Agenda

• An Introduction To Honeywell’s UOP
• Biofuels Landscape
• UOP Biofuels Vision
• Sustainable Technology Solutions
Honeywell UOP

UOP Creates Knowledge Via Invention And Innovation And Applies It To The Energy Industry

- 1,570 scientists and engineers
- 2,600 active patents
- Expertise
- Experience

- Process technology
- Catalysts
- Adsorbents
- Equipment
- Services

Petroleum  Petrochemicals  Natural Gas  Renewables

More Than 60% Of The World's Gasoline And 85% Of Biodegradable Detergents Are Made Using UOP Technology
UOP Renewables Vision

- Building on UOP technology and expertise
- Produce real “drop-in” fuels instead of fuel additives/blends
- Leverage existing refining, transportation, energy, biomass handling infrastructure to lower capital costs, minimize value chain disruptions, and reduce investment risk
- Focus on path toward second generation feedstocks & chemicals

**Oxygenated Biofuels**
- Ethanol
- Biodiesel

**Renewable Energy**
- Fuel & Power

**Hydrocarbon Biofuels**
- Diesel
- Jet
- Gasoline

**First Generation**
- Natural oils from vegetables and greases

**Second Generation**
- “Other” Oils: Camelina, Jatropha
- Lignocellulosic biomass, algal oils
Mega Trends

• Global Energy Demand is Expected to Grow at CAGR 1.6% Through 2017
  - Primary Energy diversity will become increasingly important over this period with coal, natural gas & renewables playing bigger roles

• Fossil Fuels are Expected to Supply 83% of Energy and 95% of Liquid Transportation Needs

• Biofuels are Expected to Grow at 8-12% per year to ~3.0 MBPD

Source: IEA, 2008
Petroleum Refining Context

- Fossil Fuel production ~100 years
- ~750 refineries
- ~85M BBL of crude refined daily
- ~50M BBL transport fuels; ~6M BBL of aviation fuel (~250 M gallons/day; 90 B gallons/year)
- Complex but efficient conversion processes
Global Legislation Overview

**Canadian Law C-33 Mandates:**
- E5 by 2010
- B2 by 2012
- B5 in British Colombia by 2010

**EU-27 – Adopted Mandates:**
- RED – 10% by Energy content by 2020
- GHG – 6% reduction by 2020 from 2010 levels

**EISA 2007:**
- RFS mandate – 36 Billion Gal by 2022
- Several State mandates in effect
- California – LCFS mandated
- GHG initiatives established in NE States

**Mandates:**
- Brazil: E25/B3
- Colombia: E10/B5

**Canadian Law C-33 Mandates:**
- E5 by 2010
- B2 by 2012
- B5 in British Colombia by 2010

**EU-27 – Adopted Mandates:**
- RED – 10% by Energy content by 2020
- GHG – 6% reduction by 2020 from 2010 levels

**EISA 2007:**
- RFS mandate – 36 Billion Gal by 2022
- Several State mandates in effect
- California – LCFS mandated
- GHG initiatives established in NE States

**Mandates:**
- Brazil: E25/B3
- Colombia: E10/B5

**Legislation Spurring More Biofuel Use Globally**

E_ : % Renewable content in Gasoline
B_ : % Renewable content in Diesel
Biofuels: Variable Performance to Date

- **Corn Ethanol** — Low production costs and scalable yet suffered in the food versus fuel debates. Life Cycle Analysis currently a subject of debate.

- **Biodiesel** — Regional legislation in a global market created economic bubbles which collapsed as legislation amended, and short term micro-economic shocks corrected.

- **Cellulosic Ethanol** — Great promise but rate of commercialization arguably behind initial DOE expectations. Technology innovations still required.

- **Biomass To Liquids (BTL)** — Excellent fuel properties, but thus far, a high capital route to fuels, and still faces some technical hurdles.

- **Biomass To Power (BTP)** — Incumbent direct firing routes using steam turbines work well, but leave efficiency (and profitability) on the table.

**UOP Technologies Are Feedstock Flexible, And Leverage Existing Assets And Technologies**
UOP Renewable Energy Technologies

**Feed**
- Natural Oil/Fats
- Hydrogen

**Process**
- Ecofining™ Process
- Renewable Jet Process
- RTP™ (Pyrolysis)

**Product**
- Honeywell Green Diesel™
- Green Jet (if req)
- Honeywell Green Jet™
- Green Diesel
- Green Power / Fuel Oil (now)
- Green Fuels (2011)

**Envergent Technologies – UOP/Ensyn JV**

**Sustainable Technologies – Feedstock Flexible And 2nd Gen Ready**
UOP/ENI Ecofining™ Process

- Superior technology that produces Honeywell Green Diesel rather than an oxygenate additive
- Uses existing refining and transportation infrastructure, and can be used in existing automotive fleet
- Two units licensed in Europe, a further under engineering in US
- Feedstock flexible – enabling access to 2nd Gen or low cost feedstocks
- Can be used as an approach to increase refinery diesel output

**Process Comparison vs. Biodiesel**

<table>
<thead>
<tr>
<th>Natural Oil/Grease</th>
<th>→</th>
<th>Biodiesel (FAME) + Glycerol</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Methanol</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Natural Oil/Grease</th>
<th>→</th>
<th>Green Diesel + Propane</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Hydrogen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Process Overview**

- Feed
- Reactor System
- Acid Gas Removal
- Make-up Hydrogen
  - 2.2 – 3.5 Wt-%
- CO₂
- Propane
  - 1 – 10 Vol-%
- Water
- Green Diesel Product
  - 88 – 98 Vol-%
- Green Naphtha or Jet
  - 88 – 98 Vol-%

Jefferies Global Clean Technology Conference – March 17, 2010
Honeywell Green Diesel™ Product Comparison

<table>
<thead>
<tr>
<th></th>
<th>Petroleum ULSD</th>
<th>Biodiesel (FAME)</th>
<th>Honeywell Green Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen Content, %</td>
<td>0</td>
<td>11 (−)</td>
<td>0 (+)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>0.84</td>
<td>0.88 (−)</td>
<td>0.78 (+)</td>
</tr>
<tr>
<td>Cloud Point, °C</td>
<td>-5</td>
<td>-5 to +15 (−)</td>
<td>-20 to +10 (+)</td>
</tr>
<tr>
<td>Cetane</td>
<td>40 - 52</td>
<td>50-65 (+)</td>
<td>70-90 (+)</td>
</tr>
<tr>
<td>Sulphur, ppm</td>
<td>&lt;10</td>
<td>&lt;2 (+)</td>
<td>&lt;2 (+)</td>
</tr>
<tr>
<td>Energy Density, MJ/kg</td>
<td>43</td>
<td>38 (−)</td>
<td>44 (+)</td>
</tr>
<tr>
<td>Energy Content, BTU/gal</td>
<td>129 K</td>
<td>118 K (−)</td>
<td>123 K (+)</td>
</tr>
<tr>
<td>Poly-Aromatics, vol-%</td>
<td>4 - 12</td>
<td>0 (+)</td>
<td>0 (+)</td>
</tr>
<tr>
<td>Colour</td>
<td>Clear</td>
<td>Light to Dark Yellow (−)</td>
<td>Clear (+)</td>
</tr>
<tr>
<td>Oxidative Stability</td>
<td>Baseline</td>
<td>Poor (−)</td>
<td>Baseline</td>
</tr>
<tr>
<td>Production cost $/gallon</td>
<td>Baseline</td>
<td>Baseline - $0.22</td>
<td></td>
</tr>
</tbody>
</table>

**UOP’s Proven Refining Technologies Create High Quality Diesel Fuel At A Lower Cost Than Biodiesel**
Renewable Aviation Fuel Market Drivers

**EU GHG Emissions by Sector as an Index of 1990 Levels**

- **US Military’s National Security Driven Goals to Achieve Both Greater Substitution and GHG Reduction**

- **EU Emission Trading Scheme Extending to Aviation Sector:**
  - Aviation emissions: Fastest growing of any sector

**Key Drivers of Emissions Reductions**

-UOP Process Closes An Unaddressed Gap If Aviation Is To Grow At Or Beneath Carbon Neutrality
UOP Renewable Jet Process Overview

- Initially a DARPA-funded project to develop process technology to produce military jet fuel (JP-8) from renewable sources
- An extension of UOP Ecofining™ process, with selective cracking to make jet-range material
- Produces Honeywell Green Jet™ that meets all properties of ASTM D7566
- Certification for blending up to 50% in progress

Now Available For License
UOP Renewable Jet Process

- Feedstock flexible
- Costs
  - Capex: similar to typical refinery process unit
  - Opex: cost subject to feedstock cost, but can be competitive with Jet A-1
- High quality green hydrocarbon products
  - Swing between Green Jet and Green Diesel production to meet demand and reduce new market uncertainty
Completed Flight Demonstrations

- Successful ANZ Flight Demo
  Date: December 30 2008
  Feedstock: Jatropha oil

- Successful CAL Flight Demo
  Date: Jan. 7 2009
  Feedstock: Jatropha and algal oil

- Successful JAL Flight Demo
  Date: Jan. 30 2009
  Feedstock: Camelina, Jatropha and algal oil
Completed Flight Demonstrations - Continued

UOP Green Jet Fuel Technology Powers KLM Biofuel Demo Flight
On November 23, 2009

- Europe’s first biofuel test flight
- First biofuel test flight to carry observers (42) on board
- One engine of a Boeing 747 was powered with 50/50 blend of green jet and petroleum-derived jet fuel
- Feedstock: Camelina oil, inedible oil
- KLM founded SkyEnergy consortium with North Sea Petroleum and Spring Associates to ensure a steady supply of jet fuel
UOP / Ensyn Joint Venture

- Announced September 2008
- Pyrolysis Oil technology for fuel oil substitution & power generation
- JV is commercialization channel for UOP R&D on upgrading pyrolysis oil to transportation fuels

- Core competence in engineering and technology scale-up
- Experienced Fluidized Catalytic Cracking (FCC) technology licensor
- Modular process unit supplier
- Leader in fundamental catalyst and process development (Upgrading)

- ~20 years of commercial fast pyrolysis operating experience
- Developers of innovative RTP fast pyrolysis process
- 8 commercial RTP units
- Now applying technology to fuel oil and energy

2nd Generation Renewable Energy Company – Global Reach
Rapid Thermal Process (RTP™) Technology

- Patented process
- Biomass converted to liquid pyrolysis oil
- Similar to existing UOP technology
- High yields, >70 wt% liquid on woody biomass
- Suitable for installation in biomass-rich areas

Pyrolysis Oil

Solid Biomass

Proven Technology, Full Scale Designs Available
Pyrolysis Oil Energy Applications

- Replacement of fossil fuel for heat/steam generation ~25% lower energy cost than fossil fuel oil
- Production of green electricity at competitive rates
- Energy densification play compatible with many upcoming technologies
- Considered a key renewables platform technology

Renewable Electricity ~10-12c/kW-h Targeting Renewable Fuels At Fossil Fuel Costs

Current Applications
Emerging Applications
Summary

- UOP has 90 years of oil refining technology expertise and is creating a renewable energy technology portfolio
- Rigorous development process reduces technology risk, and results in high quality fuels
- Feedstock flexibility bridges generational issues related to feedstock sourcing and indirect impacts
- UOP continues to develop its portfolio to meet the challenges of a sustainable renewable fuel future