Realities of GTL Base Oils: Costs, Supplies, Pricing, Impact

Argus Americas Base Oils Summit
Houston—May 2012

Iraj Isaac Rahmin, PhD
E-MetaVenture, Inc.
Houston, Texas

Ron Sills, PhD
Director—XTL and DME InstituteSM
Houston, Texas

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GTL in the News

Shell Pearl start-up in 2011

- First shipment of base oils arrived in Houston on November, 2011

- When operating at full capacity: 30 KBD Group III base oil

- Shell Lubricants will use GTL base oil in its premium motor oils

Under Study:
Sasol USGC 90 KBD
Announced: 2011

Under Study:
Shell USGC 140 KBD
Announced: 2012
Realities of GTL Base Oils

Topics

- GTL technology and commercial status
- Why the new US Interest? Production costs v. product values
- Impact of GTL lubes: Products, quality, supply & demand
- US GTL growth issues
Routes for Conversion of Methane

After “Natural Gas Production, Processing, Transport” by Rojey et al.
Key GTL Steps

- **Gas Separation and Purification**
- **Syngas Production**
  - Partial oxidation: \( \text{CH}_4 + \text{O}_2 \rightarrow \text{CO} + 2 \text{H}_2 \) (exothermic)
  - Steam reforming: \( \text{CH}_4 + \text{H}_2\text{O} \rightleftharpoons \text{CO} + 3 \text{H}_2 \) (endothermic)
- **Fischer-Tropsch Process**
  - \( \text{CO} + 2 \text{H}_2 \rightarrow \text{C}_n\text{H}_{2n} + \text{H}_2\text{O} \) (very exothermic)
- **Product Upgrade**
**Brief GTL History**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1922</td>
<td>Franz Fischer and Hans Tropsch used iron-based catalyst to convert CO + H₂ to liquid products</td>
</tr>
<tr>
<td>1925</td>
<td>Cobalt-based catalysts developed</td>
</tr>
<tr>
<td>WW II</td>
<td>Chemistry contributed to German war effort</td>
</tr>
<tr>
<td>50s-90s</td>
<td>South Africa SASOL developed F-T commercially to convert coal to liquid products</td>
</tr>
<tr>
<td>80s-00s</td>
<td>Shell Bintulu Malaysia; Significant interest &amp; technology development</td>
</tr>
<tr>
<td>00s-Present</td>
<td>Shell &amp; Sasol plants in Qatar; Additional developments &amp; interest in the US</td>
</tr>
</tbody>
</table>
Approx. 400 KBD Total GTL Liquid Production

- Sasol & PetroSA, South Africa 215 KBD (Multiple Facilities, Mix of GTL & CTL)
- Shell Bintulu, Malaysia 15 KBD
- QP/Sasol Oryx I, Qatar 33 KBD 2007-08 Startup
- QP/Shell Pearl, Qatar 140 KBD 2011-12 Startup

Some Growth Predictions

- CA Energy Commission GTL Diesel Estimate:
  400 KBD (2015)
  800 KBD (2020)
- Sasol Chevron Estimate:
  600 KBD (2016-19)
- EIA 2009 Estimate:
  < 700 KBD (2030)
# Commercial Status & Directions

<table>
<thead>
<tr>
<th>Plant</th>
<th>Year Startup</th>
<th>Total Capacity, KBD</th>
<th>Base Oil Production, KBD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sasol II/III Secunda, RSA</td>
<td>1980-84</td>
<td>160</td>
<td>Some wax production</td>
</tr>
<tr>
<td>Sasol I Sasolburg, RSA</td>
<td>1955</td>
<td>8</td>
<td>some wax production</td>
</tr>
<tr>
<td>Shell Bintulu, Malaysia</td>
<td>1993</td>
<td>15</td>
<td>small</td>
</tr>
<tr>
<td>PetroSA Mossel Bay, RSA</td>
<td>1993</td>
<td>47</td>
<td>none</td>
</tr>
<tr>
<td>Sasol/QP Oryx I, Qatar</td>
<td>2007</td>
<td>33</td>
<td>none</td>
</tr>
<tr>
<td>Shell/QP Pearl, Qatar</td>
<td>2011-2012</td>
<td>140</td>
<td>up to 30</td>
</tr>
</tbody>
</table>

| **Near Term**                |              |                     |                              |
| Sasol Chevron Escravos, Nigeria | 2013 (?)   | 33                  | none                         |

| **Possible Future (2017-2020)** |              |                     |                              |
| Sasol/Uzbekneftegaz/Petronas, Uzbekistan |            | 33                  | none                         |
| Sasol, Canada                |              | 48                  | not announced                |
| Sasol, USGC                  |              | 48-96               | not announced                |
| Shell, USGC                  |              | 140                 | not announced                |
Why New US Interest in GTL (1)?

New shale plays

- Shale Gas
- Tight Gas
- CBM
- Conventional

Lower 48 US NG Resources (TCF)

<table>
<thead>
<tr>
<th>Year</th>
<th>Shale Gas</th>
<th>Tight Gas</th>
<th>CBM</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>35</td>
<td>35</td>
<td>190</td>
<td>58</td>
</tr>
<tr>
<td>2007</td>
<td>202</td>
<td>109</td>
<td>202</td>
<td>109</td>
</tr>
<tr>
<td>2008</td>
<td>163</td>
<td>202</td>
<td>202</td>
<td>109</td>
</tr>
<tr>
<td>2011</td>
<td>202</td>
<td>159</td>
<td>202</td>
<td>159</td>
</tr>
<tr>
<td>2012</td>
<td>482</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Production (BCF/D)

- 2003: 61
- 2007: 63
- 2008: 64
- 2011: 67
- 2012: 69

After Schneider/Mckinsey & Company (Zeos Conference, 2012)
New Shale Plays & US NG Pricing

Argus US prices

WTI month 1, NYMEX close, midpoint, USD/BBL, FIP

Natural gas Nymex (USP) month 1, Houston close, settlement, USD/mmBtu, delivered
Impact of US NG Pricing on GTL Economics
Argus USGC prices; EMV internal GTL design and economics studies

![Graph showing the impact of US NG pricing on GTL economics over the years from January 2011 to April 2012. The graph compares the cost of various liquid products and the GTL per BBL cost, including CAPEX and OPEX, with NYMEX prices for GTL NG feed cost per BBL liquid product.]

- **BASE OIL GRP III (4 cst) US**
- **ULS DIESEL (61, 10 ppm) Houston**
- **JET/KERO (54) Houston**
- **NAPHTHA (40 N+A) Houston**

GTL per BBL COST (incl. CAPEX, OPEX) (EMV Internal)
GTL NG FEED COST per BBL LIQUID PRODUCT (NYMEX)
# Major GTL Products

<table>
<thead>
<tr>
<th>Product</th>
<th>Characteristics</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>Similar to other plant (LNG, refinery) LPG</td>
<td>Can be co-processed and marketed with them</td>
</tr>
<tr>
<td>Naphtha</td>
<td>Straight chain paraffinic&lt;br&gt;Near zero sulfur</td>
<td>Preferred use: steam cracker feed</td>
</tr>
<tr>
<td>Jet-Kero /Diesel</td>
<td>High cetane&lt;br&gt;Near zero sulfur</td>
<td>Low density&lt;br&gt;Low aromatics</td>
</tr>
<tr>
<td>(“Middle Distillates”)</td>
<td>From isomerization of GTL wax&lt;br&gt;High isoparaffins: good pour point; high VI (140+); low volatility</td>
<td>Low viscosity&lt;br&gt;Virtually no sulfur, nitrogen, aromatics&lt;br&gt;Narrow HC distribution</td>
</tr>
<tr>
<td>Lubes</td>
<td>Low naphthenes: good oxidation stability</td>
<td>Low viscosity&lt;br&gt;Virtually no sulfur, nitrogen, aromatics&lt;br&gt;Narrow HC distribution</td>
</tr>
<tr>
<td>Wax</td>
<td>High quality</td>
<td>Primarily linear</td>
</tr>
<tr>
<td>Specialty</td>
<td>α-Olefins, Solvents, Detergents, Drilling Fluids, ...</td>
<td></td>
</tr>
</tbody>
</table>
# GTL Basestock Properties

After Fiato/ExxonMobil (Energy Frontiers Int’l, 2005)

<table>
<thead>
<tr>
<th></th>
<th>Typical Group III (Manuf. A)</th>
<th>Typical Group III (Manuf. B)</th>
<th>Typical Group III (Manuf. C)</th>
<th>GTL</th>
<th>Typical PAO (Manuf. D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic Viscosity, cSt @ 100°C</td>
<td>4.1</td>
<td>4.2</td>
<td>3.9</td>
<td>3.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>124</td>
<td>122</td>
<td>143</td>
<td>140</td>
<td>124</td>
</tr>
<tr>
<td>Noack Volatility, wt% off</td>
<td>15.5</td>
<td>15.0</td>
<td>15.6</td>
<td>14.5 max</td>
<td>12.7</td>
</tr>
<tr>
<td>Pour Point, C</td>
<td>-24</td>
<td>-15</td>
<td>-18</td>
<td>-21</td>
<td>&lt; -64</td>
</tr>
<tr>
<td>Sulfur, ppm</td>
<td>200</td>
<td>&lt;5</td>
<td>&lt;4</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cold Flow/CCS @ -35°C, cp</td>
<td>2600</td>
<td>2900</td>
<td>1700</td>
<td>1200</td>
<td>1300</td>
</tr>
</tbody>
</table>
Lubes Markets

Paraffinic

- Paraffinic basestock global market size ~ 870 KBD

- Rationalization of less efficient (Group I) plants

- Expansion of Group II/III capacity in south and east Asia

- Assuming 1.6% growth rate:
  - 1,000 KBD market size in 2020
  - 1,300 KBD in 2035

- GTL basestocks: closest to Group III

- Group III: 5% in 2008 ➔ 7% in 2010
  - 45 KBD ➔ 62 KBD
How Much Lube Can a World Class GTL Facility Produce?

Sample product slate for 100 KBD facility

<table>
<thead>
<tr>
<th></th>
<th>KBD (No Hydrocracking Operation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>2</td>
</tr>
<tr>
<td>Naphtha</td>
<td>18</td>
</tr>
<tr>
<td>Jet-Kero /Diesel</td>
<td>50</td>
</tr>
<tr>
<td>Lubes</td>
<td>30</td>
</tr>
<tr>
<td>Wax</td>
<td>10</td>
</tr>
<tr>
<td>Specialty</td>
<td>α-Olefins, Solvents, Detergents, Drilling Fluids,...</td>
</tr>
</tbody>
</table>

- One world-scale GTL could produce as much as 30 KBD lube basestocks (50% of current Group III supply)
- Globally, possibility of 200 KBD of GTL lube base stocks by 2020
- Aside: global wax market ~ 100 KBD
- Potential market destruction due to low elasticity
### Sample product slate for 100 KBD facility

<table>
<thead>
<tr>
<th></th>
<th>No Hydrocracking</th>
<th>With Hydrocracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPG</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Naphtha</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>Jet-Kero /Diesel</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td>Lubes</td>
<td>30</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Wax</td>
<td>10</td>
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<tr>
<td>Specialty</td>
<td>α-Olefins, Solvents, Detergents, Drilling Fluids,...</td>
<td></td>
</tr>
</tbody>
</table>
Cracking from Higher to Lower Value Products!

![Graph showing price trends for various liquid products from January 2011 to April 2012. The graph includes lines for different products such as BASE OIL GRP III (4 cst) US, ULS DIESEL (61, 10 ppm) Houston, JET/KERO (54) Houston, and NAPHTHA (40 N+A) Houston.](image-url)

GTL per BBL COST (incl. CAPEX, OPEX) (EMV Internal)

GTL NG FEED COST per BBL LIQUID PRODUCT (NYMEX)
FT Diesel v. Global Middle Distillates

Projections at 3% annual growth

Unlikely to Have Large Supply v. Demand Impact

XTL Diesel Supply (proj.): 1.3-2.4 million BPD
Were US GTL Economics Always Good?
Argus prices; EMV internal GTL design and economics studies

- Sasol announces study of 48-96 KBD US GTL
- Shell announces study of 140 KBD US GTL

GTL PER BBL COST (incl. NG feed, CAPEX, OPEX) EMV Internal

ULS DIESEL (61, 10 ppm)
US GTL Growth Issues

- Low-price natural gas availability
  - Shale gas, coal bed methane,...
  - Environmental concerns (e.g., fracking), politics, policy

- Competition for capital
  - $60-80,000/BBL capacity (100 KBD ~ $6-8 billion)

- Liquid fuel product price stability

- Federal and State policy development
  - Climate change and energy security policy
  - Cap & trade coming?
  - Tax and regulatory advantages for alternative energy technologies
  - Permitting environment and timeline

- Not to forget: New US GTL facilities may or may not produce base oils
Impact of GTL Lubes

US GTL economics primarily based on gas monetization to fuels

First commercial US GTL now more likely due to lower cost natural gas

GTL lubes of high quality—closest to Group III

Some GTL lubes manufacture in line with market demands

GTL lubes already being imported into the US

Will help trigger (ongoing) shutdown of less efficient (Group I) lube capacity
About E-MetaVenture, Inc.

- Consulting, Design, Training firm established in 2000
- XTL, petroleum refining & gas processing, novel technologies
- Feasibility studies, technology evaluation, process design, energy optimization, project development, litigation support, customized training, strategy development
- Active in the Middle East, East Asia, North & South America, Europe

www.e-metaventure.com
About the XTL & DME Institute℠

- An educational service provided by Dr. Ron Sills (Ronald A. Sills, LLC) and Dr. Theo Fleisch (Fuel Conversion Solutions, LP), Co-Directors, on all aspects of the XTL supply chain.

DME Fundamentals Tutorial at DME4 in Stockholm, September, 2010

XTL Tutorial at Future Fuels for Australia Conference in Brisbane, July, 2011

www.XTLinstitute.com
Contact Information

Iraj Isaac Rahmim, PhD
E-MetaVenture, Inc.
P. O. Box 271522
Houston, Texas 77277-1522
USA
Email: iir at e-metaventure dot com
www dot e-metaventure dot com