Renewable Fuel Oil – A Commercial Perspective

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Technical Information Exchange on Pyrolysis Oil:
Potential for a Renewable Heating Oil Substitution Fuel in New England
May 9 – 10, 2012, Manchester, New Hampshire
Envergent Technologies LLC – UOP / Ensyn Joint Venture

• Formed in October 2008
• Provides pyrolysis technology for fuel oil substitution and electricity generation
• Development of technology for upgrading RTP green fuel to transportation fuels

Second Generation Renewable Energy Company – Global Reach

UOP
• Leading process technology licensor~$2 billion in sales, 3000 employees
• Nearly 100 years of refining technology development, scale-up and design
• Modular process unit supplier
• Global reach via Honeywell & UOP sales channels

Ensyn
• Over twenty years of commercial fast pyrolysis operating experience
• Developers of innovative RTP fast pyrolysis process
• Seven commercial RTP units designed and operated
RTP – Second Generation Residues to Energy

Available Today
- Electricity Production
- Fuel Oil Substitution

Under Development
- Upgrade to Transport Fuels (Gasoline, Jet & Diesel)

RTP Green Fuel

Decouples Biomass from Energy Generation

Forest Residue, Agricultural Waste, Construction & Demo Waste

Energy/Fuels

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## RTP Green Fuel Properties

- Pourable, storable and transportable liquid fuel
- Contains approximately 50-55% energy content of fossil fuel

### Comparison of Heating Value of RTP Green Fuel and Typical Fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>MJ / Litre</th>
<th>BTU / US Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>17.5</td>
<td>62,500</td>
</tr>
<tr>
<td><strong>RTP Green Fuel</strong></td>
<td><strong>19.9</strong></td>
<td><strong>71,500</strong></td>
</tr>
<tr>
<td>Ethanol</td>
<td>23.5</td>
<td>84,000</td>
</tr>
<tr>
<td>Light Fuel Oil (#2)</td>
<td>38.9</td>
<td>139,400</td>
</tr>
</tbody>
</table>

**Suitable for Energy Applications**
RTP Green Fuel End Markets

- Transportation dominates liquid fuel markets
- But industrial heat and power markets offer significant opportunity that can be addressed today
- Currently focused on industrial projects in areas where feed/product spread is favorable (with or without incentives)

Address Today’s Markets While Developing Tomorrow’s Technology
RTP Green Fuel Applications

Multiple Applications Drive Multiple Market Opportunities

- Current Applications
- Emerging Applications
RTP Green Fuel-Replacement of Fossil Fuel Oil

- Low emissions (NOx, SOx)
- Fuel consistency - ASTM D7544 standard
- GHG emission reduction of 70-90%
- Low cost liquid biofuel

Example Basis
- Replacement of #6 fuel oil at equivalent heating value price
- Assumed $2.80/gal for #6
- Feed cost = as received, 40% moisture

A Cost Effective Green Alternative to Fuel Oil

RTP Green Fuel Production Cost, $/BTU Equiv. Gal

*does not include incentives
• RTP green fuel *Life Cycle* foot print *Greener* than other alternatives
• Carbon neutral combustion emission 70-88% lower GHG emissions
• \( \text{SO}_x \) emissions similar to Natural Gas
RTP Green Fuel – Renewable Heat Experience

• 20+ years industrial experience combusting RTP liquids
  - Red Arrow, Wisconsin
  - Manitowoc Public Utilities, Wisconsin
  - Over 65 million liters delivered for process heat

• Recent successful demonstrations in a variety of applications
  - Power boiler
  - Iron Ore pellet furnace
  - Various process and heating boilers
Commercial/Industrial Boiler

- American specialty paper products company
- Ran up to 19.2 MMBtu/hr to produce space heat
- Fired exclusively on RTP green fuel
- Babcock and Wilcox heavy fuel oil burner and boiler
- Compared emissions to HFO
  - Virtually eliminated SOx
  - NOx emissions lowered
- November 2010
Commercial/Industrial Boiler

Sulfur Dioxide Concentration in Flue Gas

NOx Concentration in Flue Gas

Fuel Inputs on a Higher Heating Value Basis

Boiler #1 Stack Opacity
RTP Green Fuel Delivery Skid

Burner Nozzle

No.6 Fuel Line

Tie in

RTP Green Fuel HFO Connections
Process Boiler

- European forestry company
- Ran at 20 MWth, replacing HFO
- Produced steam for use in plant
- PetroKraft rotating cup burner
- October 2009
Iron Ore Pellet Furnace

• Canadian iron ore company
• Ran up to 22 GJ/hr
• Fired one burner exclusively on RTP green fuel, replacing HFO
• Application was ideal for RTP green fuel
• June 2011
Oilon Burner Commercial Development

- Oilon has developed a full burner solution for pyrolysis oil
  - Includes fuel conditioning and burner controls
- Recent testing at their Energon facility in Lahti, Finland
  - 2.5 MWth boiler
  - 18 metric tonnes of RTP green fuel burned
IBR – Biomass to Transportation Fuel Pilot

- Pilot-scale conversion of biomass into liquid transportation fuels
- Located at the Tesoro Refinery in Kapolei, HI
- Backed by a $25 million award from the U.S. Department of Energy
- Utilizes a wide range of locally available biomass (switchgrass, algae, forest and agricultural residuals)
- Commercial units could create up to 800 construction jobs and 1,000 new jobs in biomass production and refinery operations
- Greater than 60% reduction in greenhouse gas emissions
- Phase 1 Start-up Underway 4/2/2012
- Fully Operation 1Q 2013

Making Cellulosic Biofuels a Reality
History and Commercial Experience

• Commercialized in the 1980’s
• 7 units designed and operated in the US and Canada
• Continuous process with >90% availability

New Projects Under Development:

<table>
<thead>
<tr>
<th>Location</th>
<th>Application</th>
<th>Size (TPD)</th>
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</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Power Generation</td>
<td>150</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Industrial Process Heat</td>
<td>400</td>
</tr>
<tr>
<td>Northern Europe</td>
<td>Power Generation</td>
<td>2 x 400</td>
</tr>
<tr>
<td>North America</td>
<td>Industrial Process Heat</td>
<td>400</td>
</tr>
<tr>
<td>Northern Europe</td>
<td>District Heating</td>
<td>up to 3 x 400</td>
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RTP Summary

• RTP green fuel is cost-competitive with fossil fuel oil

• Commercially proven technology: 7 units in operation; 3 new projects announced

• Decouples biomass conversion from energy generation

• Greater than 70% LCA green house gas emission reduction

• Heavy fuel oil replacement commercially available today