Creating Alternative Fuel Options for the Aviation Industry: Role of Biofuels

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UOP LLC

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Montreal, Canada
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UOP

- Leading supplier and licensor of process technology, catalysts, adsorbents, process plants, and technical services to the petroleum refining, petrochemical, and gas processing industries
- 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

2003 National Medal of Technology Recipient

Biofuels: Next in a Series of Sustainable Solutions

Macromarket Summary: Through 2015

- **Global energy demand is expected to grow at CAGR 1.6%.**
  - **Feedstock 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%/year to > 2.2 MBPD**

Key: Overlaying Sustainability Criteria on Alternatives (GHG, water etc.)

Source: IEA, 2008

Biofuel Targets

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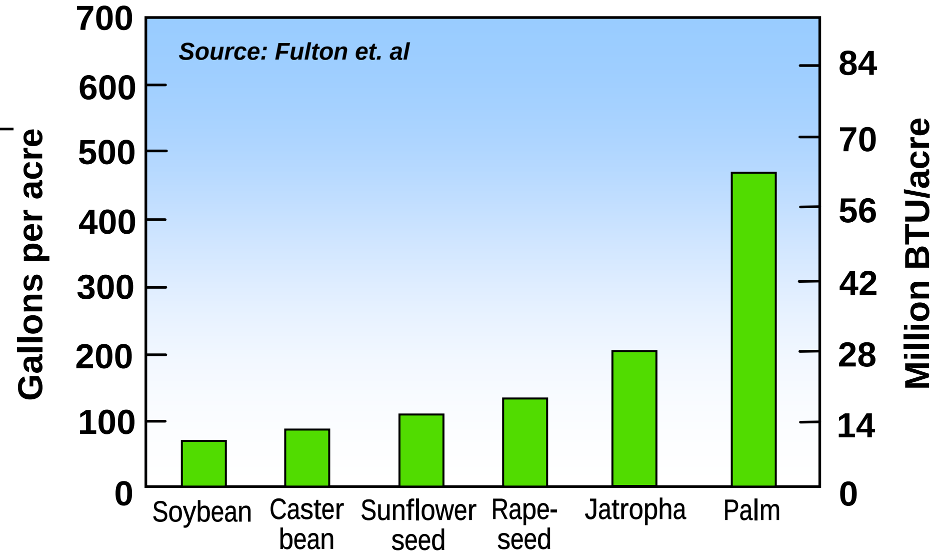
Region	Targets: Current	Targets: Future
Brazil	25% Ethanol in gasoline 2.0% of diesel by 2008	5.0% of diesel by 2011
China	2.0% of gasoline & diesel by 2010	8.0% by 2020
Europe	5.75%* of gasoline & diesel by 2010	10%* by 2020
India	5.0% Ethanol in gasoline	*E5, B5 by 2012*
USA	*15.2 B* gal 2012	*36 B gal by 2022* *(~20% of transport pool)*

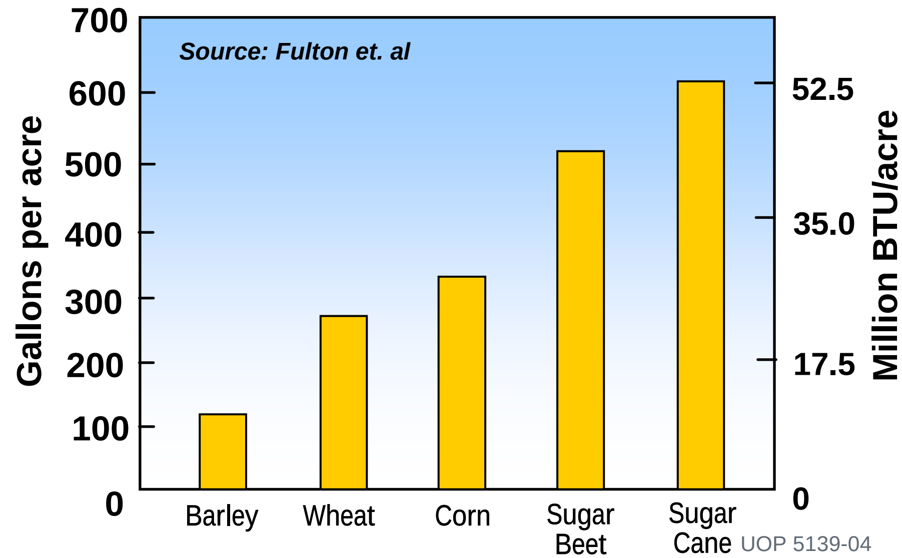
** Energy content basis*

20% Substitution Equivalent to the Land Mass of ~CA, IN, NV, MI

Biodiesel Production from Oils



Ethanol Production from Sugars



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Critical Issues

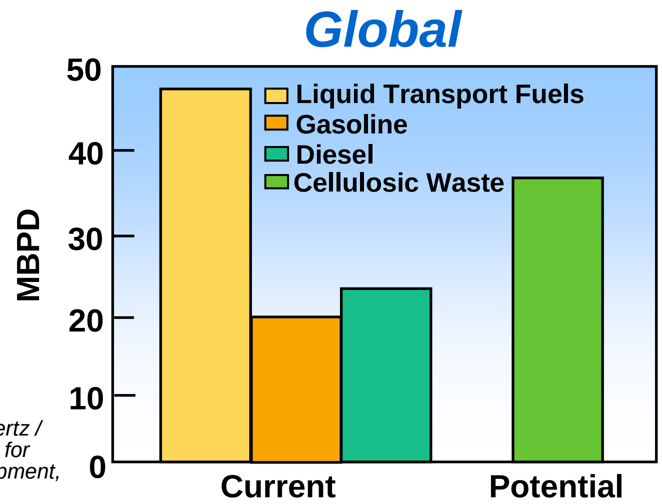
Food supply: small impact on the fuel market, yet large impact on food supply

Land and water: competition for land and water resources that are already in high demand

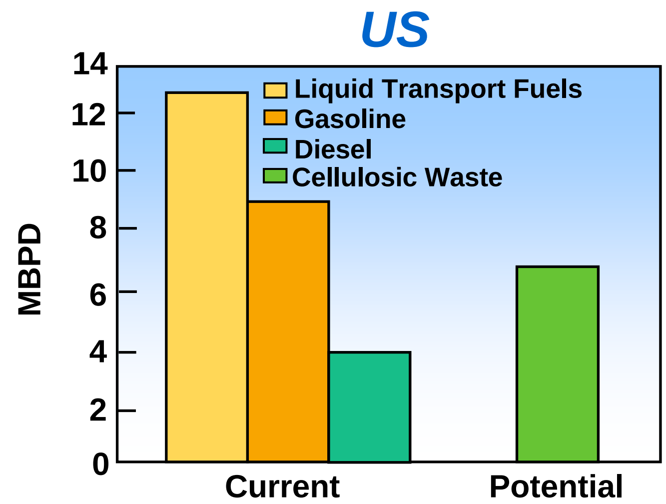
Environmental: loss of biodiversity, soil erosion, nutrient leaching, soil and water pollution and deforestation

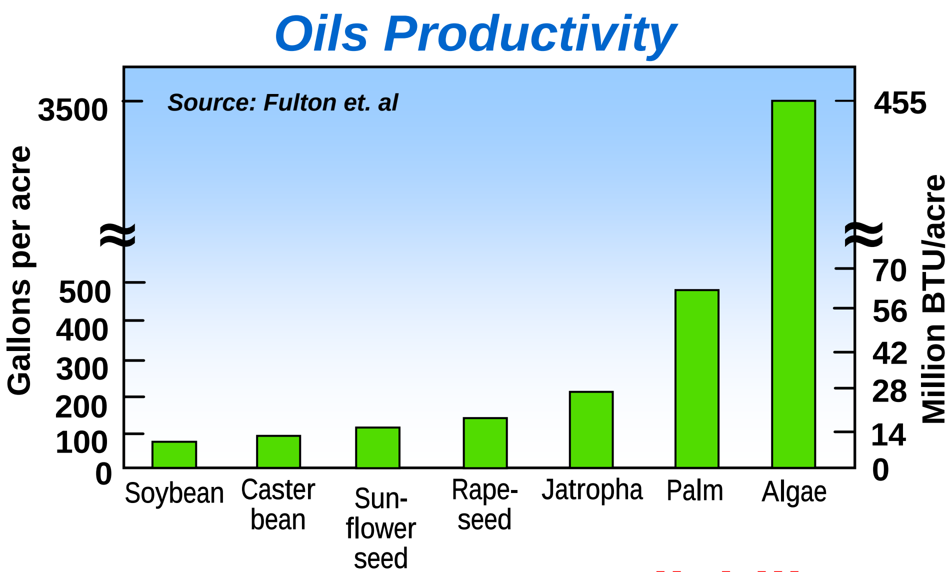
Second Generation Development Required to Ameliorate these Risks

Enablers for a Sustainable Biomass Infrastructure



Source: Purvin & Gertz / Eric Larsen: Energy for Sustainable Development, 2000

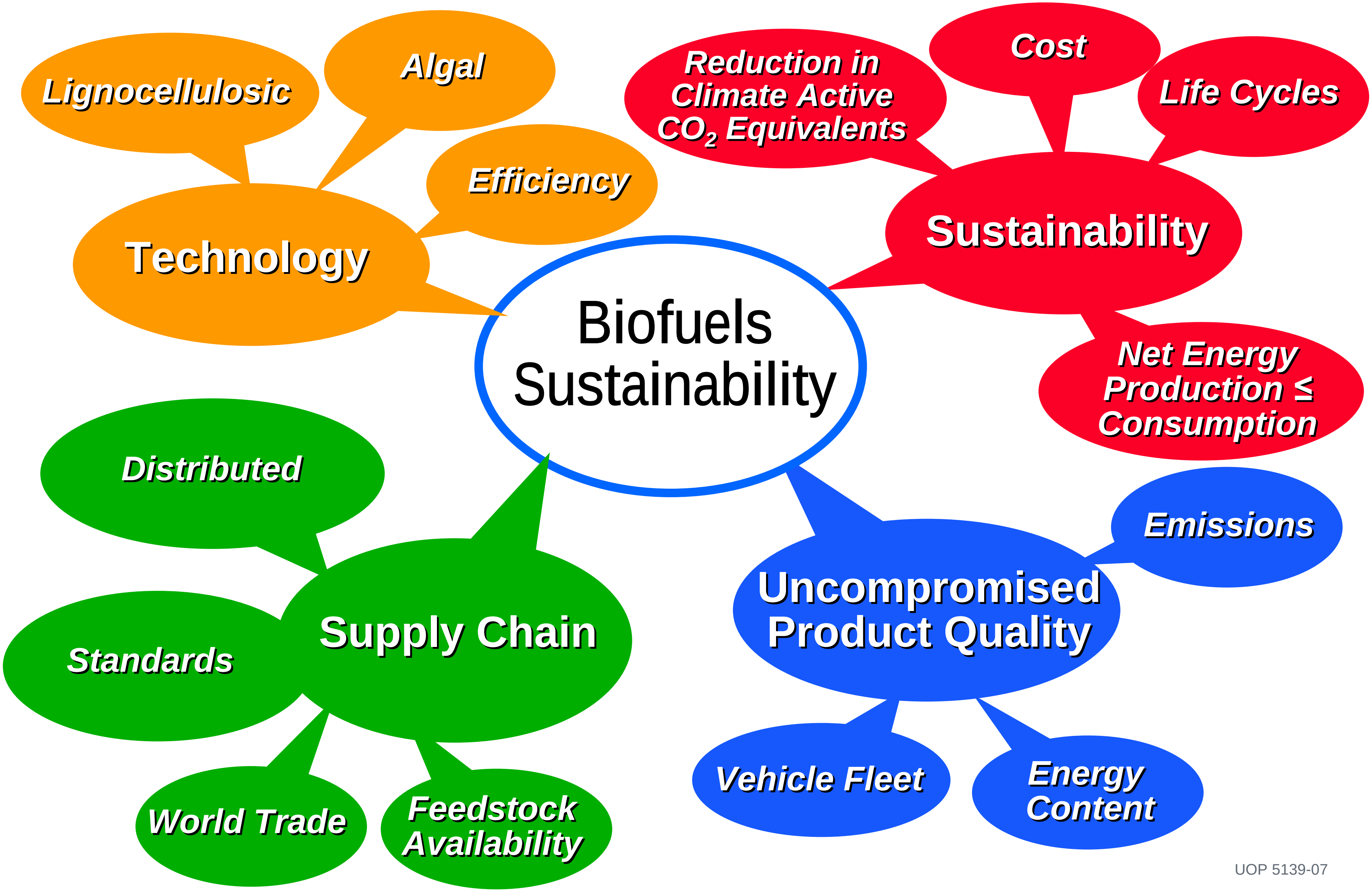




- **Cellulosic waste could make a significant contribution to liquid transportation pool.**
- **Algal Oils could enable oils route to biodiesel, Green Diesel and Green Jet.**

Increases Availability, Reduces Feedstock Cost
Technology Breakthroughs Required

Renewable Fuels:
Achieving Sustainability



Our Biofuels Vision

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- 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**

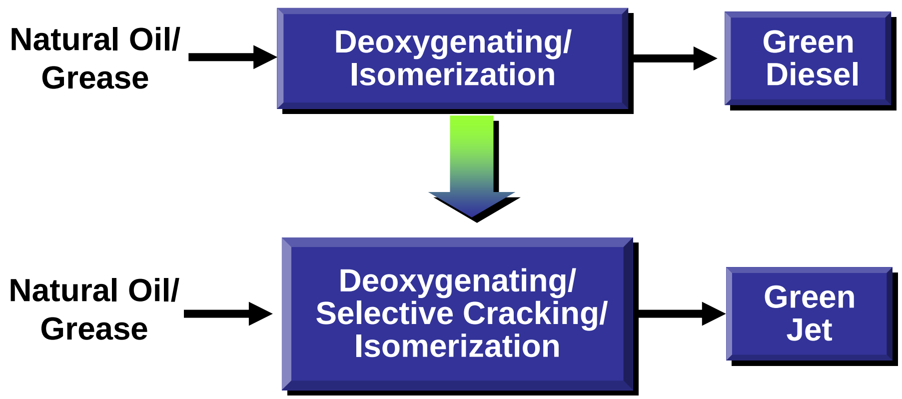
Hydrocarbon Biofuels

Diesel **Jet** **Gasoline**

Green Jet Fuel

- DARPA-funded project to develop process technology to produce military jet fuel (JP-8) from renewable sources
- Leverage Ecofining process technology for diesel production
- Green Jet Fuel can meet all the key properties of petroleum derived aviation fuel, flash point, cold temperature performance, etc.
- Extend to commercial aircraft

Built on Ecofining Technology



DARPA Project Partners

Southwest Research Institute
Sandia National Laboratories
DARPA
Cargill
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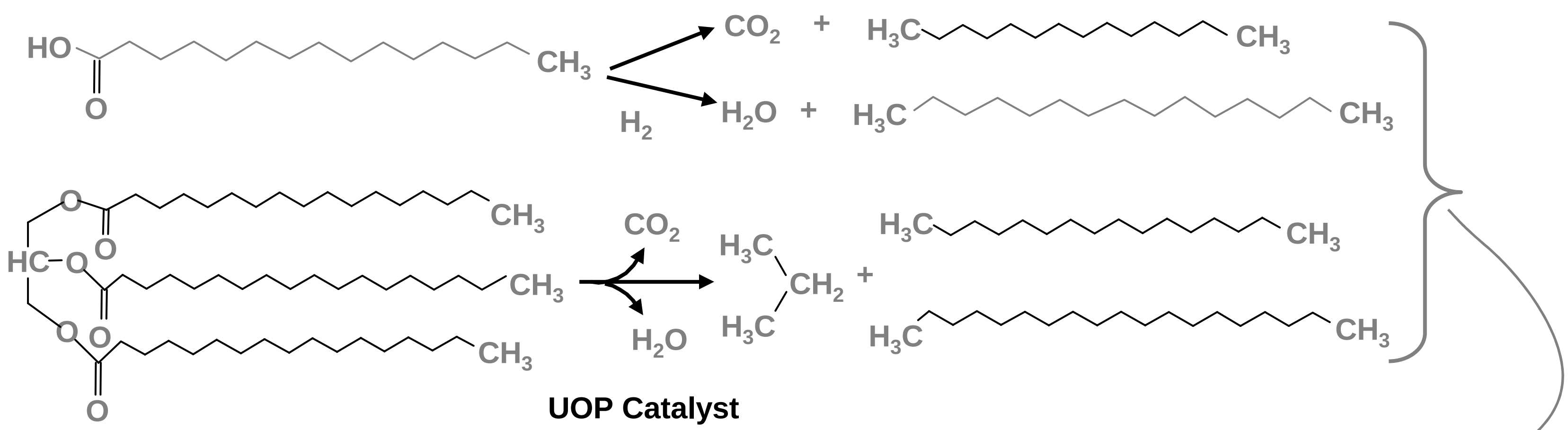
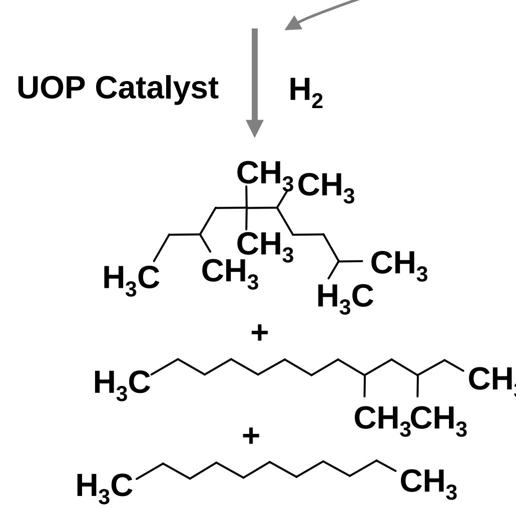
Honeywell
Air Force Research Laboratory

Target Commercialization by 2009

Renewable Jet Process Chemistry



- Natural oils contain oxygen, have high molecular weight.
- First reaction removes oxygen – product is diesel range waxy paraffins
- Second reaction “cracks” diesel paraffins to smaller, highly branched molecules
- End product is same as molecules already present in aviation fuel
- End product is independent of starting oil



Feedstock flexible, but with consistent product properties

Properties of UOP's Bio-SPK

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Table A2.1 Detailed Requirements of Synthetic Paraffinic Kerosene

Property		*SPK*	*ASTM Test Method*	*Composition*		
				Jatropha	*Coconut*	*Soybean/ Canola*
Hydrocarbon, vol %	min	99.8	D2425			
Cycloparaffin, vol %	max	5	D2425			
Paraffin, vol % [1]			difference from D 1319	99.3	99.5	99.5
1. Aromatics, vol %	max	0.05	D 1319	0	0	0
2. Aromatics, vol %	max	0.053	D 6379	0	0	0
Sulfur, total mass %	max	0.015	D 1266, D 2622, D 4294, or D 5453	0.00009	0.0003	0.001
1. Physical Distillation			D 86			
Distillation temp, °C:						
10% recovered, temp (T10)	max	205		172	188	189
50% recovered, temp (T50)		report		192	200	214
90% recovered, temp (T90)		report		223	231	248
Final boiling point, temp	max	300		243	263	261
T90-T10, °C	min	25		51	43	59
Distillation residue, %	max	1.5		1.2	1.3	1.2
Distillation loss, %	max	1.5		0.4	0.5	0.8
2. Simulated Distillation			D 2887			
Distillation temp, °C						
10% recovered, temp	max	185		151.6	162	168
50% recovered, temp		Report		195	190.8	218.6
90% recovered, temp		Report		237.6	238	267.2
Final boiling point, temp	Max	340		273.8	299	284.4
Flash Point, °C	min	38	D 56 or D 3828	50	64	62
Density at 15 °C, kg/m^3		751 to 840	D 1298 or D 4052	751	755	763
Fluidity						
Freezing Point, °C	max	-47 Jet A-1	D 5972, D 7153, D 7154, or D 2386	-63	-56	-52
Viscosity -20°C, mm 2/s *H*	max	8.0	D 445			
Combustion						
Net heat of combustion, MJ/kg	min	42.8	D 4529, D 3338, or D 4809	44.4	44.2	43.5
Metal Content			D7111			
Copper, ppb	max	100		<0.01 ppm	<0.01 ppm	<0.01 ppm
Iron, ppb	Max	100		<0.01 ppm	<0.01 ppm	0.04 ppm
Zinc, ppb	Max	100		<0.01 ppm	<0.01 ppm	<0.01 ppm
Vanadium, ppb	Max	100		<0.01 ppm	<0.01 ppm	<0.01 ppm
Thermal Stability						
JFTOT (2.5 h at control temp of 280°C min)						
Filter pressure drop, mm Hg	max	25	D 3241	<0.1	25	0
Tube deposits less than		3		<1	<1	1

[1] Balance of composition is olefins.

Moving Bio-SPK Forward

- **Collaboration to demonstrate viability of biofuels in commercial aviation**
- **Large scale fuel production for flight demonstrations enables demonstration of:**
  - **Process scalability**
  - **Feedstock flexibility**
  - **Life cycle benefits**
- **Data from large fuel samples enables creation of data library for certification**
  - **Analytical**
  - **Ground tests**
  - **In flight data**

Goal: Share all results with broader scientific community to accelerate commercialization of alternative fuels

Completed Flight Demonstrations

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- **Successful ANZ Flight Demo**
  Date: December 30 2008

AIR NEW ZEALAND Rolls-Royce terasol ENERGY

Feedstock:
Jatropha oil

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- **Successful CO Flight Demo**
  Date: Jan. 7 2009

Continental Airlines cfm Sapphire Energy

Feedstock:
Jatropha and algal oil

BOEING

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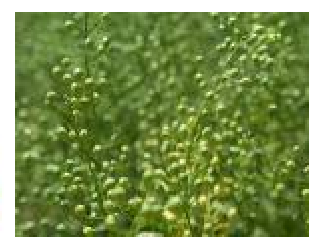
nu

- **Successful JAL Flight Demo**
  Date: Jan. 30 2009

JAL Pratt & Whitney A United Technologies Company Sustainable Oils Your trusted energy growth partner.

Feedstock: Camelina,
Jatropha and algal oil



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Key Properties of Bio-SPK

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	Jet A-1 Specs	Jatropha Derived SPK	Camelina Derived SPK	Jatropha/ Algae Derived SPK
Description				
Flash Point, ºC	Min 38	46.5	42.0	41.0
Freezing Point, ºC	Max -47	-57.0	-63.5	-54.5
JFTOT@300ºC				
Filter dP, mmHg	max 25	0.0	0.0	0.2
Tube Deposit Less Than	< 3	1.0	<1	1.0
Net heat of combustion, MJ/kg	min 42.8	44.3	44.0	44.2
Viscosity, -20 deg C, mm^2/sec	max 8.0	3.66	3.33	3.51
Sulfur, ppm	max 15	<0.0	<0.0	<0.0

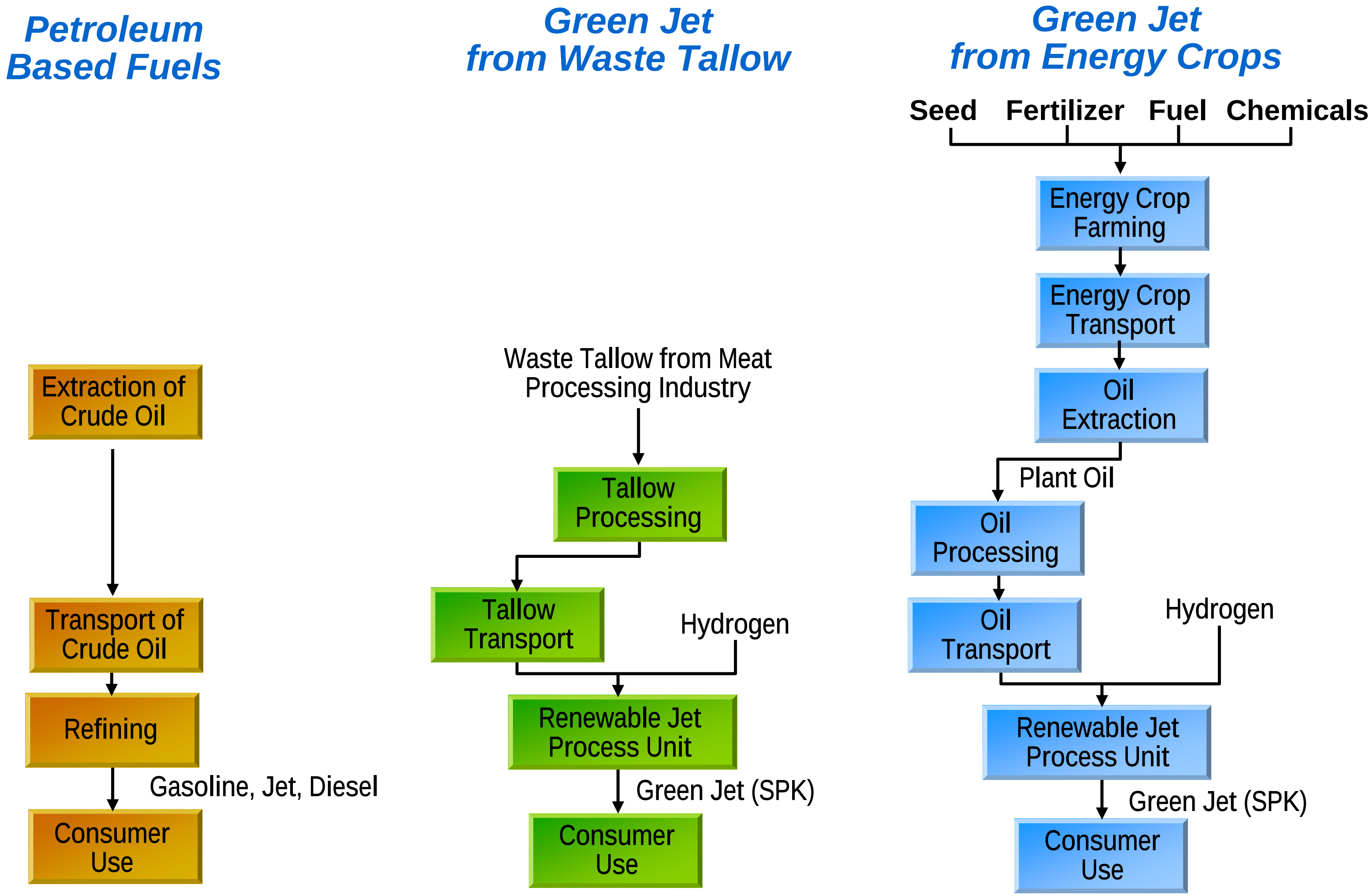
Production Viability Demonstrated
Fuel Samples from Different Sources Meet Key Properties

Work in Progress

- Analytical
  - D1655
  - DXXXX
  - Materials compatibility
- Engine Tests
  - Engine performance
  - Operability
  - Emissions

Compile into a Report by May 2009

Scope of Jet Fuel WTW* LCA



*WTW is either "well-to-wheels" or "well-to-wings"

David Shonnard & Kenneth Koers
Michigan Technological University

Calculation of GHG emissions *(E)*
European Commission Proposal, January 2008

Methodology

Greenhouse gas emissions from the production and use of transport fuels, biofuels and other bioliquids shall be calculated as:

$E = e_{ec} + e_l + e_p + e_{id} + e_u - e_{ccs} - e_{ccr} - e_{ee},$

Portion of E assigned to co-products based on energy allocation method

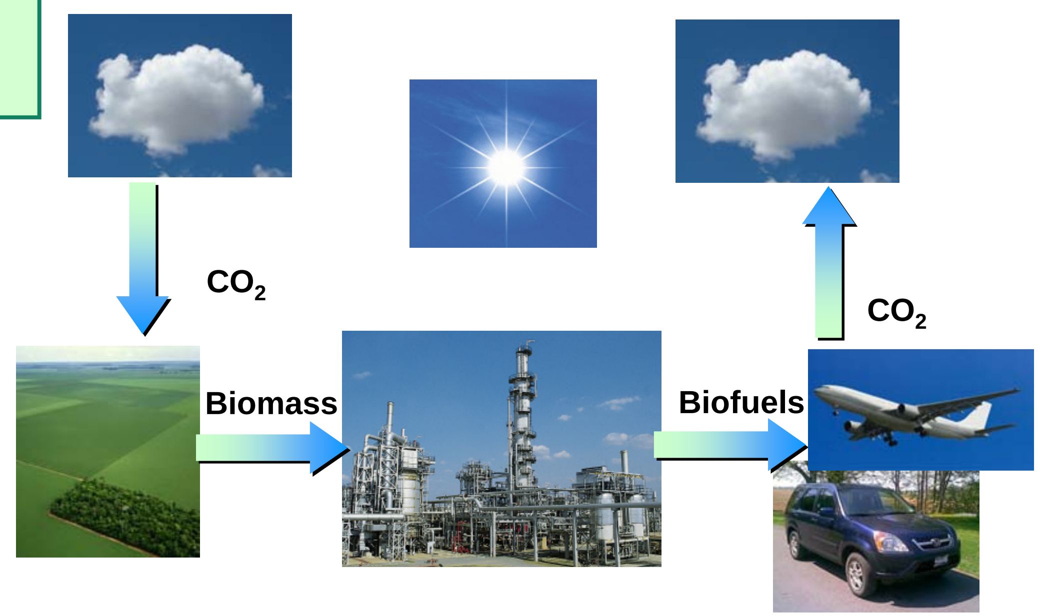
where

- E = **total emissions from the use of the fuel**
- e_{ec} = **emissions from the extraction or cultivation of raw materials**
- e_l = **annualized emissions from carbon stock changes caused by land use change**
- e_p = **emissions from processing**
- e_{id} = **emissions transport and distribution**
- e_u = **emissions from the fuel in use**
- e_{ccs} = **emission savings from carbon capture and sequestration**
- e_{ccr} = **emissions from carbon capture and replacement; and**
- $e_{ee,}$ = **emission savings from excess electricity from cogeneration**

Emissions from the manufacture of machinery and equipment shall not be taken into account

Critical Input Parameters

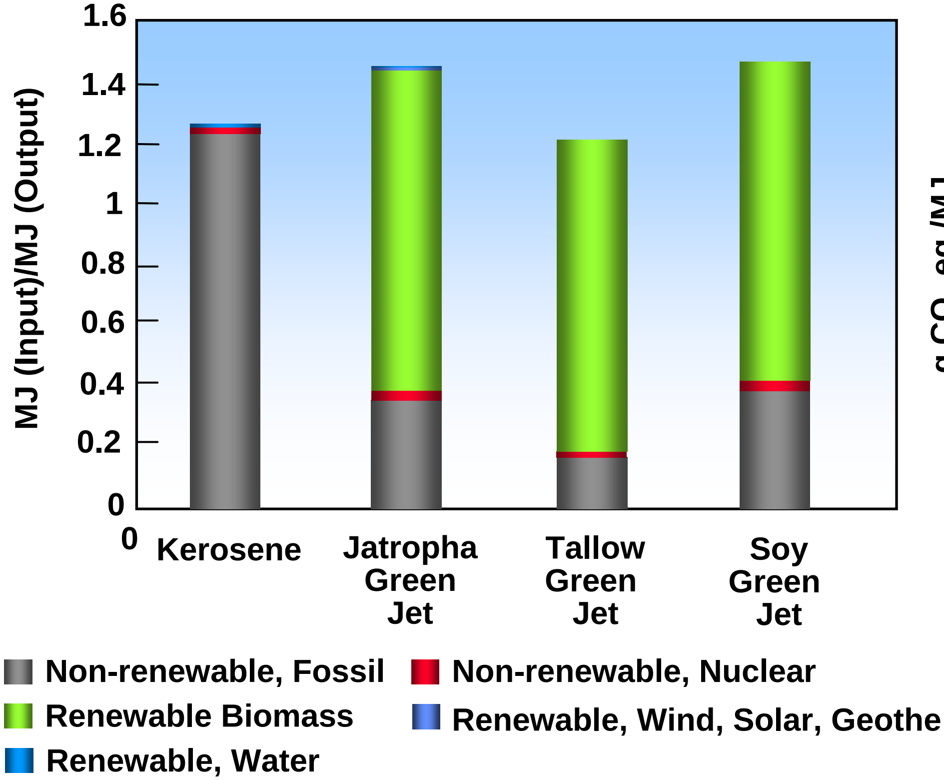
- **Local farming emissions (N_2O)**
- **Land use change impacts**
  - **direct**
  - **indirect**
- **Process emissions**
  - **pretreatment**
  - **conversion**



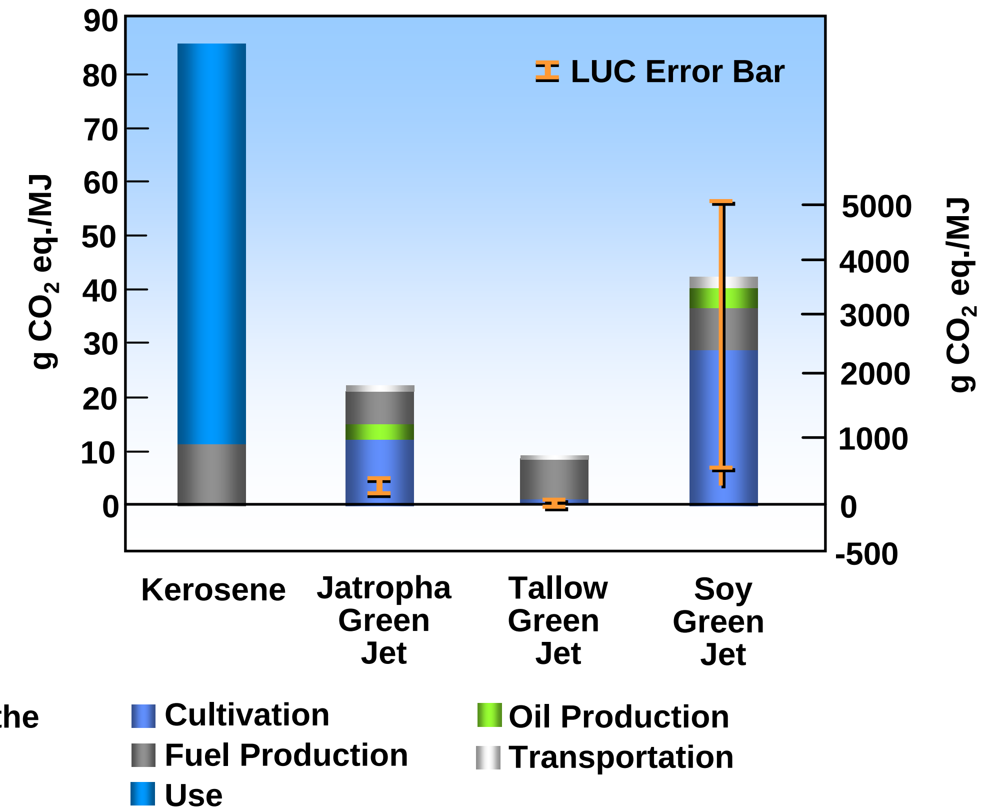
Biofuels are considered "climate neutral" fuels

LCA for Bio-SPK

Cumulative Energy Demand



Greenhouse Gases



Significant GHG Reduction Potential

Basic Data for Jatropha Production and Use. **Reinhardt, Guido et al.** IFEU June 2008
Biodiesel from Tallow. **Judd, Barry.** s.l. : Prepared for Energy Efficiency and Conservation Authority, 2002.
Environmental Life-Cycle Inventory of Detergent-Grade Surfactant Sourcing and Production. **Pittinger, Charles et al.** 1, Prarie Village, Ka : Journal of the American Oil Chemists' Society, 1993, Vol. 70.

Sustainable Aviation Fuel Users Group

Airline Members

Supporting Members

Represents ~15% of global jet fuel demand

Mission of Group

- **Enable Viable Markets for Sustainable Aviation Fuels**
- **Establish solid, world-leading fact base for sustainability practices**
- **Drive Movement in Roundtable for Sustainable Biofuels Process**

Third Party Support From:

- **Natural Resources Defense Council**
- **Yale University, School of Forestry and Environmental Studies**
- **Other NGOs and philanthropic organizations**

2nd Generation Renewable Jet Fuel from Oils and Biomass

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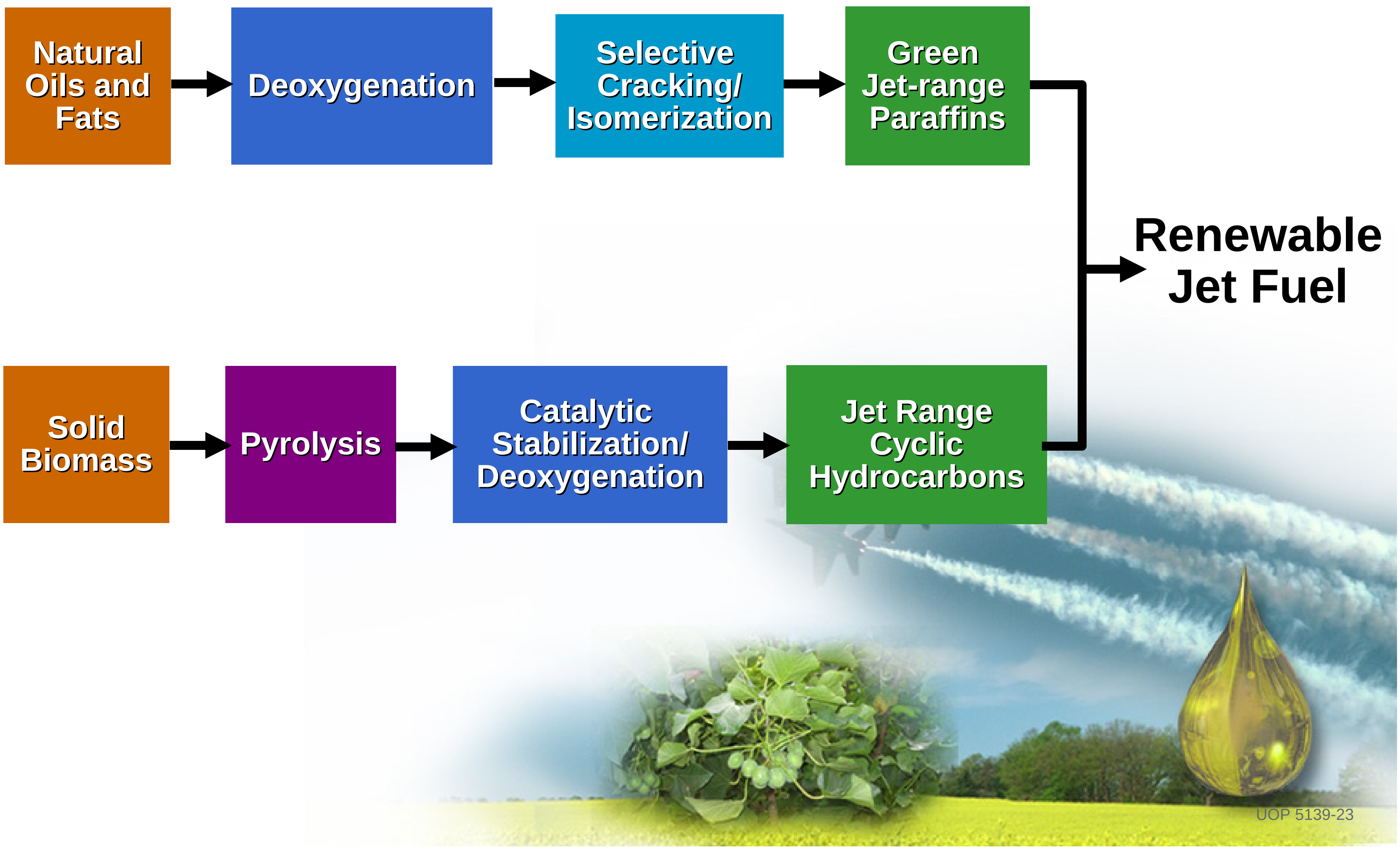


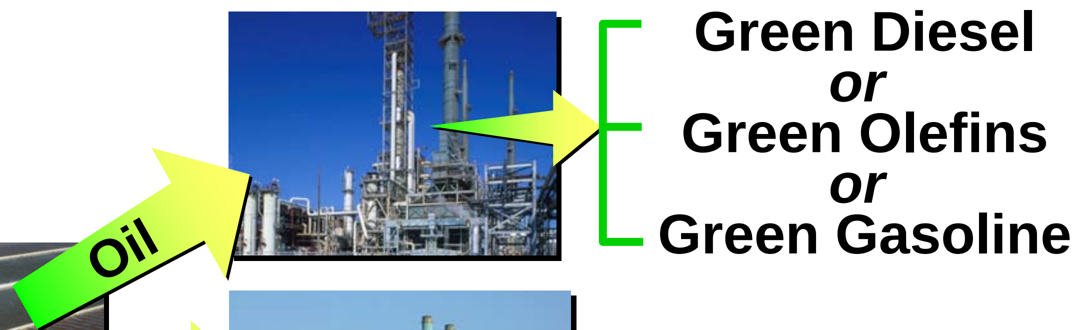
Properties Bio Jet: Renewable Aromatics

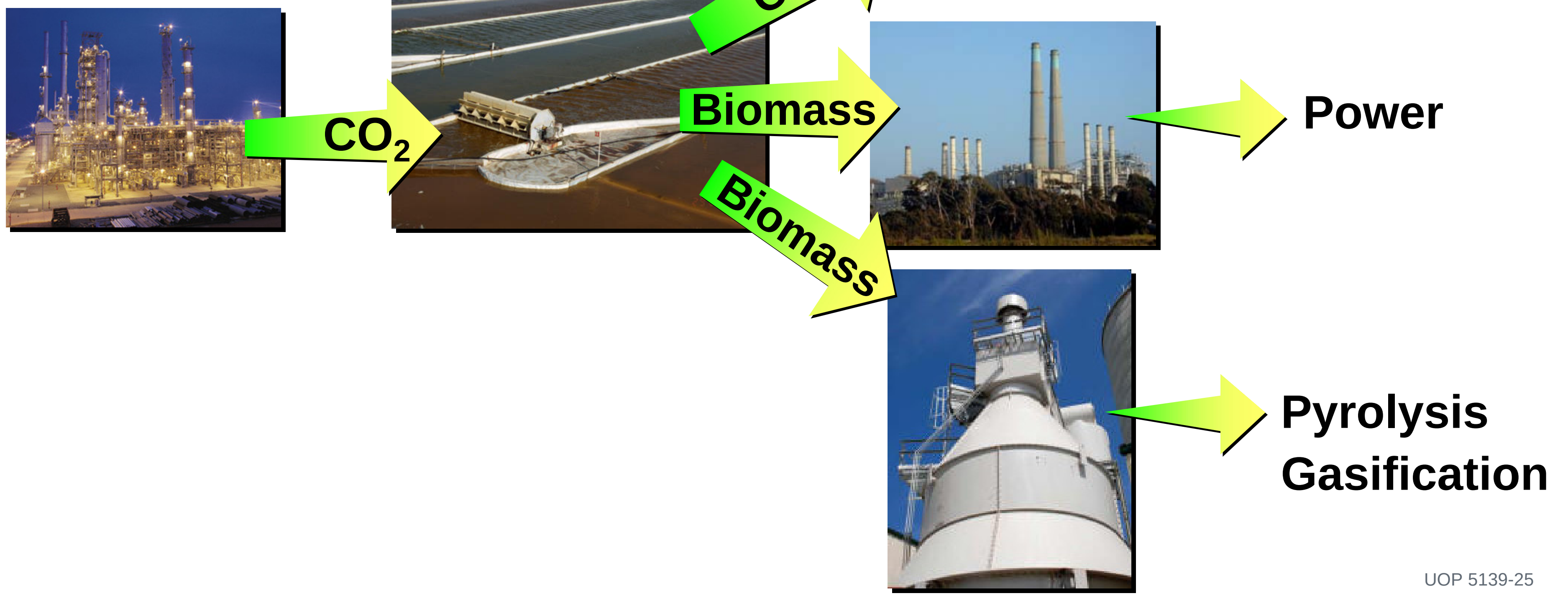
	JP-8 Spec	Starting Bio Paraffin	Corn Stover Pyrolysis Oil	Woody Pyrolysis Oil
Freeze Point (°C)	-47	-53	-56	-54
Flash Point (°C)	39	53	49	54
Density (g/mL)	0.775	0.759	0.790	0.782

100% Bio-derived Jet successfully prepared

Integrated Algal Processing

- Oil content: ~50wt%
- Photosynthetic efficiency: 10~20%
- Water: < 1/40 of land plants; saline/brackish/waste water
- Land: desert/arid
- Excellent CO_2 capture and sequestration capability





Options for Making Aviation Fuels

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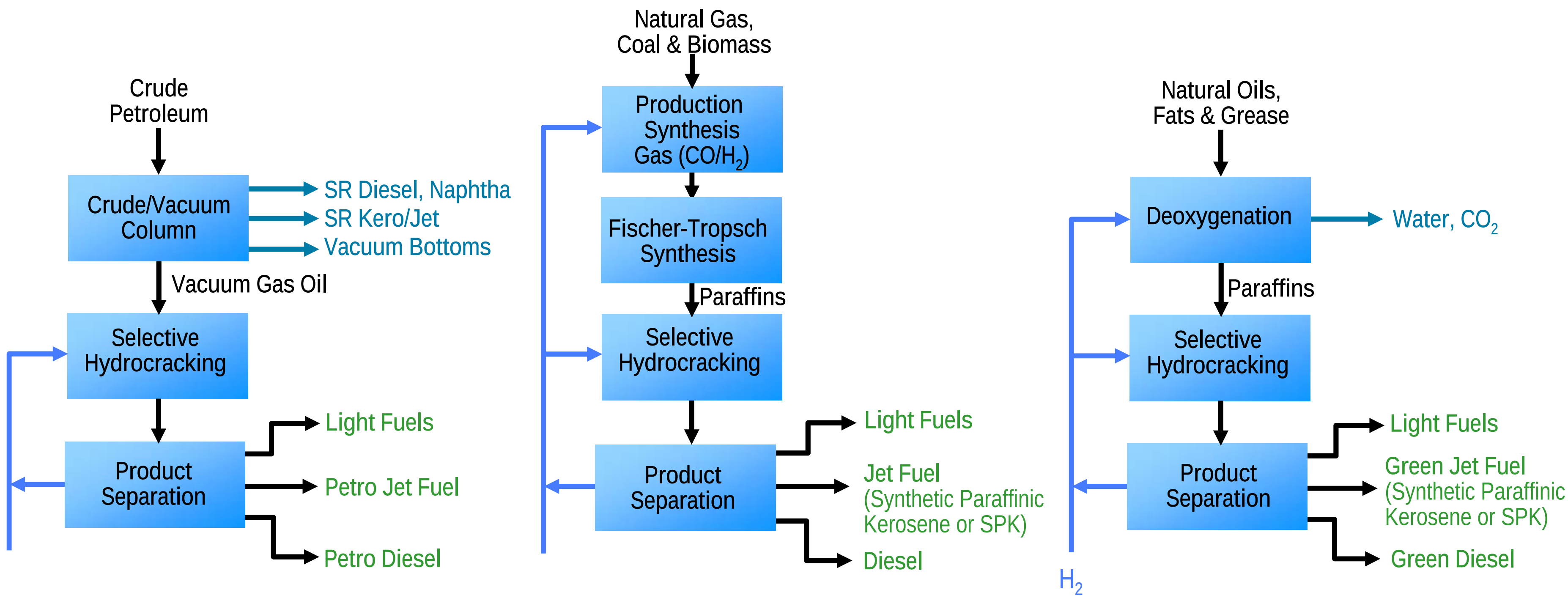

<u>*Economic Driver*</u>

OPEX	***CAPEX***	***OPEX***

<u>*Sustainability Driver*</u>

GHG	***GHG/Water***	***Feedstock/LUC***

All routes rely on the same technology to make the end fuel.
Therefore, all routes will result in fuels which are chemically similar.

Commercialization Timeline

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Natural Oils and Fats → Deoxygenation → Isomerization → Diesel + Jet Range Paraffins

~ 10% Synthetic Paraffinic Kerosene

Feedstock: Soybean, Jatropha, Algae, Palm, Canola, Coconut Tallow (4 kinds); Used cooking oil; Yellow Grease

Natural Oils and Fats → Deoxygenation → Selective Cracking/ Isomerization → Diesel + Jet Range Paraffins

~50-70% Synthetic Paraffinic Kerosene

Feedstock: Soy; Canola; Soy/Canola blend; Coconut; Palm; Jatropha; Algae

Solid Biomass → Fast Pyrolysis → Catalytic Stabilization/ Deoxygenation → Jet Range Cyclic Hydrocarbons

Renewable Gasoline & Aromatics

Feedstock: Wood Waste, Corn Stover

2007	2008	2009	2010	2011	2012	2013	2014
Ecofining Introduced		*Green Jet Introduced*	*Cellulosics Introduced*				
			Ecofining Commercial Operation - Q1		*Green Jet Commercial Operation - Q4*	*Cellulosics Commercial Operation – Q4*	

Industry Interest & Impact

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ATA AIA CAAFI ACI FAA

Air Transport Association

IATA

AIRBUS

jetBlue AIRWAYS

IAE International Aero Engines

Honeywell

BOEING

Virgin atlantic

AIR NEW ZEALAND

Continental Airlines

JAL

GE

Rolls-Royce

cfm

Pratt & Whitney
A United Technologies Company

Objectives:

- **Demonstrate viability of biofuels in commercial aviation**
- **Generate the data necessary to support certification of biofuels (analytical, ground, flight)**

Industry Actively Engaged in Enabling Biofuels

Achieving Sustainability

- **Renewables are going to make up an increasing share of the future fuels pool**
  - **Multitude of bioprocessing approaches possible**
  - **Fungible biofuels are here**
  - **Essential to overlay sustainability criteria**
- **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, have the potential to make significant contributions.**
- **Important to promote technology neutral and performance based standards and directives to avoid standardization on old technology.**

Create a Portfolio of Options

Acknowledgements

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  - Tim Rahmes
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  - Michael Kennedy
  - Ian Purdle
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  - Leah Raney
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Nodan mamomamo
Teşekkür ederim
Danke schön
감사합니다
Спасибо
Thank You
धन्यवाद
Obrigado
Kiitos
جزاكم الله خيراً
Gum xia
Merci
Tawdi
Terima kasih
Sha sha
Gracias
Ang kêun
Maulanenga
Añachaykin
Efcharisto
Hvala
Ookini
謝謝
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