Advanced Biofuels
A Truly Sustainable Renewable Future

Advanced Biofuels USA
www.AdvancedBiofuelsUSA.org

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What Are Advanced Biofuels?

Why are they important?
What Are Advanced Biofuels?  
A Practical Definition

• Advanced Biofuels are high-energy liquid fuels, usually used for transportation
• Derived from
  • Low nutrient input
  • High-yield crops,
  • Agricultural or forestry waste, or
  • Other sustainable biomass feedstocks including algae

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Examples of Advanced Biofuels

• Gasoline substitutes
  (Grassoline; Green Crude)
• Biodiesel or renewable diesel from non-food feedstocks
• Jet fuel made from biomass or algae
  (JP-8; Commercial Aviation fuels)
• “Designer” fuels tailored to obtain the most efficient, most powerful performance from specific engines
• Hydrogen Carriers for Fuel Cells
The Transportation Advanced BioFuel Universe

Bio-Automotive Fuels
- High Mileage Bio-Gasoline
- High Energy Alcohols
- High Performance Clean Diesel
- Hydrogen/Liquid Carriers

Bio-Aviation/Turbine Fuels
- Commercial (Jet-A)
- Military (JP-8)
- Military Ship Turbines
- General Av Gasoline

Bio-Heavy Duty Diesel Fuels
- Railroad Locomotives
- Truck Transport
- Construction Equipment
- Ships

Bio-Lubricants
- Engine Oils
- Diesel Engine Oils
- Drivetrain Lubricants
- Turbine Lubricants

Atlantic Biomass Conversions, Inc.
Why Replacing Oil With Advanced Transportation Biofuels is Important

16 Million Barrels of oil imported each day by US

- 90% oil used as transportation fuel
- Rest to produce plastics & related products
• Virtually no oil is used to produce electricity in the US.

• Windmills and solar can produce electricity but cannot power jet airplanes.
Why Advanced Biofuels Are Important

Advanced Biofuels

Produced from non-food crops on marginal, non food-crop lands.

Improved conversion technologies would raise total significantly. 70% of current oil consumption could be replaced.

50% of current oil use could be eliminated without affecting food costs (estimated by USDA)

Direct substitute for all current transportation fuels without performance loss: jet fuels, gasoline, diesel.

70% of current oil consumption could be replaced.

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Additional Benefits of Advanced Biofuels

Do Not Increase Food Prices or Disrupt Food Supplies

Create good-paying jobs

Revitalize forestry and agricultural communities

Mitigate Adverse Climate Change Effects

- May use indigenous crops world-wide
- Jobs in science, engineering, construction, manufacturing, Transportation and agriculture
- Increase the Value of marginal land
- Add value to agricultural & forestry leftovers
- Give rural youth new reasons to stay on the farm
- Reduce Green House Gases in the atmosphere
- Reduce our “carbon footprint”

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Examples of Potential Feedstocks or Energy Crops

- Algae
- Corn stover
- Corn cobs
- Energy cane
- Sorghum
- Forestry waste
- Municipal waste
- Sawdust
- Chicken manure
- Agricultural residues

- Grasses such as
  - Switchgrass
  - Miscanthus
- Sugar beets
- Coffee grounds
- Jatropha
- Camelina
- Paper/pulp mill waste
- Halophytes...
What Is Being Done to Encourage or Promote Development of Advanced Biofuels?
Congressional Initiatives for Advanced Biofuels

• The US Congress has passed two key pieces of legislation that affect the production of Advanced Biofuels
• The Energy Independence and Security Act of 2007 “Energy Bill”
• The Food, Energy and Conservation Act of 2008 “Farm Bill”
• Bills have different emphasis, use different definitions
2007 Energy Bill Established a Renewable Fuel Standard (RFS) ("Energy Bill" Section 202)

• 36 Billion Gallons/Year of Renewable Fuel produced by 2022. (19% of current fuel use)
• Standard will be phased in.
• Three categories of renewable fuel included:
  - Corn Ethanol: (15 BGY by 2022)
  - Cellulosic Biofuels: (16 BGY by 2022)
  - Additional Advanced Biofuels (5 BGY by 2022)

• If Biofuels meet RFS Greenhouse Gas (GHG) reductions they are eligible for tax credits and subsidies
2007 Renewable Fuels Standard
(Billion Gallons/Year)
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<tr>
<th>Year</th>
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<th>Biomass-based diesel requirement</th>
<th>Advanced biofuel requirement</th>
<th>Total renewable fuel requirement</th>
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*a* To be determined by EPA through a future rulemaking, but no less than 1.0 billion gallons.

*b* To be determined by EPA through a future rulemaking.
Why Was a Renewable Fuels Standard Enacted?

• The intent was to provide lenders, investors, farmers, and all types of renewable fuels producers with assurances that a substantial, sustainable market exists for a variety of renewable fuels.

• The RFS goals are “floors,” not “ceilings.”

• Research and investment produced by the RFS are intended to produce additional quantities of renewable biofuels.

• Amounts beyond the goals of any type of renewable fuel will also benefit our society, environment and economy.
Food, Energy and Conservation Act of 2008 (Farm Bill)

- Title IX of the Farm Bill includes:
  - Loan guarantees for Biorefinery construction
  - Payment programs for biofuel biomass growers
  - Program to develop forest biomass for biofuel use
  - Program to expand biofuel research
  - More expanded definitions of eligible biomass and biofuel than Energy Bill
Administration of Energy and Farm Bill Biofuel Programs

• US Dept. of Energy (DOE) and US Dept. of Agriculture (USDA) have established a joint program to issue grants, loans, and evaluate progress.

• It is called the Biomass Research and Development Initiative

http://www.brdisolutions.com
Additional Federal Agencies With Biofuel Responsibilities and Programs

• **US Environmental Protection Agency (EPA)** is responsible for calculating Green House Gas (GHG) impacts of biofuels applying for Renewable Fuel Standard Credit.

• **US Dept. of Defense (DOD)** is funding the development of a biofuel replacement for a military jetfuel called JP-8.
Additional Federal Agencies With Biofuel Responsibilities and Programs

- **National Science Foundation (NSF)** has program to fund “Grassoline” chemical catalysts.

- **Bureau of Land Management (BLM)** has responsibility for much marginal land that could be used for energy grasses.
How Will We Economically Produce and Transport Renewable Advanced Biofuels?
Economical Sustainable Advanced Biofuels

• Crop development
• Waste and Residues
• Use Existing Infrastructure
  • Processing
  • Transportation
• Increase Efficiencies in Biomass Conversion
Identify Potential Energy Crops

- Grasses
- Trees and Forest Waste
- Agricultural Residues
- Algae
- Food Processing Residues
- Energy Crops
What bioenergy crops might grow where you live? How can you find out?

• Ask your
  • local Agricultural Extension Service
  • local Farm Bureau members
  • State Land Grant University
• Talk to advisors of local 4-H or FFA organizations
• Contact your local Agricultural Economic Development Office
Examples of potential crops/plants which can be used for production of biofuels

[Image of Sorghum - Sudan Grass information sign]

[Copyright information]
Examples of potential crops/plants which can be used for production of biofuels
Examples of potential crops/plants which can be used for production of biofuels
Examples of potential crops/plants which can be used for production of biofuels
Maybe bioenergy crops are not suitable for your area. What are other advanced biofuels feedstocks?

• Is Forestry big in your area?
• Does your area process agricultural products leaving waste when food production is completed?
• What about biomass that is now dumped into your landfill?
Processes

**Biochemical**
- Fermentation
- Plant extraction
- Transesterification
- Hydrolysis
- Enzymatic Catalysis

**Thermochemical**
- Gasification
- Plasma arc gasification
- Pyrolysis
- Thermochemical conversion of sugars
Multiple Biomass/Multiple Biofuel
Decentralized/Centralized Production System™
Year-Round Production/Multiple Fuel Markets

Step 1
Multiple Biomass Production
Sustainable in Selected Environments

Agricultural Residues
Pectin, hemicelluloses, cellulose

Harvesting Mechanical Pretreatment

Energy Grasses
Prairie and salt resistant
Hemicelluloses, cellulose

Forest Biomass
Trees, Processing Waste,
Black Liquor
Lignin, hemicelluloses,

Short-Haul Truck

Enzymatic or Chemical
“Common-Use”
C5/C6 Sugars
and BioFuel Precursor Production

Step 2
Biofuel Precursor Production
Decentralized, Low Capital Costs
Co-located with Crop Processors

Biofuels Produced
BioJet Fuels (JP-8, Jet-A)
Ship Gas Turbine Biofuels
High Performance BioDiesel
High Performance BioGasoline

Multiple Biofuel Production
Existing Hydrocarbon Refinery Processes

Sugar-to-Hydrocarbon Conversion
Biochemical, Enzymatic, & Hybrid Systems

Step 3
Biofuel Production
Centralized
Existing Refineries

Unit Train or Pipeline Transport

Atlantic Biomass Conversions, Inc.
<table>
<thead>
<tr>
<th>SOURCE</th>
<th>PROCESSES USED</th>
<th>END – PRODUCT</th>
<th>CHEMICAL FUELS</th>
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<td>Biodiesel</td>
<td>Mono-alkyl esters of long chain fatty acids</td>
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<td>Animal fats</td>
<td>Hydro treating</td>
<td>Renewable diesel</td>
<td>Hydro cracked &amp; refined</td>
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**Biodiesel and Renewable Diesel**

- Transesterification
- Hydro treating (Removes sulfur impurities)
- Vegetable Oils
- Animal fats
Products

- Cellulosic Ethanol
- Biodiesel
- Renewable Diesel
- “Drop-In” Biofuels
- Co-Products
Advantages of biodiesel and renewable fuels over petroleum fuels

• Renewable, non-toxic, biodegradable
• Reduces greenhouse gas emissions hydrocarbons, carbon monoxide and particulate matter)
• Produced from a variety of feedstock, grown on farms or taken from the waste stream
• Reduces reliance on non-renewable oil that pollutes environment
• Reduces foreign oil imports leading to energy independence.
Principles of Sustainability

Economic  Environmental  Social
Principles of Sustainability

- **Economic**  
  - Everyone in the value chain needs to make a living
  
- **Environmental**
  
- **Social**
  
- The operation must be financially stable
  
- The price of the product must be competitive in its market
Principles of Sustainability

- Economic  Environmental  Social

- Carbon Cycle/Climate Change
  - Reduce Green House Gases in the atmosphere
  - Reduce our “carbon footprint”
  - Reduce Black carbon from cooking fires
Principles of Sustainability

• Economic  Environmental  Social

➢ Government

➢ Land ownership

➢ Transportation

➢ Infrastructure
Barriers and Challenges

- Technical Challenges
- Financing “new” and “never done before” technologies
- Controversies
- Policy Issues
Barriers & Challenges

- Technical Challenges
- Policy Issues
- Controversies
- Financing "new" & "never done before" technologies
Barriers and Challenges

TECHNICAL CHALLENGES
Overcoming the Technical Roadblocks to Low-Cost Advanced Biofuel Production

1. Make all components of biomass available for biofuel production (Use the appropriate parts of specific plants)

2. Improve the efficiency of biomass to biofuel conversion (Do it faster, cheaper, sustainably)

3. Minimize the cost of biomass transportation (Move more for less)
Making Plant Biomass Available for Biofuel Production
Overcoming The Limits of Sugar Fermentation

- Ethanol made from grains (like corn) or from sugar cane is made by a process called **fermentation**, or anaerobic respiration.

- **Only single or two unit,** monosaccharide or disaccharide, **sugars** can be easily fermented into ethanol using 8000 year old technologies.
Making Plant Biomass Available for Biofuel Production

Overcoming The Limits of Sugar Fermentation

• These “simple” sugars, such as glucose, fructose, or sucrose (table sugar) are in limited supply in all plant cells walls, except for fruits.

• So, supplies of biofuels produced from naturally occurring simple sugars are limited.
Making Plant Biomass Available for Biofuel Production

Sugar Availability in Plant Cell Walls

- Additional “simple” sugars are available in plant and tree cell walls, but are in more complex forms that are not readily available for biofuel production.

- Plant cell walls are composed primarily of three components: cellulose, hemicellulose, and pectin.
Making Plant Biomass Available for Biofuel Production

Sugar Availability in Plant Cell Walls

- Tree and grass cell walls have an additional component, **lignin**.
  
  This is the “woody” material that gives trees great tensile strength

- Cellulose, hemicellulose, and pectin are composed of monosaccharides strung together, they are called polysaccharides

- Lignin is composed of polysaccharides and alcohols

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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: acid, ammonia, steam, or pressure are energy and cost intensive.
Researchers are pursuing four different approaches to overcome biomass recalcitrance

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
Making Plant Biomass Available for Biofuel Production
Overcoming Biomass Recalcitrance

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
Making Plant Biomass and Other Feedstock Available for Biofuel Production

Other Options

• Thermochemical
• Gasification
• Pyrolysis
• Fischer-Tropsch
• Deconstruction
Gasification → High heat → Syngas → Fischer-Tropsch synthesis

Pyrolysis → medium heat → Biocrude

Deconstruction → Low heat → sugar in water → Hydro treating → Aqueous phase forming

Plant Biomass: poplar, switchgrass, corn stover, and others

Jet fuel

Diesel

Gas

Plastics
Minimizing the Cost of Biomass Transportation

The Transport Conundrum

How can we gather enough Biomass to support a Cost-Efficient Biorefinery?

- Plant biomass is low-density low-value bulky material, transporting large quantities of it long distances is expensive.

- Fuels are high density, high value liquids, long distance transportation by train or pipeline is economical.
Minimizing the Cost of Biomass Transportation

The Transport Conundrum

• The size of current generation of ethanol production plants is limited by the **amount of crop** that can be economically **trucked** to the plant

• Production plants can not take advantage of **economies of scale**

• Production plants may not operate year-round because of **harvest patterns**

• Production plants may not be able to **switch crops to reduce costs** because of longer transport distances
Minimizing the Cost of Biomass Transportation

Breaking the Transport Conundrum

Separating biorefinery functions is an answer to the conundrum

1. **Conversion of biomass** to high density liquid sugars or other intermediate compounds would occur at a network of decentralized, low-capital facilities, often co-located with grain elevators

2. **Intermediate liquids** ("Green Crude") would be transported by truck or rail to existing petroleum refineries
3. Existing petroleum refineries would be retrofitted to utilize intermediates as a feedstock alternative to oil.

4. Biofuel production would be year-round, utilizing a variety of different biomass sources harvested at different times of year.

5. Multiple biofuels and other bio-chemicals would be produced at one facility, provides market response flexibility.
Barriers and Challenges

FINANCING “NEW” AND “NEVER DONE BEFORE” TECHNOLOGIES
Funding of “new” and “never been done before” technologies

Private Investors

Government

Long-term Personal Passion

Credit Markets/Banks

Federal

Venture Capital

Valley of Death

States

New Ideas?

Exit Strategy 2-3 years; 20% ROI
Financing

Technologies

• “New”
• “Never Done Before”
• Capital Intensive

Ethos/Expectations

• Based on IT and Pharma Experiences
  • Little capital investment
  • ROI 20% or more (think Viagra) within 2-3 years
  • Much basic research conducted and funded by federal government (NIH)
• NOT connected in any way to Commodities Markets
Research Project: Research and explain how “new” and “never been done before” technologies get funded.

• An in-depth discussion of this question involves understanding how new technologies with great public benefit get financed. And the role of government in encouraging or discouraging investment.

• Advanced biofuels research involves expensive equipment, expensive supplies, need for safe and secure laboratory space, and other expenses. Someone has to pay for this.

• Students might also study the trials and tribulations of Henry Ford as he tried to finance building cars for the masses.
Research Project: Research and explain how “new” and “never been done before” technologies get funded.

- Explore how grants are provided; what do individuals or institutions have to do to apply for/receive grants for scientific research.

- Explain how new industrial facilities are funded.

- Describe “venture capital” funding; the concept of “The Valley of Death” in funding of innovative technologies.

- Discuss what investors are looking for from an investment.
Research Project: Research and explain how “new” and “never been done before” technologies get funded.

- Describe the roles of the federal government and private enterprise in funding projects such as the Internet, the atom bomb, landing on and exploring the moon, exploring Mars and the far reaches of space, and advanced biofuels research and development.
Barriers and Challenges

CONTROVERSIES
Controversies

- Food/Fiber/Feed/Fuel/Fun/Residential, Commercial, Industrial Development
- International Indirect Land Use Change Analysis
- Direct Land Use Change Analysis
- Direct and Indirect Emissions Analysis
- Land Use Competition
- Distribution Systems
- End Users
Pros and Cons

Look at different types of biofuels productions. Identify the strong points and weaknesses of each process. Some questions to ask:

👍 What is good about this process?
+ Is it sustainable?
+ Does it use high yield, low input crops?
+ Can it be used to sustainably produce the most efficient (i.e., powerful) liquid transportation fuels?
+ Is it easy to transport?
  • Feedstocks to processing plant
  • Final fuel product to consumers

👎 What challenges are being worked on to improve this process? For example:
- How easily does the process fit into existing agricultural processing systems?
- Can the product be transported to users in existing systems?
- Can existing refineries or mothballed industrial facilities be retrofitted for this new process?
- How efficient is the process
- Can feedstock be obtained at a fair price to the grower/producer?
A Few Types of Jobs Available in Advanced Biofuels Production

- Biologists
- Biologists specializing in genetic research
- Biologists specializing in plant cells
- Chemists
- Chemical engineers
- Systems engineers
- Researchers into bioenergy crop development
- Agriculture/horticulture experts
- Farmers
- Farm workers
- Industrial engineers
- Industrial architects
- Construction workers, managers
- Truck drivers
- Plant operations managers
- Fueling station operators
- Freight railroad operators, engineers, loaders, unloaders
- Equipment operators, technicians
- Farm product purchasers/traders
- Agricultural and Forestry Supervisors
- Agricultural Inspectors
- Computer Software Engineers
- Refinery Equipment Manufacturers
- And many others
In depth analysis of our current fuel options shows that there must be a better way to achieve oil independence, to transform much of the US transportation fuels to sustainable, renewable power.

Advanced biofuels is one part of the answer.
What’s so Advanced about Advanced Biofuels?

Find out more: www.AdvancedBiofuelsUSA.org

For a Truly Sustainable, Renewable Future

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