Advanced Biofuels Meeting Challenges: Fuel Supplies and Energy Efficiency

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Part One

Advanced Biofuel Challenges

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Why Replacing Petroleum Transportation Fuels is Important

- The US <u>imports</u> about <u>8-9 Million Barrels </u>of Oil <u>Each Day.</u>
- At $100/barrel: **$800 million dollars/day is exported.**
- Approximately <u>90%</u> of oil is used for <u>transportation</u>; gasoline, diesel, jetfuel, lubricants, and asphalt for paving.
- Virtually no oil is used to produce electricity in the US.
- Electricity is used for transit and some trains but, **windmills and solar can not power jet airplanes.**

What Are Advanced Biofuels?

- **Advanced Biofuels are high-energy <u>liquid transportation fuels.</u>**
- Derived from
  - Low-input high-yield **crops,**
  - Agricultural or forestry **waste,** or
  - Other **sustainable** biomass feedstocks including algae

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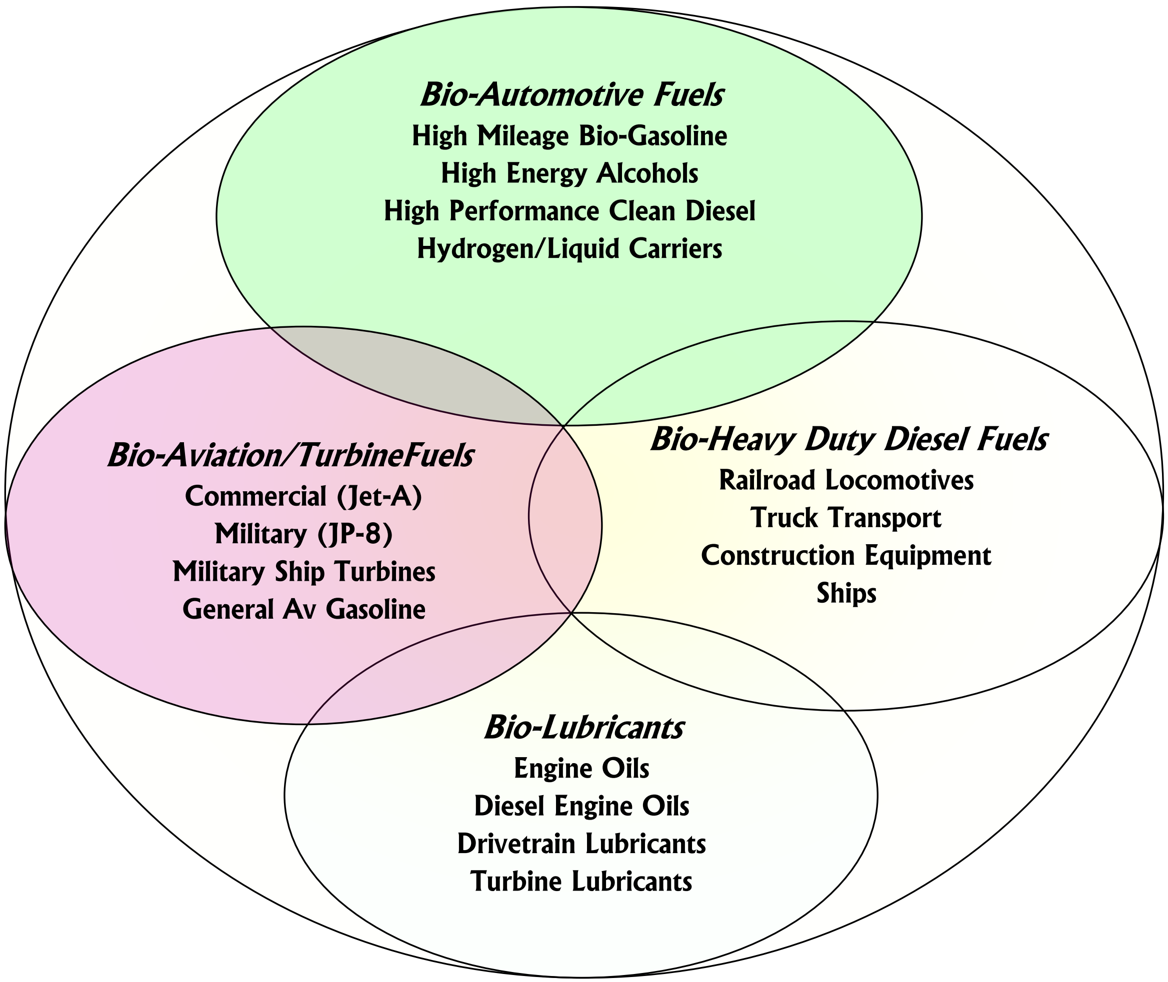
The Transportation Advanced BioFuel Universe



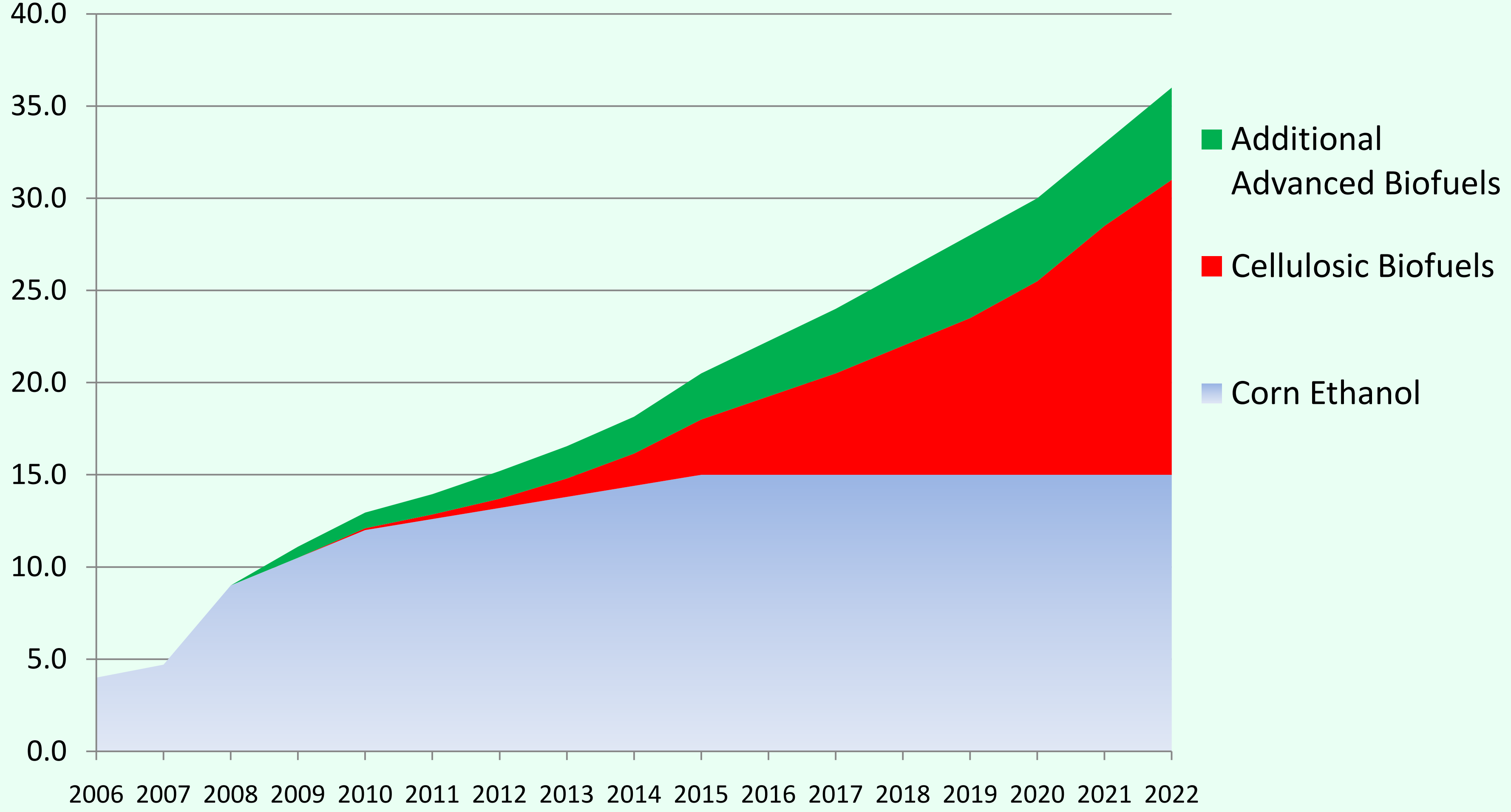
Promise of Advanced Biofuels

- USDA (2005 “Billion Ton” study) estimates that with current crops and advanced biofuels technologies, **over 50% of oil use (with new vehicle fuel standards) could be eliminated without affecting food costs**.

- New low nutrient/high yield perennial “energy grasses” could raise this total significantly. USDA perennial grass test plots indicate that **70% of oil consumption could be replaced.**

2007 Renewable Fuels Standard

Sec. 202 Energy Independence and Security Act of 2007
(Billion Gallons/Year)



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Biomass Conversion
Technical Roadblocks to Low-Cost Advanced Biofuel Production

- *"The major bottleneck in the development of fuels from biomass is a sustainable source of sugars which does not displace the production of food." James Dumesic, developer of the aqueous reforming process used to produce alkanes from sugars.*

1. Make **all components of biomass** available for biofuel production (*Use the whole plant*)
2. Improve the **efficiency** of biomass to biofuel **conversion** (*Do it faster, cheaper, sustainably*)

Plant Cell Wall Biomass For Biofuels

- **Multiple Sugars Available for Biofuels**
- **Cellulose > Glucose (6-carbon)**
- **Hemicellulose > Xylose, Arabinose (5-carbon)**
- **Pectin > Galacturonic Acid (6-carbon)**

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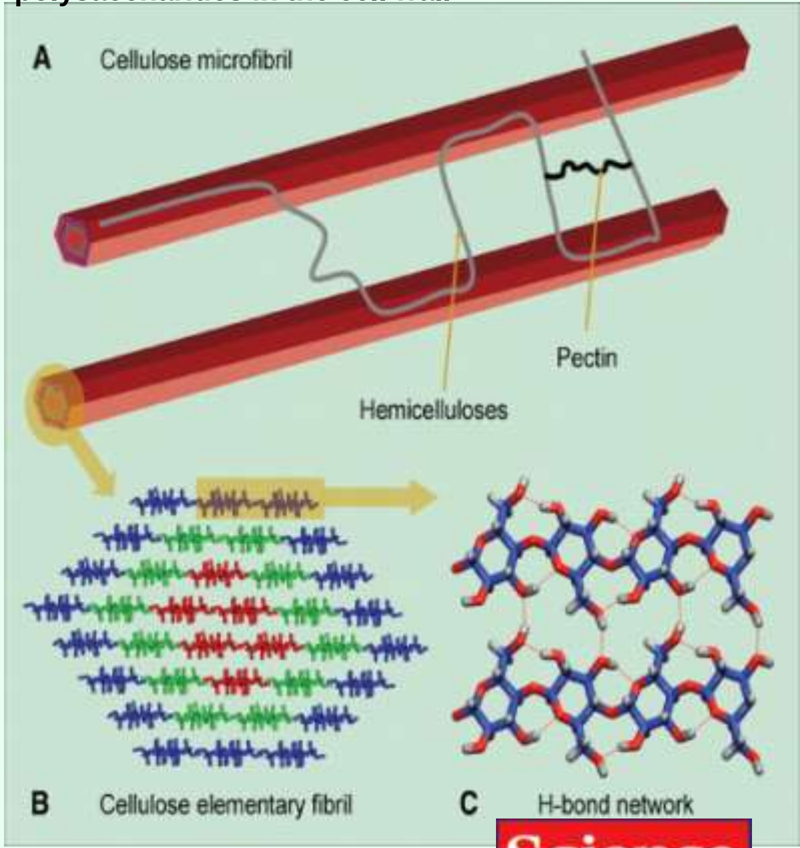
Biofuel Research Challenge I: Overcoming Biomass Recalcitrance

- Cellulose, hemicellulose, pectin, & lignin intertwine to create **complex cell wall** matrices
- This complex structure protects plants and trees from disease, moves nutrients, and provides for growth
- These complex structures also **restrict access to the "simple sugar" components**
- Current technologies to break up biomass are energy and cost intensive.
- New enzyme and bacterial processes are under development

A simplified model showing the interaction of the major polysaccharides in the cell wall



M. E. Himmel et al., Science 315, 804 -807 (2007)

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Overcoming Biomass Recalcitrance Research Paths

1. Reverse engineer plant cell wall genetics to discover enzymes that will “deconstruct” cell wall matrices
2. Adapt microbial “rotting” enzymes to dissolve cell wall sugars
3. Breed plants and trees with cell wall structures more amenable to chemical or enzyme solubility
4. Reduce costs and energy requirements of chemical processes

Biofuel Research Challenge II: Improve Conversion of Biomass to Biofuel

- **Expand Fermentation to Produce Fuel Components other than alcohols** such as ethanol ($2CH_3CH_2OH$)
- **Expand the Types of Sugars** that can be used for **Fermentation. "Simple Sugars"** and **Polysaccharides** need to be used.
- **To Produce Higher Energy Fuels**; gasoline, diesel, or jet fuel, **Hydrocarbon Compounds with 5 or more Carbon Atoms need to be produced**.

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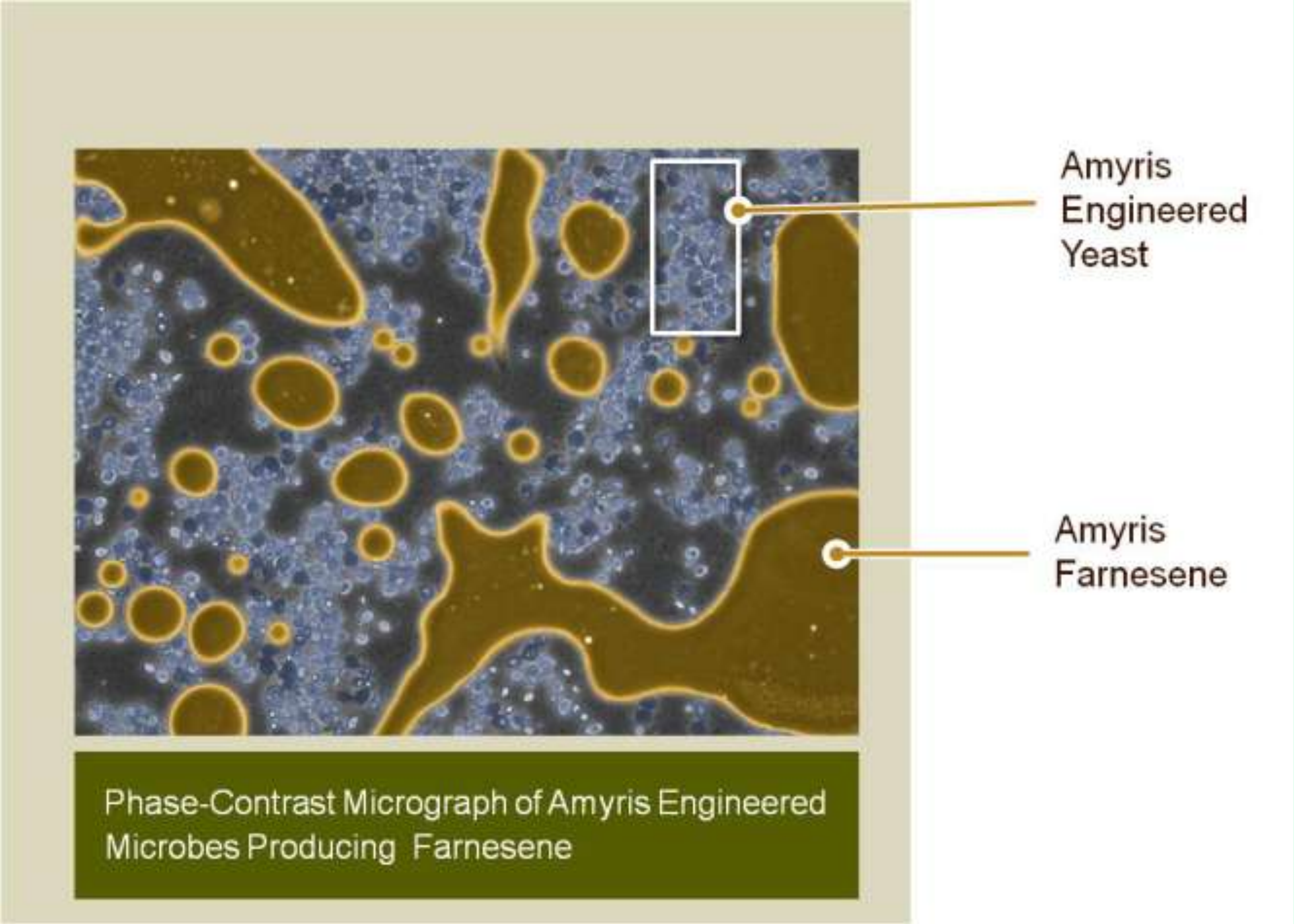
Research Progress
Farnesene: A 12-Carbon Diesel Fuel Compound Fermented From Sugars



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Why Not Electric Cars and Plug-In Hybrids?

"Because of considerable inefficiency in the conversion of primary energy into electricity during generation and losses in its distribution, the ***electrical energy received by the end user*** *is only about* ***one-third*** *of the primary* ***energy invested in generating it****."*

" *Our electricity is generated in several ways but the major pathways are from coal burning (52%), nuclear power (20%), natural gas (19%) and renewable energy including hydropower (8.5%). While still small, electricity generated from wind power grew by over 25% compounded annually from 2001-2005."*

Ralph J. Cicerone, President of the National Academy of Sciences.

Liquid Fuel Advantage
Batteries Have Very Low Energy Density

ENERGY FUTURE: Think Efficiency

American Physical Society, Sept. 2008, Chapter 2, Table 1

	Energy density per volume		Energy density per weight	
	kWh/liter	vs gasoline	KWh/kg	vs gasoline
Gasoline	9.7		13.2	
Diesel fuel	10.7	110%	12.7	96%
Ethanol	6.4	66%	7.9	60%
Hydrogen at 10,000 psi	1.3	13%	39	295%
Liquid hydrogen	2.6	27%	39	295%
NiMH battery	0.1-0.3	2.1%	0.1	0.8%
Lithium-ion battery (present time)	0.2	2.1%	0.14	1.1%
Lithium-ion battery (future)			0.28 ?	2.1%

Part Two

Automotive Engineering and Biofuels

Increasing Combustion Efficiency

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Biofuels and Racing
NASCAR Using E-15 in 2011

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Biofuels and Racing
American Le Mans Series

GT Class: Cellulosic E-85

Dyson Prototype: Bio-Butanol

Racing Series Can Be Proving Grounds for New Biofuels and Engine Technologies

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Engine Design and Bio-Alcohol Fuels

- **Goal of All Engine Design**: extract the maximum amount of energy contained in the fuel delivered to the combustion chamber.
- **Maximum Thermal Efficiency** is Restricted by Two Realities:

1. Economics and technology of engine construction, and
2. Characteristics of the fuel being used.

Ethanol Fuel Energy Value is Lower Than Gasoline

(In British Thermal Units: BTU)

BTU information from US EIA/DOE

Fuel	BTUs/Gallon	Percent
Gasoline	124,000	100%
E-10	120,280	97%
E-85	94,190	76%

Automotive Technology Challenge:
Can We Recover Mileage Loss with Other Ethanol Characteristics?

Maximizing Thermal Efficiency: Using Ethanol's Higher Octane

- **Increased Octane** can be used to **Increase Thermal Efficiency/Mileage.**

- **E-85 could reach 97% of regular fuel.**

Fuel	BTUs/ Gallon	Thermal Efficiency	"Power" BTUs	% "Power" BTUs
E-10	120,280	33%	39,692	
E-85 (108+ Octane)	94,190	41%	38,618	**97 %**

- **Do Flex-Fuel Engine Technologies** exist that could **Optimize Different Ethanol/Gasoline mixtures?**

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New Engine Technologies Do Exist That Could Be Used

Ford 1.6L Eco-Boost Engine

- ***Ford Eco-Boost™***
- ***GM Ecotec™***
- Both Combine:
- *Direct Fuel Injection*
- *Turbocharging*
- *Variable Intake/Exhaust Valve Timing*
- ***In Fords, Chevys, Buicks***

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Eco-Boost/Ecotec Technologies Based on Proven Concepts

Maximizing Thermal Efficiency

<u>The Atkinson Cycle</u>

Maximizing Power

<u>The Miller Cycle</u>

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Maximizing Thermal Efficiency: The Atkinson Cycle

- James Atkinson, 19th Century English engineer.
- To maximize thermal efficiency in an internal combustion (IC) engine the power stroke had to have more time for combustion than for compression.
- Used in Ford and Toyota hybrids.
- Delay the closing of the intake valves to create a shorter compression stroke as compared to the power stroke.
- Increases thermal efficiency through a longer period of combustion, but decreases power.
- Decreasing the compression stroke, the size of the engine is actually smaller than if Otto Cycle valve timing was used.

Gaining Back Power: The Miller Cycle

- 1920s: American racing engine builder/designer Ralph Miller overcame power deficiencies of the Atkinson cycle engine by adding a supercharger to the intake system.

- Supercharger increased the pressure of the air/fuel mixture coming into the cylinder during the shortened Atkinson compression stroke to several times atmospheric pressure.

- Raised the amount of fuel and air available for combustion thereby increasing power and thermal efficiency.

- Miller controlled all this mechanically (including the valve timing). Maintaining peak efficiency was virtually impossible.

- Miller engines were very successful and won several Indy 500s, they were not suited to production cars.

More Advanced Biofuel Info:

www. AdvancedBiofuelsUSA.org

Produced by Robert Kozak