The Economics of Enhanced Oil Recovery: Does it Make Cents?

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4 Key Drivers of EOR Profitability:

1. Reservoir characteristics
2. Future price of oil
3. Price of CO$_2$
4. How you perform your economics
Is the *Net Present Value* (NPV) of future cash flows positive?
\[
\text{NPV} = \sum_{t=1}^{T} \frac{P_t Q_t (1 - x^R)(1 - x^{SP}) - pq^p_t - c^r_t q^r_t - c^o_t}{(1+r)^t} - K
\]

- \( P_t \) = price of oil in year \( t \)
- \( Q_t \) = the projected *incremental* amount of oil recovered in period \( t \)
- \( x^R \) = royalties
- \( x^{SP} \) = severance and property taxes
- \( pq^p_t \) = cost of CO\(_2\)
- \( c^r_t q^r_t \) = cost of recycling and reinjecting CO\(_2\)
- \( c^o_t \) = other incremental operating costs
- \( K \) = upfront investment costs
- \( r \) = discount rate

Future Oil Prices: What Can We Say Intelligently?

Figure 2.1: World Oil Prices (1950-2008)

They will fluctuate!

Source: Energy Information Administration
Forthcoming Book with Yale University Press:


Dr. James M. Griffin
1. China’s Oil Demand Has Mushroomed

Figure 2.2: Annual Increase in Oil Consumption by Areas (2001-2007)

2. OPEC’s Capacity Limits Prevented Increased Production

Figure 2.3: Spare Capacity in OPEC vs. Oil Prices

3. Worldwide Refining Capacity Is the Bottleneck

Figure 2.4: Price Premium for Light Sweet Crude Oil
(Price WTI Crude - Price Mayan Crude)

Source: Energy Information Administration (2008)
4. Shortage of Low-Sulphur Diesel Fuel

Figure 2.5: Premium for Diesel Fuel Over Crude Oil
(Price Diesel - Price WTI Crude)

Source: Energy Information Administration (2008)
5. Declining Value of the Dollar

Oil Prices in Dollars vs. Euros
(January 2004 = 100)

[Diagram showing the comparison of oil prices in dollars and euros from January 2004 to June 2008, with a significant increase by July 2008.]

Jul 08
$477

Jul 08
€382
6. The real culprits are the international oil companies.
7. Wall Street speculators are the culprits

- Tremendous influx of funds to commodity index funds
8. Peak oil production proponents

- Non-OPEC production has or is nearing its peak – Colin Campbell

- OPEC production has peaked as well
  --Matthew Simmons – “Twilight in the Desert”
  - Ghawar is in decline
  - Saudi Reserves are a fabrication?
9. OPEC Cartel
9. The OPEC Cartel Is Propping Up Prices

Figure 2.6: Demand Growth Met by OPEC and Non-OPEC Sources 2001-2007

Long Run Oil Prices Will Be Determined by Supply & Demand Fundamentals

- China’s oil demand has mushroomed
- OPEC’s capacity limits prevented increased production
- Worldwide refining capacity is the bottleneck
- The shortage of low-sulphur diesel fuel is driving up oil prices
- The declining value of the dollar is the cause of high oil prices
- The real culprits are the international oil companies
- No, Wall Street speculators are the culprits
- World oil production has peaked
- The OPEC cartel is propping up prices
Four Keys to the Future Oil Price Puzzle

1. Emergence of China & other Asian countries as major oil consumers
2. Can and will OPEC expand capacity?
3. What is the long run price elasticity of oil demand?
4. What is the supply responsiveness from non-OPEC sources?
   - Conventional oil outside OPEC
   - Oil substitutes – oil sands, GTL, Ethanol
Key 1: Robust Demand Growth from China and Other Asia

<table>
<thead>
<tr>
<th>Decade</th>
<th>World GDP Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decade of 1990s</td>
<td>2.8% / yr</td>
</tr>
<tr>
<td>Decade of 2000s</td>
<td>3.9% / yr</td>
</tr>
</tbody>
</table>

Every 1% higher GDP growth = extra 750,000 B/D
Key 2: Can and Will OPEC Expand Capacity?
The Problem Is Not the Limits of the Resource Base

Figure 5:
Physically Possible Saudi Production through 2050
# The Supply Potential of Six OPEC Countries

## Table 1

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves+</th>
<th>Estimated Undiscovered</th>
<th>Total</th>
<th>Years Remaining*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saudi Arabia</td>
<td>263</td>
<td>87</td>
<td>350</td>
<td>86.9</td>
</tr>
<tr>
<td>Iraq</td>
<td>115</td>
<td>45</td>
<td>160</td>
<td>240.9</td>
</tr>
<tr>
<td>Iran</td>
<td>133</td>
<td>53</td>
<td>186</td>
<td>125.9</td>
</tr>
<tr>
<td>Venezuela</td>
<td>77</td>
<td>20</td>
<td>97</td>
<td>88.4</td>
</tr>
<tr>
<td>Kuwait</td>
<td>99</td>
<td>4</td>
<td>103</td>
<td>106.8</td>
</tr>
<tr>
<td>The United Arab Emirates</td>
<td>98</td>
<td>8</td>
<td>106</td>
<td>105.6</td>
</tr>
</tbody>
</table>

+In billion barrels as of 2005; *Assuming current production rate

Sources: British Petroleum Statistical Review, United States Geological Survey
Response to Doomsdayers

Some Interesting Arithmetic:

- Oil Reserves in 1975: 386 bil bbl
- Cumulative Oil Production (1976-2006) - 800 bil bbl
- Current Oil Reserves: 1317 bil bbl

MIT’s Workshop on Alternative Energy Strategies (1977)

- Peak between 1983 and 1993

Hubbert Curve for 2000

- 50% of actual

Even if peak in conventional oil...

- What about EOR, Oil Sands, and GTL?
Key 2: Can and Will OPEC Expand Capacity?

Possible Constraints

- Physical limits of resource base
- NOC’s Access to technical expertise
- Investment funds necessary
  - Paradox of Riches
- Geo-political constraints
  - Iraq, Iran, and Venezuela
Keys 3 & 4: The Long Term Effect of Prices

High Oil Price Scenario

Figure 5
The Supply/Demand Balance Under Continued High Prices
Keys 3 & 4: The Long Term Effect of Prices

Low Oil Price Scenario

Figure 6
The Supply/Demand Balance Under Reversion to Low Prices

- Non-OPEC Oil + NGL
- Non-Conventional Fuels
- OPEC Oil + NGL

Millions of Barrels Daily
What’s my Bottom Line on Oil Prices?

- Plan for Considerably Lower Oil prices
- And Hope you’ll be pleasantly surprised!
  - Is a Project Viable at $40 oil?
  - What’s the upside at $60, $80, $100?
Break Time: Watch those Urinals
4 Key Drivers of EOR Profitability:

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2. Future price of oil
3. Price of CO$_2$
4. How you perform your economics
## How Important is Price of CO$_2$?

### Example of Elk Basin fields ($P_{oil} = $100)

<table>
<thead>
<tr>
<th>Price of CO$_2$</th>
<th>NPV @ 20% (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 / mcf</td>
<td>$1,375</td>
</tr>
<tr>
<td>$2 / mcf</td>
<td>$1,132</td>
</tr>
<tr>
<td>$3 / mcf</td>
<td>$889</td>
</tr>
</tbody>
</table>

What Do CO₂ Contracts Look Like?

\[
\text{Standard Contract Price} = \text{Base Price} + x[\text{maximum}[(\text{Poil}_t - \text{floor}) \text{ or } 0]]
\]

e.g.

\[
\$2.00 / \text{mcf} = 1.00 + .02[\$100 - \$50]
\]
Optimal Contract:

- Set Base Price = Marginal Cost of Production + Transportation

  - Structure the contract so that even in low oil price world, you will continue CO$_2$ injection

- $x = \text{Allows CO}_2\text{ seller to share oil price risk}$

  - Set $x$ so that CO$_2$ Provider shares in upside
Usual Approach:

- Build in oil price risk with higher discount rate ($r$)
  
  $$r = 0.20 \text{ or } 0.25 > \text{cost of capital}$$

Alternative Approach:

1. Adopt a much lower discount rate
   
   $$r = 0.12$$

2. Build in oil price risk with conservative oil price assumptions
Alternative Approach Cont...

- **Analyze 4 states of the world:** using lower discount rate & conservative oil prices as discussed earlier
  
  - \( r = .12 \)
  
- (1) \( P_{oil} = $40 + \text{inflation} \)
- (2) \( P_{oil} = $60 + \text{inflation} \)
- (3) \( P_{oil} = $80 + \text{inflation} \)
- (4) \( P_{oil} = $100 + \text{inflation} \)
Lance Creek/Leo - CO2 and Incremental Oil
Powder River Basin

Source: Owen Phillips et al.
What is the NPV of oil prices at $100 / barrel in 20 years?

@ 12% discount rate $10.36

@ 20% discount rate $2.61

Isn’t there an option value to Lance Creek post EOR flood?

- Chemical floods
- New technologies not even dreamed of today
The End!