MIXED ALCOHOLS SYNTHESIS WITH A MODULAR EMPHASIS

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RAVI RAVIKUMAR
Topics

- Introduction
- Overview of Potential Gasification Products
- Mixed Alcohols Synthesis Process
- Features of Mixed Alcohols Synthesis
- Plant Performance
- Modular Fabrication and Execution
Fluor Overview

♦ One of the world’s leading publicly traded engineering, procurement, fabrication, construction, maintenance, & project management companies

♦ #109 on the FORTUNE® 500 list in 2014

♦ Over 1,000 projects annually, serving more than 600 clients in 81 different countries

♦ 40,000+ employees executing projects globally

♦ Offices in 33 countries on 6 continents

♦ 103-year company legacy

♦ Visit us at www.Fluor.com
2014 Financial Performance

- Revenue: $21.5 billion
- New awards: $28.8 billion
- Backlog: $42.5 billion

Fluor Corporation is rated at one of the higher investment grade levels:

- Long-term Ratings:
  - Standard & Poor’s “A-”
  - Moody’s “A3”
  - Fitch “A-”

- Short-term Ratings:
  - Standard & Poor’s “A-2”
  - Moody’s “P-2”
  - Fitch “F-2”

- Outlook:
  - Standard & Poor’s - Stable
  - Moody’s - Stable
  - Fitch - Stable
Potential Gasification Feeds and Products

Potential Feeds:
- Natural gas
- Residual oils
- Orimulsion
- Petroleum coke
- Coal
- Waste Oils
- Biomass
- Black liquor
- Sewage Sludge

Gasification Plant

Slag for Construction Materials

Combined Cycle

Electric Power
- Oxygen
- Nitrogen
- Argon
- Carbon Dioxide
- Sulfur/Sulfuric Acid
- Steam

Potential Products

Chemical Production
- Hydrogen
- Carbon Monoxide
- Fertilizer (Urea, ammonium nitrate)
- SNG
- Industrial Chemicals
- Methanol/Higher Alcohols
- Acetic Acid
- Naphtha
- Diesel
- Jet Fuel
- Wax

Fischer-Tropsch Synthesis
## Product Pricing Summary

<table>
<thead>
<tr>
<th>Product</th>
<th>$ / MMBtu (LHV)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>$3.89</td>
<td>Based on NG (Henry Hub) price of $2.50 / MMBtu (HHV)</td>
</tr>
<tr>
<td>Gasoline</td>
<td>$11.36</td>
<td>Gasoline price of $1.39 / gal (RBOB)</td>
</tr>
<tr>
<td>Power</td>
<td>$12.90</td>
<td>4.4 cents/kWh at 3,413 Btu/kWh</td>
</tr>
<tr>
<td>Ammonia</td>
<td>$18.74</td>
<td>Ammonia price of $400 / tonne</td>
</tr>
<tr>
<td>Methanol</td>
<td>$16.17</td>
<td>Methanol price of $366 / tonne</td>
</tr>
<tr>
<td>Ethanol</td>
<td>$20.31</td>
<td>Ethanol price of $1.55 / gal</td>
</tr>
<tr>
<td>Acetic Acid</td>
<td>$39.74</td>
<td>Acetic Acid price of $550 / tonne</td>
</tr>
<tr>
<td>Propanol (as fuel)</td>
<td>$20.31</td>
<td>Assumed same as Ethanol</td>
</tr>
<tr>
<td>Propanol (as chemical)</td>
<td>&gt; $50</td>
<td></td>
</tr>
<tr>
<td>Butanol (as chemical)</td>
<td>&gt; $50</td>
<td></td>
</tr>
</tbody>
</table>
Reactions for the Synthesis of Alcohols

**Alcohols Synthesis**

\[(n+1) \text{H}_2 + (2n-1) \text{CO} = C_n\text{H}_{2n+1}\text{OH} + (n-1) \text{CO}_2\]

**Shift Conversion**

\[\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2\]
Hydrogen to CO Ratio

<table>
<thead>
<tr>
<th>Product</th>
<th>$H_2/CO$ Stoichiometric Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>2.0</td>
</tr>
<tr>
<td>Hydrogen (Full Shift)</td>
<td></td>
</tr>
<tr>
<td>F-T Liquids</td>
<td>2.0</td>
</tr>
<tr>
<td>Ammonia (Full Shift)</td>
<td></td>
</tr>
<tr>
<td>Ethanol</td>
<td>1.0</td>
</tr>
<tr>
<td>Propanol</td>
<td>0.8</td>
</tr>
<tr>
<td>Butanol</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Features of Mixed Alcohols Production

- The synthesis catalyst is sulfur tolerant making syngas cleanup simpler and less expensive
- Raw Syngas is produced from Petcoke in a Gasifier – chosen for unique $\text{H}_2 / \text{CO}$ ratio near 1.0 and shift conversion is not required
- Propanol can be separated for sale as a higher value chemical if market exists
- Methanol yield is relatively small compared to ethanol production
High alcohols produced can be used on-site for gasoline blending avoiding transportation and large storage costs – lower RVP and still very good octane vs Ethanol

Production of carbon containing fuel ethanol is an indirect method of carbon capture

CO₂ is removed from the recycle gas stream using Fluor Solvent Process based on flash-regeneration
  – CO₂ compressed to 2000 psig for pipeline/EOR
Alcohols Synthesis - PFD

- Syngas Feed
- CO₂ Removal
- Fuel Gas to Superheater
- BFW Make-up
- Methanol Wash
- Methanol / Water Separation
- Alcohols Reactor
- Alcohols Knockout
- Alcohols Separation
- Alcohols Product
- Condensate to Grinding Mills
Generic Block Flow Diagram
Electrical Power Production with Mixed Alcohols Synthesis

**Notes:**
- BFW = Boiler Feedwater
- CO = Carbon Monoxide
- CWS = Cooling Water Supply
- CWR = Cooling Water Return
- H₂ = Hydrogen
- HP = High Pressure
- N₂ = Nitrogen
- O₂ = Oxygen
### Alcohols Synthesis Performance Summary

<table>
<thead>
<tr>
<th>Performance Summary</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke Feed (AR)</td>
<td>stpd</td>
<td>2,260</td>
</tr>
<tr>
<td>Raw Water</td>
<td>gpm</td>
<td>2,118</td>
</tr>
<tr>
<td>HP O₂</td>
<td>stpd</td>
<td>2,238</td>
</tr>
<tr>
<td>Alcohols</td>
<td>stpd</td>
<td>1,100</td>
</tr>
<tr>
<td>Ethanol</td>
<td>bbl/day</td>
<td>2,049</td>
</tr>
<tr>
<td>Propanol</td>
<td>bbl/day</td>
<td>2,397</td>
</tr>
<tr>
<td>Butanol</td>
<td>bbl/day</td>
<td>3,341</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>stpd</td>
<td>422</td>
</tr>
<tr>
<td>CO₂</td>
<td>stpd</td>
<td>3,405</td>
</tr>
<tr>
<td>Power Consumed</td>
<td>MW</td>
<td>98</td>
</tr>
<tr>
<td>Power Generated</td>
<td>MW</td>
<td>62</td>
</tr>
<tr>
<td>Power Export/(Import)</td>
<td>MW</td>
<td>-36</td>
</tr>
</tbody>
</table>
## Alcohols Synthesis with Biomass Gasification – Performance Summary

<table>
<thead>
<tr>
<th>Performance Summary</th>
<th>Petcoke Gasi</th>
<th>Biomass Gasi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasifier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coke Feed (AR)</td>
<td>stpd</td>
<td>2,260</td>
</tr>
<tr>
<td>Biomass Feed</td>
<td>stpd</td>
<td>1,270</td>
</tr>
<tr>
<td>Raw Water</td>
<td>gpm</td>
<td>2,118</td>
</tr>
<tr>
<td>HP O₂</td>
<td>stpd</td>
<td>2,238</td>
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<tr>
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<td>stpd</td>
<td>422</td>
</tr>
<tr>
<td>CO₂</td>
<td>stpd</td>
<td>3,405</td>
</tr>
<tr>
<td>Power Consumed</td>
<td>MW</td>
<td>98</td>
</tr>
<tr>
<td>Power Generated</td>
<td>MW</td>
<td>115</td>
</tr>
<tr>
<td>Power Export/(Import)</td>
<td>MW</td>
<td>2</td>
</tr>
</tbody>
</table>
Process Advantages

- Gasoline Octane Enhancement – Adding <10 vol% product increases octane from 87 to 91
- Reduced tail pipe emissions \((CO \text{ and } NOx)\)
- Mixed alcohols product Ecalene certified for gasoline blending by US EPA
- Ideal facility for refinery product enhancement
  - Feed (coke) is a refinery by-product for export
  - Product (Alcohols) is a refinery product blend import
- Biomass Gasification allows for power balance and could qualify for carbon credit
- DOW and WRI \((Western \text{ Research Institute, Larame, Wyoming})\) are potential licensors
- Fluor received a patent on the overall flowsheet configuration
Generic Block Flow Diagram
Modular Execution

**Notes:**
- BFW = Boiler Feedwater
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- O₂ = Oxygen
Modular Fabrication & Execution

Very Large Module

Module on a Barge

Pipe Racks

Truck-able Module
Modular Fabrication & Execution
General Considerations

- Evaluate Cost Effectiveness between Stick Build vs Module Design
- Site Labor Availability
- Shop Labor vs. Site Labor Posture
- Site Labor Agreement
- Site Location/logistics
- Truckable vs. Large Modules (weight and size)
1st Generation Modular Execution
- Piperacks
- Super Modules for Piperacks
  - First used on AEF in 1991
  - Now extensively used on most Fluor projects
2nd Generation Modular Construction Execution

1st Generation plus

- Equipment or PAUs (Preassembled Units)
- Equipment on module
- Modules around equipment
- Pre-Dressed Vessels
- Improvement with Hours Moved Offsite
3rd Gen Modular Execution™

- Proprietary design layout work process
- Modularization drives layout
- Reduces quantities and field work
- Optimizes process block
- Promotes cost savings and schedule certainty
- Early pre-commissioning activities in controlled environment
3rd GEN Modular Execution™
Very Large Module
Why 3rd GEN Modular Execution℠?

- Clients looking for execution / project delivery improvements
  - Cost Effectiveness
  - Predictability – Cost and Schedule
- Cost and execution improvements through modularization are generally recognized
- Fluor have been steadily increasing level of modularization with consideration of site specifics
- Challenged by several Clients to increase level of E&I on modules
  - Overcome the traditional barrier
- Recognized In-Situ projects are being executed in “Traditional” manner
- Results:
  - Developed new approach ideally suited to Canadian In-situ Business and other difficult environments
  - Cost savings
  - Predictability improvements
Site Envelope Statistics

Traditional
320,000 m²

2nd Generation
200,000 m²

3rd Generation
84,000 m²
Expected Results from 3rd GEN Modular Execution™

♦ Reduced TIC
  - Up to 20% against previous “best-in-class”
  - Reduced plot area lowers quantities
  - Improved labor productivity with work shift to shop vs. field
  - Reduced on-site construction

♦ Enhanced Cost and Schedule Certainty Through Reduced Risk
  - Reduced E&I field scope
  - Back-end completion scope and complexity minimized
  - Less winter concrete

♦ Improved Safety and Quality

♦ Minimized Environmental Footprint

♦ Repeatable and Portable

♦ Operations & Maintenance Needs Maintained
Fluor Modularization Experience

CNRL
Horizon Phase 1
Project U&O

Nexen
Long Lake Upgrader
Phase 1

Shell
Ouest Carbon Capture

BP
Whiting Refinery
Modernization

Marathon
Detroit Heavy Oil
Upgrade Project

TOTAL
Deep Conversion
Project

ExxonMobil
Kitomba “K” & “E” FPSO

ConocoPhillips
Bahrain Development
Project

Exxon Neftegas
Salihlin 1

Supreme Modular
Fabr., Inc. (SMFI)
Edmonton, Canada
• Fabrication Yard

ICA Fluor
Tampico, Mexico
• Fabrication Yard

AG&P Fluor
Batangas, Philippines
• Fabrication Yard

Gladstone Pressure
Welders (GPW)
Gladstone, Australia
• Fabrication Yard

Standard Piperack Module

Truckable Process Module

Super Module

Offshore Platform Module
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