HTI’s Coal Process  DCL Technology

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Presentation Outline

- Coal-to-Liquids via Coal Liquefaction
- HTI’s Coal Process DCL Technology
- Technology Applications
  - Philippine Hybrid DCL Project
  - Assam DCL Project
- Concluding Remarks
Coal Chemistry

Direct Coal Liquefaction
Coal + Catalyst + Hydrogen → Hydrocarbons ($H_xC_y$)

Indirect Coal Liquefaction
1. Gasification
   Coal + Oxygen + Steam → Syngas (H2 + CO)
2. FT Synthesis
   $H_2 + CO +$ Catalyst → Hydrocarbons ($H_xC_y$)
Coal Liquefaction Routes

- **Direct Coal Liquefaction**
  - Partial dismantling of the coal structure under high H\textsubscript{2} partial pressure
  - Further hydrocracking of primary coal fragments
  - Refining of coal liquids
  - Products retaining ring structure

- **Indirect Coal Liquefaction**
  - Complete destruction of the ring structure in coal
  - Gasification to produce syngas (H\textsubscript{2}/CO)
  - Removal of hetero-atoms (S, N) from syngas
  - Catalytic synthesis of ultra clean paraffins
  - Hydrogenation and wax hydrocracking
Key Features of HTI’s DCL Technology

- Fully Back-mixed reactor
- Iron based catalyst with heavy end recycle
- Inter-stage Vapor/Liquid Separation
- Integrated Raw Product/Donor Solvent hydrogenation
- Solvent de-ashing for high ash coal to improve distillate yield
Direct Liquefaction Process

- Make-up Hydrogen
- Coal + Catalyst
- Recycle H₂
- H₂S, NH₃, COₓ
- C₁ – C₂
- LPG
- Gas Recovery Treatment
- De-Ashed Oil (DAO)
- Solvent De-ashing
- Gas Oil (HVGO)
- Heavy Vacuum Gas Oil (HVGO)
- Ash Reject
- Diesel Fuel
- Gasoline
- De-ashing
- Slurry
- Fractionation
- Hydro-treating
- Refining
DCL Background

- Originally developed in Germany in 1917
- Used to produce aviation fuel in WWII
- US spent $3.6 billion on DCL from 1975-2000
- Headwater DCL licensed to China in 2002

Lawrenceville, NJ: 30 bpd
Catlettsburg, KY: 1800 bpd
Inner Mongolia, China: 17,000 bpd
Other DCL Activities in Asia

- Completed PFS on Assam coal for Oil India Limited (44,000 BPD, DCL Plant)
- Completed Project definition on Philippine coals for H&W (60,000 BPD, Hybrid Plant)
- Signed a new license on production of transportation fuels using lignite as feedstock (50,000 BPD, DCL plant)
- Several enquiries from India, Indonesia, other Asian countries.
Commercializing CTL Technologies in U.S.

- CTL projects are capital intensive ($70,000- to $120,000 per BPD)
- CTL products are compatible with and perform similar to the petroleum-derived products
- Economy of scale is critical to project economic (40,000 BPD + plant capacity)
- CTL project economic is very sensitive to capex and world crude oil price
- Planning to start FEED for a CTL project in North Dakota.
Philippine Hybrid CTL Plant
Basis for the Philippine Hybrid Plant

- Plant location closer to market
- Flexibility in coal feed
  - Low quality coal for syngas production
  - Higher quality coal for direct coal liquefaction
- Products blending to reduce refining cost
- Process integration to maximize heat utilization
- Self sufficient in energy requirement
- Large power generation not required
Hybrid Plant - Block Flow Diagram

- **Gasification**
- **Fischer Tropsch Synthesis**
  - FT tail gas
- **Recovery of Hydrogen**
  - \( H_2 \)
- **Direct Coal Liquefaction**
  - \( H_2 \)
- **Product Blending and Refining**
  - Raw FT products
  - Final Products

- **Coal 1**
- **Coal 2**
- **Coal**
- **Raw FT products**
- **Raw DCL products**
Coal Feed Rates to Hybrid Plant

Total feed rate: 23,000 coal short ton/day (maf basis)
- Lignite A: 9,400 stpd
- Lignite B: 7,900 stpd
- Sub-bituminous: 5,800 stpd

Products (BPSD):
- C3/C4: 11,200
- FT Naphtha: 11,500
- DCL Naphtha: 15,600
- FT Diesel: 13,400
- DCL Distillate: 6,500
- DCL VGO: 2,800
- Total Liquids: 61,000

By-Products:
- Sulfur - 520 stpd; Net Power - 67 MW
## Capital Investment (million 2005$)

<table>
<thead>
<tr>
<th>Major Units</th>
<th>million, 2005$</th>
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<tbody>
<tr>
<td>Syngas/H₂ production</td>
<td>1,260 (66%)</td>
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<tr>
<td>Direct Coal Liquefaction</td>
<td>330 (17%)</td>
</tr>
<tr>
<td>FT Synthesis &amp; Product Upgrading</td>
<td>330 (17%)</td>
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<tr>
<td>Total ISBL</td>
<td>1,920 (100%)</td>
</tr>
<tr>
<td>OSBL (35% of ISBL incl. power block)</td>
<td>660</td>
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<tr>
<td>Power Block</td>
<td>270</td>
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<tr>
<td>Total EPC Cost (USGC location)</td>
<td>2,850</td>
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<tr>
<td>Total EPC Cost (Philippine location)</td>
<td>2,760</td>
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<tr>
<td>Contingency (25%)</td>
<td>690</td>
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<tr>
<td>Owner’s cost</td>
<td>420</td>
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<tr>
<td>Interest during construction</td>
<td>330</td>
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<tr>
<td>Total Project Cost</td>
<td>4,200</td>
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## IRR Sensitivity

<table>
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<th>Parameter</th>
<th>+20%</th>
<th>Base IRR</th>
<th>-20%</th>
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<tbody>
<tr>
<td>EPC</td>
<td>29</td>
<td>38</td>
<td>48</td>
</tr>
<tr>
<td>Fuel Revenue</td>
<td>49</td>
<td>38</td>
<td>22</td>
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<tr>
<td>Coal Price</td>
<td>34</td>
<td>38</td>
<td>41</td>
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</tbody>
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Other major assumptions:

- 330 days on-line, 15% equity, capacity-51%, 1\textsuperscript{st} yr: 81%, 2\textsuperscript{nd} yr.
- Fuels price April/2005 FOB Philippines price; Crude price- $43 to 50 per bbl.
Liquefaction of Assam Coals

Oil India Limited
Performing of Assam Coal

- Assam coals have a high reactivity for direct coal liquefaction (>98% conversion)
- Potential distillate yield into the range of 73 to 77 s% maf coal
- Requires effective hydrogen transfer system to match with the high reactivity of Assam coals

Action Plans:
- License arrangement including a process warranty pilot plant test to generate design basis
- Develop basic engineering design for better investment cost estimate
- Develop product upgrading strategy for coal liquids
Assam DCL Complex Summary

- **Feed Coal**: 10,419 Tons/d
  - 7,000 T/d DCL
  - 3,420 T/d H₂ production (Gasifier)

- **Products**
  - LPG 341 T/d (3,971 bbl/d)
  - Naphtha 1,660 T/d (14,077 bbl/d)
  - Kerosene 600 T/d (4,744 bbl/d)
  - Diesel 2,804 T/d (21,379 bbl/d)
  - Total C₃+Liquid Products 44,171 bbl/d
Economic Analysis Summary

- 44,000 BPD DCL Plant
- CAPEX = US$2.16 billion
- Annual Revenue = US$1,139 million
- Annual Expenses = 471 million
- Income before state tax = 668 million
- 1/3 Equity
- IRR of 30% ($50/ton); 23% ($90/ton)
- $962 Million NPV @ 12% Discount Rate
Concluding Remarks

- CTL is a viable option to monetize coal reserve
- CTL technologies are commercially-ready
- Economy of scale and crude oil price are critical to CTL project viability
- Government assistance in project finance is needed for the first generation CTL plants
- Government guarantee on CTL product floor prices is essential
- Future R&D efforts on plant efficiency and cost reduction are needed