Refinery Coprocessing Options for Advanced Biofuels Production

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Agenda

- UOP Technologies for Drop-in Renewable Fuel Production
- DHT Co-processing
- FCC Bio-Crude Co-processing
- Conclusion
UOP Technology Solutions for Renewable Fuel Production

Inedible Fats, Oils & Grease
- Ecofining™ Process
  - Honeywell Green Diesel™
  - Green Jet (optional)

Petroleum Distillate
- UOP Renewable Jet Fuel Process™
  - Honeywell Green Jet™
  - Green Diesel
  - Partial Green Diesel
  - Partial Green Jet

Biomass
- RTP® (Pyrolysis)
- UOP FCC Co-Processing
  - RF Gasoline
  - RF Diesel

Proven Technologies for Feedstock Flexible Drop In Fuels
Ecofining™ Process

Green Diesel Product Description
- Pure “drop-in” hydrocarbon biofuel
- Meets ASTM D975, blends meet EN590
- Adjustable cold flow properties
- 50-90% GHG Savings relative to fossil diesel depending upon feed source
- Low density, high cetane allows blending of heavier, low cetane diesel components
- Ultra low sulfur, low NOx emissions

Benefits
- Reduce costs and risks of compliance by making biofuels instead of buying them
- Feedstock flexible – utilize lower cost feeds
- High yields – minimize feedstock consumption
- Attractive economics with impressive payback, high IRR with moderate capital cost

Commercial Scale, Proven Technologies, Repeat Customers
Potential Feedstocks for Green Diesel & Green Jet Fuel Production

- **Plant Oils**
  - Rapeseed/Canola
  - Soybean
  - Palm, PFAD
  - Carinata
  - Camelina
  - Jatropha
  - Inedible Corn Oil
  - Tobacco oil

- **Animal Fats**
  - Tallow (beef)
  - Choice White Grease (pork)
  - Poultry Fat

- **Waste Greases**
  - Used Cooking Oil
  - Yellow Grease

- **Algal and Microbial Oils**

Flexibility to utilize the low cost feedstocks without compromising product quality.
Operating Plants Using UOP’s Renewable Fuel Technology

2013
Diamond Green Diesel
• First New Ecofining Unit installed at Norco, Louisiana, USA
• Expansion to 48,000 BPSD in progress

2014
ENI #1
• First refinery retrofit to Ecofining Unit at Venice, Italy
• Expansion to 560,000 MTA (11,200 BPD) in progress at Venice

2016
AltAir
• First refinery retrofit to UOP Renewable Jet Fuel Unit at LA, USA
• Produces Green Jet and Green Diesel
• Expanding to 20,000 BPSD

2018
ENI #2
• Second refinery retrofit to Ecofining Unit at Gela, Italy
• Plant to process 750,000 MTPY

Refinery integration for all four projects...three were refinery revamps
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Bio-Feedstock Coprocessing in DHT Units

Technical Considerations

- Displaced petroleum hydrotreating capacity
- Increased H\textsubscript{2} consumption
- Increased Acid Gas handling and Sour Water handling requirements
- Increased heat of reaction and competing reactions
- Limited feedstock types…“clean” feedstocks only (moderate Carbon Intensity)
- Careful monitoring of performance and corrosion

Less than 3-5% renewable coprocessing

- Low capital investment
- Process configuration changes may be needed to meet cold flow properties requirements
- LCFS credits applicable in USA
- Not applicable for Blender’s Tax Credit in USA

Greater than 5% coprocessing

- Moderate capital investment
- More significant process configuration changes may be needed to meet cold flow properties requirements
- LCFS credits applicable in USA
- Not applicable for Blender’s Tax Credit in USA
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“Feed Flexible” RTP™ Technology for Biomass to Bio-Crude conversion in just 2 seconds

- Highest Energy-densification of Biomass (~ 72%)
- High yield as 100% Biomass is used
- Decouples Biomass Value Chain, Ease of Storage

RTP™ Unit Renfrew, Canada

<table>
<thead>
<tr>
<th>Biomass Feedstock Type</th>
<th>Typical RTP Green Fuel Yield (wt% of Dry Feedstock)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardwood</td>
<td>70 – 75</td>
</tr>
<tr>
<td>Softwood</td>
<td>70 – 80</td>
</tr>
<tr>
<td>Hardwood Bark</td>
<td>60 – 65</td>
</tr>
<tr>
<td>Softwood Bark</td>
<td>55 – 65</td>
</tr>
<tr>
<td>Corn Fiber</td>
<td>65 – 75</td>
</tr>
<tr>
<td>Bagasse</td>
<td>70 – 75</td>
</tr>
<tr>
<td>Waste Paper</td>
<td>60 – 80</td>
</tr>
</tbody>
</table>

Bio-Crude is energy-dense “Liquid Biomass” made from Biomass
Converting “Biomass Challenge” to “Bio-Crude Opportunity” in the region

1. Agri/Crop and Wood residues like Paddy/ Corn/ Cottonseed/ Wheat straw or waste wood
2. Collect straw bales from field for truck shipment
3. Send straw bales from field to RTP facility
4. RTP converts biomass to RTP Green Fuel
5. Transport RTP Green Fuel to customer site by truck, rail or ship
6. RTP Green Fuel burned in customer boiler, furnace or kiln

Commercially Proven RTP Process to Convert Biomass into BioCrude
Benefits of FCC Bio-Crude Co-Processing

• Generate cellulosic gasoline and diesel volumes from residual biomass
  – Similar product yield to petroleum feed
  – Same product quality as petroleum feed

• Processing benefit to refiner
  – Minimal capex for implementation
  – Short payback time

• Fuels produced have one of the lowest Carbon Intensity values
  – Carbon intensity of co-produced fuels 21-25 gCO$_2$/MJ)

### Weight %

<table>
<thead>
<tr>
<th>Product</th>
<th>100% VGO</th>
<th>95% VGO + 5% Bio-oil</th>
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</thead>
<tbody>
<tr>
<td>Dry Gas</td>
<td>3.5</td>
<td>2.8</td>
</tr>
<tr>
<td>LPG (C$_3$-C$_4$)</td>
<td>13.8</td>
<td>13.8</td>
</tr>
<tr>
<td>Gasoline (C$_5$-220°C)</td>
<td>39.9</td>
<td>40.6</td>
</tr>
<tr>
<td>Diesel (220-344°C)</td>
<td>20.3</td>
<td>19.6</td>
</tr>
<tr>
<td>Bottoms (+ 344°C)</td>
<td>16.1</td>
<td>14.4</td>
</tr>
<tr>
<td>Coke</td>
<td>6.4</td>
<td>6.0</td>
</tr>
<tr>
<td>CO</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Water</td>
<td>0.0</td>
<td>1.4</td>
</tr>
</tbody>
</table>


### Select LCFS Pathway Carbon Intensities (gCO$_2$e/MJ)

<table>
<thead>
<tr>
<th>Product</th>
<th>Carbon Intensity (gCO$_2$e/MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Baseline</td>
<td>99.8</td>
</tr>
<tr>
<td>Diesel Baseline</td>
<td>102.0</td>
</tr>
<tr>
<td>Midwest Corn Ethanol</td>
<td>76.0</td>
</tr>
<tr>
<td>California Corn Ethanol</td>
<td>68.4</td>
</tr>
<tr>
<td>Soybean Biodiesel</td>
<td>57.0</td>
</tr>
<tr>
<td>Brazilian Sugarcane Ethanol</td>
<td>56.7</td>
</tr>
<tr>
<td>Ensyn Renewable Diesel</td>
<td>21.7</td>
</tr>
<tr>
<td>Ensyn Renewable Gasoline</td>
<td>20.1</td>
</tr>
<tr>
<td>Biodiesel from used cooking oil</td>
<td>19.8</td>
</tr>
</tbody>
</table>

Source: LCFS Readopted Regulation, Ensyn Pathway Application
Commercial Status and Regulatory Recognition

- Four commercial scale FCC co-processing trials completed

- Multiple full-scale installations of technology scheduled
  - USA
  - Europe
  - Asia

- Regulatory recognition and verification
  - Completion of US EPA Part 79 Fuel Registration
  - Application of US EPA Part 80 Facility Registration for Co-processing
  - Application of ISCC certification for recognition of biofuel in Europe
Modular “RTP 400” Approach – Key Advantages

Partial Modular delivery to lower TIC
- Cold section delivered as Pre-Fab Modules to decrease time & cost of installation
- Uses only pre-qualified fabrication shops worldwide
- Modules are fully inspected to minimize field work

Modular Advantages
- Controlled Fab shops produces superior quality
- Minimize impact at customer site and operations
- Leverage UOP experience of > 180 modular units
- Fixed Delivery Schedules ensure no delays, less cost
- Fixed Price = Peace of Mind, Less Risk, No Surprises
Increased Green Diesel and Green Jet activity across the globe
• North America/Europe/Middle East/Asia
• New units, Revamps and DHT Coprocessing

Growing interest from refiners for FCC Coprocessing
• Numerous projects to implement technology around the world in progress

Driven by:
• Climate change and GHG reduction commitments
• Air pollution mitigation
• Rural/Agriculture Job creation, Farmer support
• Corporate social responsibility
• Continuing development of new technology pathways

The Future of Biofuels is Bright – Creating Value for All Stakeholders
Honeywell is committed to providing technology options that better enable our customers to produce better quality Renewable fuels & Energy for a more sustainable future.

THANK YOU