



# Ethanol Opportunities and Questions

A Publication of ATTRA - National Sustainable Agriculture Information Service • 1-800-346-9140 • www.attra.ncat.org

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ATTRA—National Sustainable Agriculture Information Service is managed by the National Center for Appropriate Technology (NCAT) and is funded under a grant from the United States Department of Agriculture's Rural Business-Cooperative Service. Visit the NCAT Web site ([www.ncat.org/agri.html](http://www.ncat.org/agri.html)) for more information on our sustainable agriculture projects.



Ethanol is a valuable alternative to petroleum-based transportation fuels. This publication offers a brief and non-technical description of how ethanol is made, explains some of its uses and advantages, discusses several common questions about ethanol, and offers suggestions for further reading. Ethanol can provide significant environmental benefits, can be produced sustainably from renewable sources, and lends itself to local and regional production. Emerging technologies that produce ethanol from cellulosic feedstocks are discussed, as well as economic opportunities for American farmers and rural communities. References and resource listings follow the narrative.

## Introduction

Despite the recent rapid growth of the U.S. ethanol industry, farmers and the general public hear the same recurring questions. For example:

- Can ethanol be produced cost-effectively, or does its viability in the marketplace depend on subsidies?
- Does ethanol manufacturing consume more energy than it produces?
- Do air quality and other environmental benefits of ethanol come at the expense of depleted soils and polluted waterways?
- In a world of hungry people and growing populations, is it appropriate to “burn food”—using food crops to fuel vehicles?
- Is it realistic to expect local ownership of ethanol production facilities, or will ownership inevitably become concentrated into the hands of a few large corporations?

This publication sheds light on these and some other common questions about ethanol. As much as possible, the discussion avoids details about ethanol manufacturing processes, organic chemistry, toxicology, and other technical issues. Many publications about ethanol are written for engineers and chemists; this one is written for farmers and interested members of the general public.



Photo by Warren Gretz, DOE/NREL.

## Sound bytes from the ethanol debate

You hear all kinds of opinions about ethanol. For example:

“Ethanol provides a tremendous economic boost to the U.S. economy and is a prime source of value-added income for American farmers.” (Renewable Fuels Association)

“Ethanol moves our nation toward energy independence. Its use cleans America’s air and offers consumers a cost-effective choice at the pump.” (American Coalition for Ethanol)

“The huge ethanol subsidies given out year after year have benefited few besides corn growers and ethanol producers, who are often just different units of the same large company.” (Taxpayers for Common Sense)

“Ethanol is actually an environmental nuisance when all aspects of its production are taken into account.” (Grewell, 2003)

“Ethanol production is a highly speculative, dangerous business. This year has witnessed ethanol plant closures, explosions, tanker sinkings, and an unprecedented rise of community activism, lawsuits, and petitions reflecting growing concerns over ethanol. New ethanol facility construction is facing rising opposition and spooked investors around the country.” (The Agribusiness Examiner, 2004)

## Ethanol Basics

Ethanol, also known as *grain alcohol* or *ethyl alcohol*, is the kind of alcohol produced by fermenting and distilling simple sugars from biological sources. It is the same kind of alcohol found in all alcoholic beverages, although commercial ethanol plants add a poison (two to five percent) to make it unfit for human consumption.

Over 90 percent of U.S. ethanol is made from corn, but in Brazil, the world's largest producer, most ethanol is made from sugar cane. Ethanol can also be made from wheat, barley, sorghum, beets, cheese whey, potatoes, and many other *feedstocks*.

Like making bread, wine, or beer, ethanol production depends on *fermentation*, the process by which certain species of yeast or bacteria metabolize simple sugars and convert them into alcohol and carbon dioxide. Although there are many ways to make ethanol, most methods require sugar and yeast. There are basically three steps in the ethanol manufacturing process: first, converting feedstocks into simple sugars; second, fermentation; and finally, recovering ethanol and useful co-products.

Corn ethanol in America today is made by either *dry milling* or *wet milling*. During conventional dry milling, the whole corn kernel is ground into a powder, mixed with water to form a mash, and then cooked with added enzymes that turn the starch to glucose. After cooling, the mash is fermented with yeast and finally distilled to separate alcohol from the solids and water. Valuable co-products of the dry milling process are *distiller's grain* used for animal feed (also known as *distiller's dried grain with solubles* or DDGS) and carbon dioxide. About one third of the corn kernel mass ends up in DDGS. (Wang, 2005)

During conventional wet milling, corn is steeped in water and sulfur dioxide before grinding. This soaking allows the separation of germ, fiber, gluten, and starch components. The starch is fermented into



Photo by Warren Gretz, DOE/NREL.

ethanol and then distilled, while the fiber, gluten, and germ are made into corn oil, corn gluten, and corn gluten meal. Some wet mills also capture and sell the carbon dioxide produced during fermentation. Compared to dry milling, the wet mill process can produce a much wider variety of valuable co-products. In fact, most wet mills were built in the 1970s and 80s, mainly for the purpose of making high fructose corn sweetener.

Although wet mills produced more than 80 percent of all U.S. ethanol in 1990, dry milling has become the primary method of ethanol production, with over 90 percent of all new production coming from dry mills. (Morris, 2005) A modern dry mill makes 2.6 to 2.8 gallons of ethanol and 18 pounds of distiller's grain from a bushel of corn. (Eidman, 2004) Among other advantages, dry mills are considerably more energy-efficient than wet mills.

Ethanol production capacity has increased dramatically since the late 1990s, leaping from 1.6 billion gallons in 2000 to more than 4 billion gallons in 2005. More than 100 ethanol production facilities were operating in 20 U.S. states in mid 2006. The vast majority of this production is centered in the Midwest, where corn feedstocks are plentiful. Illinois and Iowa together have 45 percent of the nation's ethanol capacity. Another 30 plants are under construction, with a combined capacity of 1.8 billion gallons. (American Coalition for Ethanol)

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## What Is Cellulosic Ethanol?

Newer manufacturing processes allow ethanol to be made from *cellulosic* feedstocks, also sometimes called *biomass* feedstocks. Cellulosic ethanol is currently the subject of intensive scientific research and speculation. While not yet widely commercialized, cellulosic ethanol has some great advantages compared to corn-based ethanol, and is often viewed as the future of the U.S. ethanol industry.

*Cellulose* is the main component in the cell walls of plants, and is the main structural or stiffening material in plants. Cellulosic materials that can be made into ethanol are generally classified under four headings: agricultural waste, forest residue, municipal solid waste, and energy crops. Agricultural waste includes wheat straw, corn stover (leaves, stalks and cobs), rice straw, and bagasse (sugar cane waste). Forestry residue includes wood and logging residues, rotten and dead wood, and small trees. Municipal solid waste contains paper, wood, and other organic materials that can be converted into ethanol. Energy crops, grown specifically for fuel, include fast-growing trees and shrubs, such as hybrid poplars, willows, and grasses such as switchgrass.



Corn stover. Photo by Warren Gretz, DOE/NREL.

Besides being potentially less expensive than corn ethanol, cellulosic ethanol has many other advantages:

- While corn ethanol production is focused heavily in the Midwest, cellulosic feedstocks are available in almost all parts of the country.
- The same plant materials that are being used for feedstocks can often be burned to fuel the ethanol plant, avoiding the fuel expenses (usually natural gas) and the consumption of fossil fuels required by conventional grain ethanol plants.
- A 1999 study by Argonne National Laboratory found that substituting cellulosic ethanol for gasoline would result in a net greenhouse gas reduction of 86-128 percent, compared to a 35 percent reduction in greenhouse gases by substituting corn ethanol for gasoline. (Wang et al., 1999)
- Cellulosic feedstock prices should be more stable and less volatile than corn prices.
- Cellulosic ethanol plants can dispose of a wide variety of organic wastes.

A few small-scale cellulosic ethanol plants are under construction or operating in the U.S. and Canada, using sugar cane residue, municipal solid wastes, rice straw, and timber residue as feedstocks. The widespread commercialization of cellulosic ethanol would greatly increase U.S. ethanol production, but hardly anyone expects ethanol to replace petroleum completely. One recent study found that “bioenergy from agriculture could displace 25 to 30 percent of U.S. petroleum imports with fully developed biomass ethanol technology.” (Gallagher et. al, 2003) The Natural Resources Defense Council predicts that a combination of biofuels, “better vehicle efficiency, and smart-growth urban planning, could virtually eliminate our demand for gasoline by 2050.”(NRDC) Annual production of biodiesel, the second-largest U.S. biofuel, is currently less than two percent of ethanol production, but (like ethanol) has the potential to become much greater.



Sugar cane bagasse. Photo by Warren Gretz, DOE/NREL.

Cellulosic materials are generally less expensive than corn but also harder to convert to sugar. Chemically, cellulose is a long chain of tightly bound sugar molecules. The conversion of cellulose to sugar is generally accomplished by using sulfuric acid, through either *dilute*

*acid hydrolysis* or *concentrated acid hydrolysis*. Many researchers today are most enthusiastic about a process called *enzymatic hydrolysis*, where an enzyme called *cellulase* is used, instead of sulfuric acid, to convert cellulose to sugar. In processes known as *thermal gasification* and *pyrolysis*, cellulosic material is heated to extremely high temperatures (up to 2200° F), creating a gas or oil that can be converted into ethanol using microorganisms or a catalytic reactor. Ethanol has also been made from methane, which can be captured from landfills or anaerobic digesters.

According to a 2004 U.S. Department of Energy (USDOE) report, “The production



Wood chips. Photo by Warren Gretz, DOE/NREL.

of ethanol from corn is a mature technology that is not likely to see significant reductions in production costs.” (DiPardo, 2004) On the other hand, many are optimistic that the cost of producing cellulosic ethanol will eventually drop far below the cost of producing corn-based ethanol. Until recently, the cellulase enzymes used for enzymatic hydrolysis were prohibitively expensive, costing five or six dollars per gallon of ethanol. In 2005, though, two companies—Novozymes Biotech and Genencor International—reported achieving costs as low as 10 to 20 cents per gallon of ethanol, in laboratory trials funded by USDOE and the National Renewable Energy Laboratory.

## Uses and Advantages of Ethanol

In the U.S. today, ethanol has two main uses. It is often used as an “extender,” adding volume to conventional gasoline. Since ethanol contains 35 percent oxygen, it is also used as an *oxygenate* or *octane enhancer*, an oxygen-boosting fuel additive that is blended with gasoline to ensure more complete burning, reduce air emissions, and enable high-compression engines to run more smoothly, without “knocking.”

In the future, three other uses of ethanol may become important.

- Ethanol can be blended with diesel fuel, creating an experimental fuel called *E-diesel*.
- Ethanol can be used in the manufacturing of biodiesel, serving as a more environmentally benign alternative to methanol (commonly known as *methyl alcohol* or *wood alcohol*).
- Ethanol is currently the most cost-effective renewable source of hydrogen, making it a strong candidate for use in fuel cells.

Ethanol has been used as a transportation fuel in the U.S. since about 1908. Henry Ford designed the Model T to run on either gasoline or ethanol, and ethanol continued to be widely available as an automobile fuel

through the 1930s. (DiPardo, 2004) The U.S. ethanol industry has had a lively and frustrating history, with repeated setbacks when the industry seemed on the verge of success. One setback was caused by Prohibition. Another was caused by the petroleum industry's choice of lead instead of ethanol as a gasoline octane-enhancer. A third setback was caused by the petroleum industry's choice of *MTBE* (see below) instead of ethanol as a fuel oxygenate. Ethanol's supporters often—and plausibly—blame Big Oil for their historically small share of the transportation fuel market.

Over 30 percent of all gasoline sold in the U.S. is blended with ethanol, and ethanol comprises about two percent of the gasoline consumed in the U.S. (Renewable Fuels Association) Many states require gasoline to contain ethanol. Minnesota, New York, and Connecticut currently require gasoline to include a 10 percent ethanol blend, known as E10. (The term *gasohol* generally refers to a blend of gasoline with at least 10 percent ethanol.)

*Flexible fuel vehicles* can accept a range of fuel mixtures including gasoline and E85, a blend of 85 percent ethanol and 15 percent gasoline. Flexible fuel vehicles cost at most a few hundred dollars more to manufacture than standard vehicles. A sensor automatically detects the fuel mixture and adjusts the timing of spark plugs and fuel injectors so the fuel burns cleanly. General Motors, Ford, Chrysler, and other major automobile manufacturers are actively promoting the use of ethanol and introducing flexible fuel vehicle models. General Motors unveiled its first ethanol commercial during the 2006 Super Bowl, urging viewers to “Live Green—Go Yellow.”

Ethanol has many attractive features. It is biodegradable, made from renewable sources, and offers a home-grown alternative to the imported oil that now accounts for about 60 percent of U.S. gasoline and diesel fuel consumption. (USDOE, 2004) Substituting ethanol for fossil fuels also reduces tailpipe emissions of carbon dioxide, and many studies have shown a

reduction in greenhouse gases, although there is an ongoing and highly technical debate about the overall impact that an expanded ethanol industry might have on greenhouse gases.

Ethanol has great potential to replace the only other common oxygen-boosting fuel additive, methyl tertiary-butyl ether or MTBE. MTBE is a volatile organic compound derived from methanol. Methanol, in turn, is usually derived from natural gas but can also be made from other fossil fuels such as coal. MTBE has been used as an octane-enhancing fuel additive at low levels in the U.S. since 1979 and at higher levels since the early 1990s, when the 1990 Clean Air Act Amendments began requiring gasoline to be *reformulated* in parts of the country with poor air quality. Reformulated gasoline was required to have high oxygen content and low levels of smog-forming compounds and other air pollutants.

MTBE is easily dissolved in water, has proven difficult to contain in underground storage tanks, and is classified as a potential human carcinogen by the U.S. Environmental Protection Agency (EPA). Since it started being used widely, MTBE has been found in many water sources across the U.S. In 1999, an EPA panel recommended that MTBE usage be reduced, with some members of the panel recommending that it be phased out entirely. As of early 2006, MTBE has been banned in 17 states. The elimination of MTBE has created a large market opportunity for ethanol, since ethanol is far less toxic than MTBE and poses no known water quality threat.

## Air Quality

The use of ethanol as a transportation fuel has many undisputed air quality benefits. Adding ethanol to gasoline has been shown to reduce tailpipe emissions of many toxic air pollutants, including particulate matter, benzene, and carbon monoxide. Many studies show, however, that ethanol slightly raises the volatility of gasoline, causing increased emissions of hydrocarbons and nitrogen oxide (NO<sub>x</sub>), which can

**O**ver 30 percent of all gasoline sold in the U.S. is blended with ethanol, and ethanol comprises about two percent of the gasoline consumed in the U.S.

contribute to smog formation. Other studies have shown that mixing ethanol with gasoline increases emissions of a few other toxic air pollutants.

In a decision widely seen as a setback to the ethanol industry, the federal Energy Policy Act of 2005 eliminated the oxygenate requirement for reformulated fuel in the state of California (by far the nation's largest consumer of ethanol). The state had argued that reformulated gasoline *without* ethanol was better for California's air quality than reformulated gasoline containing ethanol. In February 2006, the EPA eliminated the oxygenate requirement entirely, for all parts of the country. These decisions mean that reformulated gasoline in the U.S. will no longer need to contain either MTBE or ethanol, raising many uncertainties about ethanol's future as a fuel oxygenate.

Besides the debate about emissions from the tailpipe, concerns have also been raised about emissions from ethanol plants. In 2002, the U.S. Department of Justice, EPA, and the Minnesota Pollution Control Agency reached a civil settlement with 12 ethanol plants that were alleged to be violating Clean Air Act standards. These plants agreed to pay civil penalties and install equipment reducing emissions of volatile organic compounds and carbon monoxide.

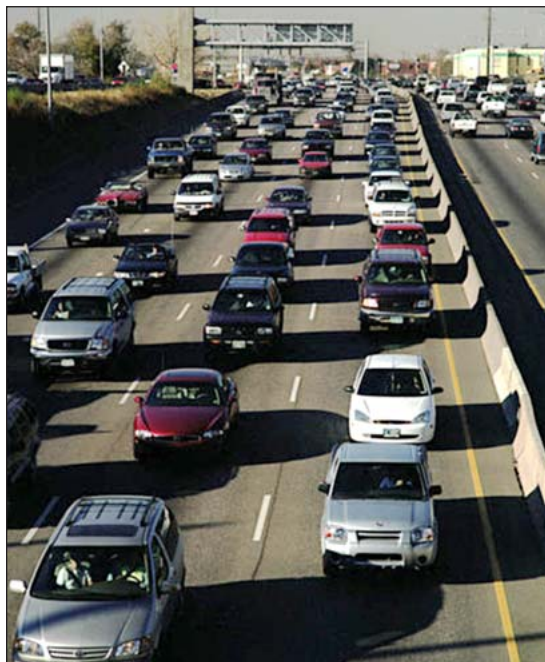


Photo by Warren Gretz, DOE/NREL.

## Ethanol Incentives

Advocates claim that the production and use of ethanol have a strongly positive impact on the U.S. economy: creating jobs, generating tax revenues for local communities, raising corn prices, reducing trade deficits, and decreasing dependence on

imported oil. Critics reply, however, that ethanol is expensive in relation to other fuels and cannot compete in the marketplace without heavy subsidies.

Since 1978, a federal ethanol production tax credit of between 40 and 60 cents per gallon has been in place. Through 2010 this credit is expected to be 51 cents per gallon. Certain ethanol producers and developers are also eligible for various other federal tax credits, incentive payments, grants, and loans.

The federal Energy Policy Act of 2005 promotes ethanol by requiring the use of 7.5 billion gallons of renewable fuels by 2012, a target that would nearly double ethanol production compared to 2005 levels. The Energy Policy Act also creates a wide range of other new incentives, adds funding for various research and demonstration projects, and defines a Renewable Fuel Program to be created by EPA.

Over and above the federal incentives and funding, many states add their own incentives, generally in the form of fuel excise tax exemptions and producer credits. Other state incentives include requiring a blend of ethanol in all gasoline, requiring fleet vehicles to use ethanol-blended gasoline, and offering an assortment of tax credits, grants, rebates, and low-interest loans.

For many observers, the reliance of the ethanol industry on government incentives is a cause for concern because the future of the industry is subject to changes in the political climate. A reduction in incentives would certainly harm the industry, and many still recall the wave of bankruptcies that swept through the ethanol industry in the 1980s, when oil prices dropped.

On the other hand, federal ethanol incentives have now been in place since 1978, and recent fluctuations in oil prices have proven that ethanol prices can sometimes drop below those of gasoline. Ethanol prices tend to track corn prices, since higher corn prices generally increase the cost or reduce the supply of ethanol. Between 1982 and 2004, wholesale

ethanol prices were generally 30 to 50 cents per gallon higher than unleaded gasoline prices. In the spring of 2005, though, wholesale ethanol prices dropped as low as \$1.20 per gallon, compared to \$1.60 for unleaded gasoline. (Hart, 2005)

Some have argued that heavy government investments in ethanol would be better spent promoting fuel-efficient vehicles, public transportation, wind or solar energy, or other clean energy industries.

Of course, any fair comparison between ethanol and petroleum-based fuel must consider the enormous federal subsidies that have been paid to the oil industry, too—more than \$130 billion in tax benefits from 1968 to 2000, according to the U.S. General Accounting Office. (USGAO, 2000)

## The Energy Balance of Ethanol

Ethanol's *energy balance* is sometimes defined as the difference between the amount of energy stored in a gallon of ethanol and the amount of energy needed to grow, produce, and distribute that gallon of ethanol. While the topic has been hotly debated for years, the current prevailing opinion is that ethanol has a net positive energy balance.

Since 1979, David Pimentel, PhD, of Cornell University has consistently argued—in more than 20 published articles—that the amount of fossil fuel energy needed to produce ethanol is greater than the energy contained in the ethanol. According to Pimentel and his colleague Tad Patzek of the University of California, Berkeley, “There is just no energy benefit to using plant biomass for liquid fuel.” (Pimentel and Patzek, 2005)

Numerous recent studies have found that ethanol has a positive energy balance. (In fact, ethanol advocates sometimes say that *all* other credible studies since 1992 have calculated a positive energy balance.) Some studies calculate an energy balance as high as 2.62, meaning more

than two-and-a-half times as much energy comes out of the ethanol fuel as was used to produce it. Most published studies since 1990 come up with a ratio between 1.2 and 1.8. Nonetheless, Pimentel and a small number of other authors continue to argue that ethanol production is an energy-loser.

Energy balance calculations are important in deciding among energy options and in making manufacturing processes of all kinds more energy-efficient. Nonetheless, David Morris of the Institute for Local Self-Reliance offers several compelling reasons to believe that the energy balance controversy has gotten far more attention than it deserves. (Morris, 2005) To recap three of Morris's main points:

1. *If state-of-the-art and next-generation technologies are considered, the energy balance criticism of ethanol looks very weak.* The energy balance of ethanol has improved and will likely continue to improve. Since 1980, ethanol plants have reduced energy inputs per gallon by about 50 percent, while U.S. corn farmers have increased their yields by 40 percent and reduced their fertilizer usage by 20 to 25 percent. (Morris, 2005) (Nitrogen fertilizer accounts for around 40 percent of all energy inputs in corn farming.) Cellulosic manufacturing processes are also rapidly improving. Whether the feedstocks are agricultural wastes (e.g., corn stover, wheat straw), forest residue (e.g., underutilized wood and small trees), or energy crops (e.g., fast growing trees and switchgrass), almost all studies agree that a mature cellulosic ethanol technology will require much smaller energy inputs than corn ethanol.



Harvesting switchgrass. Photo by Warren Gretz, DOE/NREL.

**G**enetic engineering is being used and tested in virtually all aspects of the ethanol production process.

2. *Ethanol is a high quality fuel, and quality counts in the energy balance debate.* Some forms of energy are higher quality than others, i.e., more useful to humans. For example, it often makes perfectly good sense to cook food (making it edible) or dry food (retarding spoilage), even if these processes take more energy than is contained in the product. A small amount of energy contained in cooked or dried food is far more useful to humans than a larger amount of energy contained in inedible or highly perishable foods. As Morris points out, ethanol combines energy and storage. In this respect, ethanol is more useful than wind or solar energy, which must be stored in batteries or some other system. Even if we suppose that it takes more energy to create a gallon of ethanol than is contained in the fuel, this might be a reasonable tradeoff in order to turn the solar energy embodied in plant feedstocks into a high quality liquid fuel.

3. *The use of ethanol unquestionably displaces large quantities of imported oil, regardless of the outcome of the energy balance debate.* Ethanol production relies heavily on non-petroleum fuels such as natural gas and coal, with diesel and gasoline making up only 8 to 17 percent of the fossil fuel energy used. (Morris, 2005) If only *petroleum* fuel inputs are considered—as opposed to all fossil fuels—the energy balance of ethanol is strongly positive. According to Morris, “the net energy ratio with respect to petroleum would be close to 8 to 1.” So the use of ethanol unquestionably reduces U.S. consumption of petroleum fuels. Neither Pimentel nor any other credible researcher has ever said that “It takes more than a gallon of oil to make a gallon of ethanol.” Yet this statement, based on a confusion between fossil fuels and petroleum fuels, is frequently repeated as a criticism of ethanol.

The three points above might be summed up this way: Most studies show that ethanol contains more energy than is required to produce it. But even if ethanol’s energy balance were currently negative, it offers such great benefits and future potential that it might very well be worthy of continued government support, since it is made from renewable sources, reduces most

forms of air pollution, and offsets U.S. oil consumption.

## Genetic Engineering

While the energy balance controversy has received a lot of attention, the role of genetic engineering in ethanol production has received very little. Genetic engineering is being used and tested in virtually all aspects of the ethanol production process. For example:

- In 2005, 52 percent of the U.S. corn crop was grown from genetically engineered seed. (USDA, 2005)
- As of 2002, genetic engineering was the single largest expenditure in the federal research and development budget for biomass research. (Morris, 2002)
- A University of Florida researcher has genetically engineered a strain of *E. coli* bacteria that produces ethanol from cellulosic sources at an estimated cost of \$1.30 gallon. (Woods, 2005)
- A Purdue University team has developed a genetically engineered yeast that converts both glucose and xylose into ethanol, reportedly increasing ethanol yields from agricultural residues by up to 40 percent. (Venere, 2004)
- Since 1997, researchers at the National Renewable Energy Laboratory have been trying to genetically engineer unique “biocatalysts” making it possible to ferment the sugars in corn fiber. (NREL, 2006)
- Other researchers are trying to genetically engineer plants with high sugar or starch content, or containing greater amounts of cellulose. Genetic engineering is being used to improve poplar and other woody biomass crops, for example, improving resistance to insects and herbicides and changing wood chemistry to facilitate pulp production. (James et al., 1998)





Poplar harvest. Photo by Warren Gretz, DOE/NREL.

The genetic engineering of crops raises concerns for farmers and the general public that include food safety concerns, herbicide resistance (the creation of “super weeds”), pesticide resistance, antibiotic resistance, harm to beneficial organisms, and loss of genetic diversity. There are also marketing and trade issues (since many countries refuse genetically modified products), liability issues, and a wide variety of food safety issues. For more discussion, see the ATTRA publication *Genetic Engineering of Crop Plants*.

There are important differences between genetically engineered ethanol and genetically engineered food crops, beginning with the fact that ethanol is burned and not eaten. Nonetheless, this issue will probably attract a great deal of attention in the future, in relation to biodiesel as well as ethanol. The major feedstocks for U.S. biodiesel production are overwhelmingly genetically engineered varieties, including more than 80 percent of all U.S. soy and over half of all U.S. canola. (Pew, 2004)

## Soil and Water Impacts

The growth of the ethanol industry and the prospect of increased corn production raise serious concerns about soil depletion and water quality.

Large-scale corn production in the U.S. unquestionably uses large amounts of pesticides and fertilizers, and these chemicals are well-known to contribute to water pollution. Industrial corn production also contributes to erosion and soil nutrient depletion. According to a 1994 USDA study, approximately 12,000 pounds of topsoil were being lost per-acre per-year on land farmed

with large-scale techniques. (USDA, 1994) Some ethanol critics calculate and report pounds of topsoil lost per gallon of ethanol produced.

Ethanol’s supporters often reply that these criticisms are really complaints about corn-growing techniques, not about ethanol. Ethanol can be made from raw materials other than corn. Corn can also be grown more sustainably, using techniques such as “conservation tillage” to reduce erosion, as well as crop rotations, compost, and manures (both animal and plant) to maintain and enhance soil quality.



Corn planted into no-till soybean residue. Photo courtesy of NRCS.

Numerous ATTRA publications describe techniques for more sustainable corn production. See, for example, the following:

- Sustainable Corn and Soybean Production
- Organic Field Corn Production
- Sustainable Soil Management
- Conservation Tillage
- Pursuing Conservation Tillage Systems for Organic Crop Production
- Overview of Cover Crops and Green Manures
- Manures for Organic Crop Production
- Farm Scale Composting Resource List

From the standpoint of protecting soils and water, cellulosic ethanol promises numerous advantages in comparison to corn ethanol. Deep-rooted cellulosic crops such as switchgrass can decrease soil erosion and often require no irrigation, pesticides, or fertilizer. Switchgrass is native to North America, has a high resistance to many pests and plant diseases, requires little fertilizer or agricultural chemicals, and can tolerate poor soils, flooding, and drought. Because it is a perennial grass, no annual tillage is required. (Bransby, 2006)



*Switchgrass. Photo by Warren Gretz, DOE/NREL.*

Large-scale harvesting of cellulosic feedstocks does pose environmental challenges of its own. Crop residue removal needs to be done carefully, leaving enough residues in place to reduce erosion and returning enough residues to the soil to maintain or improve organic matter content.

Besides harvesting crop residues, other ethanol proposals under discussion call for growing energy crops on some or all of the 17 million acres of Conservation Reserve Program (CRP) lands that have been withdrawn from agricultural use. Concerns have been raised, however, about the sustainability of growing energy crops on these sensitive lands, including dangers of erosion, lost wildlife habitat, and depleted soil nutrients.

## Using Food Crops to Produce Fuel

The U.S. ethanol industry is currently using between 10 and 13 percent of total U.S. corn production. In a world where so many people are hungry or malnourished, does it make sense to “burn food” using corn and other food crops to power vehicle engines?

According one British commentator:

Switching to green fuels requires four and [a] half times our arable area. Even the EU’s more modest target of 20 percent [of fuels from ethanol and biodiesel] by 2020 would consume almost all our cropland. If the same thing is to happen all over Europe, the impact on global food supply will be catastrophic: big enough to tip the global balance from net surplus to net deficit. If, as some environmentalists demand, it is to happen worldwide, then most of the arable surface of the planet will be deployed to produce food for cars, not people. This prospect sounds, at first, ridiculous. Surely if there was unmet demand for food, the market would ensure that crops were used to feed people rather than vehicles? There is no basis for this assumption. The market responds to money, not need. People who own cars have more money than people at risk of starvation. (Monbiot, 2004)

Given the current small size of the ethanol and biodiesel industries, worrying about carpeting the planet with bioenergy crops may sound like worrying about becoming too muscular

on a person's first visit to the gym. Nonetheless, concerns about feeding the world's growing population certainly deserve to be taken seriously. Bioenergy crops have already begun to compete with food crops and cause environmental problems in some parts of the world.

For example, in order to meet its goal to produce 5.75 percent of its fuels from biofuels by 2010, and 20 percent by 2020, the European Union has greatly increased its acreage of rapeseed, a crop that provides most of the vegetable oil for European biodiesel. Europe now has more than three million hectares (7.4 million acres) under rapeseed cultivation, an area approximately the size of Belgium. The 2010 target is expected to increase industrial rapeseed plantings in Europe to eight million hectares (19.8 million acres). (USDA, 2003)

Many developing countries, including South Africa and India, promote cultivation of jatropha for biodiesel production—an oilseed crop inedible for humans and livestock. Other countries are promoting palm oil. The clearing of forests to make way for palm plantations has been blamed for deforestation in Malaysia, Indonesia, Borneo, and Sumatra. (Webster et al., 2004)

Population growth, food availability, and agricultural land use patterns are vitally important topics far beyond the scope of this publication. No doubt, the continued growth of the ethanol and biodiesel industries will cause changes in crop markets and land use patterns. In the long run, these changes will raise new environmental problems, and it is possible that these changes will cause higher food costs and related problems of scarcity and distribution. Below are a few key points about using food crops to produce fuel:

- Corn ethanol is made from the starch portion of corn, and there is currently no scarcity of starch for human consumption. Dry milling produces distiller's grains, which are used for animal feed.
- In today's world, poverty and distribution problems are far more common causes of hunger than food scarcity. Almost all developed nations,

and many developing ones, produce far more food than they need.

- Two thirds to three quarters of the corn grown in the U.S. is used for animal feed, and ethanol is made from "field corn," not intended for human consumption. Most U.S. grain exports likewise feed livestock, not people.
- Cellulosic ethanol is less susceptible than corn ethanol to "food vs. fuel" criticisms, since it relies on crop residues, municipal wastes, grasses, and trees that generally have no value as human food. Also, many of the promising energy crops for ethanol production can be grown in marginal areas unsuitable for food crop production.

## Local vs. Corporate Ownership

In the late 1980s a single company, Archer Daniels Midland (ADM) produced almost 80 percent of the nation's ethanol. Since that time, though, the industry has witnessed a remarkable growth in small and medium-sized ethanol facilities owned by farmers. Today, at least 25,000 farmers own shares in one or more ethanol plants, as members of cooperatives or limited liability corporations. (Morris, 2003) Farmer-owned cooperatives now produce nearly half of all U.S. ethanol. (American Coalition for Ethanol) Many have hailed the growth of farmer-owned ethanol facilities as an encouraging trend that allows farmers to add value to their crop, keep more of the profits, and keep dollars in rural communities.



*Ethanol plant. Photo by Tom Richard, Penn State University.*

Unlike oil or natural gas, ethanol feedstocks can't be delivered in a pipeline and must be transported by truck, rail, or barge. For this reason, David Morris has argued that local and regional production facilities tend to have inherent advantages:

Unlike petroleum, plant matter in its raw state is bulky and expensive to transport. Thus most biorefineries buy their raw materials from within 50-75 miles of the facility (and often sell their end-products in a radius not that much wider). In part because of the transport economics, the size of biorefineries is only a fraction that of petroleum refineries (1-10 percent). That modest scale enables farmers and local residents to raise sufficient equity investment to own the facility. (Morris, 2003)

"In the United States, the tripling of ethanol consumption since 2000 may have raised the price of corn by 10-15 cents per bushel. But the 20,000 or so U.S. farmers who own a share of an ethanol plant receive far more, in annual dividends, usually 50-75 cents per bushel."(Morris, 2005)

Minnesota has led the nation in promoting locally owned ethanol facilities. In the late 1980s, the state created a producer payment program of 20 cents per gallon, limited to in-state ethanol produc-

ers and limited to a maximum of 15 million gallons per year. This law encouraged the creation of many small and locally-owned ethanol plants. Twelve of Minnesota's current 14 ethanol plants were originally organized as farmer-owned cooperatives.

Since 2002, when the Minnesota Corn Processors voted to sell their shares in Minnesota's largest ethanol facility to ADM, the state passed additional laws limiting producer payments to farmer-owned plants and requiring repayment of these incentives if the ethanol plant is sold to another corporation. Because of state budget problems, in 2003 the state reduced producer payments drastically, to 13 cents per gallon and limited to a maximum of only 3 million gallons. More recently, though, the state has considered increasing its ethanol requirement from 10 percent ethanol to a 20 percent blend. (New Rules Project, 2005)

Farmers who consider buying shares in an ethanol plant should understand that it is an investment with very substantial risks.

Energy markets are volatile and unpredictable. The history of Minnesota ethanol shows how quickly subsidies can change, dramatically altering the economics of ethanol production. New technological breakthroughs could make today's dry mills obsolete. Overproduction, caused by too many new plants, could reduce prices. So could increased production by large corporate-owned plants. So could competition caused by the entry of additional large corporations into the ethanol business.

Noting that several large (100 million gallon) dry mills are under construction, David Morris asks,

Will the ethanol industry begin to look like traditional agriprocessing industries, dominated by a handful of large companies? Will farmer ownership stagnate at present levels? Washington is neutral on these questions. Federal incentives do not differentiate between a 15 million gallon ethanol facility owned by 500 farmers and a 150 million gallon ethanol facility (or multiple 150 million gallon facilities) owned by a single multinational corporation. (Morris, 2003)

For a summary of some state incentives for local and cooperatively-owned ethanol and biodiesel plants, see the New Rules Project Web site, [www.newrules.org](http://www.newrules.org).

## Conclusion

The energy problems confronting the U.S. are so profound that they will likely require dramatic changes in our way of life within the next decade or two. It is unrealistic to hope that ethanol will replace petroleum or that it will allow us to continue using energy as we have for the past seventy-five years. The first and most urgent priority of any sensible national energy strategy will be efficiency and conservation, reducing our energy usage to more sustainable levels.

Nonetheless, ethanol is probably our most promising biofuel option right now from the standpoint of reducing our reliance on imported oil and making the transition to a more sustainable transportation system. Ethanol has many clear tailpipe emission benefits and is generally far more environmentally benign than the gasoline and

MTBE it is replacing. Ethanol might also continue to play a role in rebuilding America's rural communities, although that outcome is far from certain.

Two concerns about ethanol have received more attention than all the others combined: the high cost/incentives issue and the energy balance issue. These concerns are over-emphasized. The more important questions about ethanol concern its possible impacts on air, water, and soils, especially if large-scale corn ethanol continues to dominate the industry and if the U.S. pushes to maximize ethanol production.

As the cost of cellulosic ethanol continues to drop, the ethanol industry will start to look far different from what it is today. In many ways, cellulosic ethanol looks more environmentally benign than corn ethanol, but it will bring its own challenges and dangers, including risks of soil deple-

tion and a long list of new genetically engineered organisms.

A sustainable U.S. ethanol industry would begin with sustainable farming practices. Corn and other energy crops would be grown sustainably, in ways that protect soils and water while reducing or eliminating the use of energy-intensive nitrogen fertilizer and hazardous chemicals. Enough crop residue would be left in the field to minimize erosion and maintain or improve soil nutrient levels. Agricultural lands would be put to their highest and most sustainable use, which in many locations would be food production rather than energy production. Genetically modified organisms would play a carefully limited role. The scale, design, and ownership of ethanol production facilities would allow farmers and rural communities to share in the economic benefits.

**T**he first and most urgent priority of any sensible national energy strategy will be efficiency and conservation.

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## Further Resources

### Organizations and Online Resources

The Agricultural Marketing Resource Center  
1111 NSRIC, Iowa State University  
Ames, IA 50011-3310  
Phone: (866) 277-5567  
[www.agmrc.org](http://www.agmrc.org)

Alternative Fuels Data Center  
[www.eere.energy.gov/afdc](http://www.eere.energy.gov/afdc)  
*A comprehensive source of information about alternative fuels and vehicles.*

American Coalition for Ethanol  
2500 S. Minnesota Avenue #200  
Sioux Falls, SD 57105  
Phone: (605) 334-3381  
[www.ethanol.org](http://www.ethanol.org)  
*"The grassroots voice of the ethanol industry, a membership-based association dedicated to the use and production of ethanol."*

Ethanol Promotion and Information Council  
17295 Chesterfield Airport Road, Suite 200  
Chesterfield, MO 63005  
Phone: (636) 530-3666  
[www.drivingethanol.org](http://www.drivingethanol.org)

*“An alliance of ethanol producers and industry leaders who have come together to create a consistent, positive message and identity for ethanol.”*

Journey to Forever

[www.journeytoforever.org](http://www.journeytoforever.org)

*A wealth of information about biofuels, including links and a discussion of the “food vs. fuel” controversy.*

Minnesota Department of Agriculture’s Ethanol Page

[www.mda.state.mn.us/Ethanol](http://www.mda.state.mn.us/Ethanol)

*Includes reports, news, and links to ethanol companies and organizations. The Minnesota Ethanol Program has been a national leader in promoting farmer-owned ethanol plants.*

National Renewable Energy Laboratory (NREL)

1617 Cole Boulevard

Golden, CO 80401

Phone: (303) 275-3000

[www.nrel.gov](http://www.nrel.gov)

*The leading center for U.S. renewable energy research. A source of technical articles and case studies.*

The New Rules Project

The Institute for Local Self-Reliance

1313 5th Street SE

Minneapolis, MN 55414

Phone: (612) 379-3815

[www.newrules.org](http://www.newrules.org)

*Offers consistently excellent articles, information, and resources, including discussions of the scale and ownership of ethanol facilities.*

Renewable Fuels Association

One Massachusetts Avenue, NW - Suite 820

Washington, DC 20001

Phone: (202) 289-3835

[www.ethanolrfa.org](http://www.ethanolrfa.org)

*“The national trade association for the U.S. ethanol industry.”*

**Ethanol Opportunities and Questions**

By Mike Morris and Amanda Hill

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