An Alternative Route for Coal To Liquid Fuel
applying the ExxonMobil Methanol to Gasoline (MTG) Process

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Options for Coal To Liquids

- All three routes: three step processes
- Thermal efficiencies: essentially governed by the carbon hydrogen ratio of the feed and the fuel products.
Reactions for Coal to Transportation Fuels

Gasification → MeOH → MTG

2CH\textsubscript{x} + (1+x)/2 O\textsubscript{2} + (1-x) H\textsubscript{2}O = (CH\textsubscript{2}) + CO\textsubscript{2}

**Theoretical Balance**

- All routes have the same end states
- Theoretical efficiencies will be approx. equivalent and dependent of Coal composition
- Each mole of CH\textsubscript{2} production will requires approx. two moles of carbon
- Each mole of CH\textsubscript{2} production will have approx. one mole of carbon rejected as CO\textsubscript{2}

Coal → Gasification → Fischer Tropsch → Refining → Liquid Fuels
Coal Type and Process Selectivity Affect Efficiency

- Gasification
- MeOH
- MTG
- Real World
  - Actual coal consumption will be a function of thermal efficiency regarding CO+H₂ production of the gasification process and the product selectivity of the fuel process.
  - Coal type and type of gasification will affect overall efficiency
  - Significant issues
    - Capital costs
    - Operating complexity
    - Meeting acceptable fuel quality
- Liquid Fuels
- Coal
- Gasification
- Fischer Tropsch
- Refining

Real World

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- Coal type and type of gasification will affect overall efficiency
- Significant issues
  - Capital costs
  - Operating complexity
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### Product and Process Simplicity for MTG

<table>
<thead>
<tr>
<th>COAL TO LIQUID</th>
<th>Fischer Tropsch Co Catalyst @220C</th>
<th>Fischer Tropsch Fe Catalyst @340C</th>
<th>MTG</th>
<th>H-Coal™ Direct Liquefaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Gas</td>
<td>6</td>
<td>15</td>
<td>1.1</td>
<td>Not Reported</td>
</tr>
<tr>
<td>LPG</td>
<td>6</td>
<td>23</td>
<td>10.0</td>
<td>36.7</td>
</tr>
<tr>
<td>Naphtha</td>
<td>19</td>
<td>36</td>
<td>88.8</td>
<td>43.3</td>
</tr>
<tr>
<td>Distillate</td>
<td>22</td>
<td>16</td>
<td>43.3</td>
<td>20</td>
</tr>
<tr>
<td>Fuel Oil/Wax</td>
<td>46</td>
<td>5</td>
<td>1.1</td>
<td>0.34</td>
</tr>
<tr>
<td>Oxygenates</td>
<td>1</td>
<td>5</td>
<td>Not Reported</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**Refinery Processes:**

- **Naphtha Reforming**
- **Polygas Process**
- **DEWAX**
- **HDT/HDC**
- **Naphtha Reforming**
- **HDT**
- **HDT/HDC**
- **Recovery**

*Date Sources: FT Date Sasol 2004 publication. H-Coal data from HRI1982 publication*
Unique Shape Selective Chemistry

- Unique “Shape Selective” chemistry discovered in the early 1970’s
- Development complete through the 70’s/80’s on a variety of process options
- Plant started up 1985 and operated successfully for ~10 years until conversion to chemical grade Methanol production
- Second generation Coal based plant scheduled for end of 2008 start-up in China
- Two additional plants in Engineering for US applications
MTG Was Commercially Operated

Commercial 14500 BPD plant in New Plymouth New Zealand. Plant ownership 75% NZ Government and 25% ExxonMobil.
# New Zealand Finished Gasoline Quality

<table>
<thead>
<tr>
<th>Property</th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Octane Number, RON</strong></td>
<td>92.2</td>
<td>92.0 – 92.5</td>
</tr>
<tr>
<td><strong>Octane Number, MON</strong></td>
<td>82.6</td>
<td>82.2 – 83.0</td>
</tr>
<tr>
<td><strong>Reid Vapor Pressure, kPa</strong></td>
<td>85</td>
<td>82 – 90</td>
</tr>
<tr>
<td><strong>Density, kg/m³</strong></td>
<td>730</td>
<td>728 – 733</td>
</tr>
<tr>
<td><strong>Induction Period, min.</strong></td>
<td>325</td>
<td>260 – 370</td>
</tr>
<tr>
<td><strong>Durene Content, wt%</strong></td>
<td>2.0</td>
<td>1.74 – 2.29</td>
</tr>
<tr>
<td><strong>Distillation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Evaporation at 70° C</td>
<td>31.5</td>
<td>29.5 – 34.5</td>
</tr>
<tr>
<td>% Evaporation at 100° C</td>
<td>53.2</td>
<td>51.5 – 55.5</td>
</tr>
<tr>
<td>% Evaporation at 180° C</td>
<td>94.9</td>
<td>94 – 96.5</td>
</tr>
<tr>
<td><strong>End Point, °C</strong></td>
<td>204.5</td>
<td>196 - 209</td>
</tr>
</tbody>
</table>
**MTG Gasoline vs. U.S. Conventional Gasoline**

- MTG Gasoline is completely compatible with conventional gasoline infrastructure.
- MTG Gasoline contains essentially no sulfur and low benzene contents.

<table>
<thead>
<tr>
<th></th>
<th>2005 Summer</th>
<th>2005 Winter</th>
<th>MTG Gasoline</th>
<th>US Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen(Wt%)</td>
<td>0.95</td>
<td>1.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>API Gravity</td>
<td>58.4</td>
<td>61.9</td>
<td>61.8</td>
<td></td>
</tr>
<tr>
<td>Aromatics(%Vol)</td>
<td>27.7</td>
<td>24.7</td>
<td>26.5</td>
<td></td>
</tr>
<tr>
<td>Olefins(%Vol)</td>
<td>12</td>
<td>11.6</td>
<td>12.6</td>
<td></td>
</tr>
<tr>
<td>RVP(psi)</td>
<td>8.3</td>
<td>12.12</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>T50(F)</td>
<td>211.1</td>
<td>199.9</td>
<td>201</td>
<td></td>
</tr>
<tr>
<td>T90(F)</td>
<td>330.7</td>
<td>324.1</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>Sulfur(ppm)</td>
<td>106</td>
<td>97</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Benzene(%Vol)</td>
<td>1.21</td>
<td>1.15</td>
<td>0.3</td>
<td>1 (0.62)</td>
</tr>
</tbody>
</table>

Date Sources: US Average gasoline data from US EIA website.
2nd Generation MTG Technology

- Second Generation Design based on 10 years learning's from NZ operation
- Improved heat integration
- Improved process efficiency
- Process re-optimized for coal-based methanol

ExxonMobil is the world leader in catalyst development and we manufacture our own catalysts.
Case Study: CTL based on MTG

Concept: CTL Complex, self-sufficient....Import of a small amount of power to avoid black. start facilities and redundancies

- **CO2 to Compression**
- Appr. 2% CO2
- Purge Gas
- Gasoline
- LPG
- Raw Methanol
- Sulfur
- MTG Unit
- ASU
- N2 & CO2 Compression
- CO-Shift
- Gasification
- Oxygen
- Air
- CO2 from AGR
- S Recovery
- Rectisol
- AGR
- Methanol Unit
- ExxonMobil
- Uhde

**MTG: ExxonMobil**

**PRENFLO with Direct Quench (PDQ): Uhde**
Case Study: CTL based on MTG, self-sufficient
Case Study: PRENFLO PDQ, Gasifier and Key Features

- Pressurized entrained-flow gasification: 25-42 bar
- Dry coal dust feeding: with N₂ or CO₂ as transport gas
- Oxygen as gasification agent
- Temperature in gasifier: 1,350-1,600 °C (slagging conditions)
- 4-6 side burners, tangential flow
- Gasifier protected by membrane wall (steam) and slag layer
- Full water quench for syngas saturation
- Simple and robust process concept
### Case Study: CTL based on MTG, self-sufficient - Overview

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Lignite</th>
<th>Hard Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal Feed as Received</td>
<td>t/h</td>
<td>913</td>
<td>378</td>
</tr>
<tr>
<td>Coal Feed to Gasifier</td>
<td>t/h</td>
<td>570</td>
<td>353</td>
</tr>
<tr>
<td>Gasoline Product @92 R+0</td>
<td>bbl/d</td>
<td>18,000</td>
<td>18,000</td>
</tr>
<tr>
<td>LPG Product</td>
<td>bbl/d</td>
<td>3,300</td>
<td>3,300</td>
</tr>
<tr>
<td>Syngas to Liq. Thermal Efficiency</td>
<td>% on HHV</td>
<td>Base</td>
<td>+0.2%</td>
</tr>
<tr>
<td>CTL Thermal Efficiency*</td>
<td>% on HHV</td>
<td>Base</td>
<td>+5.4%</td>
</tr>
</tbody>
</table>

* Reported CTL efficiencies very strongly dependent on utility and upgrading assumptions, and CO2 disposition assumptions in addition to Coal quality

- Lignite with high water and medium high ash content
- Hard coal with a low water content and a medium high ash content
Current MTG Licenses

JAMG
Shanxi China

DKRW
Medicine Bow WY

SES
Benwood, West VA
MTG JAMG Project in Shanxi China

- MTG plant currently under construction at JAMG is second generation Fixed Bed MTG Process. Start up scheduled for YE 2008.
**Key Project Considerations**

**Technical Risk**
- Methanol to Gasoline (MTG), Gasification and Methanol Synthesis are commercially proven technologies

**Simplicity**
- MTG does not require a “refinery” to make a marketable fuel product.

**Operability**
- Methanol is storable which enhances operability between stages

**Constructability**
- MTG uses gas phase conventional type fixed bed reactors

**Flexibility**
- MTG can be used for methanol from other sources such as coal bed methane or coke oven gas.
- MTG can be added downstream of existing methanol plants
EMRE/Uhde Partnership Provides Full Range of CTL Services

- EMRE provides licenses for Methanol to Gasoline Technology.
- EMRE provides basic engineering design for licensees to perform detailed engineering design and construction.
- EMRE provides catalysts for the MTG process.
- Uhde provides feasibility studies for the entire process of clean gasoline production from coal. The study includes gasification, gas treatment, methanol synthesis, and MTG.
- Uhde provides licenses of different gasification technologies to meet customer's specific need.
- Uhde also provides methanol synthesis technology.
- Uhde is a full range EPC contractor.