Economic Feasibility and Investment Decisions of Coal and Biomass to Liquids

Oleg Kucher and Jerald J. Fletcher
West Virginia University

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We provide micro-economic analysis of commercial CBTL 50,000 bpd projected plant with 7.7% by weight biomass based on NETL(2009)* techno-economic design

Conclusions: Despite the technical feasibility of CBTL processes, there is little evidence of strong commercial viability of CBTL development in the U.S. under present energy prices and projected costs. In the presence of uncertainty over the payoff from investing, the high capital cost of CBTL plant is the main barrier to the construction of a large-scale CBTL plant in the U.S.

Oil Alternatives Overview: Costs and Emissions

Figure 1: Cost and emissions data for 2008–2009

Feasible Solution to the Carbon Problem?

**NETL study**: CBTL could produce “affordable & low-carbon diesel”

- Feasibility of CBTL 50k bpd plant with 8%wt at $80-$100 bbl

In U.S. 3 CBTL projects with capacity over 110k bpd:
- American Clean Coal Fuels, IL; Baard Energy, Wellsville, OH; Rentech, Natchez, MS

None of the CBTL projects have been completed

Reasons:

- Financing issues, Environmental concern, Costs, Uncertainty

Motivation and Objectives

CBTL economic feasibility and investment decisions:

• Is the CBTL project commercially viable in the U.S.?
• If yes, than why are CBTL projects delayed so far? Risks?

Research objectives:

• economic assessment of the CBTL cash flows and NPV;
• assess the value option to invest into the CBTL plant
• draw insights on investments for the CBTL plant in the U.S.
## Research Methods and Model

Figure 2: Research framework for the CBTL evaluation

<table>
<thead>
<tr>
<th>1. DCF</th>
<th>2. Risk analysis</th>
<th>3. Real options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td><strong>Techniques</strong></td>
<td><strong>Results</strong></td>
</tr>
<tr>
<td>• Valuing NPV</td>
<td>• Valuing investment opportunity</td>
<td>• NPV, IRR</td>
</tr>
<tr>
<td>• Valuation of cash flows discounted at the end of the year</td>
<td>• Uncertainty estimation</td>
<td>• Sensitivity analysis</td>
</tr>
<tr>
<td>• Sensitivity analysis</td>
<td>• Dynamic programming</td>
<td>• Value of options to invest</td>
</tr>
</tbody>
</table>
The basic continuous-time model after Dixit and Pindyck (1994)

Investor’s problem:

\[ F(V) = \max \varepsilon (V_T - I)e^{-\rho T} \]

Maximize a payoff \( V_T - I \), discounted at \( \rho \)

\[ dV = \alpha V \, dt + \sigma V \, dz \]

s.t. change in NCF, \( dV \) that follows GBM, with \( \alpha \) growth rate, \( \rho \)-discount, \( \sigma \)-st.dev.

Solution by Dynamic Programming:

\[ F(V) = \begin{cases} AV^{\beta_1} & V \leq V^* \\ V - I & V > V^* \end{cases} \]

Value of options to wait

Value of options to invest

\[ \beta_1 = 1/2 - (\rho - \delta)\sigma^2 + \sqrt{[(\rho - \delta)/\sigma^2 - 1/2]^2 + 2\rho/\sigma^2} \]

\[ A = (V^* - I)V^{\beta_1} = (\beta_1 - 1)^{\beta_1 - 1}/[\beta_1 \beta_1 I \beta_1 - 1] \]

\[ V^* = \beta_1/(\beta_1 - 1)I \]

# CBTL Project Evaluation

## Table 1: Main parameters and assumptions in DCF analysis

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant basis</strong></td>
<td></td>
</tr>
<tr>
<td>Plant type designed by NETL(2009)*</td>
<td>CBTL 50k bpd, 7.7wt% biomass</td>
</tr>
<tr>
<td>Life of project &amp; construction period</td>
<td>30 &amp; 4 years</td>
</tr>
<tr>
<td>Operating capacity</td>
<td>0.89</td>
</tr>
<tr>
<td>Coal &amp; biomass input</td>
<td>19948 tpd &amp; 1657 tpd</td>
</tr>
<tr>
<td>ULSD &amp; naphtha output</td>
<td>34292 bpd &amp; 15708 bpd</td>
</tr>
<tr>
<td><strong>Economics</strong></td>
<td></td>
</tr>
<tr>
<td>Startup prices &amp; Inflation</td>
<td>2010 year &amp; 2%</td>
</tr>
<tr>
<td>Investments (total as-spent capital)</td>
<td>$5.6 billion</td>
</tr>
<tr>
<td>Discount rate</td>
<td>8%</td>
</tr>
<tr>
<td>Tax rate</td>
<td>38%</td>
</tr>
<tr>
<td><strong>Financing</strong></td>
<td></td>
</tr>
<tr>
<td>Ownership: debt/equity, %</td>
<td>60%/40%</td>
</tr>
<tr>
<td>Debt: senior/subordinated, %</td>
<td>80%/20%</td>
</tr>
<tr>
<td>Senior &amp; Subordinated interest rates</td>
<td>5.5% &amp; 9%</td>
</tr>
</tbody>
</table>

Discount Cash Flow Analysis (DCF)

Free Cash Flow to Firm (FCFF):

\[ \text{FCFF} = \text{EBIT}(1 - \text{Tax Rate}) + \text{Depreciation} - \text{CapEx} \pm \Delta \text{Working Capital} \]

→ Cash intensive: revenue ≈ $1.87 billion, FCFF ≈ $191 million per year

![Figure 3: Product revenue](image)

![Figure 4: Free Cash Flow to Firm](image)
• NPV>0 $\leftrightarrow$ accept the CBTL project
• But IRRs are low for high risky project
• The cost of capital indicates high sensitivity of NPV

Figure 5: NPV (FCFF) at discount

Figure 6: NPV (FCFE) at discount
Sensitivity Analysis (1) for NPV, FCFF

Top sensitive variables for NPV (FCFF):

- Fuel prices, Operating Capacity, Discount, Investments

Figure 7: Impacts of major sensitive parameters (±10%) on NPV8 (FCFF)

NPV = $767 million
Sensitivity Analysis (2) for NPV, FCFE

Top sensitive variables for NPV (FCFE):

→ Investments, Operating Capacity, Discount, Debt ratio, Fuel prices

Figure 8: Impacts of major sensitive parameters (± 10 %) on NPV12 (FCFE)

NPV = $207 million
Fitting distributions of sensitive variables:

→ Capital expenditures: $5-$6.5 billion range for CBTL 50k bpd plant

→ Operating capacity: U.S. refinery utilization rate ≈ 89%; st.dev. 6.3%

→ ULSD & coal prices st. dev. up to 30%; Oil price st. dev. ≈ 45%

→ Dividend rate: mean 6% & triangular distribution with ±10% change

→ Correlation of ULSD & oil prices ≈ 0.9; Corr. coal & fuel prices ≈ 0.6
Monte Carlo Simulation

The payoff of the CBTL project is lowered by 1/3:

→ Mean NPV8 $\approx$ $497$ millions. It falls -$0.85$ & $1.7$ billion at 90% CI
→ Mean of NCF $\approx$ $185$ millions, St. Dev. $\approx$ $25$ millions (13%)

Figure 9: NPV8 and NCF forecast after 4000 simulations
Figure 10: Value of the investment opportunity

$F(V)$

Present value of Net Free Cash Flow, millions of dollars

Linear NPV $F(V)^{w}$ $F(V)^{inv}$

4.5 times
Summary

A CBTL project is feasible but in the near-term it cannot be commercially viable under uncertainty in the energy market

- NPV from FCFF≈$767 million
- The biggest impact on NPV: fuel prices, discount, investments
- Uncertainties lower payoff by 1/3 with 25% chance of NPV<0

Real options yields high value to wait:
- The value of waiting could reach 2/3 value of capital costs
- The payoff needs to exceed the traditional NPV over 4 times
In order to make the CBTL project viable:

- CBTL technology will need to be substantially more cost effective, either through:
  - reductions in capital costs,
  - increased policy incentives, (i.e., carbon legislation),
  - better project economics (i.e., optimized configuration), increase in product demand and government support to attract investment.
## Backup: Risk Assessment Parameters

Table 2: Fitted distribution parameters and distribution assumptions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Distributional Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Ultra low sulfur diesel price, $/gallon</td>
<td>$2.31</td>
<td>Lognormal 3: St. Dev. 0.61</td>
</tr>
<tr>
<td>Coal price, $/t</td>
<td>$44.6</td>
<td>Lognormal: St. Dev. 12.5</td>
</tr>
<tr>
<td>Crude oil price, $/oil barrel (bbl.)</td>
<td>$79.4</td>
<td>Lognormal: St. Dev. 35</td>
</tr>
<tr>
<td>Operating capacity</td>
<td>0.89</td>
<td>Gumbel Minimum: Beta 0.05</td>
</tr>
<tr>
<td>Dividend rate, %</td>
<td>6</td>
<td>Triangular: Min –10%, Max. +10%</td>
</tr>
<tr>
<td>Capital costs, millions of dollars</td>
<td>$5,595</td>
<td>Triangular: Min –10%, Max. +15%</td>
</tr>
</tbody>
</table>
Table 3: Real options model parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ, dividend (payout) rate</td>
<td>0.06</td>
</tr>
<tr>
<td>(I), present value of capital costs (TASC), $ millions</td>
<td>$4,972.6</td>
</tr>
<tr>
<td>(V), present value of net cash flow to the firm, $ millions</td>
<td>$5,739.6</td>
</tr>
<tr>
<td>(NPV), (NPV = V - I), millions of dollars</td>
<td>$767.01</td>
</tr>
<tr>
<td>(NCF), millions of dollars per year</td>
<td>$184.9</td>
</tr>
<tr>
<td>(\sigma), volatility of average present value of net cash flow, %</td>
<td>13.49</td>
</tr>
</tbody>
</table>

\[\beta_1 = 2.434, \quad A = 0.00000096486, \quad V^* = $8,440.95 \text{ million.}\]