Second-generation hydrocarbon fuels from oil palm by-products

Anjan Ray

International Palm Oil Sustainability Conference 2012
September 10-11, 2012
Putrajaya, Malaysia

UOP
A Honeywell Company

Agenda

- UOP Overview and Vision
- UOP/Eni Ecofining™ Process – Honeywell Green Diesel™
- UOP Renewable Jet Process – Honeywell Green Jet Fuel™
- RTP™ – Conversion of Biomass to Liquid Fuels
- Q&A

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

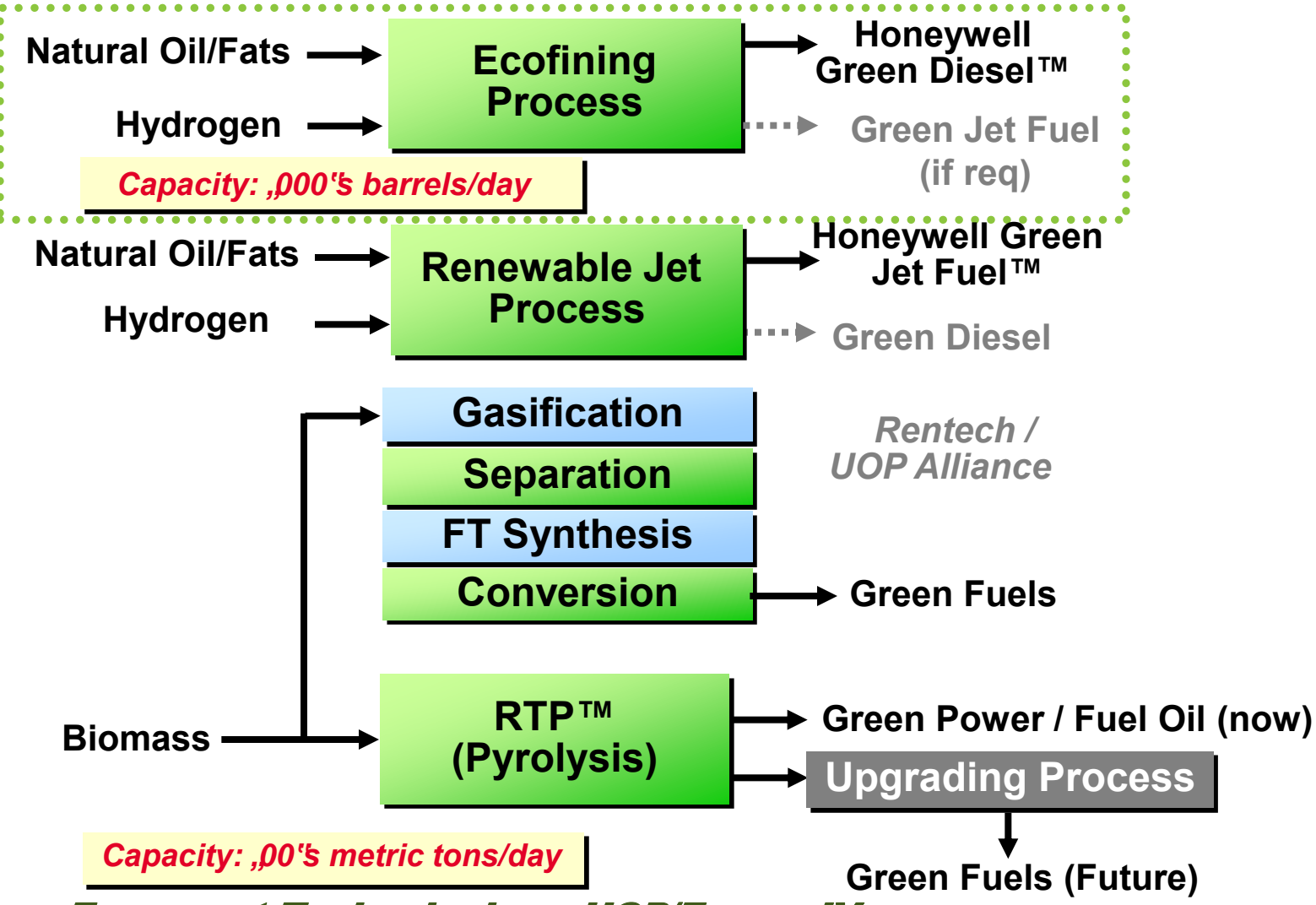
"Other" Oils: Camelina, Jatropha, Pennycress

First Generation

Natural oils from vegetables and greases

Second Generation

UOP Renewable Fuel Technologies



Envergent Technologies – UOP/Ensyn JV

Sustainable technologies – Feedstock flexible & 2nd Gen ready

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UOP/Eni Ecofining Process

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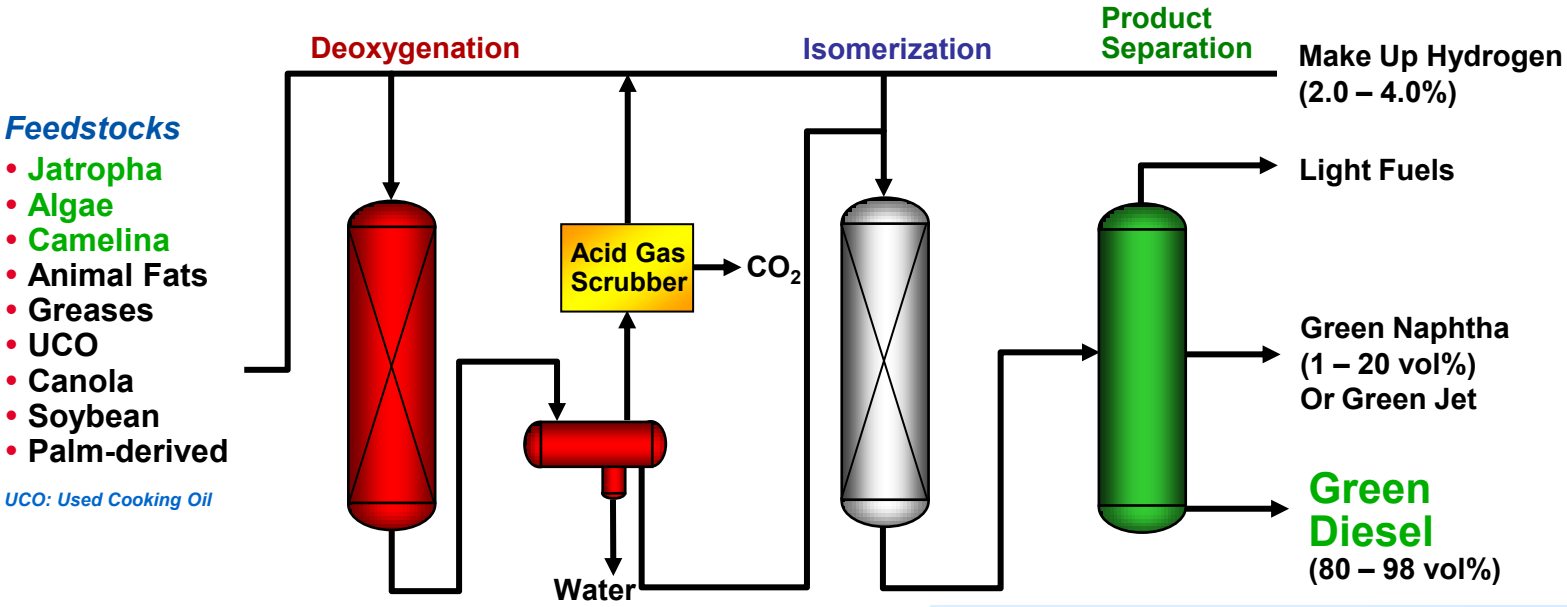

Green Diesel Product Benefits

- Pure hydrocarbon biofuel with adjustable cold flow properties
- Meets EN590/ASTM D975, can blend up to 40+% into EN590
- 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

Technology Value Proposition

- Proven, commercial technology
- Feedstock flexible → Can meet post 2017 GHG saving challenges
- Cash Cost of Production can be up to $0.05 per liter lower than Biodiesel
- Valuable hydrocarbon by-products
- Optimised Capital Cost; options to integrate/ revamp in Refineries
- OEM preference for Green Diesel (“HVO”) over FAME highlighted by ACEA (European Automobile Mfrs. Association)

Commercial scale, proven technology

Renewable Diesel Products Comparison

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	Petro Diesel (ULSD)	Biodiesel (FAME)	Green Diesel
Oxygen Content, %	0	11 ⊖	0 ⊕
Specific Gravity	0.84	0.88 ⊖	0.78 ⊕
Cloud Point, °C	-5	-5 to +15 ⊖	-20 to +10 ⊕
Cetane	40 - 52	50 - 65 ⊕	70 - 90 ⊕
Sulfur, ppm	<10	<2 ⊕	<2 ⊕
Energy Density, MJ/kg	43	38 ⊖	44 ⊕
Energy Content, BTU/gal	129 K	118 K ⊖	123 K ⊕
NOx emissions, %	Baseline	+10 ⊖	-10 to 0 ⊕
Poly-Aromatics, vol-%	4 - 12	0 ⊕	0 ⊕
Color	Clear	Light/Dark Yellow ⊖	Clear ⊕
Oxidative Stability	Baseline	Poor ⊖	Baseline

- High quality, ultra low sulfur blending component (high cetane, low density)
- 4% higher energy content (vol basis) – higher selling premium potential
- Low cloud points achievable – compare with 0°C for Soybean & 14°C for Tallow FAME
- Can use existing infrastructure – fully fungible & chemically similar
- Tested by OEM's; compatible with today's engines
- Meets EN590 as part of blend
- Meets ASTM D975 with lubricity and conductivity additives

Green Diesel is a high quality Drop-In biofuel

Biodiesel (FAME) Concerns

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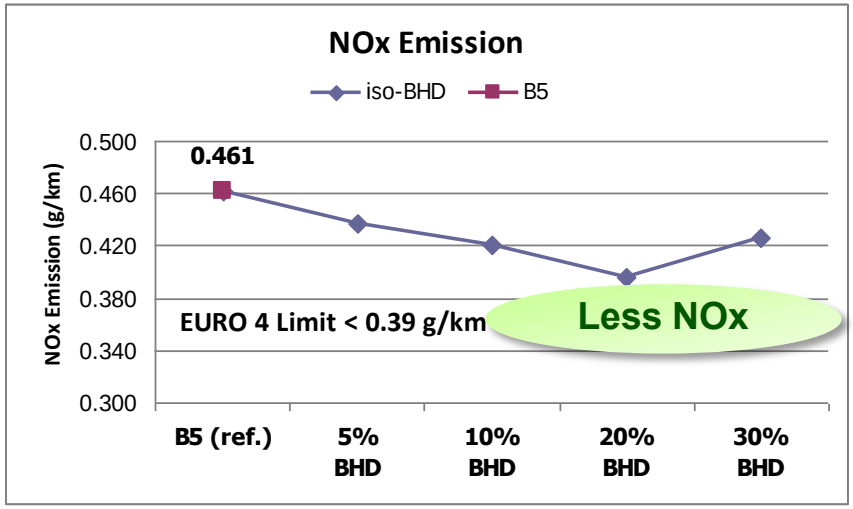
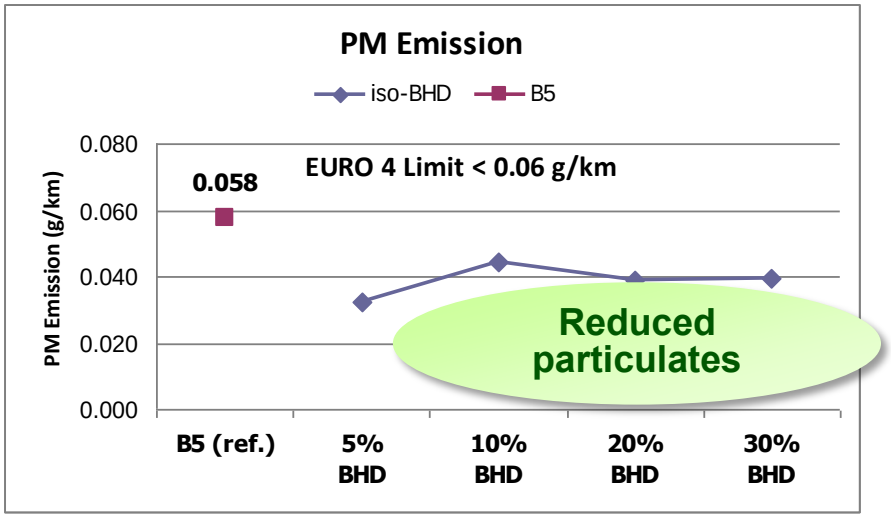
Potential Concerns	Root Cause
• Damage to Fuel line parts metal corrosion, rubber swell, etc.	• Acid Value • Ester Content • Methanol • Water • Oxidation Stability Index
• Pump failure sticking adhesive material • Filter plugging – Engine stop by stopping fuel supply	• Oxidation Stability Index • Polyunsaturated Fatty Acid • Ester Content • Metals • Solid Foreign Material • Glycerine • Water • Mono/di/tri-glyceride
• Worsen exhaust gas	• Tri-glyceride • Metal
• Poor startability @ low temperature	• Cold Flow Performance
• Deterioration of after treatment system	• Phosphorous • Metal

Source: PTT Research & Technology Institute, presented jointly with UOP at ARTC 2012, Bangkok

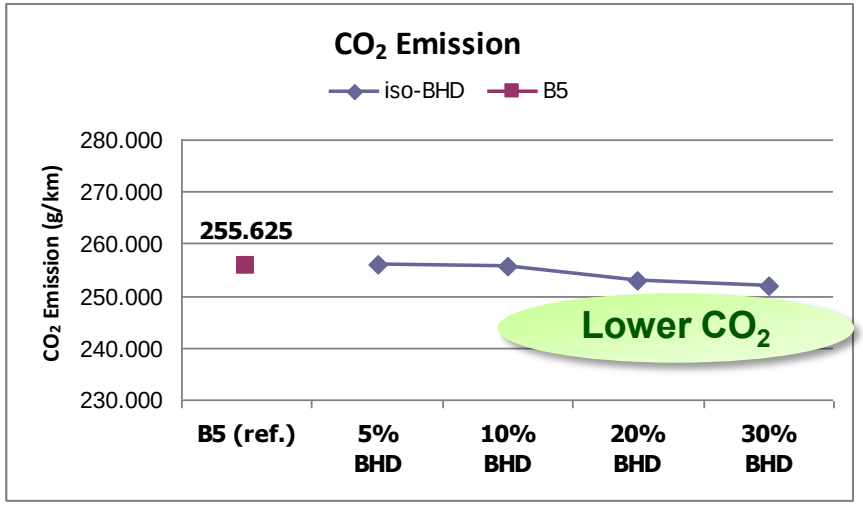
Limitations of biodiesel are an opportunity for drop-in fuels

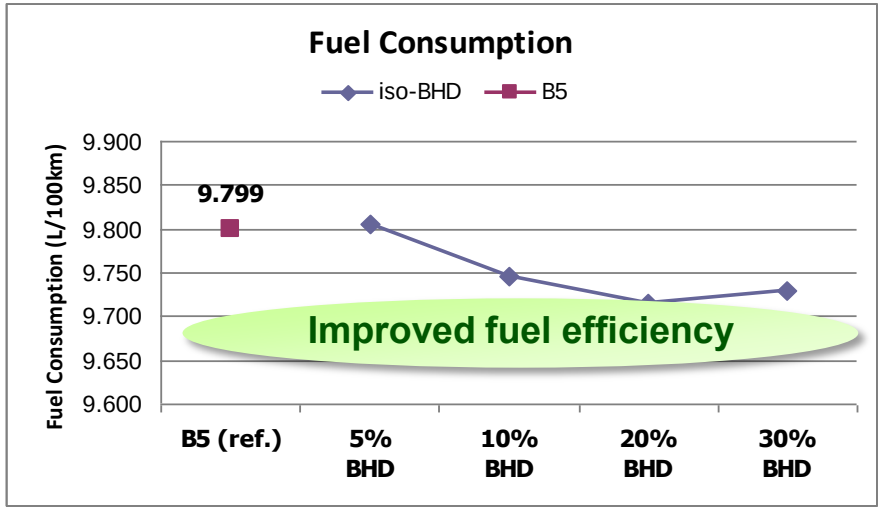
Emission and Fuel Consumption





The terms BHD / iso-BHD / Honeywell Green Diesel™ are used interchangeably





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Honeywell Green Diesel addition improves B5 emissions and fuel performance

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Renewable Jet Process Value Proposition

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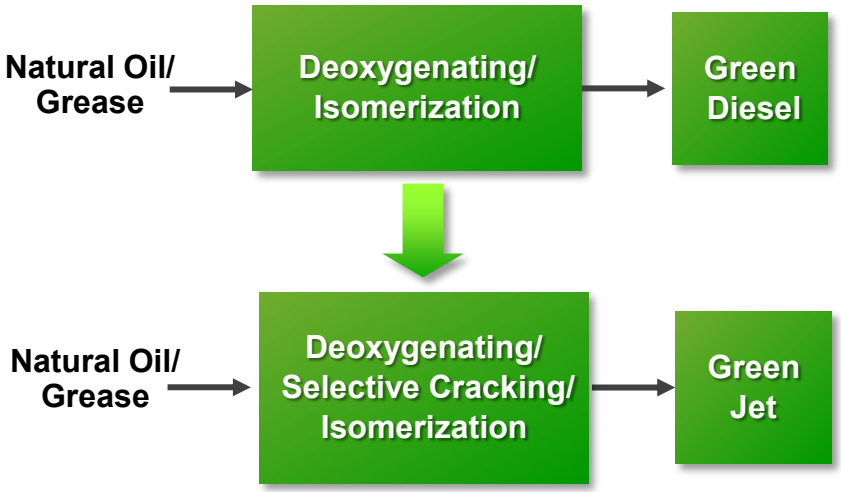
Derived from Ecofining Technology

Initially a DARPA-funded project to develop process technology for production of military jet fuel (JP-8) from renewable sources



Green Jet Product Benefits

- A „drop-in" hydrocarbon biofuel for aviation
- Certified for use in commercial aviation via ASTM D7566. Can blend up to 50% with fossil kerosene
- 50-90% GHG Savings relative to fossil diesel depending upon feed source
- Strong demand from EU Airlines due to ETS

Technology Value Proposition

- Proven, commercial technology; ability to swing from „max-jet" to „max-diesel"
- Feedstock flexible → Can meet post 2017 GHG saving challenges
- Airlines willing to pay cost of fossil kerosene + cost of carbon
- Valuable hydrocarbon by-products
- Options to integrate with / revamp in Refineries

Opportunity to Access Growing Aviation Biofuel Market

Renewable Jet Process & Bio-SPK Product

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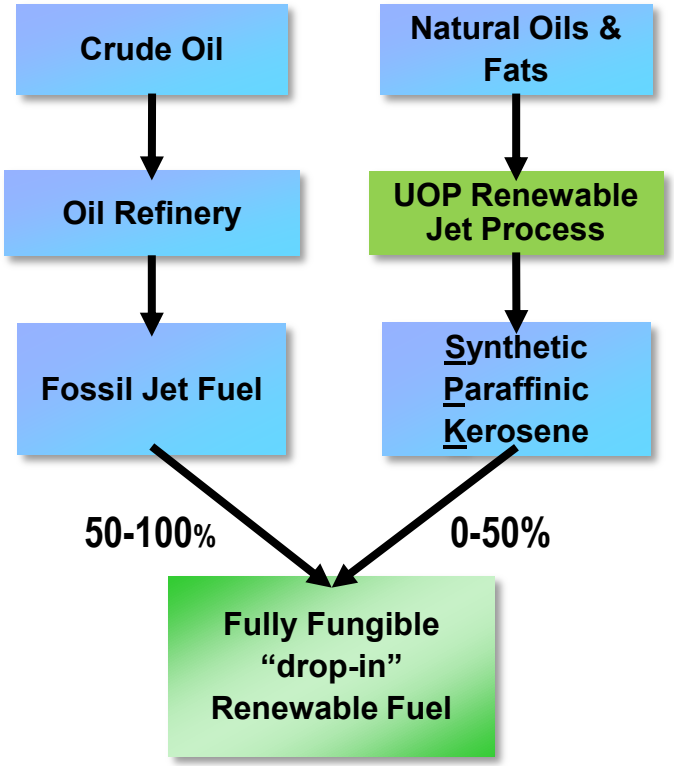


Properties	Honeywell Green Jet Fuel (Bio-SPK)*	50/50 Blend of of SPK & Jet A-1	ASTM D7566 Jet A-1 Spec.
Flash Point, °C	45	46	Min 38
Freeze Point, °C	-57	-57	Max -47
Net Heat of Combustion, MJ/kg	43.9	43.6	Min 42.8
Density @15°C, kg/m^3	760.8	778.3	Min 775 Max 840
Distillation (D86) • 10% Recovered, °C • Final Recovered, °C	 175 273	 177 272	 Max 205 Max 300
Thermal Stability (JFTOT) • Filter dP, mm Hg • Tube Deposit Rating	 0.0 1	 0.0 1	 Max 25 Max 3
Aromatics, % volume	<0.3	8.5	Min 8 Max 25
Sulfur, % mass	<0.001	0.05	Max 0.3

Different Names, Same Product

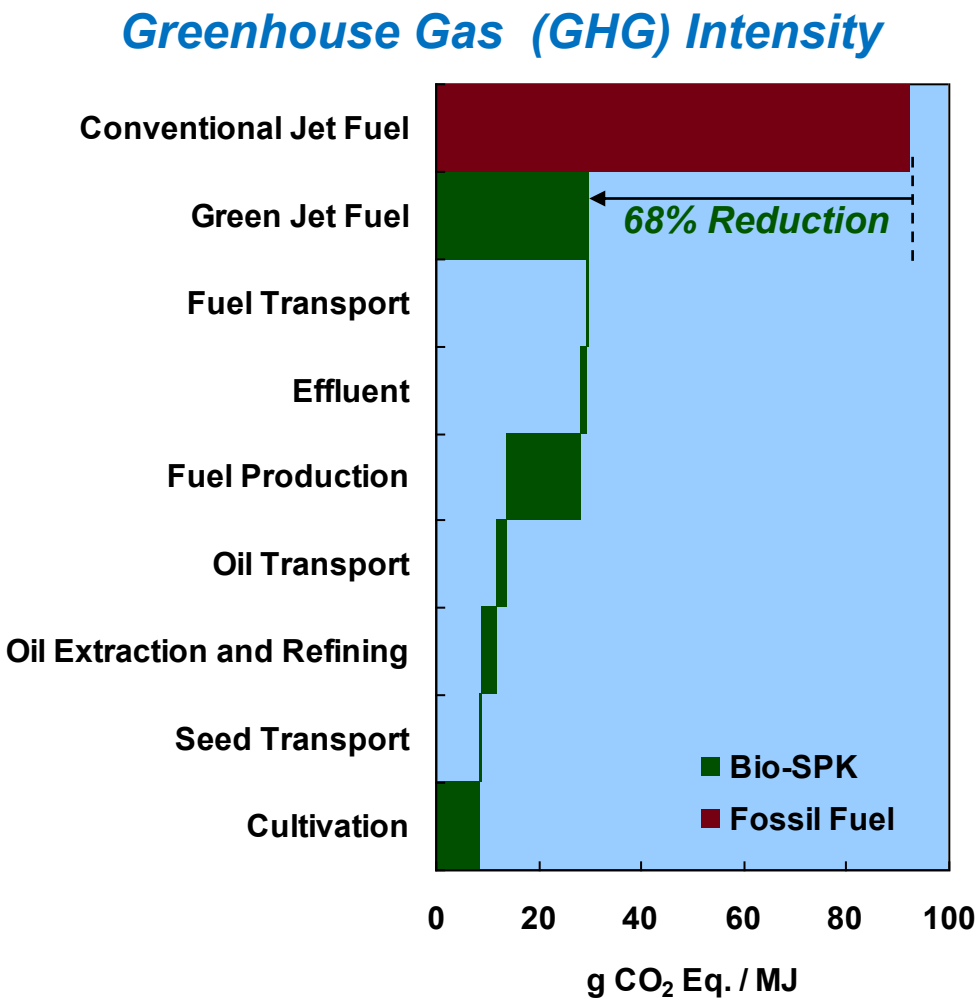
- **Bio-SPK (Bio-Derived Synthetic Paraffinic Kerosene)**
- **HRJ (Hydrotreated Renewable Jet)**
- **Bio Kerosene**
- **HEFA (Hydroprocessed Esters & Fatty Acids**
- **Green Jet**

- **Bio-SPK is very low in aromatics**
- **It must therefore be blended with a source of aromatics, such as fossil jet fuel**
- **Blended Bio-SPK meets all jet fuel requirements**

ASTM International Approval Achieved on 1 July 2011

Camelina Life Cycle Analysis (LCA)

- **Green Jet Fuel (Bio-SPK) has equal or higher energy intensity as fossil jet fuel**
- **Combustion of Bio-SPK does not count towards GHG**
  - Carbon cycle for plants
- **No significant land use changes (LUC)**
  - Camelina displaces fallow weeds in crop rotation with wheat
  - No food production is displaced by camelina seed cultivation
- **50/50 blend of SPK yields 34% savings in GHG emissions**
  - Future potential for more than 68% savings using all Bio-SPK fuel and modified production



Sustainability key to success for biofuels

UOP Green Fuel Demonstrations in 2011

- Air Force F-22 Raptor _ March 18,2011
- Interjet – April 1, 2011
- Air Force Thunderbirds F16 – May 20, 2011
- Gulfstream G450 – 1st transatlantic Flight – June 17, 2011
- Boeing 747-800 – June 19, 2011
- Navy MH-60S Seahawk – June 21, 2011
- Aeromexico 1st Commercial passenger Transatlantic Flight – August 1, 2011
- Navy T-45 ”Goshawk” Trainer - August 24, 2011
- Navy AV-8B Harrier – September 23, 2011
- Navy Fire Scout Unmanned Vehicle – September 30, 2011
- Aeromexico Weekly Passenger Flight from Mexico City to Costa Rica – began October 1, 2011
- Iberia – October 3, 2011
- Air China – October 28, 2011
- United Airlines – November 7, 2011
- US Navy Destroyer U.S.S. Paul H. Foster – November 18, 2011

Over 1500 demonstration, commercial and military flights since 2008

Green Diesel & Jet Supply Chain

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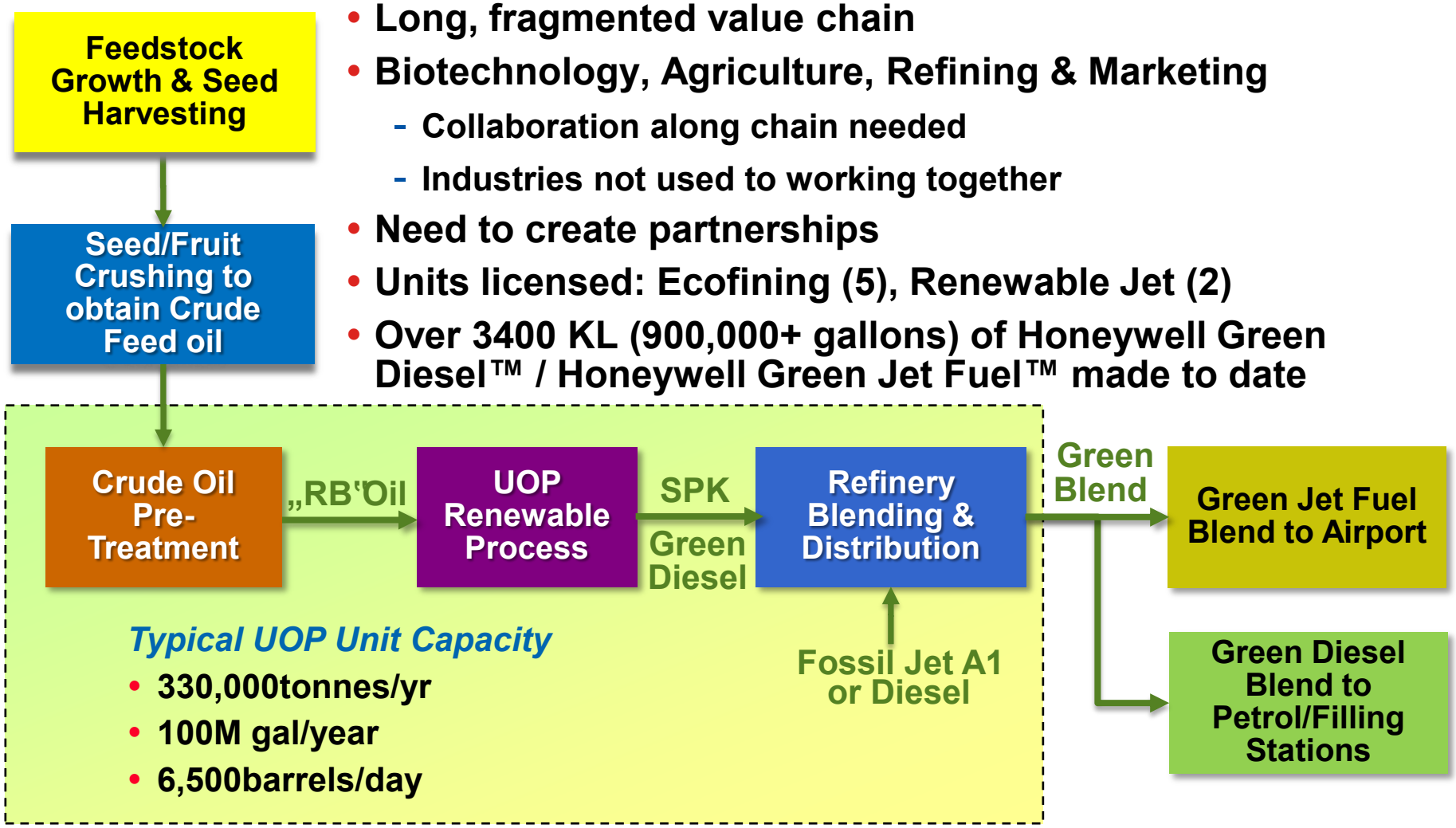
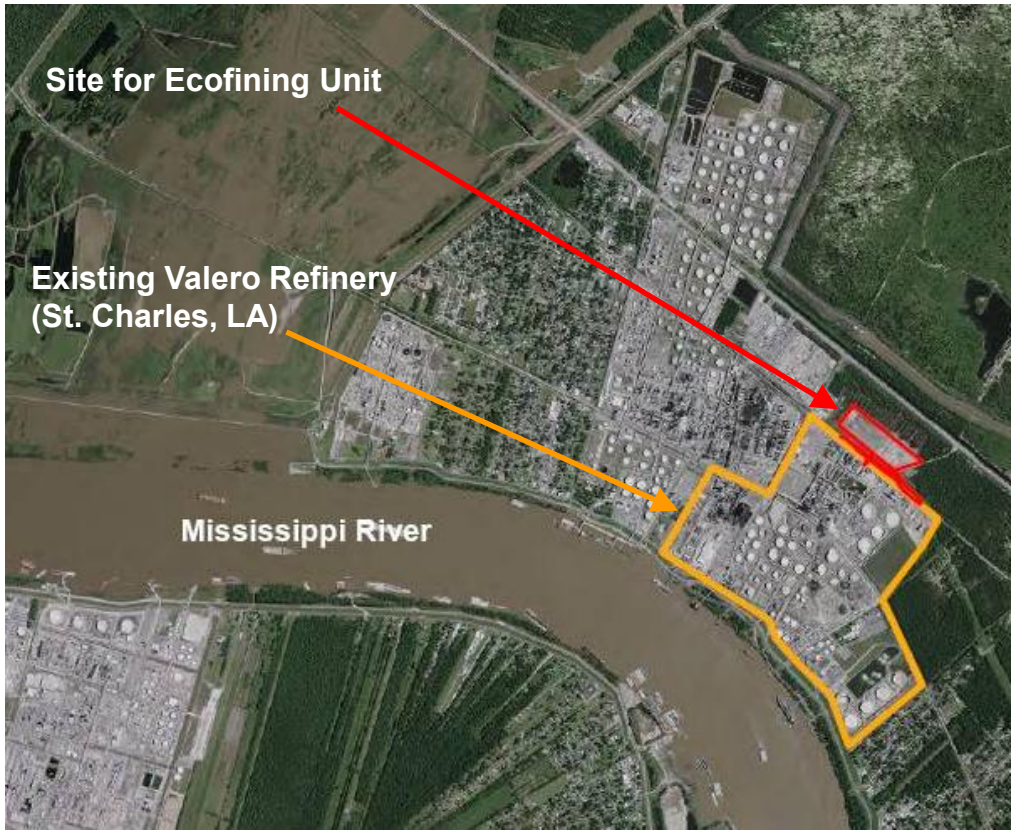


- Long, fragmented value chain
- Biotechnology, Agriculture, Refining & Marketing
  - Collaboration along chain needed
  - Industries not used to working together
- Need to create partnerships
- Units licensed: Ecofining (5), Renewable Jet (2)
- Over 3400 KL (900,000+ gallons) of Honeywell Green Diesel™ / Honeywell Green Jet Fuel™ made to date

Pulling the Supply Chain Together is the Key to Success

Diamond Green Diesel – *A Success Story*



- Using proven Ecofining technology
- 10,000 bpsd of feedstock
- Design feedstock: waste animal fats/greases
- Darling: ability to provide low cost, sustainable feed
- Valero: NA"s largest independent petroleum refiner and marketer. Extensive refinery operations, fuel distribution & retail
- Co-location at existing refinery: leverages existing assets, minimizes capital cost
- In construction. Start-up estimated in early 2013

A great example of a feedstock company & a refiner working together for a successful sustainable biofuels project

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RTP – Second Generation Residues to Energy

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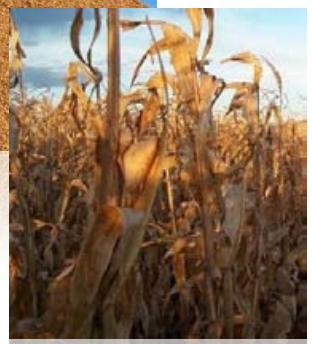
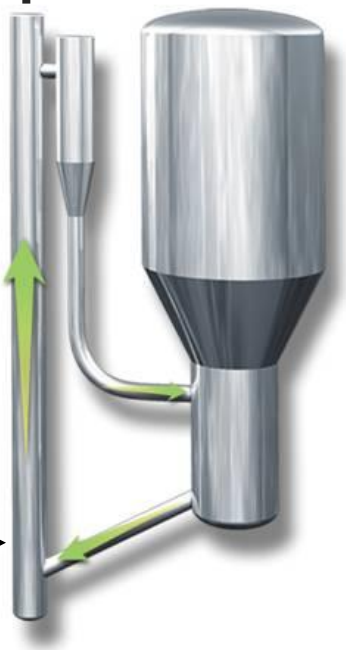
- Rapid Thermal Processing Transportable fuel
- Energy densification relative to biomass
- High yield of liquid product (65 – 75 Wt-% depending on feedstock)



Forest and Agriculture Residues



RTP Green Fuel

Fuel Oil Substitution

Electricity Production

Upgrade to Transport Fuels

Liquid Fuel Decouples Biomass Conversion from Energy Generation

History and Commercial Experience

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- **Commercialized in the 1980's**
- **7 units designed and operated in the US and Canada**
- **Continuous process with >90% availability**

New Projects Under Development:

Location	*Application*	*Size (TPD)*
Europe	Power Generation	150
Malaysia	**Industrial Process Heat**	**400**
Northern Europe	Power Generation	2 x 400
North America	Industrial Process Heat	400
Northern Europe	District Heating	up to 3 x 400

RTP Green Fuel Energy Applications

Envergent TECHNOLOGIES
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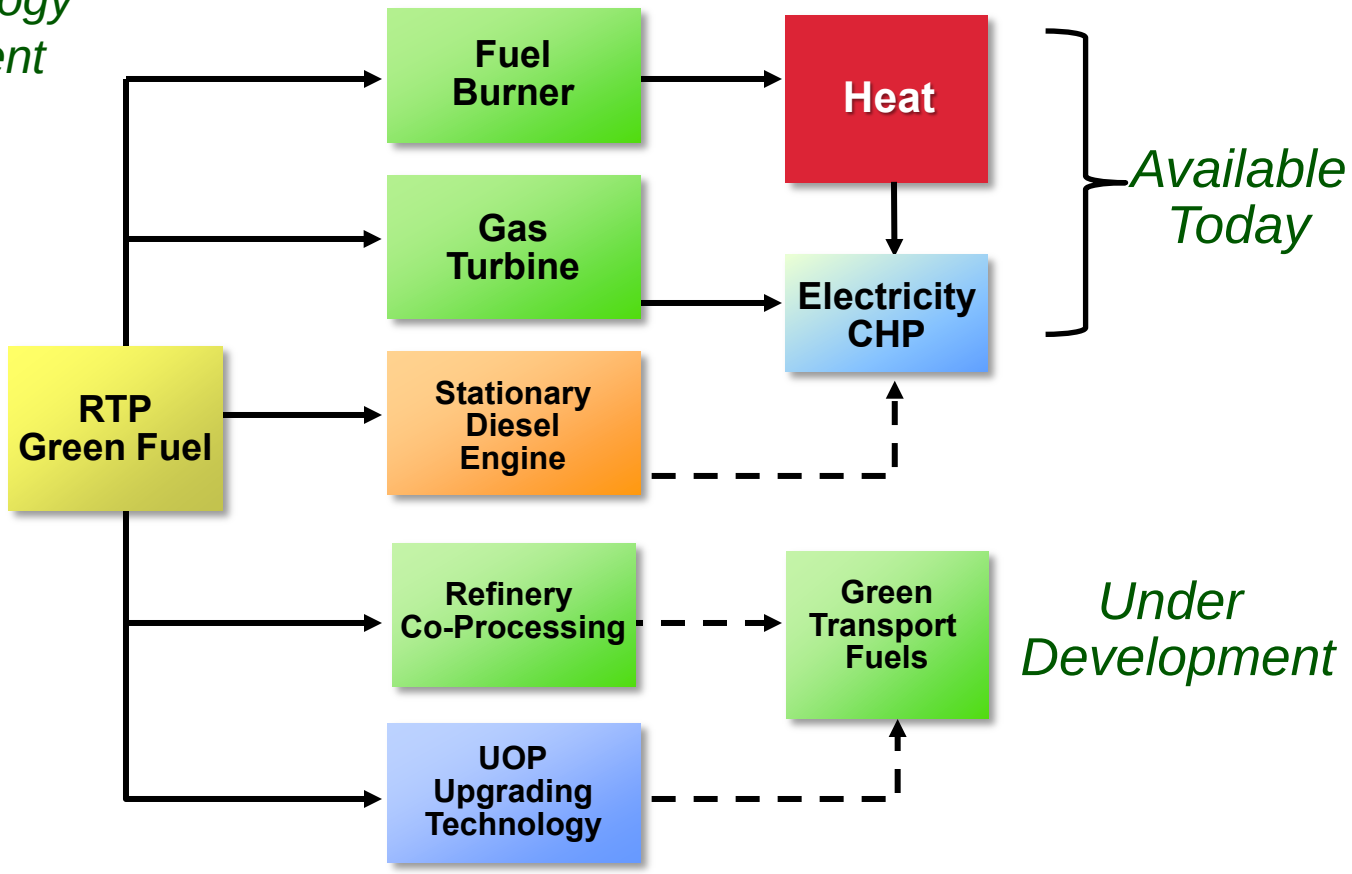
Applications Expand With Technology Development



Increasing applications broaden markets and drive optionality

RTP Green Fuel - Combustion

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- **20+ years industrial experience combusting RTP liquids**
  - Red Arrow, Wisconsin
  - Manitowoc Public Utilities, Wisconsin
  - Over 15 million gallons combusted for heat
- **RTP green fuel can be co-fired or used alone in conventional commercial and industrial boilers with little modification**
- **Combustion emissions compare favorably with fossil fuel**
  - SOX reduction > 99%
  - NOX reduction depends on feed properties

Potential To Replace Bottom-of-the-Barrel with RTP Green Fuel for Refinery Utilities

Upgrading RTP Green Fuel to Transportation Fuels

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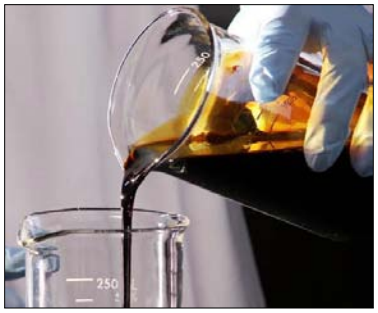
- Remove oxygen as water and CO_2 by hydrogen and catalyst
- pH neutral fuel with viscosity equivalent to refined fuels
- Produce high octane gasoline, or diesel/jet precursors

Two Stage Hydrodeoxygenation

H_2O= 10-40%
O = 40-55%

H_2O = 10-30%
O = 35-55
TAN = 100-200

H_2O = 300-1000 ppm
O = <0.2%
TAN < 2



Product Yield & Quality

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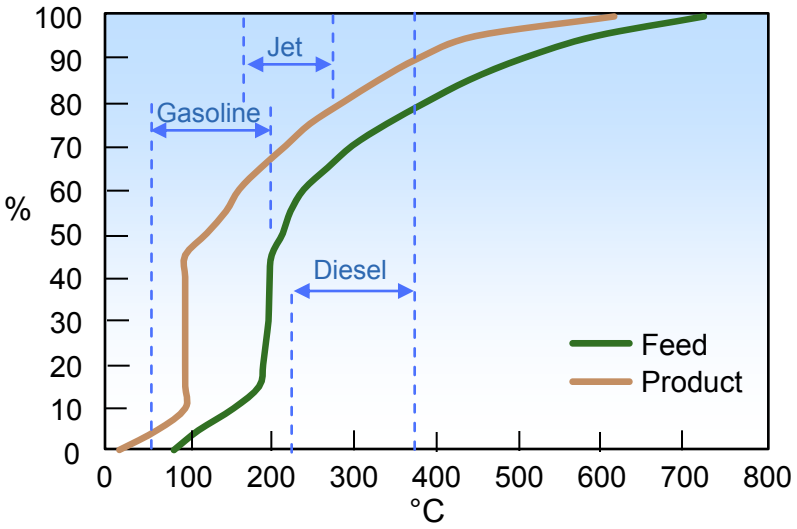
RTP Green Fuel to Fuels Feed/Product Analysis			
	RTP Green Fuel	*Stage 2 Product (Pilot Plant)*	*Gasoline Requirements*
H_2O,%	~25	0.03	<0.1
O, %	51	0.25	<2.0
TAN, meq/g	91	<0.1	<0.1

RTP Green Fuel to Liquid Hydrocarbon Yields[1]			
	Stage 1	*Stage 2*	*Overall from RTP Green Fuel*
Mass Yield %	53	78	41
Volume Yield %	65	93	60
Overall yield >90 gallons per dry MT for woody biomass			

Distillation of RTP Upgrader Product



- **~50% of material in gasoline boiling range (IBP-200°C)**
  - RON of gasoline ~ 80-89
  - Passes all tests (color, corrosion, etc) needed as gasoline blend stock
- **~40% of material in distillate (jet and diesel) boiling range**
  - Contains paraffins, isoparaffins, naphthenes and aromatics
  - Full Range

High yield of transport fuels from biomass

IBR - Biomass to Transportation Fuel Pilot

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TESORO

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- Pilot-scale conversion of biomass into liquid transportation fuels
- Located in Hawaii
- 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)
- Greater than 60% reduction in greenhouse gas emissions
- Phase 1 Start-up underway
- Fully Operational 4Q 2013

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Biomass → RTP Rapid Thermal Processing → Hydrocarbon Upgrading → Green gasoline, diesel & jet fuel

Making Cellulosic Biofuels a Reality

Summary

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To meet biofuels demand, UOP has developed:

- **Ecofining™ Process**; production of Green Diesel from natural oils & fats
- **Renewable Jet Process**; production of Synthetic Paraffinic Kerosene (Honeywell Green Jet Fuel™) from natural oils & fats
- **BTL**; applying UOP Selexol™, Unionfining™ & Unicracking™ processes to biomass to liquids projects via an alliance with Rentech
- **RTP via Envergent Technologies**; production of RTP green fuel, a transportable and storable liquid fuel for heat and power generation with potential for upgrading to transport fuels in the future

Opportunities for Malaysia and other South East Asian nations:

- Feedstock-flexible use of local lipid streams (palm stearin, PFAD, jatropha oil, nyamplung, algal oils, used cooking oil etc.)
- Reduce or eliminate cost of blending, storage and handling infrastructure associated with FAME biodiesel production
- Expand the diesel pool through blending with high-cetane hydrocarbon
- Stimulate creation of jobs in the feedstock supply chain
- Use of local residues such as EFB, palm fronds, sawdust, wood chips, rice husk
- Reduce GHG, SOx and NOx emissions significantly relative to fossil fuel

UOP Looks Forward to Supporting South East Asia in Meeting Growing Demand for High Quality Biofuels


UOP RENEWABLES
THANK YOU
UOP is committed to finding the right solutions that will protect valuable land and water resources while still offering our customers the ability to produce the highest quality transportation fuels.
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Q&A