

From Oilfields to Energy Farms

A BRIEF LOOK AT THE ENVIRONMENTAL CONSEQUENCES OF BIOFUELS

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The environmental consequences of our addiction to oil are well known, but what happens when our energy feedstocks are counted by the acre, not the barrel? Global use of biofuels, principally ethanol, has surged over the past decade. Once at the farthest edge of financial viability, biofuels are now a multi-billion-dollar industry, with a seemingly green horizon. However, the devil is in the details.

Unlike oil, the type of biofuel and where it is “farmed” matter a great deal when tallying up environmental pros and cons. Government regulations and price supports have shaped the evolution of the ethanol industry in Brazil and the United States, the predominant global producers. In the former, ethanol is produced from sugarcane at costs competitive with petroleum prices. In the latter, the price of corn and the land it’s grown on has been steadily rising, as oil companies compete with food and feed producers for a commodity that is at the core of our economy.

And other countries across South America, Africa, Asia, and Europe are shifting agricultural and forestry practices to

find better, cheaper sources of ethanol from switchgrass, palm oil, and wood.

The biofuels market today represents the 21st-century equivalent of the Oklahoma land rush in 1889. Oil companies, grain producers, politicians, and venture capitalists are racing to claim available land, niche markets, and the latest promising technologies. To help sort out the signal from the noise, here we will take a closer look at the economic and environmental implications of the major biofuel categories.

Economic Viability

Ethanol, often referred to as the first generation of liquid biofuels, has had a head start as an alternative transport energy source in the United States, due, in large part, to substantial subsidies and use requirements imposed to meet Clear Air Act considerations. Many areas of the country require that ethanol meet a certain percentage mix with gasoline, for example, 15 percent. This requirement is often put in place at certain times of the year to reduce pollution emissions.

Ethanol’s recent rapid growth in the United States was



triggered by the recent dramatic rise in oil prices and the 2005 Energy Policy Act, which mandates that 7.5 billion gallons of the nation's annual gasoline consumption, roughly 5 percent, come from renewable fuels by 2012. Subsequently, the president has proposed quintupling that figure; plans now call for a required increase in the portion of gasoline combined with ethanol so that total ethanol could increase fourfold by 2020.

The long-term economic viability of corn ethanol is questionable because it requires a high degree of protection: ethanol has received a 51 cents per gallon subsidy since 1978 and is protected from imports by a 54 cents per gallon import tariff, which has discouraged the import of cheaper sugarcane-based Brazilian ethanol. The result of these subsidies and recent higher oil prices has seen corn prices double in the past three years as ethanol use now consumes about 20 percent of the nation's corn supply. At the same time, financial returns on ethanol have been favorable and corn planting has expanded, causing land rents to double. Furthermore, land has been withdrawn from other uses, primarily soybean farming, to accommodate the growing demand for corn.

Cellulosic feedstocks, the second generation of liquid biofuels, are comprised of wood, grasses, and certain agricultural wastes (see the box on page 19 for a description of the actual processes for converting cellulose into biofuel). Currently, the costs of cellulosic ethanol are high due to the difficulty in breaking down the tough cellulose. However, progress is being made in developing new low-cost enzymes to do the job.

Cellulosic ethanol will have potential advantages in that various types of waste material can be used to produce it, including waste wood from mills, wastes for grain production and processing operations, and harvested trees and grasses. The efficacy of such materials as a feedstock depends importantly on the volume of their availability and the costs of collection.

In the United States, switchgrass, a summer perennial native to North America, appears particularly attractive. It is capable of high yields on annual rotation, averaging 11.5 tons per acre per year, enough to make 1,150 gallons of ethanol in one test. An advantage is that it is usually suitable for production on lands often viewed as marginal for high-value

grains and other higher-valued crops. Another possible grass feedstock is a mix of high-diversity native grassland perennials that can be produced on agriculturally degraded land, require low inputs, and thus need not displace food production nor cause loss of biodiversity via habitat destruction. The evidence also suggests that grasses typically are low input and exhibit carbon dioxide (CO₂) balances that are far better than for high-input grain ethanol.

Wood is another cellulosic feedstock. Forests planted in fast-growing species can generate about 5 tons of wood per acre per year on rotations of 10 to 15 years. New trees, with improved growth through breeding, show the possibility of doubling that level. Trees have benefits similar to grasses in that they can be grown on sites that are marginal for most agriculture. Also, compared to grasses, trees have a longer rotation, reducing the necessity of a short planting and harvesting cycle, thereby lowering costs. Of course, the longer rotation also lengthens the gap between investment and payout. Another advantage of trees over grasses is that wood is less perishable, providing flexibility in harvesting, storage, and use.

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Carbon Emissions and Biofuels

A recurring question with biofuels relates to their net greenhouse gas (GHG) emissions. The use of the biofuel itself does not generate net GHG emissions, since carbon releases are offset by the fact that the feedstock renews itself. However, various processing stages have net emissions releases. Corn cropping involves planting, harvesting, and transport operations, as well as the application of fertilizers. In addition, processing corn feedstock to ethanol usually requires fossil fuel energy and, consequently, substantial GHG emissions. A recent study by the Natural Resource Ecology Laboratory analyzed the capacity of various biological feedstocks to reduce GHG emissions; the results showed that cellulosic biomass (switchgrass and hybrid poplar) can reduce GHG emissions by about 115 percent when compared to petroleum. Reed canary grass, the next best, can reduce GHG emissions by 85 percent. Noncellulosic biomass (corn ethanol and soybean biodiesel), in last place, could reduce GHG emissions by only 40 percent.

Let's pause for a moment; 115 percent—how does that work? Cellulosic biofuels can offset the CO₂ emissions associated with planting, harvesting, transport, and related farm operations by sequestering atmospheric CO₂ and converting it into organic carbon in biomass and soil. In short, the carbon capture is naturally occurring in the feedstock, just as a stand of trees absorbs and stores CO₂. Grasses typically require only modest energy and pesticide inputs compared to grains. A similar argument can be made for trees with respect to energy and land disturbance. All these considerations suggest cellulose can reduce net carbon emissions compared to grains, which release a good deal of CO₂ emissions when converted into ethanol, as well as other environmental damages associated with production.

Land-Use Implications

Should biofuels become globally important, substantial land-use adjustments are likely. Rising energy demand for corn has already created serious land-use conflicts in this country: the price of corn-based foodstuffs has risen significantly, and corn land rents (the lease value of farmland) have risen even more dramatically, prompting farmers to shift production of other essential food commodities, like soybeans, over to corn.

Cellulosic biofuels also would involve land-use adjustments. However, much of the expansion of grasses and forest would occur on land that is marginal for other crops, like pastureland, because the land types involved are usually different.

Trees are most likely to become important sources of biofuel in conjunction with forest industry activities, like pulp mills, where large volumes of waste wood are available. As is common now in the forest industry, most new sources of raw wood would likely come from planted forests.

Outside the United States, sugar cane is currently in widespread use to produce ethanol in Brazil. The process appears to be efficient and inexpensive because the primary feedstock is the waste from the sugar production process. Sugar cane may become an attractive source of feedstock for biofuels in other countries with large sugar-cane production. In this case, land-use changes may not be required in sugar-cane-producing regions except for very large levels of production.

Finally, palm oil is considered a potentially economically competitive feedstock source for biodiesel and has its own set of land-use implications. In countries like Indonesia and Malaysia, palm plantations have existed for decades, but market forces are prompting more to be established. In many cases, plantations are being established on land that was previously forested. ■

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The Technology of Cellulosic Biofuels

There are three general approaches for producing biofuels from cellulose.

In **bioconversion**, cellulose can be converted to biofuels through processes that use enzymes to break down the cellulose bonds and convert the sugars to biofuels or through processes that use fermentation or heat to convert the cellulose to gases that can then be converted to biofuels. The process differs from that used for corn in that it requires a greater amount of processing to make the sugar available to the microorganisms that are typically used to produce ethanol by fermentation. Once the sugars are isolated, a fermentation process is undertaken. Cellulosic materials, however, are much more difficult than grains to break down into their var-

ious sugars. The bioconversion process typically uses a combination of physical or chemical pretreatment and enzymatic hydrolysis to convert lignocellulose into its components. The sugar components of the cellulose are then processed fuel products, like ethanol. A current limitation in this process is the need for improved low-cost enzymes.

The **thermochemical** process, sometimes called the third generation of biofuels, involves an integrated refinery approach that converts the gaseous constituents of wood—carbon monoxide and hydrogen—into a synthetic gas, essentially the same approach used with coal as the feedstock. The “syngas” can be used either directly as energy to produce electricity for the mill or can be exported via the grid. It also can be con-

verted to a biologically based synthetic fuel through a catalyzed chemical reaction known as the Fischer-Tropsch process: carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms, principally a synthetic petroleum substitute for use as lubrication oil or fuel.

A final alternative process for producing cellulosic ethanol is that of **hemicellulose extraction**. Here, wood chips are soaked before they enter the pulping process, and the hemicellulose is removed and used for producing ethanol. This process is resource efficient in that some of the hemicellulose would have gone to waste in the ordinary pulping process. This process has the advantage of requiring no enzymes but is possible only on a small scale.