CO$_2$ Capture and EOR: Can Both Be Profitable Together

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Agenda

• Present Situation
• Carbon Capture Utilization and Storage Challenge
• Where the Economics Don’t Work
• Where the Economics Do Work
• Conclusions
CCUS is Happening Now

- CO₂ flooding began with anthropogenic sources
- Val Verde Basin, Enid Fertilizer Plant, La Barge, Dakota Gasification Plant
- No power plants

U.S. Pipeline Systems
Source: Kinder Morgan
50 Million TPY (1% US Emission)
Mostly Non-Anthropogenic
To capture CO₂, transport it to an oil field, use it for EOR, securely store it
The CCUS Challenge

To capture CO₂, transport it to an oil field, use it for EOR, securely store it and do so at a profit.
Kemper Project

- “one of the most-expensive”
- “$4.7 billion and rising”
- “scaring people away”
- “calamity”

Source: WSJ, Oct 13, 2013
CCUS Often Has Unfavorable Economics

Abatement Cost – €/tCO₂e

Abatement Potential – GtCO₂e per year

Gas plant retrofit
Coal plant retrofit
Coal plant new build
Coal plant new build with EOR

CCS Activities

After: Global GHG Abatement Cost Curve v2.0, McKinsey & Company
2007 CO₂ Mitigation Costs ($/tonne)

- Nat Gas Elec Plant: $67 + $24 (Cost of CO₂ Avoided)
- Std Coal Elec Plant: $76 + $5 (Cost of CO₂ Captured)
- Gasification Elec Plant: $40 + $5 (Total Cost)
- '07 Target Price: $31

Sources: NETL, IPCC, Personal Knowledge
When Do the Economics Work?

Example Project

- 50 MMCFD
- 90 miles
- Vented Pure CO₂ (wet)
- Oil field needs CO₂ for 10 years (182.5 BCF)
- Oil field needs CO₂ at a price <= 2% of oil price

1 tonne CO₂ ~ 19.3 MCF CO₂
50 MMCFD ~ 946,000 TPY
Dehydration and Compression Cost Equations

- Plant capital = $3,000 ( HP )
- Plant operating costs (excl. power) = $0.08/MCF
- Plant Power Cost/Day =
  \[ 0.75 \times \frac{\text{HP}}{1000} \times 24 \times \text{($/MW-hr)} \]

\[ \text{CO}_2 \text{ Dehydration Equipment} \]
\[ \text{Colorado, U.S.A.} \]
\[ \text{Source: Kinder Morgan} \]
Power Price Equation

- Power Price = Wires + (Heat Rate) (Gas Price) + Adder
  $/MW-hr = $10 + 8 ( $/MMBTU gas price ) + $10

Assume natural gas price = $4/MMBTU

Power Price = 10 + (8) (4) + 10 = $52/MW-hr

Currant Creek Power Plant
Horsepower Calculation

• HP = 22 ( Rs ) ( s ) ( Q ) ( F )

Assume: Ps = 0 PSIG (15 PSIA)

Pd = 2200 PSIG (2215 PSIA)

s = no. stages = 5 (5 Stage unit)

Rs = comp ratio/stage < 3.0 to 4.0

Rs = (2215/15) ^ (1/5) = 2.7

Q = 50 MMCFD

F = 1 for s = 1; 1.07 for s = 2; 1.1 for s > 2

• HP = 22 ( 2.7 ) ( 5 ) ( 50 ) ( 1.1 ) = 16,300 HP
Dehydration and Compression Cost Calculation

• Plant Cost = $48.9 million
• Equivalent Uniform Annual Cost (15%) = $9.7 Million
• Unit Capital Cost = $0.53/MCF
• Plant Operating Cost = $0.08/MCF
• Plant Power Cost/Day = $15,300
• Plant Power Cost /MCF = $0.31/MCF
• Total Cost = 0.53 + 0.08 + 0.31 = $0.92/MCF
Transportation Costs

- Pipeline Cost = $50,000 / in-mile
- 10 inch pipe needed for the 90 mile pipeline
- Cost = (90) (10) ($50,000) = $45 million
- Equivalent Uniform Annual Cost (15%) = $8.9 million
- Pipeline Tariff = $0.49/MCF

Katz CO₂ Pipeline
Source: Kinder Morgan
Delivered Price vs. Maximum Price

- Dehydration and Compression Cost = $0.92/MCF
- Pipeline Tariff = $0.49/MCF
- Delivered Price (at 15%) = $1.41/MCF
  (at 20%) = $1.62/MCF
- Maximum CO$_2$ price is about 2% of oil price
  1.35/0.02 = $71 per barrel
  1.55/0.02 = $81 per barrel
- Therefore CCUS is economically feasible
Sources of Pure CO$_2$

- Fertilizer Plants
- Natural Gas/CO$_2$ Separation Plants
- Coal Gasification Plants  
  (not economic to build)
- IGCC Plants  
  (not economic to build)
- Underground CO$_2$ Source Fields

CO$_2$ Compressor
Source: Kinder Morgan
Conclusions

• Capture at pulverized coal power plants is too expensive to combine with EOR
• Capture at coal gasification plants including IGCC plants is economically attractive if the plant is already built
• Capture of pure CO2 is economically attractive depending on the location