Time and Cost to Commercialize an Oil Shale Retorting Technology

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Staged Development

More small scale-up steps increase time and cost of development.

Fewer large scale-up steps increase risk of not achieving design capacity.

What is the optimum number of stages to balance cost and risk?

How to compare technologies that are at different stages of development?
$250M for 6000 bbl/sd single module
• $250M for 6000 bbl/SD single module

• 0.6 cost exponent for single module
• $250M for 6000 bbl/sd single module
• 0.6 cost exponent for single module
• 25% reduction per module for 5 modules
• 33% reduction per module for 10 modules (Buchmann et al 1993)
Operating Costs

- Includes grade reduction with increase in capacity
Plants with 'unproven technology' result were often abandoned after 4 years of operation.

- Study by McNulty (1998)
- Rate is affected by design readiness and departure from prior plants.
- Plants with 'unproven technology' result were often abandoned after 4 years of operation.
# Rate of Achieving Design Capacity for Shale Oil Plants

## Shale Oil Examples

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>Scale-up Factor</th>
<th>Capacity curve achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unocal-Parachute Crk</td>
<td>1987</td>
<td>100:1</td>
<td>Unproven technology</td>
</tr>
<tr>
<td>PetroSIX</td>
<td>1992</td>
<td>5:1</td>
<td>Scale-up</td>
</tr>
<tr>
<td>ATP-Stuart</td>
<td>2000</td>
<td>50:1</td>
<td>Unproven technology</td>
</tr>
</tbody>
</table>
Example 1: Best Number of Scale-up Stages?

- **Scenario**

  Successful completion of 10 bbl/sd pilot plant

  Resource = 125 000 bbl/sd for 30 yrs = 1B bbl
Example 1: Options

1 intermediate plant
10 → 1250 → 125 000 bbl/sd

2 intermediate plants
10 → 250 → 5 000 → 125 000 bbl/sd

5 intermediate plants
10 → 50 → 250 → 1250 → 5000 → 25 000 → 125 000 bbl/sd
Example 1: Assumptions

- Discount Factor: 8%
- Plant life: 30 years
- Oil price: $50/bbl
- Design availability: 90%
- Salvage value: 0

*If unsuccessful scale-up, then abandon current plant after 4 years of operation and no follow-on plants.*
Example 1: Assumption

- Probability of success depends on scale-up factor

<table>
<thead>
<tr>
<th>Scale-up Factor</th>
<th>‘Scale-up’ curve</th>
<th>‘Unproven technology’ curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:1</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>25:1</td>
<td>67%</td>
<td>33%</td>
</tr>
<tr>
<td>100:1</td>
<td>33%</td>
<td>67%</td>
</tr>
</tbody>
</table>
Example 1: Option 1

Weighted NPV = (0.67)(-134)+(0.22)(-166)+(0.11)(6363) = $552M
Example 1: Results

<table>
<thead>
<tr>
<th>No. of intermediate plants</th>
<th>Number of possible outcomes</th>
<th>Best outcome</th>
<th>Weighted NPV $M</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NPV $M</td>
<td>Probability %</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>6363</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>3861</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>530</td>
<td>53</td>
</tr>
</tbody>
</table>
Example 2: New or Demonstrated Technology?

Scenario:

Old technology
80% availability
successfully demonstrated @ 5000 bbl/sd

New technology
95% availability
successfully piloted @ 250 bbl/sd
Example 2: Options

Old technology
1 intermediate plants
5 000 → 25 000 → 125 000 bbl/sd

New technology
2 intermediate plants
250 → 5 000 → 25 000 → 125 000 bbl/sd
Example 2: Results

<table>
<thead>
<tr>
<th>Demonstrated capacity Bbl/sd</th>
<th>Availability %</th>
<th>Number of intermediate plants</th>
<th>Best outcome</th>
<th>Weighted NPV $M</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>80</td>
<td>1</td>
<td>4991</td>
<td>3977</td>
</tr>
<tr>
<td>250</td>
<td>95</td>
<td>2</td>
<td>3369</td>
<td>1671</td>
</tr>
</tbody>
</table>
Conclusions

• Development time and costs need to be considered when evaluating shale oil projects

• Scale-up risk also needs to be considered.

• A new technology must promise a significant advantage to justify additional development time and cost.
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