Biofuels: Unlocking the Potential

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Des Plaines, IL, USA
Agenda

- UOP Introduction
- Global Primary Energy Demand Implications
- Global Renewable Legislation/Market Drivers
- UOP Biofuels Vision
- 2nd generation bio-feedstocks
- Conversion Technology Overview
- Sustainability
UOP Overview

- Leading supplier and licensor of process technology, catalysts, adsorbents, process plants, and technical services to the petroleum refining, petrochemical, and gas processing industries
- 2008 Revenues - ~$2B
- UOP technology furnishes 60% of the world’s gasoline, 85% of the world’s biodegradable detergents, and 60% of the world’s para-xylene
- Strong relationships with leading refining and petrochemical customers worldwide
- UOP’s innovations enabled lead removal from gasoline, biodegradable detergents, and the first commercial catalytic converter for automobiles

95 years of sustained technology leadership
Global Primary Energy Demand - ~45% increase by 2030

Diversification is Key to Meet Future Needs
Global Crude Oil Production by Source

- Current large fields depleting at a rapid rate
- New finds are largely smaller fields that deplete even faster
- Deep sea exploration and unconventional oils will increasingly fill the gap
- New crudes will tend to be heavier and more contaminated

Heavier Crudes also Result in a Higher Carbon Footprint
Global CO₂ Emissions by Energy Source, Region & Sector

- China surpassed the US in 2008
- China and India have low per capita emissions

**Power and Transport sector the largest CO₂ emitters**

Sustainably produced Renewable Power & Fuels will play an increasingly important role
## Biofuels: A Quickly Changing Landscape

<table>
<thead>
<tr>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<tbody>
<tr>
<td>• All biofuels are good</td>
<td>• Not all biofuels are good</td>
<td>• Credit Crisis: Stimulus focused on Green Tech</td>
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<td>• More, faster</td>
<td>• Concern for food chain impact &amp; competition for land/water</td>
<td><strong>UOP Position</strong></td>
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<td>• No criteria to measure impact of adopting biofuels</td>
<td>• Measured biofuel adoption</td>
<td>• Emphasis on life cycle analysis as a way of measuring “sustainability”</td>
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<td>• Availability of “inexpensive” bio feedstocks</td>
<td>• Utilization of LCA analysis to “qualify”: link to GHG, energy, sustainability</td>
<td>• Ensure technology is feedstock flexible</td>
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<td>• Government mandates and incentives favor ethanol and biodiesel</td>
<td>• Bio feedstocks tracking energy prices</td>
<td>• Focus on 2nd generation technologies</td>
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<td></td>
<td>• Government mandates/incentives increasingly technology neutral</td>
<td>• Create partnerships between feedstock suppliers and fuel producers</td>
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<td>• Emphasis on “real” biofuels</td>
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**Increasing Awareness of Potential Impact**
Global Legislation Overview

**Biofuels Market Drivers:**
- Government Legislation
- Energy Security
- Primary Energy Diversification
- Climate Change

**Global Biofuels use Trending Towards a Nominal E10 & B5**
US Mandates/Sustainability:

- EISA 2007 (Energy Independence and Security Act)
- Technology neutral legislation
- 36 B gallons biofuels, ~2.5M BPD by 2022
- Corn based ethanol, capped at 15 B gal
- Emphasis on transition to 2nd generation cellulosics
- Requires demonstration of LCA based GHG savings relative to baseline petroleum fuels
  - ≥20% for new corn based ethanol plants
  - ≥50% for advanced biofuels (non-corn based)
- Technology Neutral

Indirect Land Use will factor in LCA
1st gen: Will not qualify as advanced biofuels
Petroleum Refining Context

- Refining: ~100 years
- ~750 refineries
- ~85M BBL of crude refined daily
- ~50M BBL transport fuels
- Complex but efficient conversion processes
- Feedstock provider to the global petrochemical industry
- Established infrastructure for blending, distribution and traded globally

Massive Scale Technology Evolution Expected
UOP Biofuels Vision

- Produce real “drop-in” fuels instead of fuel additives/blends
- Leverage existing refining/transportation infrastructure to lower capital costs, minimize value chain disruptions, and reduce investment risk.
- Focus on path toward second generation feedstocks

**Oxygenated Biofuels**
- Ethanol
- Biodiesel

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

“Other” Oils: Camelina, Jatropha, Halophytes

First Generation
- Natural oils (vegetables, fats & greases)

Second Generation
- Lignocellulosic biomass, algal oils
Enablers for a Sustainable Biomass Infrastructure

- Cellulosic waste could make a significant contribution to liquid transportation pool.
- Algal Oils could enable oils route to biodiesel, Green Diesel and Green Jet.

Increases Availability, Reduces Feedstock Cost
Technology Breakthroughs Required
Jatropha: Key Attributes

11 million hectares → 26 million acres jatropha planned in India

- Grows well in lowland up to 1000 meters elevation
- Grows at rainfall of 300-2380 ml/year
- Grows well in porous as well as marginal soil
- Required average temperature is 20-28 °C
- Requires soil acidity between 5 – 6.5

Productivity:
- Yields high quality oil
- Yields vary from 220-450 gal/acre/year
- Seed quality, cultivation practices and water impact yields

Scale of Jatropha Plantations
2008-2015 (Acres)

Potential for ~1M BPD of Jatropha based diesel beyond 2015
Algae: Key Attributes

- Temperate & Tropical Zones Avg. temp > 15°C (Optimal = 4-10°C night/10-22°C day)
- Water Resources (hypersaline to fresh)

Algae Have Widest Climatic Tolerance and Highest Productivity Of Any Potential Energy Crop

- Current optimal ~ 1,200 gal/acre/year
- Projected genetic crop enhancement to ~4,000 gal/acre/year
Comparative Land Requirements

Algae oil yield advantage

Chart illustrates value add of algae to fuels process
- Significantly reduced footprint for producing same amount of fuel

The amount of land required to replace 50% of the current petroleum diesel usage using corn, soybean, and algae.

Courtesy of Paul Bryan
**Projected Growth in Algal Biofuels**

**Driving Force for Algal Biofuels:**

- US DARPA Algal Biofuels Program will establish initial pilot production capabilities and oil recovery, purification, and processing capabilities.
- The US DOE IBR program will promote scale up to commercial size production and refining.
- Commercial expansion driven by market and regulatory factors.
- Approximately $200 M in venture funding in 2008 alone.

Exxon Mobil’s $600M investment into Algae R&D validates this sector.
UOP/ENI Ecofining™ Green Diesel

- Technology that produces a fully fungible hydrocarbon product
- Uses existing refining infrastructure, can be transported via pipeline, and can be used in existing automotive fleet
- Two units licensed in Europe with first commercial start-up in 2010
- Excellent blending component, allowing refiners to expand diesel pool by mixing in “bottoms”
- Can be used as an approach to increase refinery diesel output

**Process Comparison vs. Biodiesel**

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<th>Petrodiesel</th>
<th>Biodiesel</th>
<th>Green Diesel</th>
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<tr>
<td>NOx</td>
<td>Baseline</td>
<td>+10</td>
<td>Baseline or better</td>
</tr>
<tr>
<td>Cetane</td>
<td>40-55</td>
<td>50-65</td>
<td>75-90</td>
</tr>
<tr>
<td>Cold Flow Properties</td>
<td>Baseline</td>
<td>Needs Additives</td>
<td>Baseline or better</td>
</tr>
<tr>
<td>Oxidative Stability</td>
<td>Baseline</td>
<td>Needs Additives</td>
<td>Baseline or better</td>
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**Performance Comparison**
Aviation Fuels: Principal Market Drivers

- **EU 27-Emission Trading Scheme (ETS):**
  - Central pillar of EU Climate Policy
  - Applicable since January 1, 2005
  - Covers around 2B MT of CO₂ emissions – ~50% of EU's total emissions
  - Cap & Trade System
  - ETS extended to aviation emissions in October’2008
  - Total emissions will be capped in 2012 at 97% of 2004-2006 average
  - Cap will decrease in 2013 to 95% of historical emissions

- **US Military:**
  - National Security & Green Vision driven
  - Consumes ~300K BPD aviation fuel
  - Goal set to have 50% of its needs met by alternative fuels primarily biojet by 2020

- **Green Jet: Production Potential:**
  - In the near term feedstock supply key determinant
    - Camelina - ~200M gpy by 2012 & ramping up
    - Jatropha - ~3B gpy by 2015
  - Longer term:
    - Algae will be primary feedstock
    - Commercial scale production, 7-10 years out
  - Acceleration of certification

**OEM Led Market Development & Supported by Legislation**
UOP Renewable Jet Process

• Initially a DARPA-funded project to develop process technology to produce military jet fuel (JP-8) from renewable sources
• Targets maximum Green Jet production
• Green Jet Fuel can meet all the key properties of petroleum derived aviation fuel, flash point, cold temperature performance, stability
• Certification of Green Jet as a 50% blending component in progress

Built on Ecofining Technology

DARPA Project Partners

Available for License Q3 2009
Completed Flight Demonstrations

- **Successful ANZ Flight Demo**
  - Date: Dec. 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
Pyrolysis Oil to Energy & Fuels

Available Today

Electricity Production
Fuel Oil Substitution
Transport Fuels (Gasoline, Jet Diesel)
Chemicals (Resins, BTX)

Conversion to Transport Fuels Demonstrated in Lab Collaboration with DOE, USDA, PNNL, NREL
Scope of WTW* LCA

Petroleum Based Fuels

Extraction of Crude Oil
    ↓
Transport of Crude Oil
    ↓
Refining
    ↓
Gasoline, Jet, Diesel
    ↓
Consumer Use

Green Distillate from Waste Tallow

Waste Tallow from Meat Processing Industry
    ↓
Tallow Processing
    ↓
Tallow Transport
    ↓
Renewable Jet Process Unit
    ↓
Green Diesel, Jet
    ↓
Consumer Use

Green Distillate from Energy Crops

Seed → Fertilizer → Fuel → Chemicals
    ↓
Energy Crop Farming
    ↓
Energy Crop Transport
    ↓
Oil Extraction
    ↓
Plant Oil
    ↓
Oil Processing
    ↓
Oil Transport
    ↓
Hydrogen
    ↓
Renewable Jet Process Unit
    ↓
Green Diesel, Jet
    ↓
Consumer Use

*WTW is either “well-to-wheels” or “well-to-wings”
Life Cycle Analysis for Renewable Jet Fuel

Significant GHG Reduction Potential

Basic Data for Jatropha Production and Use. Reinhardt, Guido et al. IFEU June 2008
Environmental Life-Cycle Inventory of Detergent-Grade Surfactant Sourcing and Production. Pittinger, Charles et al. 1,
Summary

- **Renewables are going to make up an increasing share of the energy pool**
  - Fungible biofuels enable industry expansion
  - Essential to overlay sustainability criteria
- **Feedstock availability is an important enabler**
  - First generation biofuels, though raw material limited, are an important first step to creating a biofuels infrastructure. Bridging feedstocks are key
  - Second generation feedstocks, cellulosic waste and algal oils, are on the horizon
  - Diverse feedstock initiatives are enabling regional sustainable solutions
- **Important to promote technology neutral and performance based standards and directives to avoid standardization on old technology.**
- **Meeting legislation in the most cost effective manner will require a combination of solutions**