Synfuels GTX

- A 3 Step Process
The Synfuels GTL Process

Pyrolysis

Absorber

Hydrogenation

Oligomerization

Power Production

Gasoline Blendstock
Step 1 - Pyrolysis

- Pyrolysis reactor converts hydrocarbon gas to acetylene and other components.

- The Synfuels Pyrolysis Reactor is:
  - Small
  - Operates at high temperature
  - Has no internal fixtures or moving parts
  - Constructed from conventional stainless steel

- A person can touch the exterior while the interior is at 2500C.
Step 1 - Pyrolysis

Gas To Acetylene (GTA)
Step 2 - Hydrogenation

- The Hydrogenation reactor converts acetylene to ethylene

- The Synfuels Hydrogenation Reactor
  - Operates in the *liquid phase*
  - *Precludes thermal runaway*
  - Demonstrates *97% conversion* to ethylene
  - Provides for *easy separation of ethylene*
  - Uses pyrolysis byproduct hydrogen
Step 2 - Hydrogenation

Gas To Ethylene (GTE)
Step 3A - Oligomerization

- The Oligomerization Reactor converts ethylene to gasoline blendstock

- Synfuels Oligomerization Reactor

  - Converts ethylene to heavy hydrocarbons in the presence of CO, CO2, H2 and CH4
  - Utilizes a commercial catalyst
Step 3A - Oligomerization
The Synfuels GTE Process

Pyrolysis → Absorber → Hydrogenation → Purification

- Pyrolysis: Natural Gas → H₂, CO, CO₂
- Absorber: Absorbent, H₂, CO, CO₂
- Hydrogenation: Acetylene, H₂, CO, CO₂
- Purification: Ethylene, H₂, CO, CO₂
- Power Production: H₂, CO, CO₂
- Polymer Grade Ethylene: H₂, CO, CO₂

Oxygen flow is indicated at the top, and the flow of gases through the process is shown with arrows.
Step 3B - Purification

- Ethylene is separated from the other gases and purified to chemical or polymer grade

- Synfuels Purification Process
  - A cryogenic process to make polymer grade ethylene using well known technology
  - Individually separated gases can be used for energy generation or for other chemical processing
Step 3B - Purification
Benefits of Modularization

- Fabrication where skilled craftsmen, complex tools & construction supplies are more available
- Less impact on final project site
- Fewer fitting errors
- Reduced Field work and Elevated Construction
- Faster Construction Problem Correction
Benefits of Modularization

- Easier, more direct procurement
- Reduced site preparation
- Preloading of reactor catalysts
- Easier verification of instrumentation and control viability
- Reduced laydown area and time in field
Mission

- Convert Low Value natural gas to High Value Gasoline Blendstock
  - Nigeria (<$1), US Shale (<$2), CBM ($2 - $4)

- Convert abundant natural gas to High Value Ethylene (>1000/tonne)

- Reduce gas flaring worldwide

- Add value by effective energy utilization

- Bring unused gas resources to market
Implementation

- West Africa – Small (10-25 MMSCFD) prefabricated modular plants for fields that have 2-5 years of gas resources
- Offshore Worldwide – Medium (20 – 50 MMSCFD) Ship/Platform based plants processing C1+C2 gas linked to petroleum production
- Large gas fields in remote areas – (50 to 250 MMSCFD) throughout Asia, Africa and South America
Technology

- Small Pyrolysis reactors that are easy to install
- Fixed bed catalyst reactors that operate at moderate pressure and temperature
- Stable, self moderating liquid phase hydrogenation
- Broad range of feedstock gas
- Diverse pure products
- Single pass design
Attractive Economics

The chart shows the Internal Rate of Return (IRR) for GTL vs CN at different MMSCFD (Million Standard cubic feet per day) levels. The graph includes two lines representing IRR(1.5=CN) and IRR(1.0=CN), indicating the profitability of the GTL process compared to CN as MMSCFD increases.
## Attractive Economics cont.

### Gas Cost is $2/MSCF

<table>
<thead>
<tr>
<th>CN</th>
<th>GAS FEED RATE (mmscfd)</th>
<th>product value $/bbl</th>
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<tr>
<td>1</td>
<td>9.23 22.18 32.23</td>
<td>120</td>
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<tr>
<td>1.3</td>
<td>24.54 43.79 61.46</td>
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<tr>
<td>1.6</td>
<td>41.1 69.06 96.06</td>
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</table>

### Gas Cost is $5/MSCF

<table>
<thead>
<tr>
<th>CN</th>
<th>GAS FEED RATE (mmscfd)</th>
<th>ethylene value $/tonne</th>
<th>$/pound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.99 28.04 34.11</td>
<td>1500 0.68</td>
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</tr>
<tr>
<td>1.3</td>
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<td>1200 0.54</td>
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<tr>
<td>1.6</td>
<td>60.54 99.58 118.27</td>
<td>990 0.45</td>
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</table>

*Values in Chart are %IRR*
Partnerships

- TAMU - gave Synfuels access to novel process and patents
- AREF - provides marketing access to MENA countries for production
- Byogy – uses Synfuels oligomerization technology to biofuels production
- Major E&C Firms – brings excellent world wide reputation in engineering, construction, marketing and project management