeline (Lower Value Carrier Fluid)
  – e.g., High H₂S, High N₂ (ECBM)
• Shorter Run Pipelines
• Possible Special Operational Safety Issues
  – e.g., High H₂S Concentrations
# Existing Transportation Network

## The Major North American CO₂ Pipelines

*Ref. Melzer Consulting '07*

<table>
<thead>
<tr>
<th>PIPELINE</th>
<th>Owner/Operator</th>
<th>Length (mi)</th>
<th>Length (km)</th>
<th>Diameter - in</th>
<th>Estimated Max Flow Capacity (mcm/d)</th>
<th>Estimated Max Flow Capacity (million tons/yr)</th>
<th>Location</th>
<th>PL Type</th>
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<td>Este I - to Welch, Tx</td>
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<td>40</td>
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<td>98</td>
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* Tabulation does not include many shorter high pressure trunk lines to individual fields.
### CO₂ PIPELINE SPECIFICATIONS

**Example 1**

*(Type II)*

**NATURAL SOURCE (COMPANY "X")**

Permian Basin CO₂ Specifications

<table>
<thead>
<tr>
<th>Gas specifications</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>CO₂</td>
<td>95% by volume</td>
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<tr>
<td>H₂S</td>
<td>&lt;10 ppmbw</td>
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<tr>
<td>Sulphur</td>
<td>&lt;35 ppmbw</td>
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<tr>
<td>Total Hydrocarbons</td>
<td>&lt;5% by volume</td>
</tr>
<tr>
<td>CH₄</td>
<td>- not specified</td>
</tr>
<tr>
<td>C₂+ hydrocarbons</td>
<td>- not specified</td>
</tr>
<tr>
<td>CO</td>
<td>- not specified</td>
</tr>
<tr>
<td>N₂</td>
<td>&lt;4% by volume</td>
</tr>
<tr>
<td>O₂</td>
<td>&lt;10 ppmbw</td>
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<tr>
<td>H₂O</td>
<td>&lt;25 #/mmcf</td>
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*Personal Communications*
# CO₂ PIPELINE SPECIFICATIONS

**EXAMPLE 2**

(Type II)

## NATURAL SOURCE (COMPANY "Y")

Permian Basin CO₂ Specifications*

<table>
<thead>
<tr>
<th>Gas specifications</th>
<th>Requirement</th>
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<tr>
<td>H₂S</td>
<td>&lt;20 ppm bw</td>
</tr>
<tr>
<td>Sulphur</td>
<td>&lt;30 ppm bw</td>
</tr>
<tr>
<td>Total Hydrocarbons</td>
<td>&lt;5% mole %</td>
</tr>
<tr>
<td>CH₄</td>
<td>not specified</td>
</tr>
<tr>
<td>C₂+ hydrocarbons</td>
<td>not specified</td>
</tr>
<tr>
<td>CO</td>
<td>not specified</td>
</tr>
<tr>
<td>N₂</td>
<td>&lt;4% mole %</td>
</tr>
<tr>
<td>O₂</td>
<td>&lt;10 ppm bw</td>
</tr>
<tr>
<td>H₂O</td>
<td>&lt;30 #/mmcf</td>
</tr>
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* Personal Communications
**CO₂ PIPELINE SPECIFICATIONS EXAMPLE 3**

(Type III)

**Dakota Gasification Corporation**  
**WEYBURN PIPELINE**

<table>
<thead>
<tr>
<th>Gas specifications</th>
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<tr>
<td>CO₂</td>
<td>96% by volume</td>
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<td>H₂S</td>
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<tr>
<td>N₂</td>
<td>&lt;300 ppmbv</td>
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<tr>
<td>O₂</td>
<td>&lt;50 ppmbv</td>
</tr>
<tr>
<td>H₂O</td>
<td>&lt;20 ppmbv</td>
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* Ref: http://www.apgtf-uk.com/15Jan03/pdf/09%20RILEY%20Transport%2015Jan03.pdf
## SUMMARY OF CO₂ PIPELINE SPECIFICATIONS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Example 1</th>
<th>Example 2</th>
<th>Example 3</th>
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<td>CO₂ - % by volume</td>
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<td>95%</td>
<td>96%</td>
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<td>H₂S - ppmbw</td>
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<td>20</td>
<td>10,000</td>
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<td>Sulphur - ppmbw</td>
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<td>Total Hydrocarbons - % by volume</td>
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<td>CH₄ - % by volume</td>
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<td>-</td>
<td>1,000</td>
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<td>N₂ - % by volume/vol</td>
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<td>O₂ - ppm by wt/vol</td>
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<td>50</td>
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<tr>
<td>H₂O - #/mmcf* or ppm by vol</td>
<td>25*</td>
<td>30*</td>
<td>20</td>
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</table>
CONTAMINANT ISSUES
Affecting CO₂ Commodity Value

Pipeline Corrosion (Water and Oxygen)
Safety (e.g., H₂S)
Dense (Critical) Phase Degradation (e.g., N₂, CH₄)
Reservoir Microbial Activity (e.g., Oxygen)
Oil Miscibility (e.g., N₂, CH₄)
Enhanced Gas Recovery
Others?
Aggregation of Supply and Sinks and the Role of Competition

Two Lessons from the Permian Basin:

“Industrial Supplies of \( \text{CO}_2 \) are not the Primary Product of the Commercial Operation and that Often Leads to a Lower Reliability Factor than Desired”

“Competition is the Facilitator to Deal Consummation”
Ownership, Point-to-Point, and Open Access Issues
INDIVIDUAL or COMMON OWNERSHIP

CAPACITIES CONTRACTED BY PL OWNER(s)/OPERATOR

COMMON TARIFFs FOR EACH TRANSPORTER

PRIVATE PIPELINE, NO OPEN ACCESS

BRAVO AND SHEEP MTN MODELS (PERMIAN)
DIVIDED OWNERSHIP (a)

CAPACITIES CONTRACTED BY EACH OWNER

SEPARATE TARIFFS FOR EACH OWNER

PRIVATE PIPELINE, NO OPEN ACCESS

ESTE MODEL (PERMIAN)
DIVIDED OWNERSHIP (b)

- CAPACITIES CONTRACTED BY EACH OWNER
- SEPARATE TARIFFS FOR EACH OWNER
- FOR PRIVATE PORTION, NO OPEN ACCESS
- ACCOMODATION FOR GROWTH
- FOR ‘PUBLIC’ PORTION, OPEN ACCESS

PUBLIC

PRIVATE

ALBERTA MODEL?
FACILITATING THE PIPELINES

GOV’T / QUASI GOV’T AND COMMERCIAL FACILITATORS
FACILITATORS AND ROLES

- **INDUSTRY**
  - PAST SOURCE-TO-SINK MODELS DOMINATE
  - BUT EXCEPTIONS DO EXIST
  - SEPARATE PL COMPANIES AS FACILITATORS

- **QUASI-GOVERNMENT**
  - WYOMING PIPELINE AUTHORITY MODEL

- **GOVERNMENT ROLES**
  - CAPACITY ENHANCEMENTS (OWNERSHIP)
  - ROW ASSISTANCE
    - EMINENT DOMAIN
      - TRANS TEXAS CORRIDOR MODEL
LIST OF PL FACILITATORS

(FOR TYPES II AND III {PARTIAL?})

• KINDER MORGAN
• TRINITY CO$_2$
• BLUE SOURCE
• EL PASO (CIG)
• PENN WEST
• ENBRIDGE
• SEMPRRA
Special Thanks is Expressed to the Annual CO₂ Flooding Conference For Many of the Insights Provided Herein

Held Each December in Midland, Texas – Home to 53 Active CO₂ Floods

Concentrates on Actual Case Histories

Includes a CO₂ Flood Field Visit (this year to Whiting’s New N. Ward-Estes Project)

Includes a CO₂ Shortcourse (this year on Geologic Aspects of EOR & CCS)

Includes an EOR Carbon Management Workshop (this year in Dallas)

Great Networking Opportunity (Last year with 300 practitioners representing 100 companies)

Visit: www.spe-pb.org or call 432-552-2430

Dec 3 & 4 – Workshop in Dallas
Dec 5 – (Midland) Shortcourse & Field Trip
Dec 6 & 7 – (Midland) Flooding Case Histories
QUESTIONS??
A FEW TOPICS FOR LATER DISCUSSION

1) WILL OTHER STATES BE LOOKING TO WYOMING TO MODEL THE ‘NATURAL ALLIANCE’ OF CLEAN COAL AND EOR?

2) HOW CAN THE STATE BEST ASSIST BEYOND WHAT IS HAPPENING ALREADY?
   1) Pipelines?
   2) Recycle Plants?
   3) Other Ways?

3) AND HOW DOES THE STATE DO THIS WITHOUT WORRYING ABOUT ‘CORPORATE FAVORITISM’

4) WILL COMING NEW SOURCES INTERCONNECT WITH EXISTING PIPELINES?

5) WHERE ARE THE:
   1) Anchor Supply and EOR Projects?
   2) New Backbone Pipelines
   3) Key Recycle Facilities