507 North Bentz Street, Frederick, MD 21701
301-644-1395
www.AdvancedBiofuelsUSA.org

Advanced Biofuel Basics
A Financial Investment Perspective

by Greg Malone

What is a biofuel?

A biofuel is a transportation fuel derived from renewable resources such as plant biomass or municipal wastes that replaces or reduces the quantity of fossil fuel present in the U.S. transportation fuel mix.[(1)]

This definition applies to a diverse set of fuel types. However, due to the diversity that exists within the industry, further specific definitions to clarify this diversity have emerged.

The first method categorizes biofuels by "generation" - first generation, second generation or third generation. First generation fuels are created largely from feedstocks that have traditionally been used as food, second generation fuels are made from nonfood feedstocks using advanced technical processes, and third generation fuels are made from nonfood feedstocks, but the resulting fuel is indistinguishable from its petroleum counterparts [(2)].

It is worth noting that on European web sites, several web sites here in the United States, and in several articles in the popular press, the term first generation biofuels refer to more than just fuels derived from corn starch. It also refers to the fuels that have been derived from sources like sugar, animal fats and vegetable oil. On these sites, biodiesel, vegetable oil, biogas, bioalcohols, and syngas are considered first generation biofuels[(3)]. Be aware that various definitions exist in regards to biofuels, when doing further investigation.

The second method of defining biofuels emerged from the Energy Independence and Security Act of 2007 [(4)], which sorted biofuels into 3 primary categories: conventional, advanced, and cellulosic:

- Conventional biofuel refers to renewable fuel that is ethanol derived from corn starch. (first generation)
- Advanced biofuel refers to renewable fuel, other than ethanol derived from corn starch that has lifecycle greenhouse gas emissions that are at least 50% less than baseline lifecycle greenhouse gas emissions. (second generation)
  Examples of advanced biofuels are:

  1. Ethanol derived from cellulose, hemicellulose, or lignin.

2. Ethanol derived from sugar or starch (other than corn starch).
3. Ethanol derived from waste material, including crop residue, other vegetative waste material, animal waste, and food waste and yard waste.
4. Biomass-based diesel.
5. Biogas (including landfill gas and sewage waste treatment gas) produced through the conversion of organic matter from renewable biomass.
6. Butanol or other alcohols produced through the conversion of organic matter from renewable biomass.
7. Other fuel derived from cellulosic biomass

- Cellulosic biofuel refers to renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions that are at least 60% less than the baseline lifecycle greenhouse gas emissions. (second generation)
- A forth type of biofuel that is not mentioned in the energy security act, is a third generation biofuel or "drop-in fuel", which uses Algae as the feedstock. [(5)]

Why develop advanced biofuels?

Multiple reasons exist to develop advanced biofuels. The two requiring our immediate attention here in the United States are as follows:

- Our reliance on foreign oil and other energy resources to maintain the lifestyle that we currently enjoy.

- Climate change due to vehicle emissions.

Advanced biofuels offers the chance to address both of these problems. This alternate fuel source, based on feedstocks easily obtainable in the United States, would reduce our reliance on foreign energy supplies. Some estimates put the reduction of imported petroleum due to biofuels at 20 million barrels or more of oil a year [(12)]. At the same time, advanced biofuels provide a transportation fuel with much fewer greenhouse gas emissions (up to 50% less), from production of feedstock through combustion as a fuel source than our conventional petroleum-based fuel sources. As more advanced biofuels become available, we will be able to increasingly reduce our GHGs, leading the way in reducing the harmful effects of vehicle emissions on the climate.

What is the current government policy in relation to advanced biofuels?

The White House is actively pursuing alternative forms of energy.

"To take this country in a new direction, the President is working with Congress to pass comprehensive legislation to protect our nation from the serious economic and strategic risks associated with our reliance on foreign oil and the destabilizing effects of a changing climate."

"Our reliance on oil poses a threat to our economic security. Over the last few decades, we have watched our economy rise and fall along with the price of a barrel of oil. We must commit ourselves to an economic future in which the strength of our economy is not tied to the unpredictability of oil markets. We must make the investments in clean energy sources that will curb our dependence on fossil fuels and make America energy independent." [6]

The current administration outlines three priorities in relation to our energy problems:

- Breaking Dependence on Oil: Promote the next generation of cars and trucks and the fuels they run on. Encourage (through monetary incentives) the development of advanced biofuels and cars that utilize them.
- Producing More Energy at Home: Enhance U.S. energy supplies through responsible development of domestic renewable energy, fossil fuels, advanced biofuels and nuclear energy.
- Promoting Energy Efficiency: Promote (with monetary incentives) investments in the transportation, electricity, industrial, building and agricultural sectors that reduce energy bills.[6]

Advanced biofuels are one facet of the administration's efforts to secure our energy future. The government is investing several hundred million dollars into this industry.[7] As a burgeoning industry, the administration's efforts are focusing on scaling up existing advanced biofuel technology from small testing and development facilities to commercial facilities.

The government's funding strategy is to make sure that advanced biofuels are a viable, feasible and financially sound option. In the Energy Independence and Security Act of 2007 [3], lawmakers set a goal that by 2022, 36 billion gallons of biofuels must be produced for the market each year, and 21 billion of those must be from non-cornstarch products. This law means that in 13 years, 21 billion gallons of advanced biofuels must be in the marketplace. However, we currently have very few advanced biofuel refineries/production plants up and running to meet this requirement.

Two departments within the United States government have been tasked specifically with pursuing the development of advanced biofuels, the Department of Energy and the Department of Agriculture.

The Department of Energy (DOE) :[8]
Through the Department of Energy, $786.5 million of the American Recovery and Reinvestment Act funds will be used towards advanced biofuels R&D, and biorefinery demonstration projects.

- $480 million for 10-20 biorefinery projects ($25-50 million dollars each) to validate new technologies, which will spur funding by private investors for commercial-scale applications
- $176.5 million for demonstration or commercial-scale biorefinery projects requiring further funding to continue
- $130 million for research and development.
- $85 million (maximum) for the development of particular advanced biofuels: algae-based biofuels and advanced infrastructure-compatible (drop-in) biofuels.

The Department of Agriculture (USDA):[9]
The president has asked the agriculture secretary to expedite and increase the development of biofuels. To this end, as part of the Food, Conservation, and Energy Act of 2008, the USDA has agreed to provide:

- Loan guarantees and grants for the development of biorefineries
- Funding to encourage biorefineries to replace the use of fossil fuels in plant operations with biomass
- Funding to farmers to ensure growth of feedstock used in biofuels production (ensuring a stable, and growing supply of materials)
- Provide guidance, support and funding to increase the sustainability of collection, storage and transportation of feedstocks/biomass to the biorefineries.

In addition to these objectives, the USDA has made the advanced biofuels one of the 12 categories for its Small Business Innovation Research initiative. This initiative will provide grants to small businesses "to promote the use of biofuels and non-food biobased products by developing new or improved technologies that will lead to increased production of industrial products from agricultural materials. This research will lead to new opportunities to diversify agriculture and enhance agriculture's role as a reliable supplier of raw industrial materials".[9]

What is the industry landscape like today?

The advanced biofuels industry is very scattered, and lacks an easy, clear definition. Currently, there are over 159 different companies involved with advanced biofuels[13]. These companies range from biofuel producers to car manufacturers, oil companies, energy companies and investment groups who fund the research and development from the private sector. These different companies are pursuing many different technologies in advanced biofuels. Each believes that their particular technology will yield the breakthrough that will make advanced biofuels a true competitor to or replacement for petroleum based fuels.

Efforts are underway to forge a common vision of what the industry should look like, to create a roadmap for the industry to follow. The DOE and the USDA have been playing active roles in shaping the industry. The DOE and USDA, through the Biomass R&D Board and Biomass R&D Technical Advisory Committee, have been guiding a multi-agency effort to coordinate and accelerate all federal biobased products and bioenergy research and development [10]. In addition, the current administration has announced plans to develop a new biofuels interagency working group to develop a comprehensive program to develop the growing biofuels market [11].

What are some of the challenges facing the industry today?

When some people think of biofuels, the first thing that springs to mind is the food/fuel debate [14] and fears that ethanol is incompatible with existing engines [15]. Advanced biofuels must overcome these initial stereotypes and prove that they can address the problems and shortcomings of the first generation biofuels.

Fluctuating prices of gas and oil is another looming concern. This affects both public interests for biofuels as well as funding streams. When prices are high for these commodities, policymakers and the public get very interested in the industry, and push to quickly develop the technologies to make biofuels a viable option for consumers. As a result, funding for research and development increases. When prices are low for these commodities, policymakers lose interest, the public loses interest, and the funding streams decrease.

While many lawmakers support the rapid development of advanced biofuels, they feel that the technologies are not currently developed enough or are too insufficient to make any difference at this point in regards to greenhouse gas emissions. As a result, the ideas of carbon cap-and-trade[16] and sequestration[17], as well as many other projects using existing, proven technologies, are being pushed by lawmakers at the expense of advanced biofuels, slowing development within the industry.

A scientifically proven, respected way to calculate what effect innovative energy-producing technologies/systems have on climate change has not yet been established.

No generally accepted scientific standard exists for comparing greenhouse gas emissions released from "mine to wheel" vs. "seed to wheel," between traditional forms of transportation energy and biofuels.

Advanced biofuels must still overcome the barriers of entering the existing fuel markets. A few examples of market barriers include capital costs, infrastructure costs, distribution costs, establishing a brand identity in the marketplace, overcoming buyer inertia to switch to the advanced biofuels alternative, and potential price wars with existing petroleum fuel sources.

Federal legislation, especially with regard to forestry, has inconsistent definitions of renewable biomass, the feedstock for advanced biofuels. This indicates that there is not a thorough understanding of the industry among the policy makers or among the general public in regards to the biofuels industry. The industry must develop common definitions and standards that can be used universally throughout the industry, and be easily understood by those outside of it.

Conclusion:

The advanced biofuels industry is diverse and will remain that way for the foreseeable future. That diversity is a positive development, because there is no single solution that works for everyone. Because of the various technologies being developed, advanced biofuels can be tailored to address specific regional issues anywhere in the world. Solutions developed here will have applicability beyond the borders of the United States.

The political climate is ripe for the growth of the advanced biofuels industry. The current administration is pursing policies that encourage growth in all sectors of alternate energy, in an attempt to overcome our reliance on energy sources outside of our borders, as well as to make a difference in the fight against global warming and climate change. Advanced biofuels is part of that

policy, with billions of dollars of funding being provided through two key agencies, the Department of Energy and the Department of Agriculture.

As an industry in its infancy, the technology is unproven on a commercial scale. The administration is focusing its efforts on scaling up production facilities to test the feasibility in the commercial marketplace. Once the viability of advanced biofuels has been established, the administration expects that private capital will then flow into the industry to finance future growth.

Many obstacles still exist within the industry, but those can be resolved more easily once the full-scale production facilities have been established. However it is vital to the industry that lawmakers and industry leaders stay abreast of the developments that are occurring, so that they maintain favorable policies in regard to this technology, and the advanced biofuels industry has the opportunity to deliver on its potential.

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Glossary:

Alternative Fuel:
These fuels are defined as alternative fuels by the Energy Policy Act of 1992 and are currently, or have been, commercially available for vehicles.

- Biodiesel
- Electricity
- Ethanol
- Hydrogen
- Methanol
- Natural Gas
- Propane

Several emerging fuels are currently under development. Many of these fuels are also considered alternative fuels and may have other benefits such as reduced emissions or increased energy security.

- Biobutanol
- Biogas
- Biomass to Liquids (BTL)
- Coal to Liquids (CTL)
- Fischer-Tropsch Diesel
- Gas to Liquids (GTL)
- Hydrogenation-Derived Renewable Diesel (HDRD)
- P-Series
- Ultra-Low Sulfur Diesel

http://www.afdc.energy.gov/afdc/fuels/

Biofuel:

- **First Generation Biofuel:**
  First-generation biofuels are created largely from feedstocks that have traditionally been used as food. The ethanol feedstock is corn and biodiesel feedstocks are vegetable oil and animal fats. Other first generation feedstocks include soybeans, sorghum, and sugar cane.
- **Second Generation Biofuel:**
  Second-generation biofuels are made from nonfood feedstocks using advanced technical processes. Cellulosic ethanol is the most developed second-generation biofuel and is produced from the cellulose or cell wall of plant cells. Examples of potential feedstocks for the next generation of biofuels include forest residues (sawdust), industry residues (black liquor from the paper industry), agricultural residues (corn stover), municipal waste and sustainable biomass (jatropha, camelina and switchgrass).
- **Third Generation Biofuel:**
  Third-generation biofuels, like second-generation biofuels, are made from nonfood feedstocks, but the resulting fuel is indistinguishable from its petroleum counterparts. These fuels are also known as advanced biofuels or green hydrocarbons. In the future, algae will be a likely feedstock for these fuels. Also known as “drop-in” fuels.

http://www.biomassmagazine.com/article.jsp?article_id=2070

Biodiesel:
Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking grease. It can be used as an additive (typically 20%) to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines.
http://www.nrel.gov/learning/re_biofuels.html

Biodiesel is a mixture of fatty acid alkyl esters made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a petroleum diesel additive to reduce levels of particulates, carbon monoxide, hydrocarbons and air toxics from diesel-powered vehicles.
http://www1.eere.energy.gov/biomass/abcs_biofuels.html#biodfeed

Biomass:
Biomass is the term used to define the energy source made from biological material. Wood is still the largest biomass energy resource today, but other sources of biomass can also be used. These include food crops, grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills (which are methane, a natural gas) can be used as a biomass energy source.
http://www.gfc.state.ga.us/ForestMarketing/FactsAboutBiomass.cfm
http://www.nrel.gov/learning/re_biomass.html

Cellulose:
The most common form of carbon in biomass, accounting for 40%-60% by weight of the biomass, depending on the biomass source. It is a complex sugar polymer, or polysaccharide, made from the six-carbon sugar, glucose. Its crystalline structure makes it resistant to hydrolysis, the chemical reaction that releases simple, fermentable sugars from a polysaccharide.
http://www1.eere.energy.gov/biomass/abcs_biofuels.html#feed

Ethanol:
Ethanol is an alcohol, the same as in beer and wine (although ethanol used as a fuel is modified to make it undrinkable). It is made by fermenting any biomass high in carbohydrates through a process similar to beer brewing. Today, ethanol is made from starches and sugars, but scientists are developing technology to allow it to be made from cellulose and hemicellulose, the fibrous material that makes up the bulk of most plant matter. Ethanol is mostly used as blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions.
http://www.nrel.gov/learning/re_biofuels.html

Feedstock:
Raw material required for an industrial process.
http://www.answers.com/topic/feedstock

Greenhouse gas emissions:
Gases that trap heat in the atmosphere are often called greenhouse gases. Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely

through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are:

- **Carbon Dioxide (CO2)**: Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). Carbon dioxide is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH4)**: Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous Oxide (N2O)**: Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Fluorinated Gases**: Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for ozone-depleting substances (i.e., CFCs, HCFCs, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").

http://www.epa.gov/climatechange/emissions/index.html

Hemicellulose

A major source of carbon in biomass, at levels of between 20% and 40% by weight. It is a complex polysaccharide made from a variety of five- and six-carbon sugars. It is relatively easy to hydrolyze into simple sugars but the sugars are difficult to ferment to ethanol.
http://www1.eere.energy.gov/biomass/abcs_biofuels.html#feed

Lifecycle Greenhouse Gas Emissions:

Lifecycle GHG emissions are the aggregate quantity of GHGs (**G**reen**H**ouse **G**ases) related to the full fuel cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation and extraction through distribution and delivery and use of the finished fuel.
http://www.epa.gov/otaq/renewablefuels/420f09024.htm

Lignin

A complex polymer which provides structural integrity in plants. It makes up 10% to 24% by weight of biomass. It remains as residual material after the sugars in the biomass have been converted to ethanol. It contains a lot of energy and can be burned to produce steam and electricity for the biomass-to-ethanol process.
http://www1.eere.energy.gov/biomass/abcs_biofuels.html#feed

Sequestration, Carbon

Carbon capture and sequestration begins with the separation and capture of CO_2 from power plant flue gas and other stationary CO_2 sources. At present, this process is costly and energy intensive, accounting for the majority of the cost of sequestration. Post-combustion, pre-combustion, and oxy-combustion capture systems being developed are expected to be capable of capturing more than 90 percent of flue gas CO_2.

The next step is to sequester (store) the CO_2. The primary means for carbon storage are injecting CO_2 into geologic formations or using terrestrial applications. Geologic sequestration involves taking the CO_2 that has been captured from power plants and other stationary sources and storing it in deep underground geologic formations in such a way that CO_2 will remain permanently stored. Geologic formations such as oil and gas reservoirs, unmineable coal seams, and underground saline formations are potential options for storing CO_2. Storage in basalt formations and organic rich shales is also being investigated.

Terrestrial sequestration involves the net removal of CO_2 from the atmosphere by plants and microorganisms that use CO_2 in their natural cycles. Terrestrial sequestration requires the development of technologies to quantify with a high degree of precision and reliability the amount of carbon stored in a given ecosystem. Program efforts in this area are focused on increasing carbon uptake on mined lands and evaluation of no-till agriculture, reforestation, rangeland improvement, wetlands recovery, and riparian restoration.
http://www.netl.doe.gov/technologies/carbon_seq/index.html