Creating a Sustainable Biofuels Future

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UOP LLC

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UOP 5154-01

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- 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

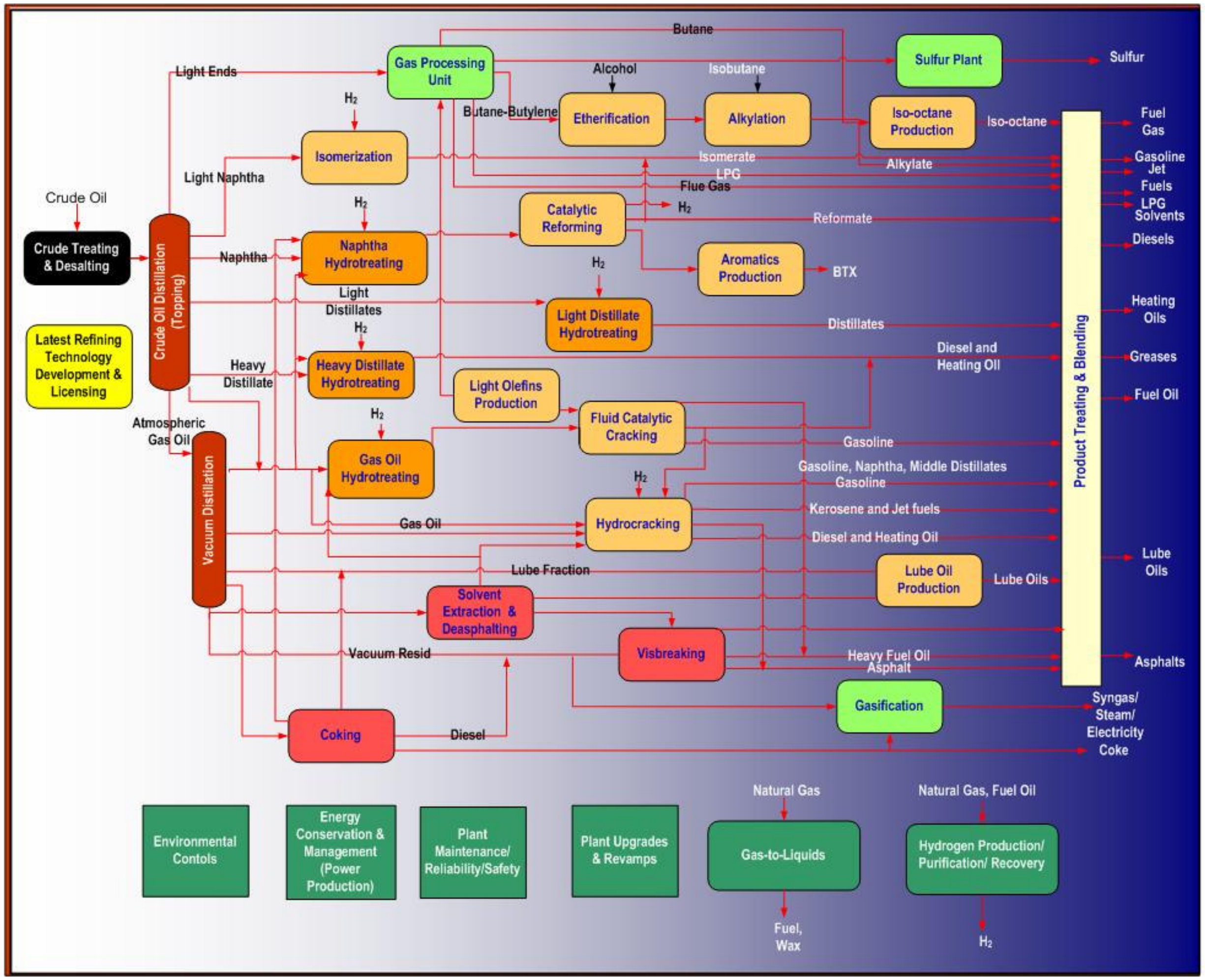
Macromarket Summary: Through 2015

- **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

Petroleum Refining for Transport Fuels



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

Massive Scale

Technology Evolution Expected

UOP Renewables Vision

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- Produce real 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

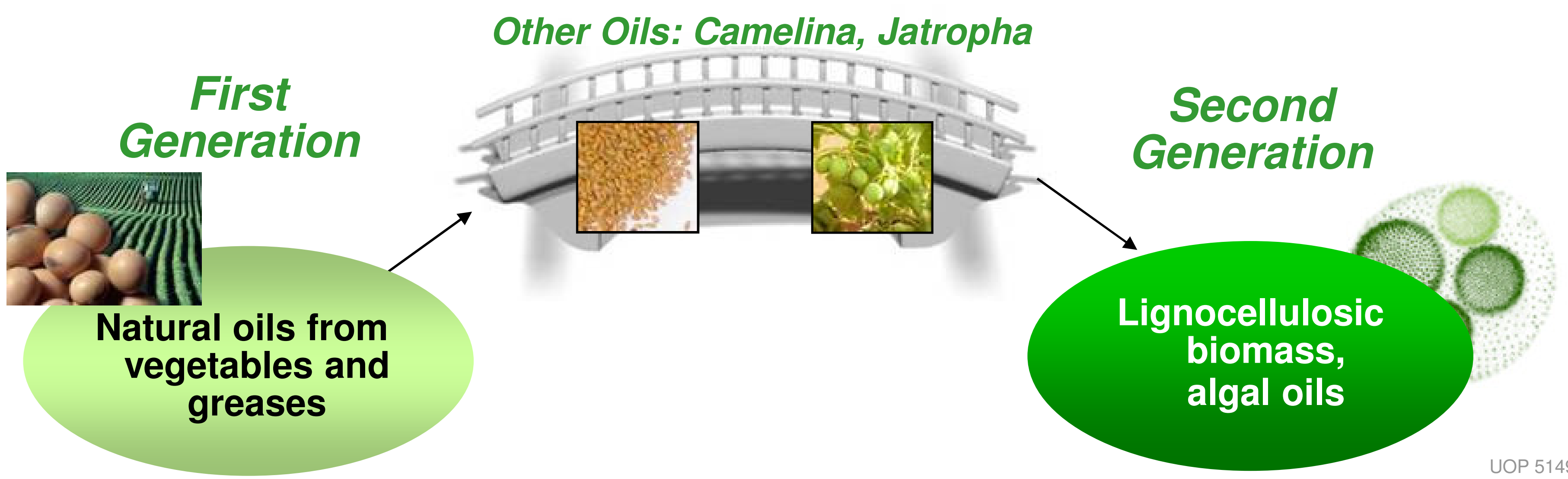
- Ethanol
- Biodiesel

Renewable Energy

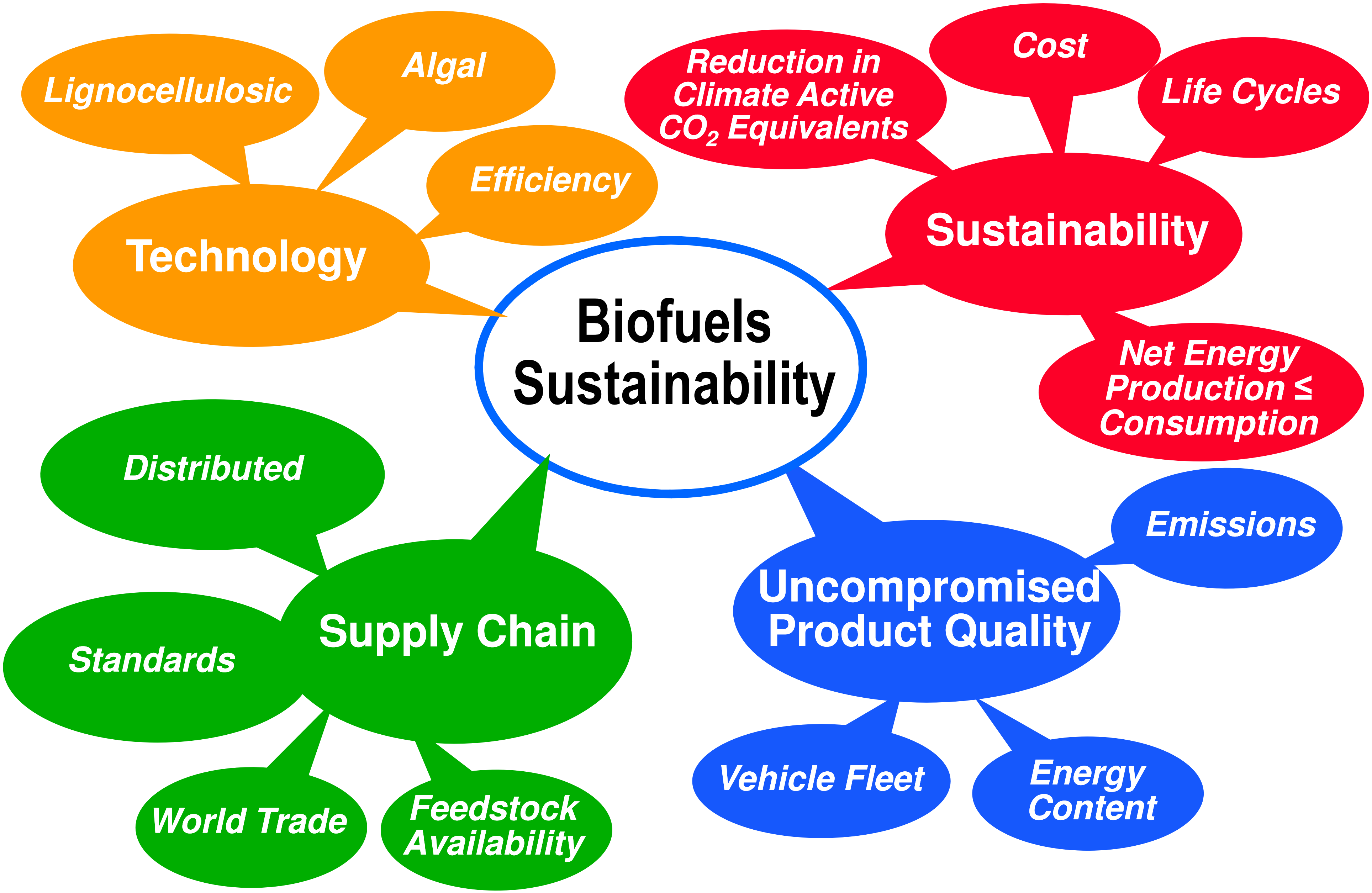
- Fuel & Power

Hydrocarbon Biofuels

- Diesel
- Jet
- Gasoline



Renewable Fuels: A Sustainable Future



Biofuels: Regional Drivers

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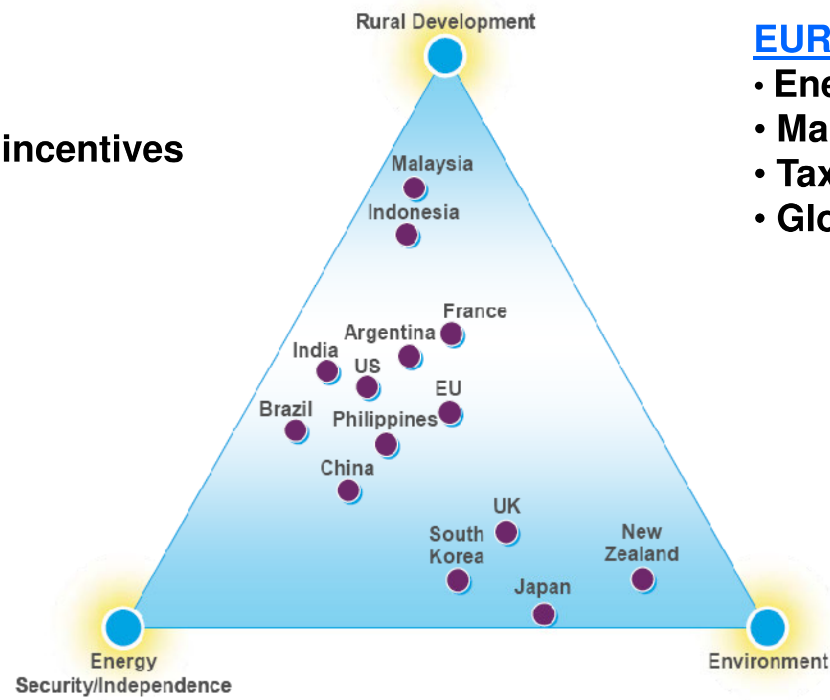
SE ASIA/ S. AMERICA

- Agro sector focus
- Production and export incentives

EUROPE

- Energy Security
- Mandates: RED
- Tax incentives
- Global warming: RED/FQD



AFRICA

- Rural development
- Employment

CHINA/INDIA

- Energy Security
- Rural development
- Employment

N. America

- Energy Security
- Mandates: RFS
- Environment
- Agro sector subsidies & Tax incentives

Drivers change priority for different economies/geographies

Global Legislation Overview

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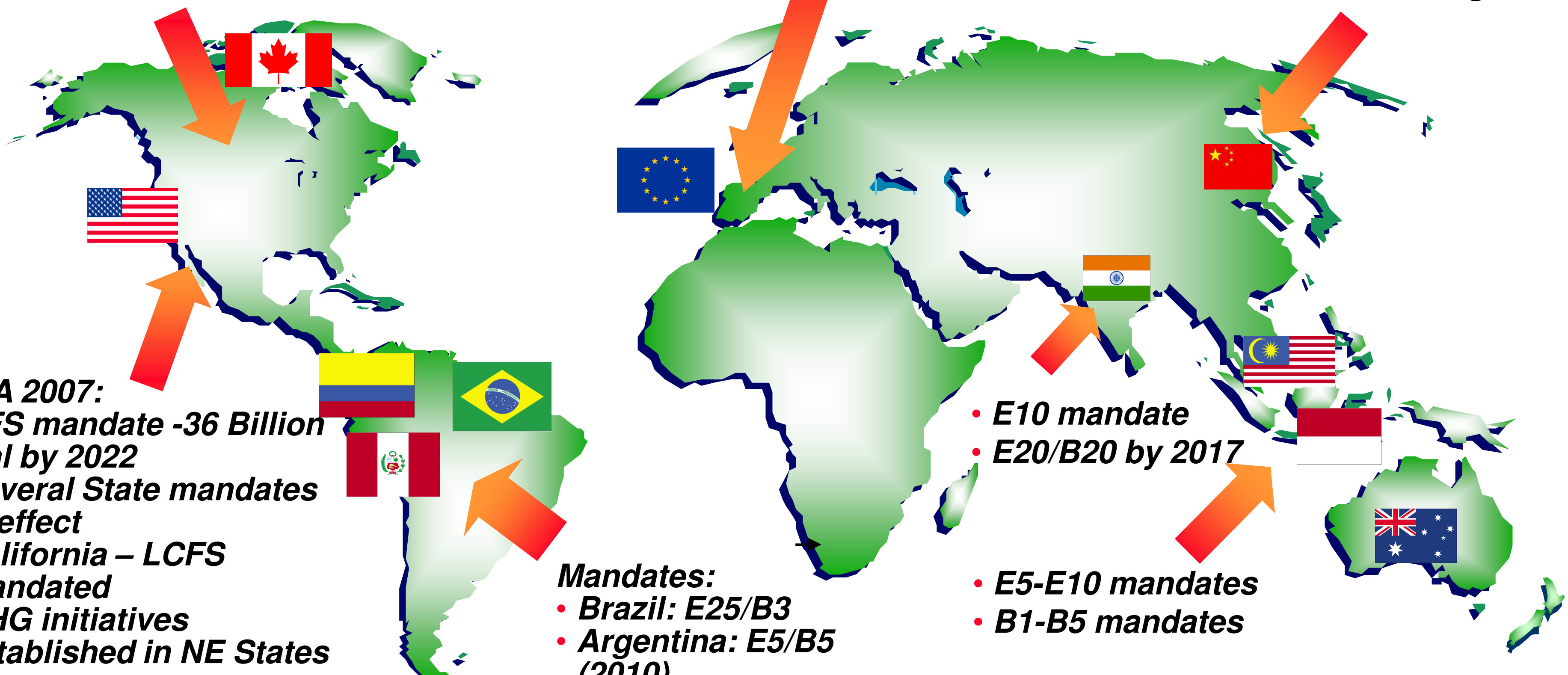
Canadian Law C-33 mandates:
- ***E5 by 2010***
- ***B2 by 2012***
- ***B5 in British Colombia by 2010***

EU-27 – Proposed Mandates:
- ***RED – 10% by Energy content by 2020***
- ***GHG – 10% reduction by 2020 from 2010 levels***
- ***Final targets still being debated***

- ***E10/B5 targets***



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***
- ***Argentina: E5/B5 (2010)***
- ***Colombia: E10/B5***

- ***E10 mandate***
- ***E20/B20 by 2017***

- ***E5-E10 mandates***
- ***B1-B5 mandates***

Global Biofuels use trending towards a nominal E10 & B5

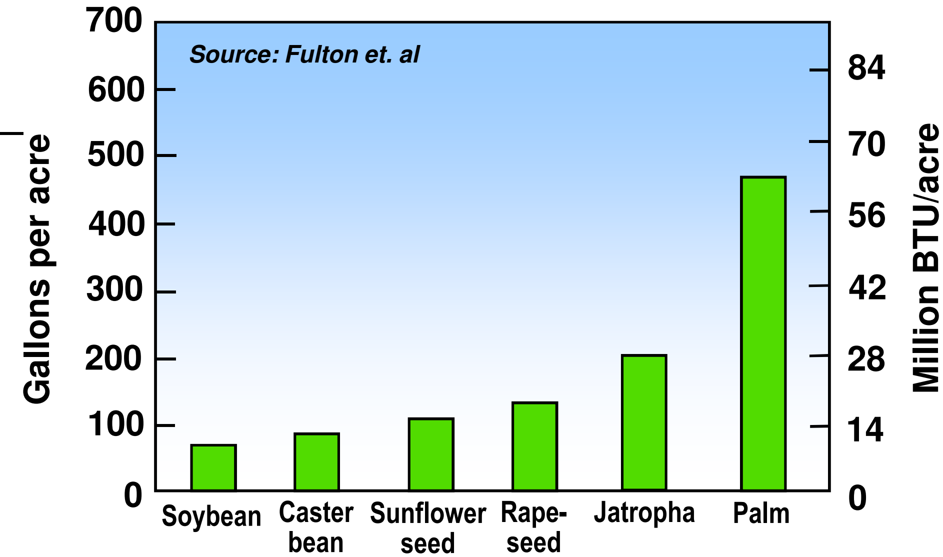
Biofuel Targets

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)*

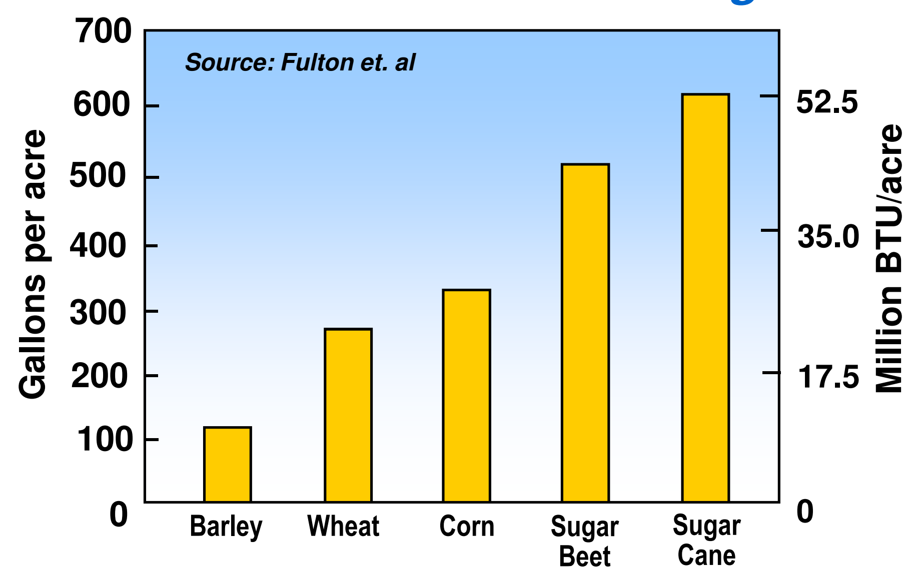
** Energy content basis*

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

Biodiesel Production from Oils



Ethanol Production from Sugars

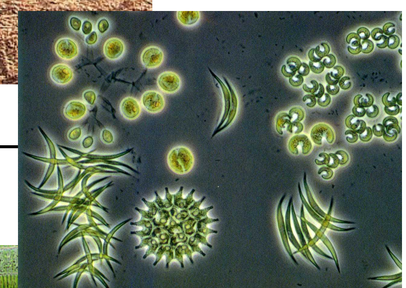


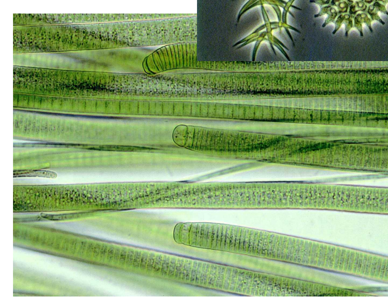
Critical Issues

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

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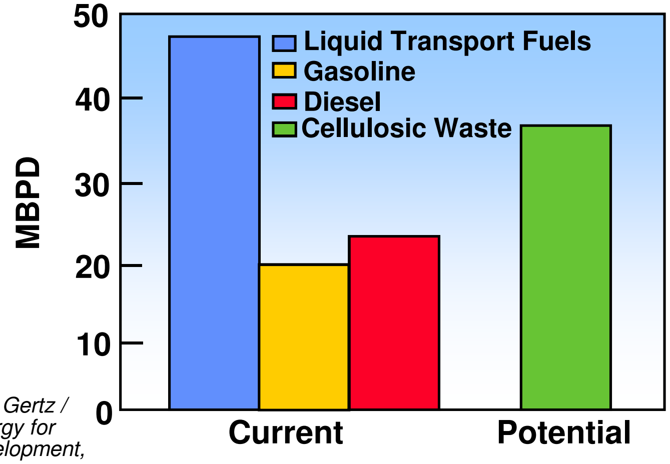
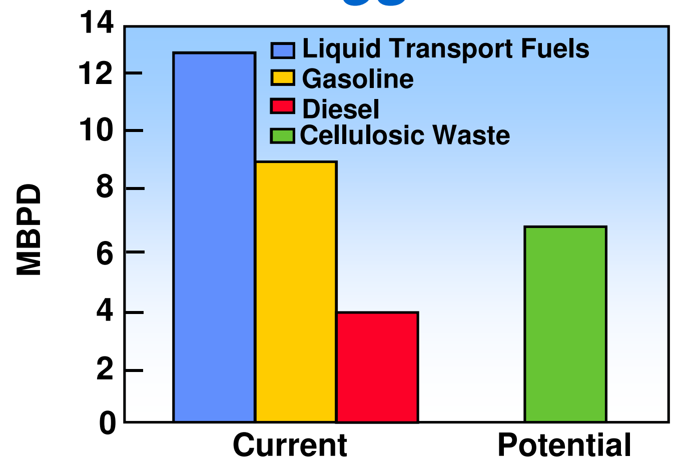
Global

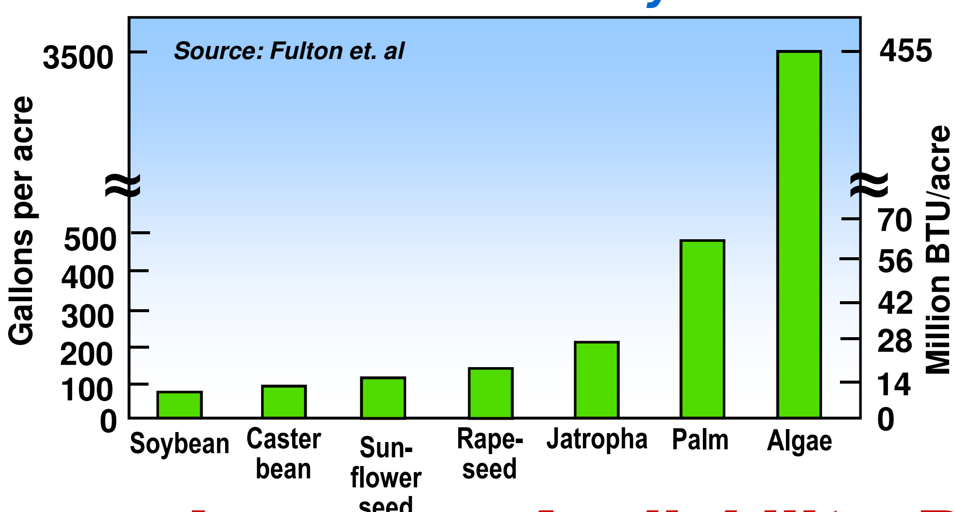


Source: Purvin & Gertz / Eric Larsen: Energy for Sustainable Development, 2000

US



Oils Productivity

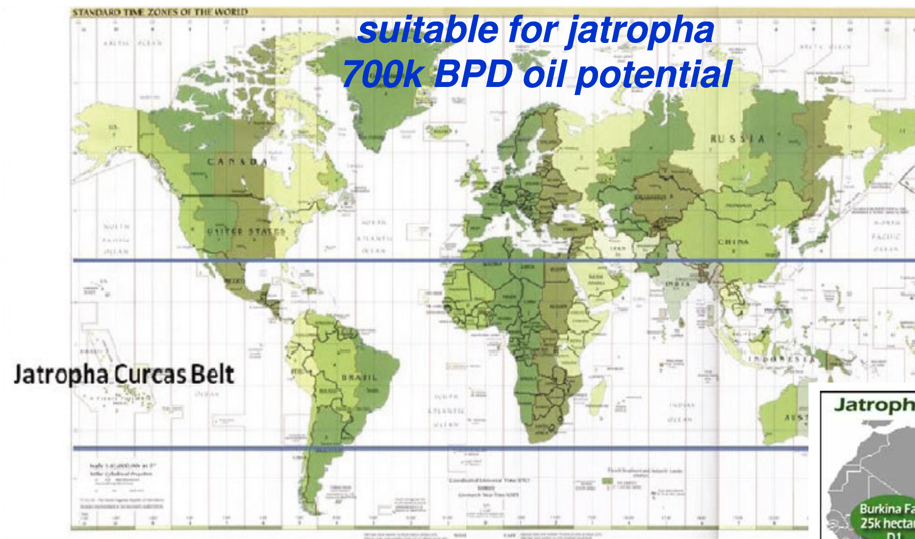


- **Cellulosic waste could make a significant contribution to liquid transportation pool.**
- **Algal Oils could enable oils route to biodiesel, Green Diesel and Green Jet.**

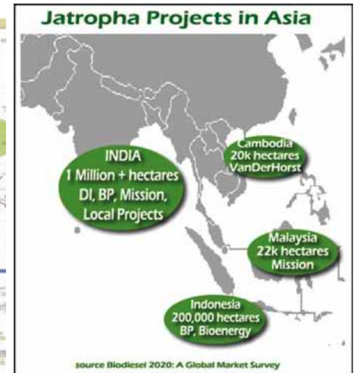
Increases Availability, Reduces Feedstock Cost
Technology Breakthroughs Required

Transition Feedstocks

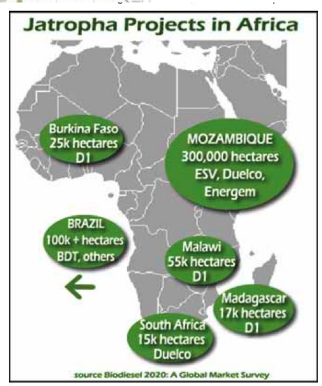
India: 60M ha identified as suitable for jatropha 700k BPD oil potential

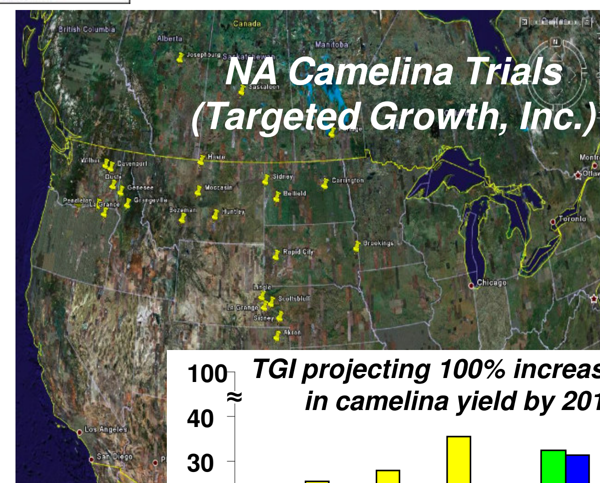


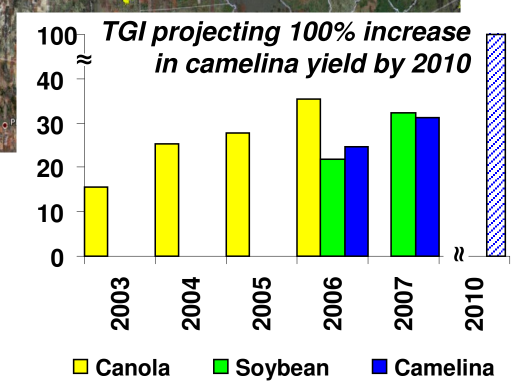
Source: Global Biofuels Center, University of Texas Library, August 2008



Jatropha
Grows on marginal land
Non-edible
Targeting $1/day economies







Rapidly increasing feedstock supplies

- **New non-edible crops (castor, halophytes)**
- **Use of marginal lands**
- **Strains with higher yields**
- **Improved cultivation practices**

Camelina
2x soy yields
Grows on marginal land
Rotate with traditional crops

Developing countries focused on biofuels to create jobs in their rural economies

Renewable Fuels: A Sustainable Future

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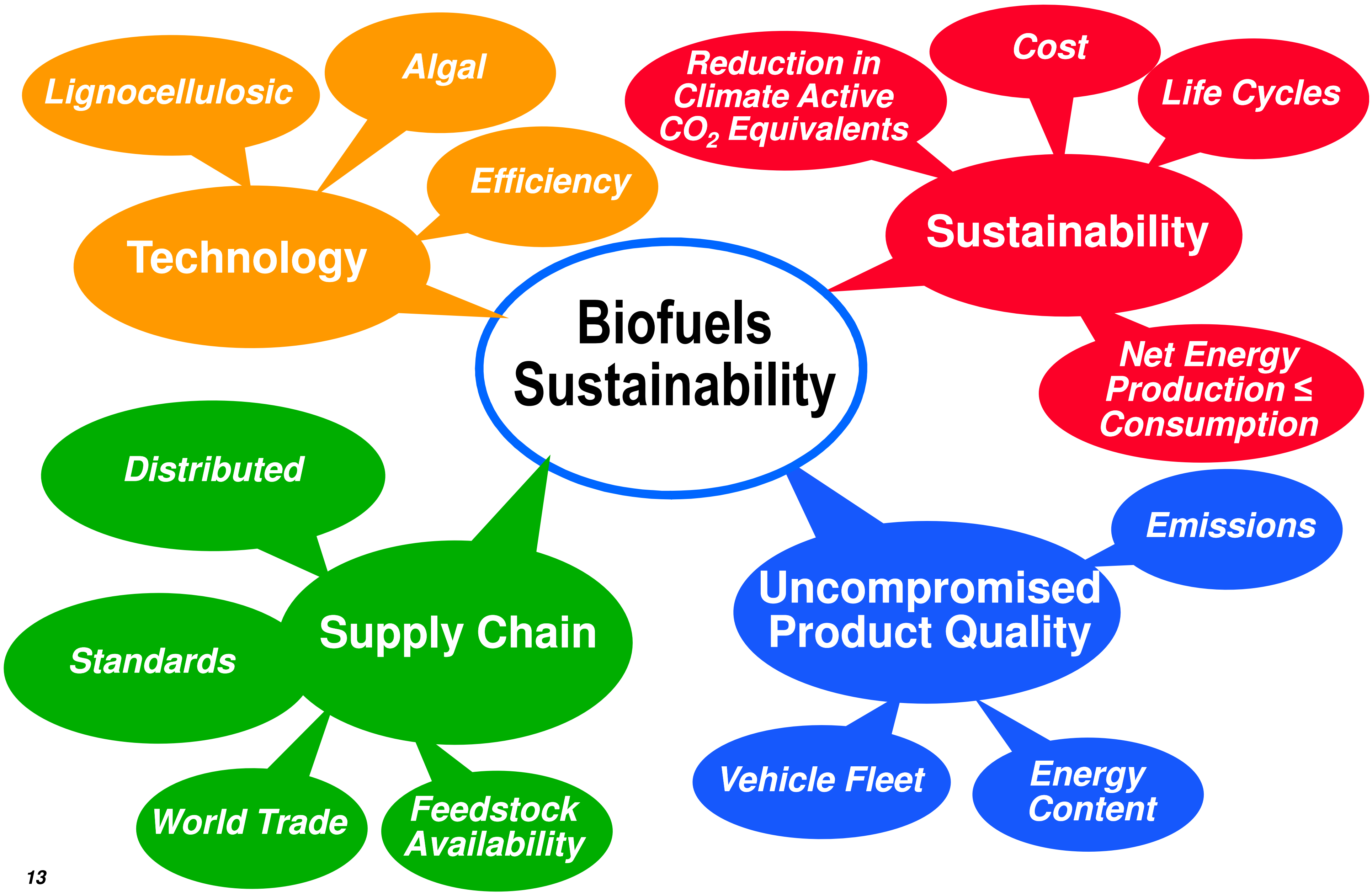
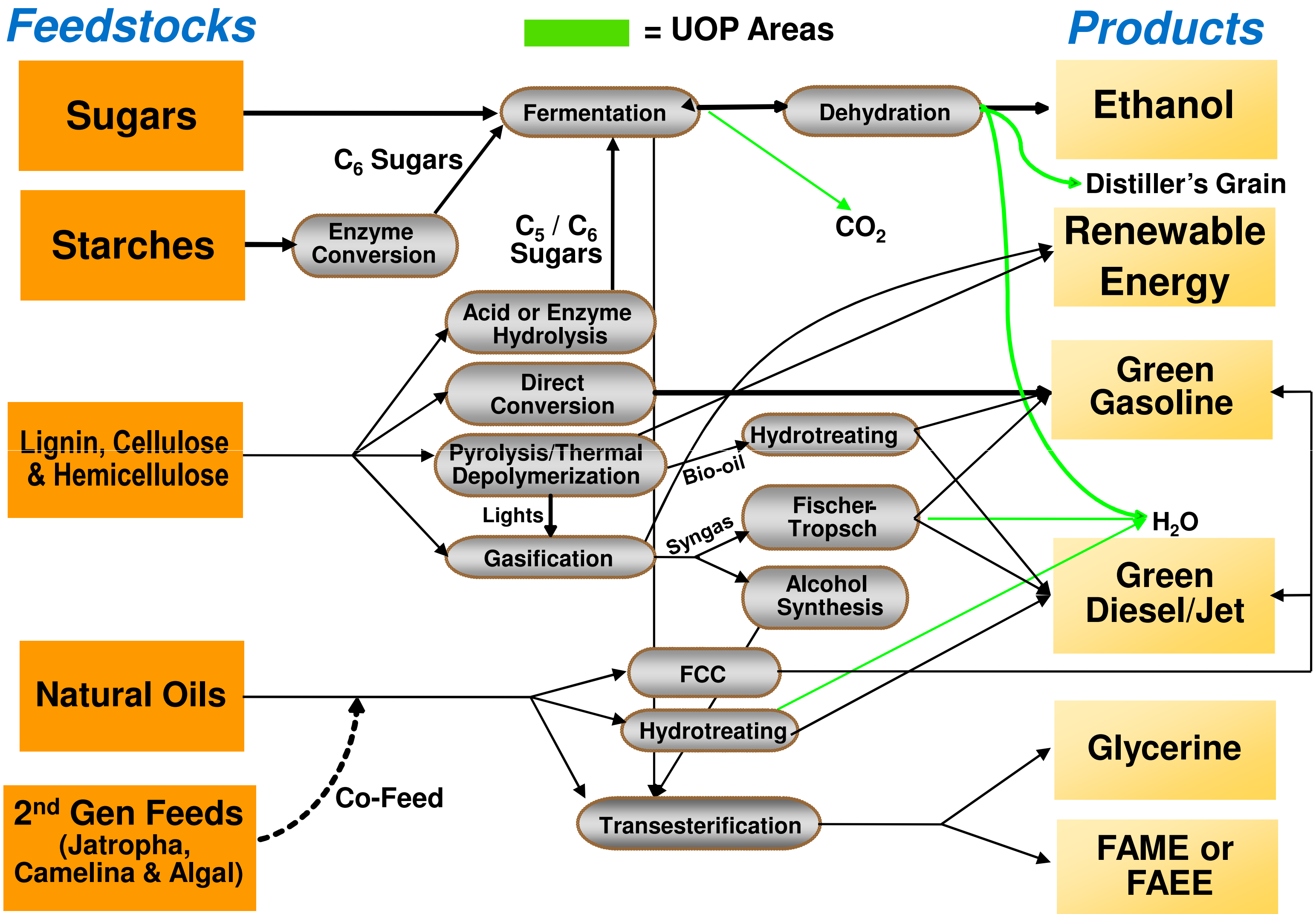


Biofuels Overview: Technology Pathways



Current biofuel market based on sugars & oils. Use bridging feedstocks to get to 2nd Gen feeds – Algae & Lignocellulosics

Ecofining™ Green Diesel

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- Superior technology that produces diesel, rather than an additive
- 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"
- Excellent results from carmaker tests

Process Comparison vs. Biodiesel

Natural Oil/ Grease + Methanol → **Biodiesel (FAME)** + Glycerol

Natural Oil/ Grease + Hydrogen → **Green Diesel** + Propane

Performance Comparison

	Petrodiesel	Biodiesel	Green Diesel
NOx	Baseline	+10	-10 to 0
Cetane	40-55	50-65	75-90
Cold Flow Properties	Baseline	Poor	Excellent
Oxidative Stability	Baseline	Poor	Excellent

Green Jet Fuel
(Bio Synthetic Paraffinic Kerosene)

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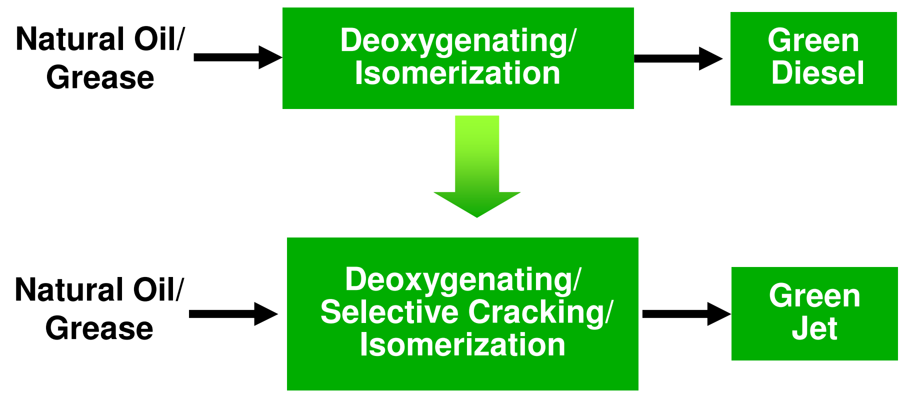
- DARPA-funded project to develop process technology to produce military jet fuel (JP-8) from renewable sources
- Leverages diesel Ecofining process technology for jet fuel
- Green Jet Fuel can meet all the key properties of petroleum derived aviation fuel, flash point, cold temperature performance,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

Key Properties of Green Jet

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Description	Jet A-1 Specs	Jatropha Derived SPK	Camelina Derived SPK	Jatropha/ Algae Derived SPK
Flash Point, °C	**Min 38**	**46.5**	**42.0**	**41.0**
Freezing Point, °C	**Max -47**	**-57.0**	**-63.5**	**-54.5**
JFTOT@300°C				
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

Over 6000 US Gallons of SPK made using UOP process

BOEING®

Production Viability Demonstrated
Fuel Samples from Different Sources Meet Key Properties

Completed Flight Demonstrations

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

AIR NEW ZEALAND — Rolls-Royce — terasol ENERGY

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

Continental Airlines — cfm — Sapphire Energy

BOEING — uop A Honeywell Company — nu

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

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

Algae – Multiple Sources for Fuels

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aquaflow

Wild Algae

Sapphire Energy

Enhanced Algae Strains

solazyme

Heterotrophically Grown Algae

Low Production Costs

High Pre-Treatment Costs

Moderate Production Cost

Moderate Pre-Treatment Costs

Moderate Production Costs

Low Pre-Treatment Costs

Ecofining™

Green Fuels
Gasoline – Jet - Diesel

Pyrolysis Oil to Energy & Fuels Vision

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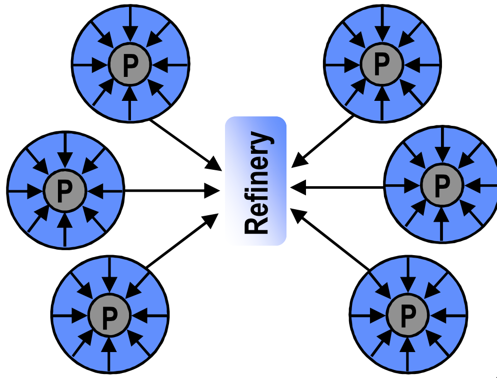
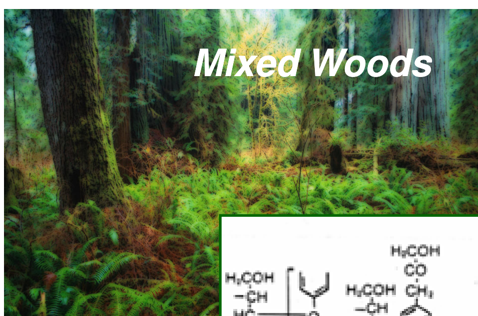
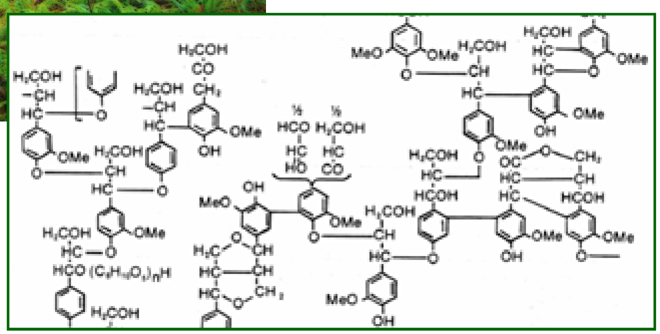


Biomass → Fast Pyrolysis → Pyrolysis Oil





Available Today:

- Electricity Production
- Fuel Oil Substitution

3 Years to complete R&D:

- Transport Fuels (Gasoline, Jet Diesel)
- Chemicals (Resins, BTX)

Transport Fuels already achieved on lab-scale
Collaboration with DOE, NREL, PNNL, USDA

Renewable Fuels: A Sustainable Future

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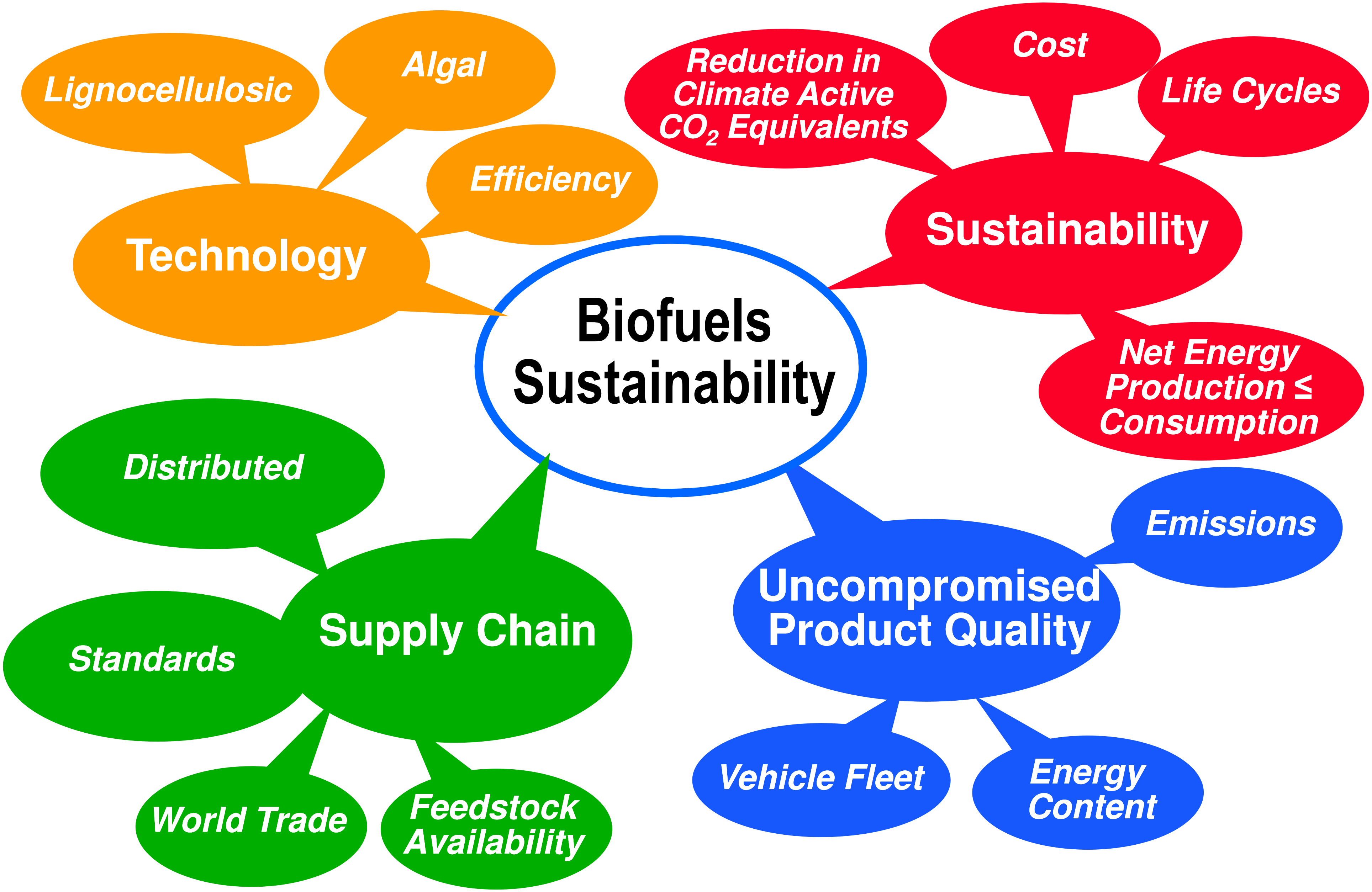
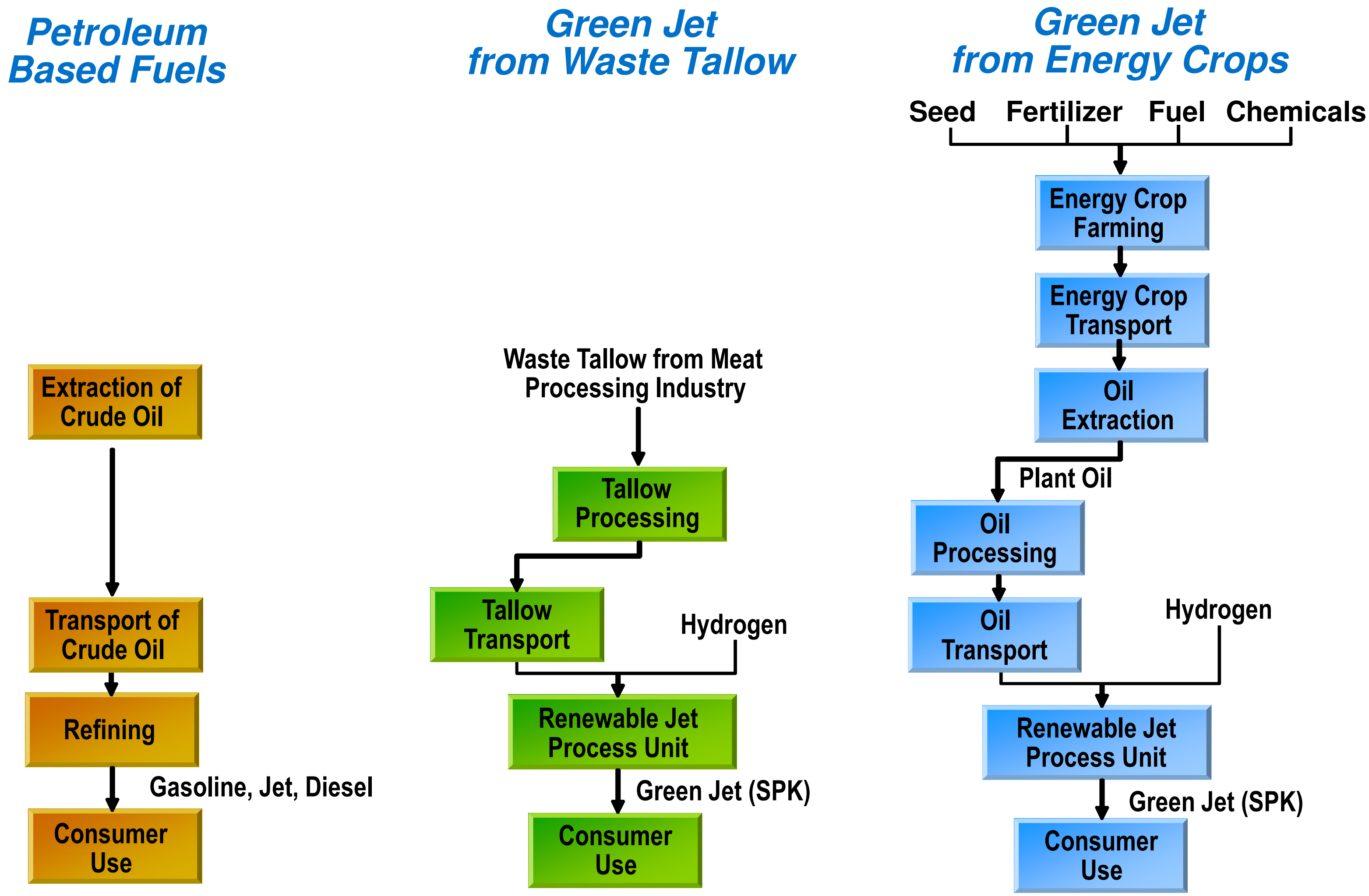


Scope of Jet Fuel WTW* LCA



*WTW for jet fuel is "well-to-wake"

Life Cycle Analysis for Bio-SPK

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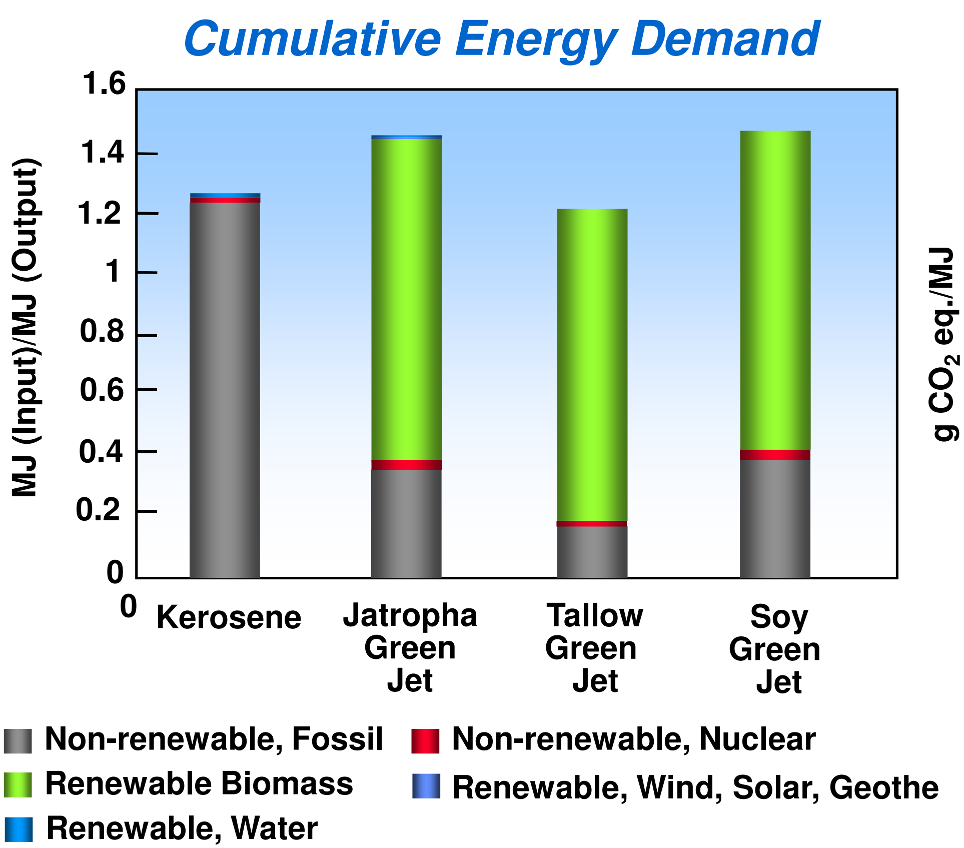

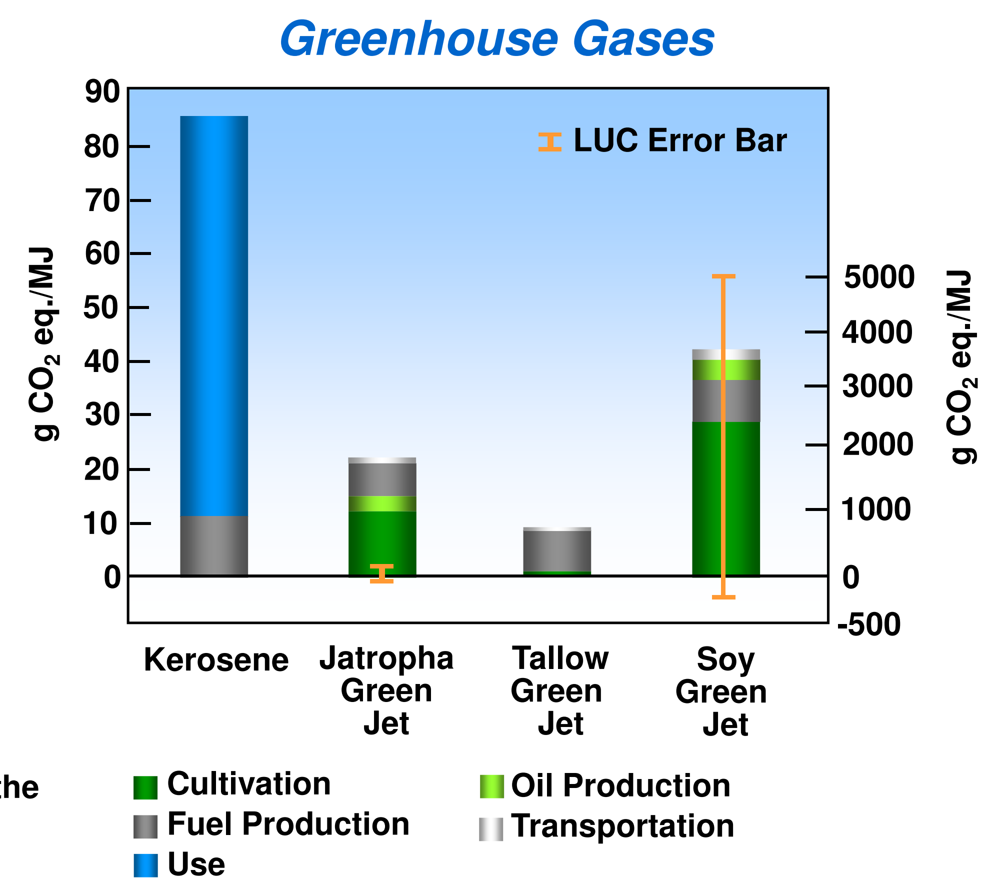

Significant GHG Reduction Potential

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.

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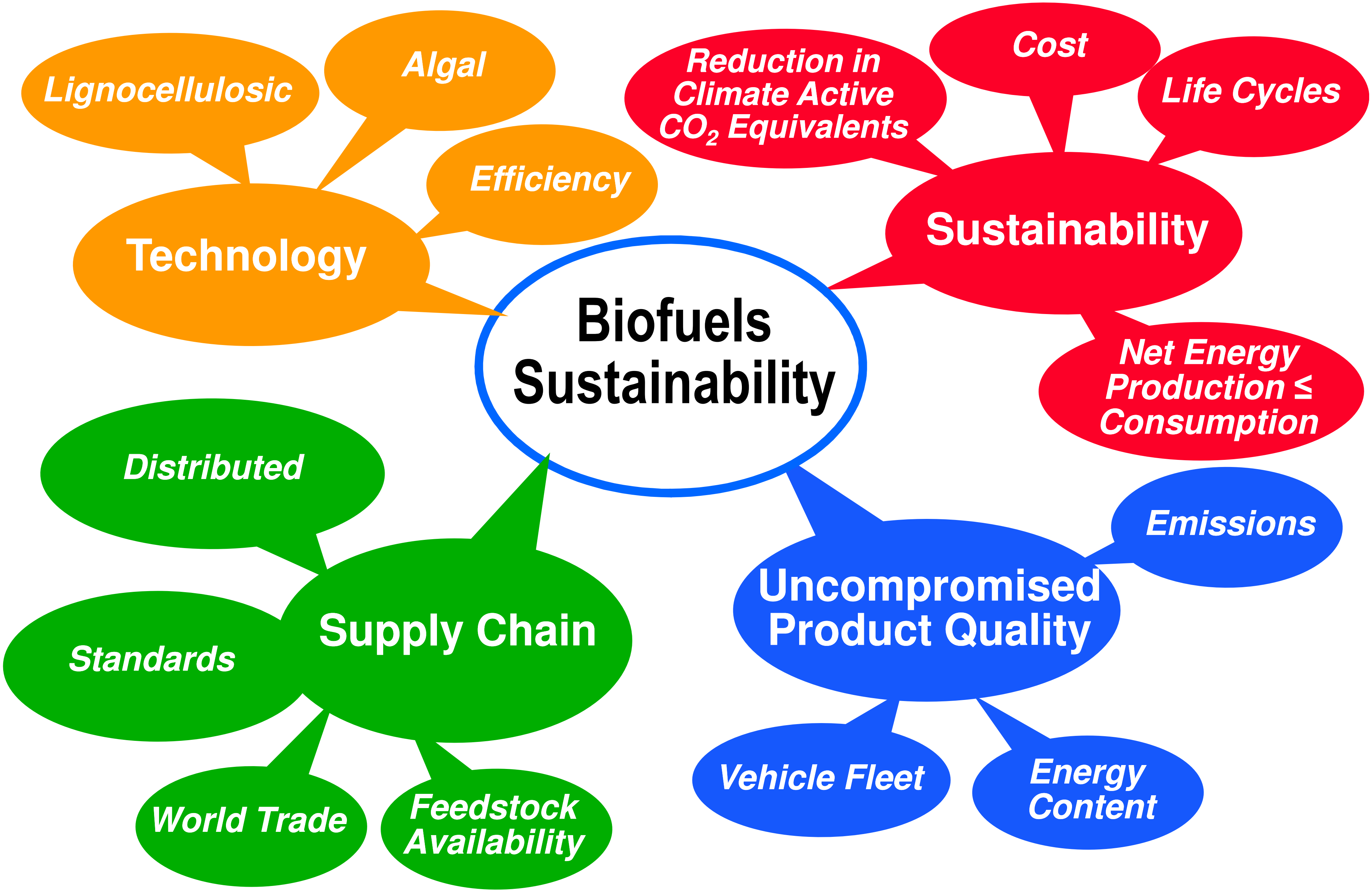

Achieving Sustainability

- 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.

Portfolio of Options Enabled by a Robust Supply Chain

Acknowledgements

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Nodan mamomamo

Teşekkür ederim

Danke schön

감사합니다

Спасибо

Thank You

धन्यवाद

Obrigado

Merci

Kiitos

جزاكم الله خيراً

Gum xia

Tawdi

Sha sha

Terima kasih

Gracias

Ang kêun

Maulanenga

Añachaykin

Efcharisto

Hvala

謝謝

Dekoju

Ookini

Danyavad

Spasibo

Grazie

Xie xie

Ngiyabonga

どうもありがとう。

Arigato

Giittus

Shukran

Eso

Dhannvaad

Gum xia

Qujanaq

Köszönöm

מרסי mersi

Wiyarrparlunpaju-yungu