Ethanol as the Renewable Naphtha: Chemicals via Catalytic Upgrade of Ethanol

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Background

Greenyug LLC is focused on using catalysis and ethanol to commercialize specialty chemicals using exiting biofuel infrastructure with low capital and operating cost and minimal carbon footprint.

**Greenyug history**

- 2008-2010: Greenyug founded. Initial technology development
- 2011: Established state-of-the-art research facility in Santa Barbara, CA
- 2012: Construction of demonstration facility in Pune, India.
- 2013: Began Ethanol to Ethyl Acetate piloting. R&D for other products.
- 2014: Ethanol to Ethyl Acetate Project site identification.
- 2015: Begun commercialization of Ethyl Acetate technology.
- 2016: Begin Plant Construction. Other products piloting.
- 2017: Ethyl Acetate plant to start-up.

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Ethanol as naphtha

- Naphtha – a fuel and gasoline precursor - is one of the main building blocks of the petrochemical industry. Like ethanol it is:
  - Abundant
  - Inexpensive
  - Scalable
  - Reactive

Approximatively 5% of the oil barrel goes into chemicals generating about 40% of its value. We can do the same for the ethanol industry using a foundation of proven petrochemical technologies.
The economics of ethanol upgrade

Greenyug technology has high mass yield above 85% and targets products valued between $1,300 and $3,000/ton. "Green" products compete on a market basis with conventional ones.

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Greenyug Technology Platform

One single main unit operation
- Process Intensification
- Liquid phase catalysis

Small footprint

Easy integration into existing ethanol plants
- No retrofit of existing assets
- No disruption of existing operations
- Low capex and opex

Product versatility
- Ethyl Acetate (pre-commercial)
- n-Butanol (piloting)
- Other specialty chemicals (R&D)

Opens a world market of over $20 Billion
Process Simplification is Key to Success: n-Butanol: Greenyug vs. OXO-alcohols

**Greenyug**
- One single main unit operation
- Significantly lower CAPEX and OPEX
- Low energy consumption
- Integrated with the ethanol plant
- No waste

**Oxo-alcohols**
- Complex process based on multiple non-renewable feedstocks
- High capital and operating cost
- Large energy needs
- Integrated with the oil refinery
- Considerable chemical waste

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Greenyug is interested in the ownership and operation of its plant and is not pursuing a licensing model.
Ethyl Acetate is a good target for ethanol upgrade

High mass yield of the Greenyug process allows to capture most of the the EA and Ethanol price spread leading to a profitable process under variable market conditions

Sources: ICIS and CME

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Main Uses of Ethyl Acetate
(US Demand by End Use Sector %)

Paints and Coatings
51.1%

Pharmaceuticals
15.3%

Cosmetics
4.1%

Printing Ink
15.7%

Other (food, packaging, industrial solvents)
9.9%

Adhesives
4.1%

$4B world-wide market
### 50 kta Ethyl Acetate Plant Comparison

<table>
<thead>
<tr>
<th></th>
<th>Greenyug</th>
<th>Conventional process</th>
<th>Former US BioTech</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl Acetate revenue, $MM</td>
<td>59</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>Co-products, $MM</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feed Cost, $MM</td>
<td>36</td>
<td>40</td>
<td>60</td>
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<tr>
<td>Operating Cost, $MM</td>
<td>11</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>EBITDA, $MM</td>
<td>18</td>
<td>6</td>
<td>?</td>
</tr>
<tr>
<td>Capital Investment</td>
<td>&lt; $30 MM</td>
<td>$80 MM</td>
<td>&gt;$100 MM</td>
</tr>
</tbody>
</table>

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Ethyl Acetate

Commercial scale project announced June 20th
Summary

- Greenyug technology platform converts inexpensive and abundant Bio-ethanol into Higher Value Chemicals competitively with No “Green Premium”
- Greenyug products address a world market of over $20 billion
- Greenyug is leveraging $150 billion global bio-fuels industry investment using bolt-on strategy at existing bio-fuels facilities to significantly reduce capital needs.
- Greenyug is pursuing partnerships for the ethanol to n-butanol process which is currently at the demo stage.
- Ethyl acetate is going commercial.
Thank you for your attention.

… by the way; YUG means era or epoch in Sanskrit, the classic Indian language.