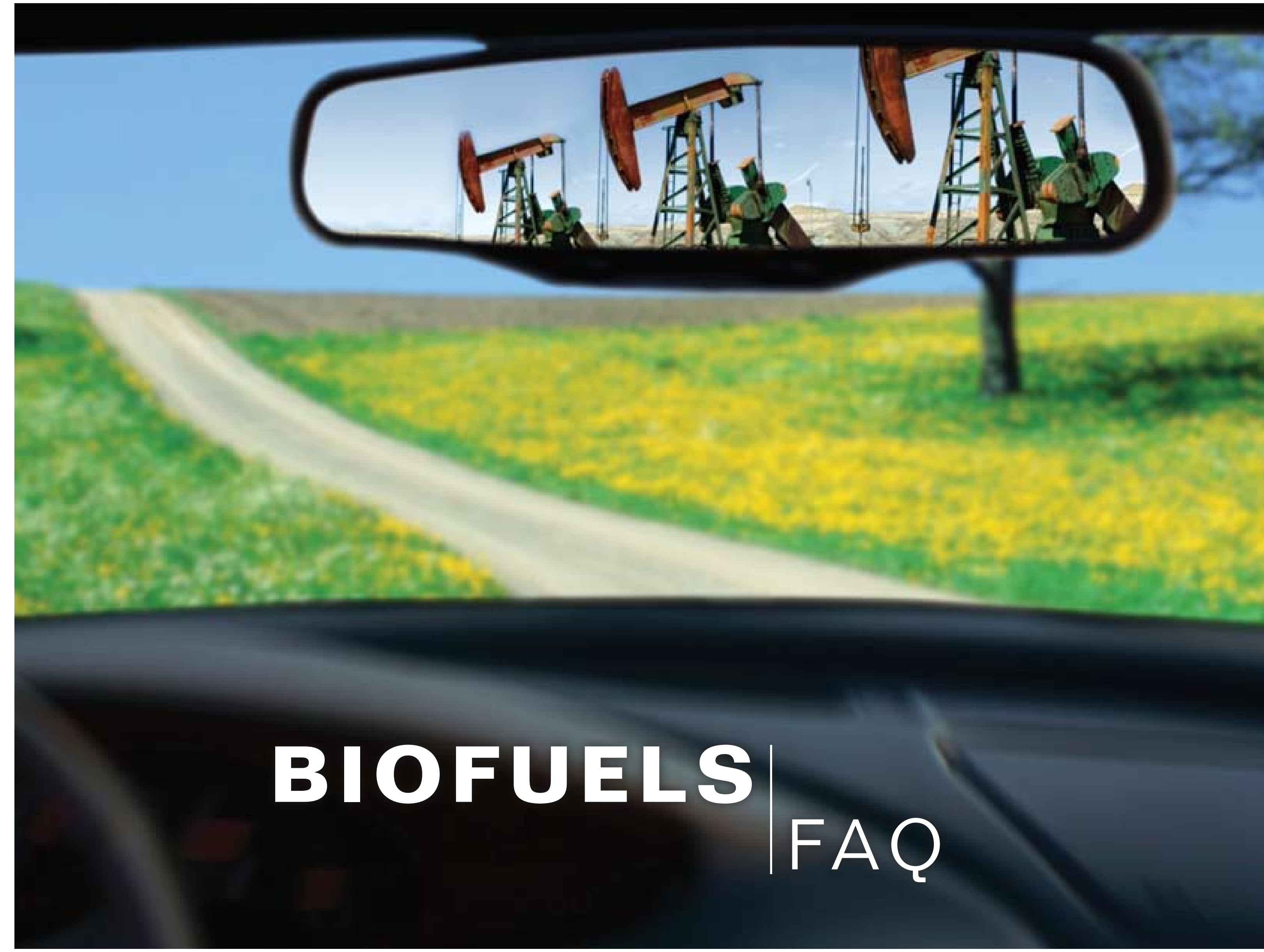
DISCOVER. DEBATE. DECIDE.

www.EnergyFutureCoalition.org/Biofuels

PRINTED WITH SOY INK



energy future COALITION

UNITED NATIONS FOUNDATION

About This Guide

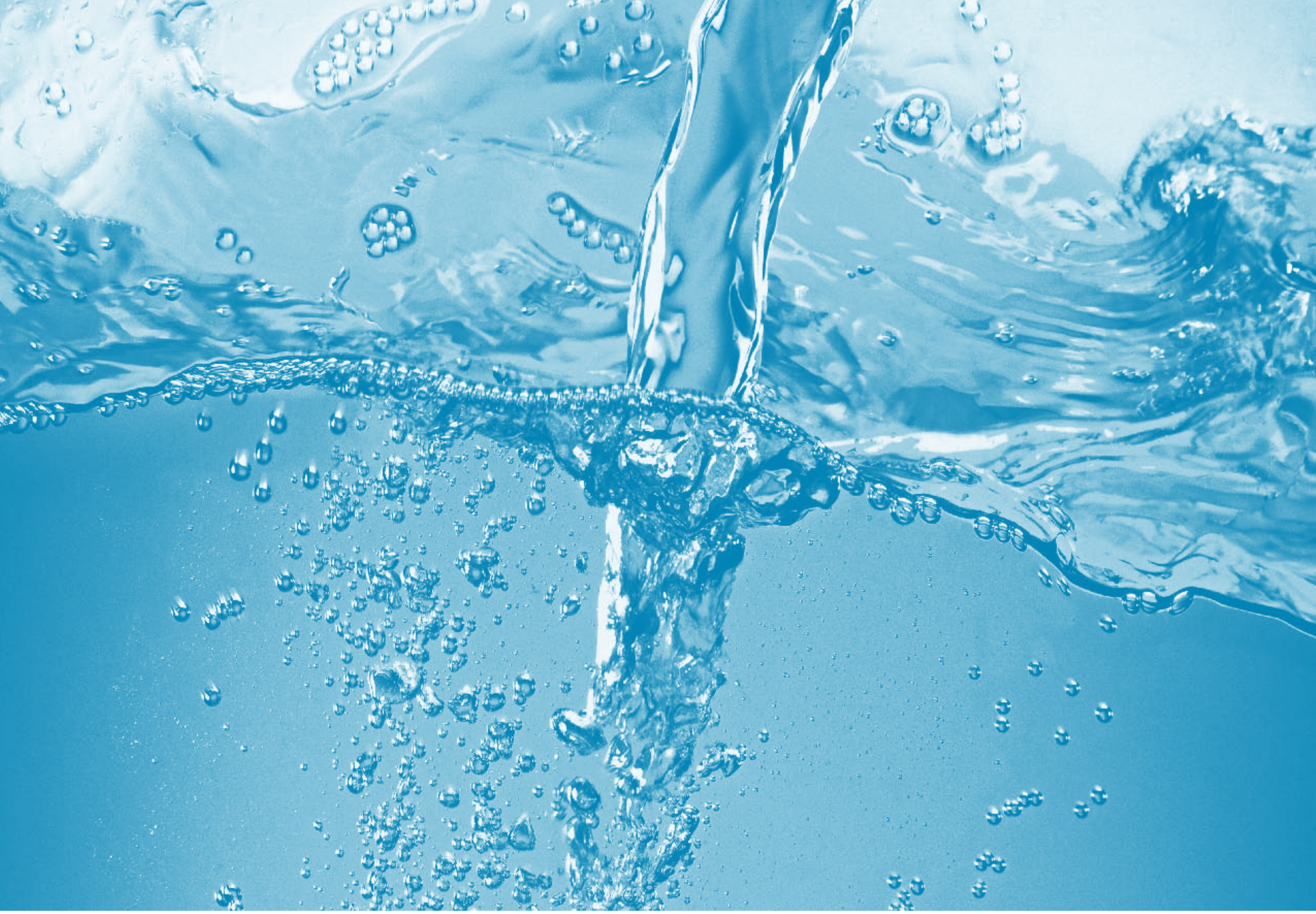
The use of biofuels in transportation has been the subject of a dizzying amount of confusion, misinformation, and disinformation. The intent of this guide is to lay the facts out clearly, dispel certain commonly held myths, and state the case for biofuels objectively.

The guide is divided into two parts: the basic facts about biofuels – how they are made, how much they cost, etc. – and the benefits of large-scale biofuels production and use.

This is meant to be a living document, not the last word on biofuels. Send us questions, corrections, and updates, and we will try to keep it fresh on our Web site at:

www.EnergyFutureCoalition.org/Biofuels

BIOFUELS FOR OUR FUTURE: A PRIMER.



Biofuels for Our Future: A Primer

Overview

America's dependence on oil jeopardizes its national security, drains billions of dollars from the U.S. economy, and contributes to global warming. The economic benefits of breaking this addiction to oil would be immense and widespread. Fortunately, the commodities best positioned to help end that dependence and enable a transition to a low-oil, high-growth economy are already growing in the fields and forests of rural America. Plants and trees, known collectively as biomass, can be converted into transportation fuel – chiefly ethanol and biodiesel. Renewable fuels from biomass are called biofuels.

The Argument for Biofuels

The U.S. economy depends on transportation, and transportation depends almost entirely on oil. This dependence on oil as the nation's only significant transportation fuel creates risk – of economic shock, should supplies be disrupted; of terrorist acts financed by oil-producing nations; and of military engagement to protect access to oil. The increased production and use of biofuels could significantly reduce the amount of oil needed to fuel U.S. cars and trucks.

Creating an abundant supply of biofuels – and the accompanying national production and distribution network – would ensure a more prosperous and secure future for America. It would mean higher incomes for farmers and an increase in skilled jobs in rural areas. Tens of billions of dollars would be invested in the U.S. economy rather than sent overseas. The transition to biofuels would also result in a more vital U.S. manufacturing sector, creating cutting-edge technologies and "flexible-fuel" cars that could be marketed to consumers around the world.

Moving to biofuels will also mean cleaner air and less global warming. Fuels made from plant material generate fewer of the pollutants that cause smog and acid rain, and they can displace toxic compounds found in gasoline that are known as "aromatics." Their use reduces emissions of the most important greenhouse gas, carbon dioxide (CO2), into the atmosphere. These emissions are causing global warming and harming the Earth's environment in ways that may prove irreversible.

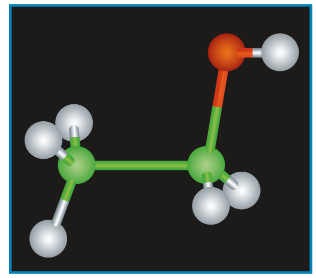
The principal objections about biofuels concern the effects of production at very large scale. Like anything else, such a task can be managed badly or well, and it is important to understand the potential impacts of poor decisions and the benefits of good ones.

Verbatim:

> "The 20th century has been the age of the hydrocarbon. The 21st century should witness a rebirth of a carbohydrate economy. Living plants are again becoming attractive raw materials for manufacturers. The signs may be modest, but the conclusion is unmistakable. The pendulum is swinging back to a biological economy."
>
> *– David Morris, The Carbohydrate Economy*

The Facts About Biofuels: Ethanol

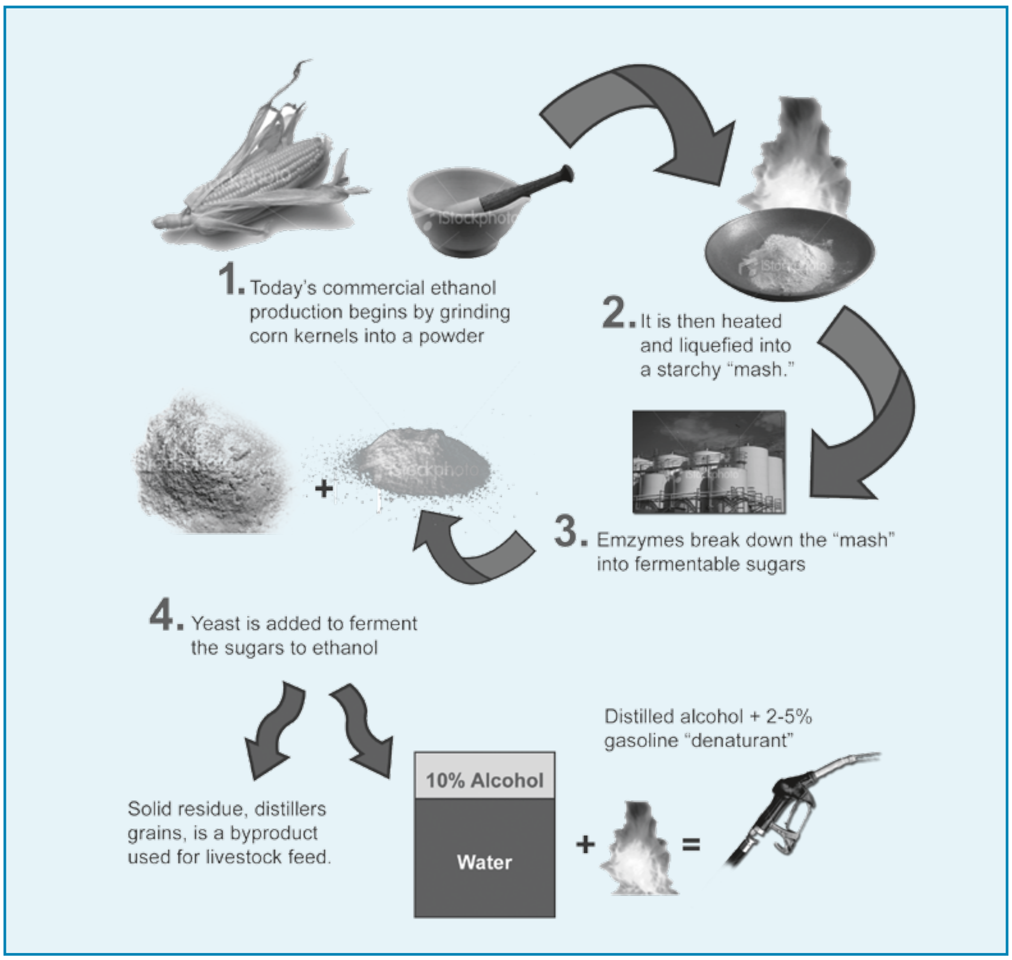
Ethanol is another name for ethyl alcohol, or "grain alcohol" (CH_3CH_2OH). The alcohol in a glass of wine, beer, or liquor is ethanol. Fuel ethanol is "denatured" by the addition of 2-5% gasoline, which makes it undrinkable. In the U.S. today fuel ethanol is mostly made from the starch in corn kernels; in Brazil it is made from the juice in sugar cane. Commercial production of ethanol from cellulose (plant fiber) is expected within the next few years.[1]



Ethanol molecule: Carbon in green, oxygen in red, hydrogen in gray.[2]

How is ethanol made?

The production of ethanol today involves the use of yeast to convert sugar into alcohol – the same fermentation process that has been used for thousands of years, although on a much larger scale. A typical dry mill production facility produces 50 to 100 million gallons of ethanol a year; the process is shown below.



Dry-mill production also results in solid byproducts known as distillers grains and solubles (DGS), which can be dried and used to feed livestock.[3] In some plants close to cattle feedlots, the grains can be fed wet to livestock, avoiding the need for drying and saving both energy and money.[4] The wet-mill process, which begins by soaking the grain in water and acid, generally produces corn oil, corn gluten meal (to feed poultry), and sweeteners in addition to ethanol. Wet mills tend to be much larger than dry mills.

As of February 2007, the ethanol production capacity of the United States was estimated at 5.6 billion gallons per year. An additional capacity of 6.2 billion gallons per year was under construction, which will bring the total capacity to 11.8 billion gallons per year spread across 23 states.[5] Corn represents roughly 95% of the feedstocks used in those facilities. The corn used for ethanol production is field corn typically used to feed livestock, not the sweet corn marketed for human consumption. Nearly 40% of the nation's ethanol production capacity is farmer-owned.[6]

Verbatim:

> "The fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust – almost anything. There is fuel in every bit of vegetable matter that can be fermented."
>
> *– Henry Ford, 1925* [7]

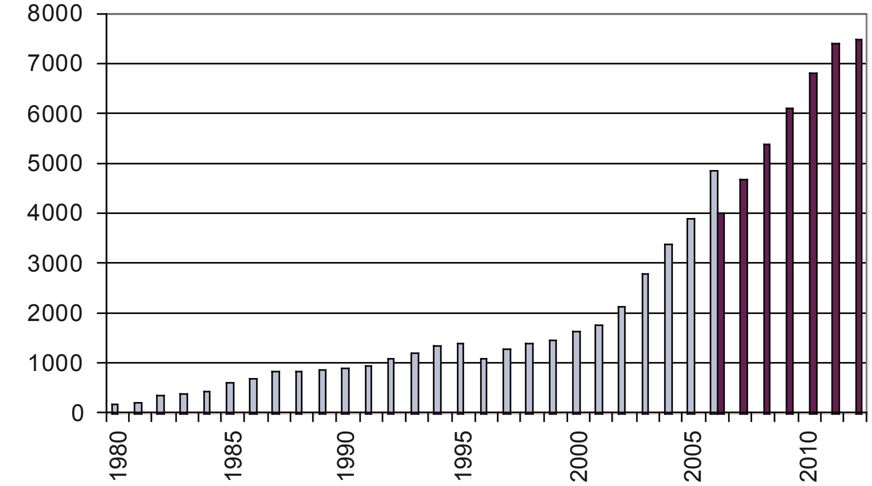
How is ethanol used?

Ethanol is a high-octane premium fuel. It improves engine performance and prevents "knock."[8] A blend of 10% ethanol and 90% gasoline, or E10, is approved for use in every vehicle sold in the U.S.; about one-third of America's gasoline contains some ethanol.[9] In the past, this blend has been called **gasohol**.

Ethanol can also be used as a substitute for gasoline. In the U.S. it is sold in blends of up to 85% **(E85)**. Gasoline, the remaining 15%, is needed to help the fuel ignite in cold weather. In very cold weather, higher proportions of gasoline may be needed. Ethanol at these higher blends should not be used in conventional vehicles but only in flexible fuel vehicles (FFVs), which are designed to run on any combination of ethanol and gasoline up to E85.[10]

Tidbit

Ethanol will become standard in Indy race cars in 2007, replacing another alcohol – methanol.[11] The higher octane of alcohols (compared to gasoline) allows engines to be set at a higher compression ratio, increasing the car's performance.



How much oil does the U.S. consume, and how much biofuel?

The U.S. consumes a little more than 20 million barrels of oil a day. The largest end uses are motor gasoline (9 million barrels) and diesel (4 million barrels).[12] That works out to about 140 billion gallons of gasoline and 60 billion gallons of diesel a year.

In 2006, the U.S. consumed nearly 5.4 billion gallons of ethanol, 12 percent of which was imported.[13] Adjusting for its lower energy content, that amounted to about 2.5% of the total U.S. demand for gasoline.[14] Biodiesel consumption was much lower, about 250 million gallons in 2006.[15]

In the Energy Policy Act of 2005, Congress enacted the Renewable Fuels Standard, which requires an annual increase in biofuels use to 7.5 billion gallons by 2012.[16] The chart above details past levels of U.S. ethanol production and the minimum levels set by the Renewable Fuels Standard.[17]

In the 2006 State of the Union address, President Bush announced a goal of replacing "more than 75% of our oil imports from the Middle East by 2025." According to the Department of Energy, meeting that goal will require 60 billion gallons of biofuels a year.[18] A year later, the President accelerated the timetable and called for "20 in 10."

Verbatim:

> "Tonight, I ask Congress to join me in pursuing a great goal. Let us build on the work we've done and reduce gasoline usage in the United States by 20 percent in the next 10 years…. To reach this goal, we must increase the supply of alternative fuels, by setting a mandatory fuels standard to require 35 billion gallons of renewable and alternative fuels in 2017."
>
> *– President George W. Bush, 2007* [19]

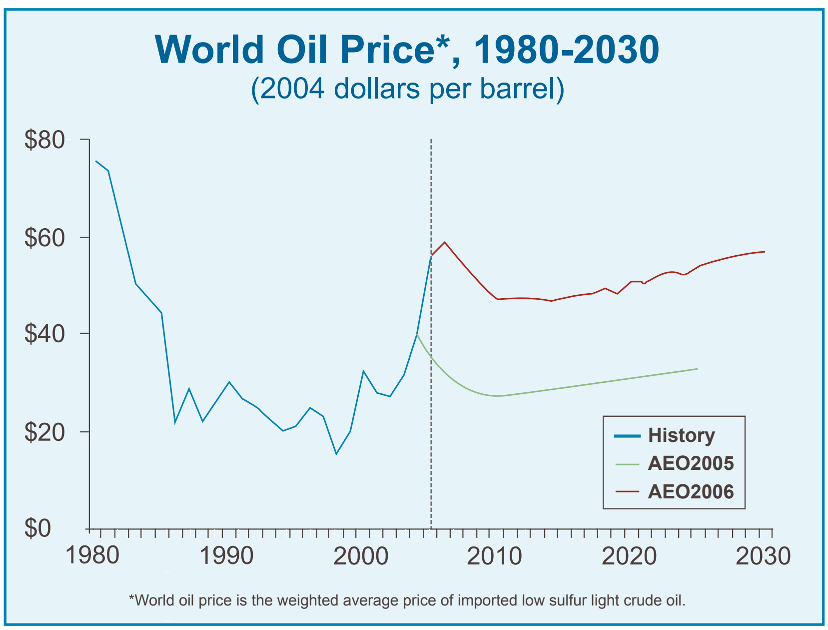
How much does it cost to make ethanol?

The two largest variables in the cost of ethanol are the cost of corn and the cost of natural gas or other sources of heat needed to process the mixture. When corn costs $2 a bushel, it costs between $1 and $1.20 to make a gallon of ethanol.[20] Because ethanol has only two-thirds the energy content of gasoline, that's equivalent to $1.50-$1.80 per gallon of gasoline (wholesale), or $50-$60 per barrel of oil. At that price of corn, ethanol is competitive with gasoline, including the current subsidy for gasoline blenders when oil costs $30 a barrel or more. It is economically competitive with gasoline without a subsidy when oil costs $50 a barrel or more.[21]

It takes a little more than a third of a bushel of corn to make a gallon of ethanol, so, if the cost of corn rises from $2 to $3 a bushel, that adds about 35 cents to the cost of a gallon of ethanol.[22] At $1.50 a gallon, ethanol competes with gasoline without a subsidy when oil costs $70 a barrel or more.[23] Corn prices spiked upward at the end of 2006 and reached $4 per bushel, but it remains to be seen if that is a temporary phenomenon.

In 2006, crude oil prices ranged from $54 to $74,[24] and wholesale gasoline prices ranged from $1.87 to $2.46 a gallon[25] as retail gasoline prices ranged from $2.28 to $3.08 a gallon.[26]

In the 2006 *Annual Energy Outlook*, the U.S. Energy Information Administration increased its oil price forecast by $20 a barrel over the next 20 years, relative to its prior-year forecast, as the chart below shows.[27] The price is now not projected to fall below $49.64 during that time.[28]



The red line on top shows the higher oil prices contained in the 2006 *Annual Energy Outlook*, compared to the 2005 forecast in blue.

It is important to note that the market price of ethanol does not always reflect the cost of production. As oil refiners abandoned the substitute MTBE in 2006, ethanol demand increased. Ethanol prices rose to match or exceed gasoline prices[29] without any major changes in production costs (although corn prices rose late in the year). In addition, most ethanol is sold under long-term contracts, so the spot price of ethanol may not represent typical transactions. Ethanol prices are expected to decline with the increase in production capacity and the accompanying competition.[30]

How do the ethanol subsidy and tariff work?

The federal government provides a tax incentive to gasoline blenders (not ethanol producers) to encourage the use of ethanol. This subsidy affects how ethanol's competitiveness with gasoline. For example, gasoline blends containing 10% ethanol earn a tax credit of 5.1 cents per gallon. In effect, the blenders can pay up to 51 cents more for a gallon of ethanol than the equivalent amount of gasoline and still break even.[31] This tax break is called the Volumetric Ethanol Excise Tax Credit. Its cost to the government ($2.5 billion in 2006) is offset by savings in crop payments to farmers. In 2006 high corn prices caused by ethanol demand reduced farm support payments by roughly $6 billion.[32]

A tariff of 54 cents a gallon is imposed on most foreign ethanol. The tariff is meant to counterbalance the ethanol tax credit and ensure that foreign producers are not subsidized. Significant exemptions were created by the Central America Free Trade Agreement. More than 700 million gallons of ethanol were imported in 2006, a five-fold increase from 2005.[33]

Some states do pay production subsidies directly to ethanol producers, but the federal tax credit for ethanol is paid to gasoline blenders, not ethanol producers. Small producers receive an additional production income tax credit of 10 cents per gallon on up to 15 million gallons of production annually.[34]

What about subsidies for farmers?

Corn growers receive government support if the price of corn falls below a certain level,[35] which encourages production. High levels of production keep the market price low, making ethanol more economically competitive by reducing the cost of corn. On the other hand, ethanol production reduces farm payments because the increased demand for corn causes its price to rise. (It also increases taxable farm income.)

Tidbit

Animals consumed most of the corn produced in the U.S. in 2005 – 54.5% of 11 billion bushels. The rest went to exports (18.2%), ethanol (14.7%), and domestic food consumption (12.4%).[36]

How efficient is ethanol at displacing oil?

Every gallon of ethanol requires a small amount of petroleum, mostly for farming. The equivalent of 5-8% of the energy in ethanol goes to such uses as diesel for farm tractors, fuel to ship corn to a processing plant, and more fuel to ship the finished ethanol to a pump.[37] Most of the energy used at a processing plant comes from natural gas or coal. Thus, ethanol is highly effective at displacing oil; just one gallon of oil is required to make 12-20 gallons of ethanol.[38] On this point, it makes little difference whether the ethanol is made from corn, sugar cane, or cellulose.

Does ethanol have a positive or negative "energy balance"?

The term "energy balance" refers to the difference between the amount of fossil energy needed to produce a fuel and the energy the fuel contains. It takes energy to transform any product from one form into another.[39] (For example, electricity contains less than 40% of the energy of the coal used to make it.[40]) For every unit of energy delivered at the pump, corn ethanol requires 0.76 units of fossil energy, and gasoline requires 1.22 units.[41] The use of ethanol thus results in the consumption of 40% less fossil energy than the gasoline it replaces.[42] Papers by a Cornell entomologist and a Berkeley petroleum geologist have asserted a more negative view of ethanol and have received much attention – but their methodology has been disputed by their peers.[43]

Most of the fossil energy consumed in making corn ethanol goes to processing the feedstock – from cooking and distilling to drying the distillers grains. Very little fossil energy is needed to make ethanol if renewable energy is used for processing. For example, in Brazil, sugar cane waste, known as "bagasse," is used for boiler fuel. Thus Brazilian ethanol contains eight times more energy than was required to make it.[44] Ethanol from cellulose is expected to have a similar fossil energy balance (and therefore greenhouse gas balance). In one assessment, cellulosic ethanol from wood residue required 0.16 units of fossil energy per unit of delivered energy; corn stover required just 0.09 units.[45] The fossil energy balance of corn ethanol would improve if corn stalks, wood waste, or methane from cattle manure were used for its process heat, as a couple of U.S. facilities already do.[46]

How is ethanol transported?

Ethanol in the U.S. is transported mostly by truck, train, and barge, unlike oil, which is generally transported through pipelines. Unlike oil, ethanol mixes with water. Because water accumulation in pipelines is a normal occurrence, unless the pipeline is cleaned out and made watertight, transporting ethanol in a pipeline risks making it unusable as a fuel.[47]

Given the time and resources required to make oil pipelines suitable for ethanol, as well as the diffuse sources of U.S. ethanol supply, it currently makes more sense to transport the fuel in other ways.[48] However, as production of ethanol increases, it may make sense to make the investment needed to "dry out" pipelines, [49] or new water-tight pipelines may be built, as they are in Brazil.[50]

The Facts About Biofuels: Ethanol from Cellulose

What is cellulosic ethanol, and how is it made?

Cellulose is the fiber contained in leaves, stems, and stalks of plants and trees – the most abundant organic compound on earth.[51] Unlike corn and sugar – the plants now used to make most ethanol – cellulose is not used for food, and it can be grown in all parts of the world. Cellulosic ethanol is expected to be less expensive and more energy-efficient than today's ethanol because it can be made from low-cost feedstocks, including sawdust, forest thinnings, waste paper, grasses, and farm residues (e.g., corn stalks, wheat straw, and rice straw). Switchgrass and other perennial grasses, in particular, are considered to be promising sources of cellulosic ethanol. Perennial grasses are less expensive to produce because they don't have to be replanted each year. Fast-growing woody crops, such as poplar and willow, are also attractive options because of harvesting and storage advantages.

Ethanol can be made from cellulose much as it is today from corn – once the very tightly bound sugars in the plant fiber are broken down by enzymes. Accomplishing this task at low cost has been the principal obstacle to commercial development.

The enzymes needed to break cellulose down into fermentable sugars are genetically improved natural organisms. One such fungus, *Trichoderma reesei*, plagued U.S. troops with jungle rot that "ate" their clothing in the South Pacific during World War II.[52] Another promising source of enzymes is termite guts. Termites, after all, sustain themselves by converting woody biomass to sugars.[53] Thanks to biotechnology, the cost of such enzymes is dropping rapidly, down 30-fold in the last five years – to 10-18 cents per gallon of ethanol produced.[54]

Acid can also be used to break down cellulose, or, alternatively, cellulose can be heated and turned into a gas that can be converted into biofuels – even bio-gasoline.[55]

Tidbits

Termites are one of the planet's most abundant creatures. There are more than 2,500 species.[56] The termites' digestion process is fast and efficient – typically achieving 95% conversion in 24 hours or less.[57]

U.S. Patent No. 5,000,000 was awarded to University of Florida Professor Lonnie Ingram in 1991 for using an E. coli bacterium to metabolize multiple sugars and make ethanol.[58]

What are the commercial prospects for cellulosic ethanol?

The success of cellulosic ethanol will depend on how fast the technology is commercialized and how much it costs compared to the alternatives. These are some of the promising recent developments:

- U.S. Secretary of Energy Samuel Bodman has set a goal of making ethanol a practical and cost-competitive alternative by 2012 (at $1.07 a gallon) and displacing 30% of gasoline (60 billion gallons) by 2030.[59]
- A Canadian company, Iogen, which specializes in industrial enzyme production, is operating a small pilot plant in Ottawa and is planning to build a commercial plant in Idaho, both operating on wheat straw.[60]
- U.S. ethanol producer Broin intends to convert one of the six corn-to-ethanol plants that it currently operates in Iowa into a biorefinery that will use both corn grain and stover – the stalk, leaves, and cobs that come with the grain. DuPont and Novozymes are partners in the project.[61]
- A Spanish company, Abengoa, is building a cellulosic ethanol plant in Spain, using wheat straw,[62] and is planning another unit for York, Neb., using corn stover and distillers grains.[63]
- An independent analysis prepared for the National Commission on Energy Policy predicts, "Advanced biofuels production facilities could produce gasoline alternatives at costs equal to between $0.59 and $0.91 per gallon of gasoline by around 2015."[64]

What are the advantages of cellulose as a feedstock?

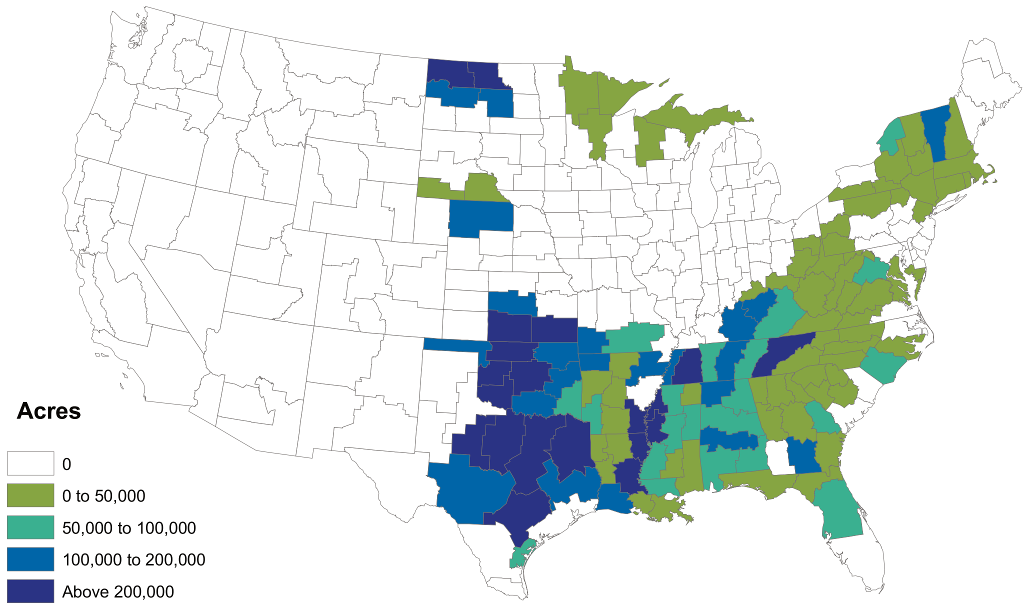
The chief advantage of cellulose is its abundance. Indeed, cellulose is estimated to make up half of all the organic carbon on the planet.[65] In the U.S., ethanol production from corn is expected to hit a limit of 15 to 20 billion gallons per year.[66] Additional feedstocks will be needed to replace a larger share of gasoline demand, now running at 140 billion gallons per year.

A second advantage to processing cellulosic biomass is that it also contains lignin, a natural fiber. Lignin can not be converted to ethanol but can serve as an energy-rich boiler fuel. There is enough lignin in plants to provide all the energy needs of an ethanol production facility, with electricity left over for sale to the power grid.

What is switchgrass?

Switchgrass (*Panicum virgatum*), shown at right,[67] is a prairie grass native to the United States known for its hardiness and rapid growth. It was once part of the tall-grass prairie that covered most of the Great Plains and also grew in Alabama and Mississippi.[68] Because it is native, switchgrass is resistant to many pests and plant diseases and is

The predicted distribution of switchgrass cultivation at a market price of \$40 per ton.[71]



capable of producing high yields with relatively low applications of fertilizer and other agricultural chemicals. It is also tolerant of poor soils, flooding, and drought. Half the plant's carbon is stored in its root system, improving soil quality and preventing erosion. It is an approved cover crop for land protected under the federal Conservation Reserve Program.

President Bush praised switchgrass in his 2006 State of the Union address[69] for its potential as a biofuel source. It can yield 6 to 8 tons per acre, compared to 4 tons per acre for corn, and progressive breeding could double that yield over time.[70]

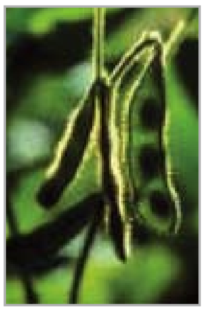
Other perennial grasses may be even more productive than switchgrass, depending on the climate. Miscanthus, shown at right,[72] is one such example. Tests in Illinois suggest that it could yield 11 to 17 tons per acre.[73] Recent research also suggests that mixed prairie grasses may be more productive than monocultures.[74]

In addition to grasses, some fast-growing trees are prodigious producers of biomass, including poplar, willow, sweetgum, and cottonwood.[75]

The Facts About Biofuels: Biodiesel

What is biodiesel, and how is it made?

Biodiesel is a fuel made mostly from crops with seeds that contain oil. Oilseed crops in the U.S. include soybeans and canola (called "rapeseed" in Europe). In tropical regions, palm and jatropha are promising oilseed crops. Palm trees are abundant oil producers, but, in some places, native forests have been cleared to allow their cultivation, raising environmental concerns. Jatropha bushes grow well under adverse conditions and are seen as a tool to fight desertification.[76] Biodiesel can also be made from used cooking oil and animal fats.



Soybean plant[77]

Canola plant[78]

African palm tree[79]

Jatropha bushes[80]

Raw vegetable oil is turned into biodiesel through a chemical process called transesterification that separates out glycerin for use in soaps and other products and leaves behind methyl esters (the technical term for biodiesel). The process can also produce valuable by-products. For example, for each pound of soybean oil crushed out of the beans, more than four pounds of a high-protein animal feed called "meal" is created.[81]

U.S. biodiesel production is growing rapidly, from 28 million gallons in 2004 to 91 million gallons in 2005.[82] That is still only 0.15% of the U.S. diesel market and less than 10% of the 1 billion gallons produced in Europe,[83] but production in 2006 was estimated at 245 billion gallons.[84]

How is biodiesel used?

Biodiesel can be used in diesel engines as a pure fuel or blended with petroleum with little or no modification. In the U.S., biodiesel is usually blended with petroleum at low levels, from 2% (B2) to 20% (B20). But in other parts of the world such as Europe, higher-level blends — up to B100 — are used.[85]

Tidbit

In 1897, Rudolf Diesel demonstrated his first engine – running on peanut oil.[86]

How does biodiesel compare to conventional diesel?

Biodiesel typically has a higher cetane rating than petroleum diesel.[87] The cetane rating is a measure of diesel's combustion quality – similar to an octane rating for gasoline.

Biodiesel also has better lubricity – a measure of lubricating properties – than current low-sulfur petroleum diesel and much better lubricity than the ultra-low-sulfur petroleum diesel introduced in 2006. This quality makes it attractive for blending. Lubricity is important for fuel injectors and some types of fuel pumps. A 1 or 2% blend of biodiesel in low-sulfur petroleum diesel improves lubricity substantially.[88]

At low temperatures, diesel fuel can clog fuel lines and filters in a vehicle's fuel system. At even lower temperatures, diesel fuel becomes a gel that cannot be pumped. The performance of biodiesel in cold conditions is markedly worse than that of petroleum diesel, and biodiesel made from "yellow grease" sources such as french fry oil is worse than soybean biodiesel. However, additives can be used to alleviate these problems.[89]

Because the energy content of biodiesel is roughly 10% lower than that of petroleum diesel, B20 has very slightly lower power, torque, and fuel economy,[90] although some users have seen gains in fuel economy, possibly due to the increased lubricity.[91]

Biodiesel dramatically reduces most emissions, including carbon dioxide. A recent analysis of biodiesel emissions found a life-cycle greenhouse gas reduction of 41%.[92] However, the effect of biodiesel on emissions of nitrogen oxides (NOx), which lead to smog formation, remains unclear. Engine tests have shown an increase of more than 13% for pure biodiesel and nearly 3% for B20,[93] but some on-road tests have shown a decrease.[94]

How much does it cost to make biodiesel, and how big is the market?

Biodiesel from soybeans costs an estimated $2 to $2.50 per gallon to produce. Biodiesel from yellow grease is about $1 a gallon cheaper, but the available supply in the U.S. is much smaller – enough to make 100 million gallons per year.[95] Producers of biodiesel from pure vegetable oil are eligible for a federal excise tax credit of $1 for every gallon blended with conventional diesel.[96] Biodiesel from used cooking oil earns a credit of 50 cents per gallon.

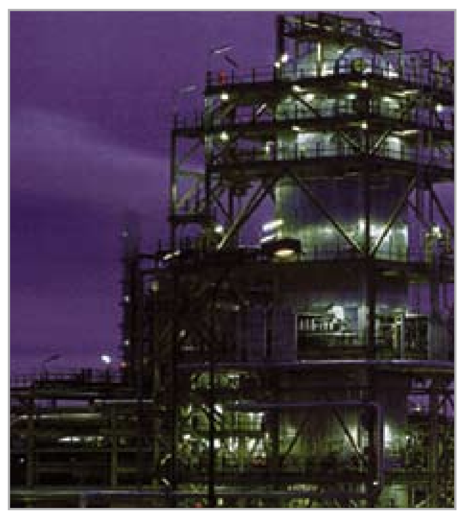
Attempting to use domestic fats and oils to replace a large share of the 60 billion gallons of diesel consumed in the U.S. each year could quickly exhaust available feedstock supplies and push vegetable oil prices significantly higher, due to the steady demand for vegetable oils in food consumption.[97] According to one analysis, the U.S. could produce 300 to 350 million gallons of biodiesel from animal fats and greases and soybean oil without major disruption of soybean oil markets but would need to utilize other feedstocks or import other oils to expand biodiesel production much beyond this level.[98] The largest markets for biodiesel probably will be as a lubricity additive, as a cetane booster, and in situations where low emissions are highly valued, such as school and transit buses.[99]

Verbatim:

> "I think what we're doing will be a light at the end of the tunnel for farmers everywhere."
>
> *– Singer Willie Nelson, promoter of BioWillie biodiesel* [100]

Can biodiesel be made from other sources?

Biodiesel is defined in U.S. law as "monoalkyl esters of long chain fatty acids derived from plant or animal matter."[101] However, it is possible to make renewable diesel from other organic materials, through thermal conversion processes, or even directly from algae. These technologies enable the use of abundant, low-value feedstocks, including municipal waste and even smokestack emissions.



Sasol Fischer-Tropsch reactor [106]

The Fischer-Tropsch process can produce a high-quality diesel fuel from biomass, as well as from fossil fuels.[102] For the past 50 years, Fischer-Tropsch fuels have powered some of South Africa's vehicles; the company Sasol produces more than 150,000 barrels a day from domestic low-grade coal.[103] The fuel is said to be competitive with oil that costs more than $40 a barrel.[104] The first commercial-scale Fischer-Tropsch plant using biomass, with a capacity just over 4,000 barrels per day (60 million gallons per year), is planned to begin operation in Germany after 2008.[105]

Thermal conversion is a general term encompassing various forms of pyrolysis, such as that used to make charcoal out of wood. Pyrolysis uses heat and pressure to break apart the molecular structure of organic solids – any kind of organic solids. One variant, known as "thermal depolymerization," is being used to convert turkey offal into bio-based crude oil at ConAgra's Butterball turkey plant in Carthage, Mo., by a company called Changing World Technologies.[107] Production costs are reported at $80 a barrel but would be lower if the company received a "tipping fee" for disposing of a waste product.[108]

Another promising technology captures smokestack emissions of carbon dioxide for use in an "algae farm," where the gas stimulates the rapid growth of algae that can be converted into biodiesel and ethanol. GreenFuel Technologies first tested the process on a 20-megawatt cogeneration facility at the Massachusetts Institute of Technology in 2004 and then commissioned a second, larger unit in 2005 at a 1,060-megawatt power plant in the southwest United States. According to the company, the results suggest that every acre of the algae farm would yield 5,000 to 10,000 gallons of biodiesel annually and a comparable amount of ethanol.[109]

The Facts About Biofuels: Other Alcohols and Ethers

Alcohols are a family of chemicals with slightly different properties, depending on the number of carbon atoms. A molecule of methanol has a single carbon atom, ethanol has two, and butanol four. Because of this, butanol has a higher energy content (92% of that of gasoline) than ethanol or methanol.

It is impossible to predict at this point whether any of these three, or some combination, will become a dominant and preferred fuel option. All can be made from renewable biomass, however, and thus all have a similar potential to reduce oil consumption and improve environmental quality.

What is biobutanol?

Biobutanol – butanol made from biomass – can be produced with the same feedstocks as ethanol but with a modified fermentation and distillation process. Butanol can be used in standard vehicles in gasoline blends up to 16%, and it can be distributed by pipeline more easily than ethanol, because it mixes less easily with water. Like methanol, it is poisonous. Butanol can also enhance low-level ethanol blends by reducing their evaporative emissions. Unlike ethanol, butanol can be easily blended with diesel.[110] Recently, BP and DuPont announced that they would partner to produce a "next generation" of biofuels, beginning with biobutanol in 2007.[111]

What is methanol?

Methanol is commonly called "wood alcohol." It can be made from biomass but is now chiefly made from natural gas. Production of methanol is one way to make use of remote natural gas that might not otherwise be brought to market. It has about half the energy content of gasoline and about three-fourths the energy content of ethanol.

Like ethanol, methanol is a high-octane, high-performance fuel used by race car drivers. Both methanol and ethanol can be used with higher compression ratios than gasoline. This can result in an increase in horsepower of up to 15%.

The U.S. methanol industry has shrunk from 18 production facilities producing 2 billion gallons of methanol per year in 1998 to four facilities producing 300 million gallons of methanol in 2005. Giant facilities are being built where there is access to cheaper natural gas, including Trinidad and Tobago, Chile, Venezuela, and Oman. The fastest-growing market for methanol in the world is in China, which plans to build as many as 80 coal-based methanol facilities.[112]

Tidbits

Unlike grain alcohol, methanol is not suitable for drinking. Indeed, its toxicity has led to concern about its suitability for widespread commercial use. (Fuel ethanol is made undrinkable by the addition of 2-5% gasoline.)

Methanol fuel cells are seen as a possible longer-lasting alternative to batteries for laptop computers and other consumer electronics.[113]

What is MTBE? What is ETBE? How are they different?

Bio-based alcohols can be blended with isobutylene (derived from petroleum or natural gas) to make liquid fuels called ethers – methyl tertiary butyl ether (MTBE) from methanol or ethyl tertiary butyl ether (ETBE) from ethanol. These ethers are attractive blending components because of their high octane and because in blends they reduce the volatility of gasoline, decreasing evaporation and smog formation.[114] In addition, gasoline blended with ethers can be shipped through conventional oil pipelines.[115]

For many years lead was used to increase the octane of gasoline, and, when it was phased out for health reasons, oil companies chose to replace it with MTBE, starting in 1979.[116] The use of MTBE increased in 1992 with the introduction of new clean-air requirements.[117] Unfortunately, MTBE does not biodegrade easily and has been found in ground water throughout the country. In some instances it has contaminated sources of drinking water.[118] Even low levels of MTBE can make drinking water supplies undrinkable due to its offensive taste and odor. As a result, in September 1999, the EPA Blue Ribbon Panel on Oxygenates in Gasoline recommended that the use of MTBE be reduced substantially (with some members supporting its complete phase-out).[119]

Several states banned the use of MTBE, and oil companies sought legal protection against lawsuits involving MTBE. When Congress failed to provide that protection in the Energy Policy Act of 2005, the oil industry largely abandoned MTBE and turned instead to ethanol.

ETBE is another alternative and is used elsewhere, notably in France. However, ETBE has not yet been adopted in the U.S., perhaps because of uncertainty about its persistence in the environment and concerns about its effect on ground water.

The Facts About Biofuels: Usage Today

Can I use ethanol or biodiesel in my car or truck? How will it run?

Low-level ethanol blends (10% or less) are approved by manufacturers for use in any automobile in the U.S. There is no noticeable difference in vehicle performance when these blends are used, apart from a slight reduction in vehicle fuel economy because of the lower energy content of ethanol.[120] In general, ethanol can corrode certain materials, and the use of higher-level blends, such as E85, may void conventional vehicles' warranties. These drawbacks can be overcome by inexpensive modifications at the time of manufacture to produce flexible-fuel vehicles.

All diesel engines can run on 100% biodiesel, though it is typically sold in lower-level blends of 2%, 5%, or 20%. In theory, adding biodiesel should slightly reduce fuel economy, power, and torque. In practice, low-level blends are practically indistinguishable from conventional diesel. Biodiesel also has superior lubricity, which reduces wear and tear on the engine and can increase the life of engine components.[121] Manufacturers are gradually certifying their engines to operate on biodiesel blends. B5 is commonly accepted, and B20 is coming into use. DaimlerChrysler recently approved the use of B20 in Dodge Ram pickup trucks.[122]

What are flexible-fuel vehicles? Are they practical to manufacture?

Flexible-fuel vehicles are vehicles that can run on blends of up to 85% ethanol (known as E85) and straight gasoline. Therefore consumers can refill their tanks with gasoline if ethanol is not available. This choice of using either E85 or gasoline introduces a new kind of competition into the fuel market. FFVs are otherwise indistinguishable from their gasoline-only counterparts. Henry Ford's Model T was an early FFV.

According to U.S. automakers, the additional cost to manufacture an FFV is less than $200. Because automakers receive fuel economy credits for selling FFVs, they have typically sold FFVs for the same price as a conventional vehicle.

In Brazil, more than 80% of all new cars sold – a million cars a year – are FFVs capable of using 100% ethanol,[123] and Volkswagen will no longer sell gasoline-only vehicles there.[124] Ethanol supplies roughly 40% of the country's non-diesel fuel.[125]

U.S. automakers predict that they will have sold 8 million FFVs by 2008. If they all run on E85, it would reduce U.S. gasoline consumption by 4.5 billion gallons a year.[126] A survey in May 2006 found that two-thirds of U.S. consumers are familiar with FFVs, and more than half are interested in buying one.[127]

Because E85 is not widely available, automakers calibrate FFVs to work equally well on gasoline. If E85 becomes a preferred fuel, however, FFVs could be optimized to take advantage of the high octane content of ethanol – improving performance and fuel economy. The Saab 9-5 Bio-Power, shown at right, delivers 20% more power and 18% more torque when it is running on E85 than when it is running on gasoline, simply because it uses a turbocharger.[128]

Is my car a Flexible-Fuel Vehicle (FFV)?

Your car may be an FFV – an estimated 6 million, including sedans, SUVs, pickups, and minivans, are on the road today.[129, 130] These include models from DaimlerChrysler, Ford, GM, Mercedes, and Nissan. If the owner's manual does not make it clear, you may need to check your vehicle identification number to see if you're driving an FFV.[131] Some of the specific models being manufactured as FFVs include the Dodge Caravan, the Ford Taurus, and the Chevy Tahoe. Toyota is reported to be planning to introduce FFV models in the U.S.[132]

An FFV gas cap

Where can I find a station with biofuels? What happens if I can't get there?

E85 refueling stations are listed on the Internet,[134] but their scarcity remains a major obstacle to use of the fuel. Only about 1,000 of the nearly 170,000 gas stations in America sell E85, and most of those stations are located in the Midwest.[135] The number is expected to grow as service station owners take advantage of tax incentives to install the tanks and pumps needed to sell E85. A similar number of filling stations – more than 800 – sell biodiesel.[136] All FFVs can run on regular gasoline when E85 is unavailable. Likewise, all diesel engines can run on traditional diesel fuel if biodiesel is not available.

Can I have my vehicle converted to an FFV?

This is not recommended. The parts are not expensive, but it requires taking apart the engine and would void the warranty.[138]

A biofuels pump: B20, E85, E10[137]

Can I use biofuels in a hybrid?

When it unveiled a prototype flexible-fuel hybrid Escape in 2006, Ford became the first auto manufacturer to build an E85-compatible hybrid as a concept vehicle.[139] Such a car, running on E85, would travel about four times farther on a gallon of gasoline than a standard hybrid – more than 110 miles per gallon. A flexible-fuel Prius, starting with a higher fuel economy, would go nearly 190 miles on a gallon of gasoline.[140] But no such cars are available on the market today.

Verbatim:

"Biofuels represent a huge opportunity to reduce fuel consumption and our dependence on foreign oil."

– Chrysler Group President and CEO Tom LaSorda [141]

"We've got on the road today about a million and a half [GM] vehicles that are capable of using E85. So we can stretch oil by a factor of six times, if you think of it that way. All of our new trucks will be ethanol-powered, so we add to the fleet at the rate of about 400,000 units each year. And we can do a lot more than that."

– GM Chairman Rick Wagoner [142]

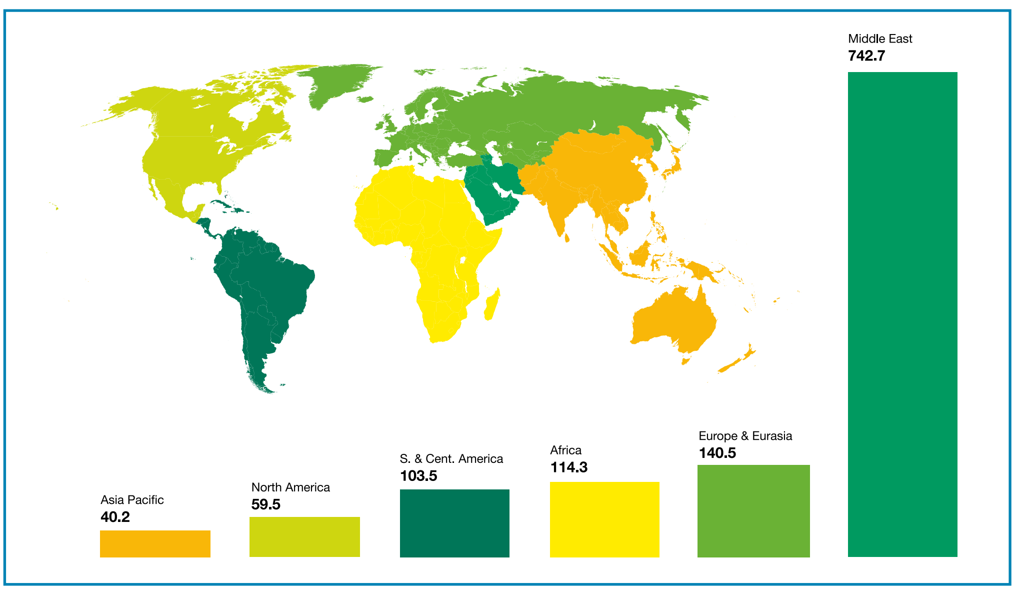
"If we want a game changer, and a game changer in very short term and in big numbers, then ethanol is a very good play for this country."

– Ford Chairman Bill Ford [143]

The Benefits of Biofuels: Oil Dependence and National Security

How dependent is the U.S. on foreign oil?

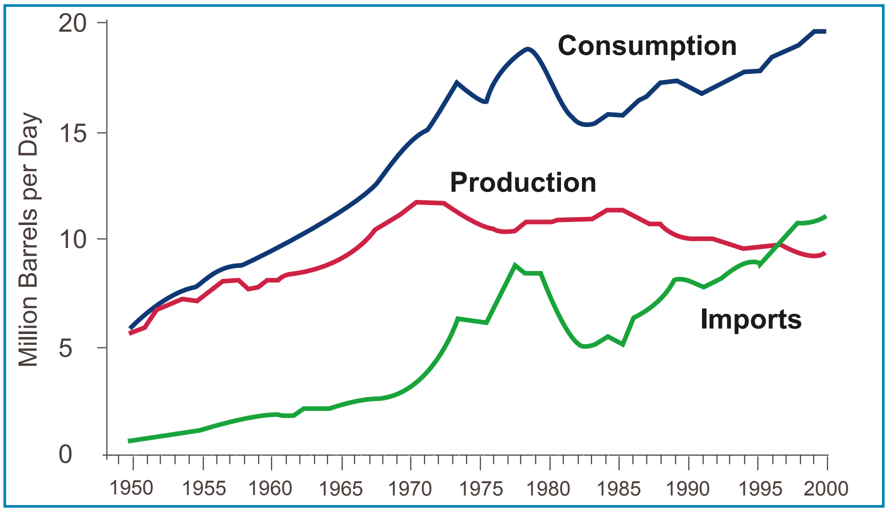
The U.S. consumes 25% of the world's oil annually,[144] but has only 2% of the world's reserves.[145] As shown below, 62% of the world's proven oil reserves are located in the Middle East.[146] As a result, world oil production increasingly will be centered in that region.



Verbatim:

"Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world."

– President George W. Bush[147]



U.S. oil imports have steadily climbed as consumption increases and domestic production declines, as shown above.[148] Imports now supply about 60% of total U.S. consumption.[149]

What does oil dependence have to do with national security?

Transportation accounts for about two-thirds of all U.S. petroleum use,[150] and oil supplies 96% of the energy consumed by transportation.[151] Thus, the U.S. transportation sector could not operate without oil.

This dependence translates into military and foreign policy risks because of the importance of protecting access to needed oil reserves in unstable areas. President Jimmy Carter put it clearly in the 1980 State of the Union address when he said: "An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force."[152]

Verbatim:

"The prices that people are paying at the gas pumps reflect our addiction to oil. Addiction to oil is a matter of national security concern … [S]ome of the nations we rely on for oil have unstable governments, or agendas that are hostile to the United States. These countries know we need their oil, and that reduces our influence, our ability to keep the peace in some areas. And so energy supply is a matter of national security."

– President George W. Bush[153]

The oil trade has resulted in an enormous transfer of wealth to oil-producing states – half a trillion dollars in 2006 alone.[154] This cash flow has financed corrupt and repressive regimes opposed to American interests. Columnist Thomas Friedman and others have observed that there is "an inverse relationship between the price of oil and the pace of freedom," and that the U.S. is "funding both sides in the war on terrorism."[155]

Unfortunately, diversifying the sources of U.S. oil supply does not materially affect the economic risks of dependence. Because oil is a global commodity, freely traded, the price of oil is determined on the world market. It responds to the forces of supply and demand and to political events, no matter where they occur. Even if the U.S. shifted all of its oil imports to relatively safe sources, such as Canada and Mexico, it would not be protected from a price shock – whether caused by politics, war, or terrorism. The only way to reduce the risks associated with oil is to reduce the demand for it – in other words, to increase the efficiency of oil consumption and increase the use of alternative fuels.

Could domestically produced biofuels replace imported oil?

Biofuels could significantly reduce the amount of oil needed to fuel American cars and trucks, which constitutes two-thirds of the nation's total demand for oil. Together with efforts to improve fuel economy, biofuels could reduce U.S. gasoline consumption to nearly zero.[157]

There is no guarantee that biofuels will directly displace imported oil; biofuels will also displace some domestically produced oil. However, biofuels will give consumers something they have never had – a choice – and thus will be a damper on both the volatility of oil prices and the effect of those swings on the U.S. economy.

Skeptics are quick to point out that the U.S. could not possibly grow enough corn to replace all of the nation's petroleum use. Indeed, the limit of ethanol production from corn is generally estimated to be 15 to 20 billion gallons per year.[158] However, the use of additional feedstocks will allow the replacement of a larger share of gasoline demand, now running at 140 billion gallons per year.

Secretary of Energy Samuel Bodman recently announced a goal of making cellulosic ethanol a practical and cost-competitive alternative by 2012 (at a cost of $1.07 per gallon) and displacing 30% (60 billion gallons) of gasoline by 2030.[159] This is consistent with the joint study published by the U.S. Departments of Energy and Agriculture on the future potential of biomass feedstocks.[160] Others have suggested a goal of 100 billion gallons a year.[161]

Of course, supply provides only half the answer to reduced oil dependence. Increased vehicle efficiency also reduces total oil consumption and enables a given amount of biofuels to displace a larger share of petroleum. Thus, doubling the fuel economy of the vehicle fleet in the U.S. – for example, through the widespread introduction of plug-in hybrids with flexible-fuel capability – would not only reduce by half the amount of oil consumed, it would also double the share displaced by biofuels.[162]

The Benefits of Biofuels: The U.S. Economy

How big an industry could this become?

The U.S. consumes about 140 billion gallons of gasoline a year. That is equivalent to 200 billion gallons of ethanol – because of ethanol's lower energy content. Replacing 25% of current U.S. gasoline use would require about 50 billion gallons of ethanol a year. It is clear that enough cellulosic biomass is available on an annual basis to produce that much fuel and probably much more in the future.[163]

What would that mean for the U.S. economy and jobs?

Economist John Urbanchuk has estimated that producing 10 billion gallons of ethanol a year from corn would add $46 billion to the U.S. economy and create up to 200,000 new jobs.[164] This relationship of employment to production – about 2,000 jobs created for every 100 million gallons produced – is roughly consistent with other studies.[165] Based on that ratio, expanding production to 50 million gallons (enough to replace 25% of current U.S. gasoline use) would add more than $200 billion to the economy and create a million new jobs, both in rural America and in major manufacturing centers.

How soon will this growth occur?

Investment in the biofuels industry has mushroomed in the last two years. According to the Renewable Fuels Association, 78 ethanol production facilities were under construction in early 2007 that will add 6.2 billion gallons of capacity, more than doubling the size of the current industry.[166] According to the National Biodiesel Board, the U.S. biodiesel industry has a capacity of 395 million gallons, with an estimated 714 million gallons of capacity under construction, an increase of 180%.[167]

What is 25x'25?

The 25x'25 Renewable Energy Alliance, a volunteer group of respected national farm leaders, believes that America's farms, ranches, and forests are positioned to make significant contributions to the development and implementation of new energy solutions. The group supports a goal for the country of "25x'25" – producing 25% of the nation's energy from renewable resources by 2025 from the agricultural, forestry, and working land of the United States, while continuing to produce safe, abundant, and affordable food, feed, and fiber.[168]

This vision, which has been embraced by a broad array of agricultural organizations and elected officials, as well as by leading businesses and environmental and labor groups, encompasses wind and solar energy as well as biofuels.

What companies are involved in the biofuels industry?

The following list is meant to be partial and illustrative only.

Corn ethanol	Biodiesel	Advanced biofuels
ADM Cargill Broin	Renewable Energy Group Imperium Renewables Southern States Power	DuPont / BP Iogen / Shell Abengoa
Flex-fuel vehicles	**Enzyme manufacturers**	**Private investors**
GM Ford Daimler Chrysler	Diversa Novozymes Genencor	Vinod Khosla Bill Gates Richard Branson

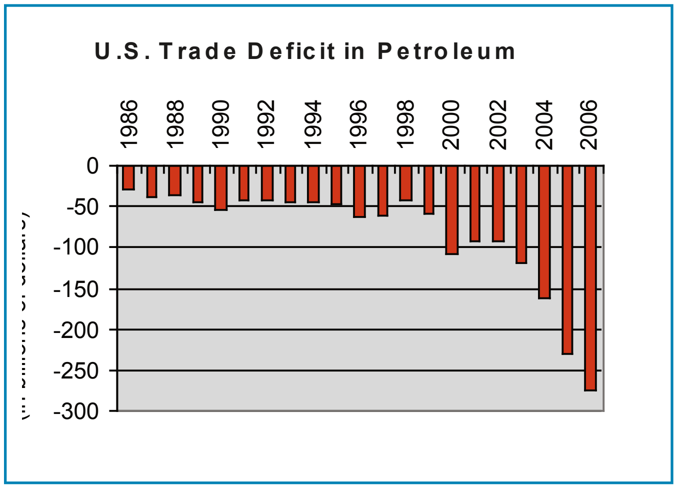
Verbatim:

> "We may be finally willing to build a new energy future. … [This] is the single most significant opportunity we have to create a new generation of high-wage jobs, something we have not done in this decade that we did in the last decade with information technology. We haven't found a substitute in this decade. It's in clean energy."[169]
>
> *– Former President Bill Clinton*

> "There are hundreds of millions of dollars of economical opportunities, and we are not organized for it. And if we gave a pittance of the tax incentive to a clean energy and energy-conservation future we give to old energy, we would create jobs like no tomorrow. People would wonder what the hell we had been wasting all this time for."[170]
>
> *– Former President Bill Clinton*

How much of the U.S. trade deficit is caused by oil imports?

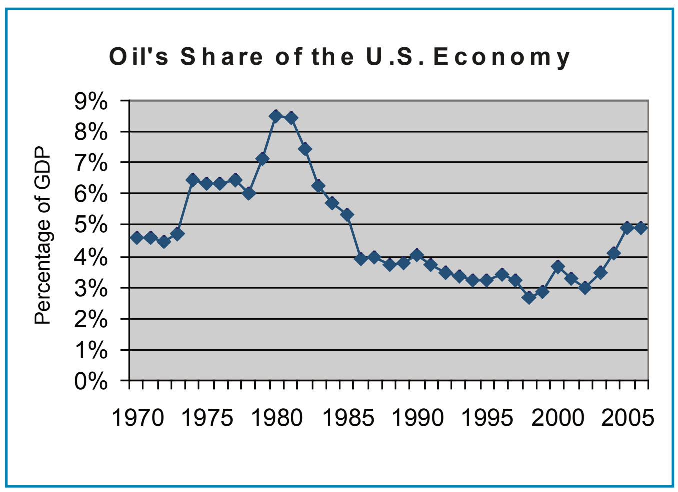
The U.S. trade deficit in petroleum has been rising rapidly, from $50 billion annually in the 1990s to $108 billion in 2000, $163 billion in 2004, $229 billion in 2005, and a projected $274 billion in 2006, as shown at right.[171]



Petroleum's share of the total U.S. trade deficit has been rising even more steeply, from 27% in 2004 to a projected 36% in 2006.[172] To the extent that domestically produced biofuels displace oil imports, they will also reduce the trade deficit, both in petroleum and in total.

What does the price of oil mean to the economy?

The U.S. economy is less vulnerable to changes in the price of oil than it was during the last period of peak oil prices (1979-80), because the U.S. consumes nearly 40% less oil for every dollar of economic output.[173] Prior to the 1973 oil embargo, petroleum expenditures amounted to less than 5% of U.S. gross domestic product. With rising prices, this increased to 8% in 1981 and then fell below 3% in the late 1990s, before climbing back to 5% in 2006.[174]



Economist David Greene has written, "Significant oil price shocks preceded every recession of the past three decades, and every one of the three significant oil price spikes was followed by a recession. Clearly, oil dependence ranks among the most significant economic problems the United States has faced over the past thirty years."[175] However, the oil price rise since 2005 has not had similar effects.

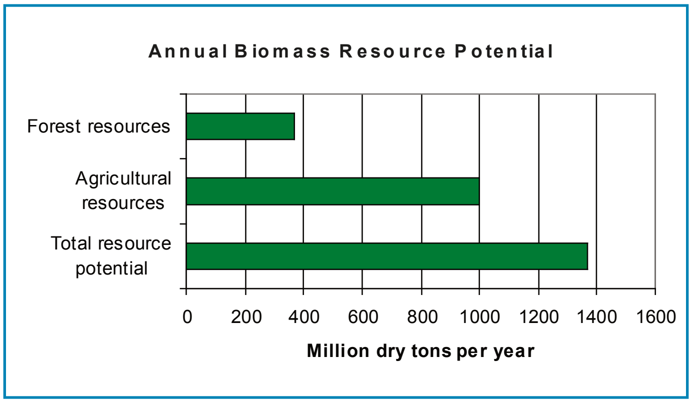
How would biofuels affect the price of oil?

By giving consumers a choice, biofuels introduce competition to the transportation fuels market. If that leads to a decline in oil demand by the United States, it will put downward pressure on world oil prices. This effect would be compounded if other countries also switched to biofuels.

Ironically, a dramatic decline in the price of oil might be counterproductive over the long haul, as it was after the oil shocks of the 1970s. Dropping prices led then to a re-addiction to oil and the abandonment of alternatives. Investor Vinod Khosla and others have suggested that this uncertainty about the future of oil prices is the single most important factor limiting investment in alternative fuels. Thus, some have suggested taking actions that would sustain biofuels prices relative to gasoline in order to encourage major long-term investments.[176]

The Benefits of Biofuels: Agriculture and Rural Economic Development

How much biofuel could the U.S. produce? How much land would it take?



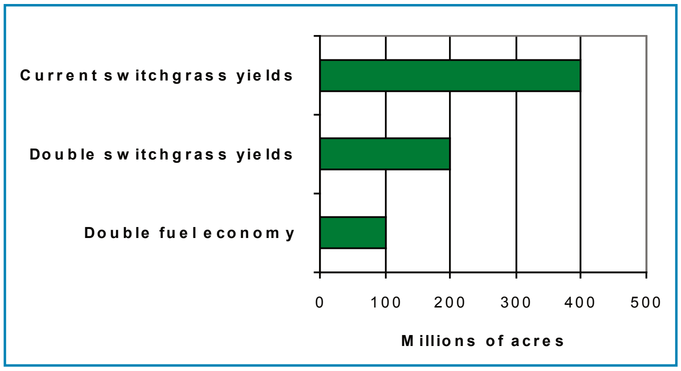
The U.S. could produce enough biomass annually to replace more than one-third of its current oil consumption, while continuing to meet demands for food, feed, and export, a major study found. Analysts at the Oak Ridge National Laboratory in 2005 concluded: “About 368 million dry tons of sustainably removable biomass could be produced on forestlands, and about 998 million dry tons could come from agricultural lands,” including energy crops grown on 55 million acres.[177] That compares to roughly 400 million acres of cropland in the U.S., including 36 million acres held out of cultivation in the Conservation Reserve Program.[178]

Estimates of agricultural yield – tons per acre – are key to projecting U.S. biofuels potential. The current productivity of switchgrass is typically reported as five tons an acre. The Oak Ridge study, looking out to 2030, estimated a yield of eight tons per acre. Most analyses of potential biofuels production have suggested targets of 60-100 billion gallons. At 10 tons per acre – seen as an achievable yield over time because energy crops like switchgrass have not yet been optimized through research – reaching those targets would require 60-100 million acres.[179]

The need for land would be further diminished if energy crops could meet more than one need. Soybeans are currently grown on 73 million acres to provide animal feed and vegetable oil. Switchgrass contains protein that could be extracted for animal feed. Thus, one analysis suggests, "While switchgrass cannot be used to produce vegetable oil, if it can provide a similar financial value to growers and a similar product to meet our animal feed protein needs, then we may be able to convert much of the soybean acreage to switchgrass."[180]

Of course, if the goal is reduced oil dependence, supply is only half of the answer. Increased vehicle efficiency also reduces total oil consumption and the need for biofuels to act as a replacement.[181]

Will there be enough land left for food?

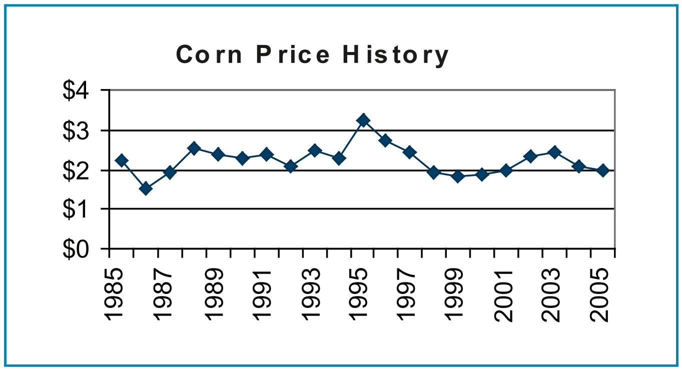


Yes, especially because biofuels can be produced from plants (and parts of plants) that now go unused. American agriculture's problem is not one of shortage but of overproduction – which is why the U.S. has perennial crop surpluses. As the Oak Ridge study found, the U.S. could displace more than one-third of its current oil consumption with biofuels while continuing to meet demands for food, feed, and export. In fact, roughly half of the nation's 2.26 billion acres have some potential for growing biomass.[182]

The perceived food vs. fuel conflict will be mitigated by producing biofuels from non-food crops and materials now considered waste. Potential feedstocks include agricultural residues (e.g., corn stalks and wheat straw, forest residues such as sawdust and wood chips, yard waste, municipal solid waste and even animal wastes). The United States could produce 40 billion gallons of ethanol a year – equivalent to 20% of current gasoline demand – from agricultural residues alone.[183] And crops such as switchgrass can be planted on marginal land, reducing the need to use productive cropland or forests for energy crop production.

Lands now planted for export – currently one out of every three U.S. farm acres – could also be devoted to domestic fuel production.[184]

Will the price of food go up?



The use of agricultural products for energy is not likely to have more than a minor impact on retail food prices. Less than 5% of the cost of corn flakes or corn syrup, for example, stems from the price of corn.[185] Other expenses involved in bringing food to market, including packaging, advertising, and transportation, represent a larger share of costs. Through 2005, as the chart above shows, the demand for ethanol did not have a long-term upward effect on corn prices because of increases in total production; corn prices spiked upward at the end of 2006 and reached $4 per bushel, but it remains to be seen if that is a temporary phenomenon. Corn is an important source of animal feed and thus a significant factor in meat prices. However, the production of ethanol yields a by-product called distillers grains that is a high-protein cattle feed and can replace corn for half of the animal's diet. It is less useful as a substitute for pork and poultry.

Projections of future biofuels production generally include no more than 15 to 20 billion gallons of ethanol from corn.[186] This is not a physical limitation as much as it is an assessment of what is economically practical. For example, the 2005 Oak Ridge study calculated the amount of biomass available after projected demands for food, feed, and export were met.[187]

Will the use of biomass for energy worsen world hunger?

Many experts believe this new demand for agricultural products could actually help ease hunger. Hunger is caused more by a lack of money or distribution than a lack of food. As analyst Jason Clay has noted, "While there is arguably more food per capita being produced in today's world than ever before, hunger and poverty are growing. Over the past 35 years, per capita food production has grown 16% faster than population. Even so, the number of hungry people in every country except China increased by an average of 11% from 1970 to 1990. In Africa, agriculture employs about two-thirds of the labor force, accounts for 37% of GNP, and is responsible for half of exports. Yet, the sector generates insufficient wealth among the rural poor to adequately address hunger."[188]

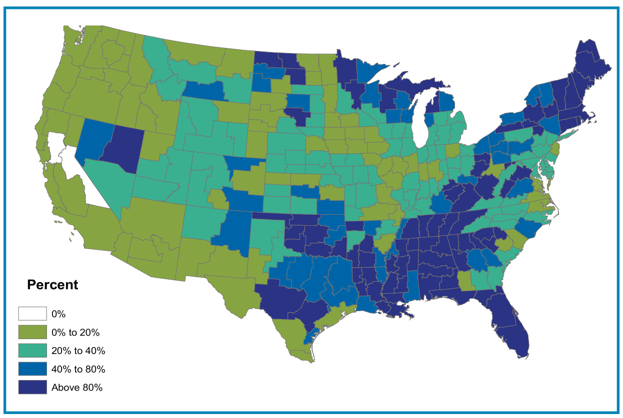
Biofuels could help change all that. In many developing countries, agricultural productivity is held back by a lack of access to fertilizer and equipment. Biofuels could attract investment that would support agricultural improvements across the board, which would benefit food production, accelerate rural economic development, and alleviate poverty and migration to the cities. Higher world crop prices will support farm income. Protein from non-food energy crops may also become available for animal feed just as it is from corn today.

Will there be enough water?

The amount of water needed to produce crops varies considerably. Perennial prairie grasses such as switchgrass are native, hardy, and drought-resistant. They require far less water than intensive row crops. Similarly, jatropha bushes, a source of biodiesel, can survive dry conditions and poor soils. Other grasses require abundant rainfall to thrive. (In the U.S. about 15% of corn acreage is irrigated.[189]) Of course, areas with low rainfall will be less productive than those with higher rainfall. For economic reasons, however, projections of biomass crop production do not include land that needs irrigation.[190]

Processing crops into biofuels also requires water, although much less than is used for irrigating crops. A new 40-million-gallon-per-year ethanol facility needs about 100 million gallons per year of fresh water.[191] This is not an unusual amount for an industrial use, such as a food processing facility. The ethanol industry has reduced its water consumption from 25 gallons per bushel of corn processed in the early 1980s to less than seven gallons per bushel today. Much of the water used in an ethanol production facility is recycled back into the process. However, water supplies are stressed in many areas of the country, and future biofuels production may be limited by access to aquifers and other water sources.

Farm income, rural economic development



Effect of Switchgrass on Major Crop Net Returns

The increased demand for corn for ethanol production clearly has a positive effect on net farm income and also reduces government outlays to farmers by raising the market price of corn. A 2000 USDA study estimated the economic effects on the farm economy if annual ethanol production grew to five billion gallons by 2010. That level of production was projected to increase the price of corn by an estimated $0.32 per bushel and to boost annual net farm income by almost $3 billion. In this scenario, the increase in ethanol production also lowered the U.S. trade deficit, and higher corn prices resulted in lower farm program payments.[192] In 2006 high corn prices caused by ethanol demand reduced U.S. farm support payments by roughly $6 billion.[193]

Production of non-food cellulosic crops will have similar economic benefits for farmers. Growing switchgrass on 40 million acres is predicted to increase net farm returns by $6 billion annually by 2013, while reducing government support payments by nearly $2 billion per year. The benefit will stem in part from increases in traditional crop prices from 9% to 14% as production is shifted away from those crops.[194] The map above shows the projected increase in net returns on major commodity crops from this scenario. The green areas gain up to 40% and the blue areas more than that.[195]

The economic benefits of processing agricultural products into ethanol and biodiesel will provide additional value for rural America. Increasing ethanol production from today's level of 4 billion gallons a year to 50 billion gallons will require construction of nearly 1,000 new production facilities.[196] Because biomass is relatively lightweight and bulky and thus costly to transport, those facilities must be built close to where their feedstock is grown – in rural areas. Conventional dry-mill corn ethanol production facilities are estimated to cost $1.40 per gallon of capacity to construct,[197] and cellulosic ethanol plants are expected to be several times more expensive. This suggests that a capital investment of at least $100 billion will be required.

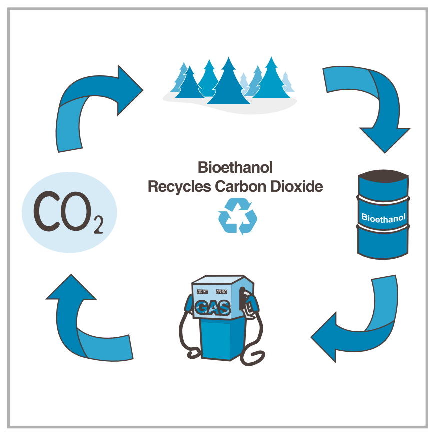
Verbatim:

> "Energy is the new cash crop of rural America."
>
> *– U.S. Secretary of Agriculture Mike Johanns*[198]

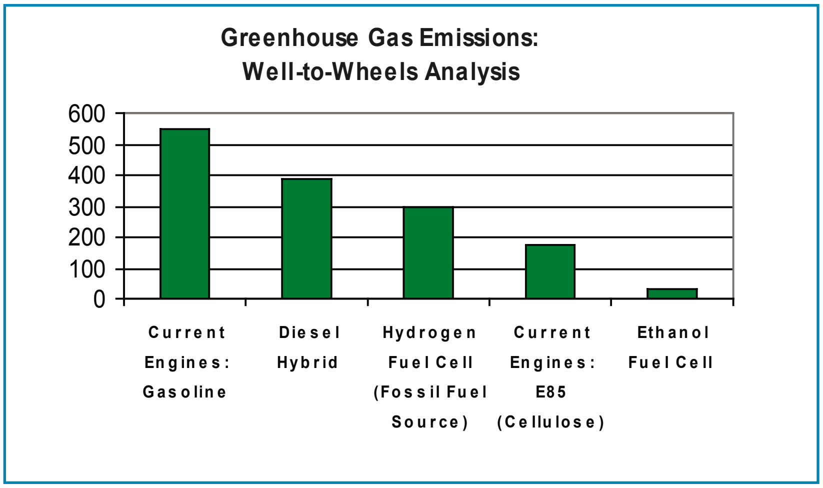
The Benefits of Biofuels: Environment and Public Health

Why do biofuels help prevent global warming?

Engines running on biofuels emit carbon dioxide (CO2), the primary source of greenhouse gas emissions, just like those running on gasoline. However, because plants and trees are the raw material for biofuels, and, because they need carbon dioxide to grow, the use of biofuels does not add CO2 to the atmosphere, it just recycles what was already there. The use of fossil fuels, on the other hand, releases carbon that has been stored underground for millions of years, and those emissions represent a net addition of CO2 to the atmosphere. Because it takes fossil fuels – such as natural gas and coal – to make biofuels, they are not quite "carbon neutral."



Argonne National Laboratory has carried out detailed analyses of the "well-to-wheels" greenhouse gas emissions of many different engine and fuel combinations.



The chart above shows a few selected examples.[199] Argonne's latest analysis shows reductions in global warming emissions of 20% from corn ethanol and 85% from cellulosic ethanol.[200] Thus, greenhouse gas emissions in an E85 blend using corn ethanol would be 17% lower than gasoline, and using cellulosic ethanol would be 64% lower.[201] A separate analysis found that biodiesel reduces greenhouse gas emissions by 41%;[202] thus, a B20 blend would achieve a reduction of about 8%.

Cellulosic ethanol achieves such high reductions for several reasons:

- Virtually no fossil fuel is used in the conversion process, because waste biomass material, in the form of lignin, makes an excellent boiler fuel and can be substituted for coal or natural gas to provide the heat needed for the ethanol process.

- Farming of cellulosic biomass is much less chemical- and energy-intensive than farming of corn.

- Perennial crops store carbon in the soil through their roots, acting as a carbon "sink" and replenishing carbon in the soil. Switchgrass, for example, has a huge root system that penetrates over 10 feet into the soil and weighs as much as one year's growth aboveground (6-8 tons per acre).[203]

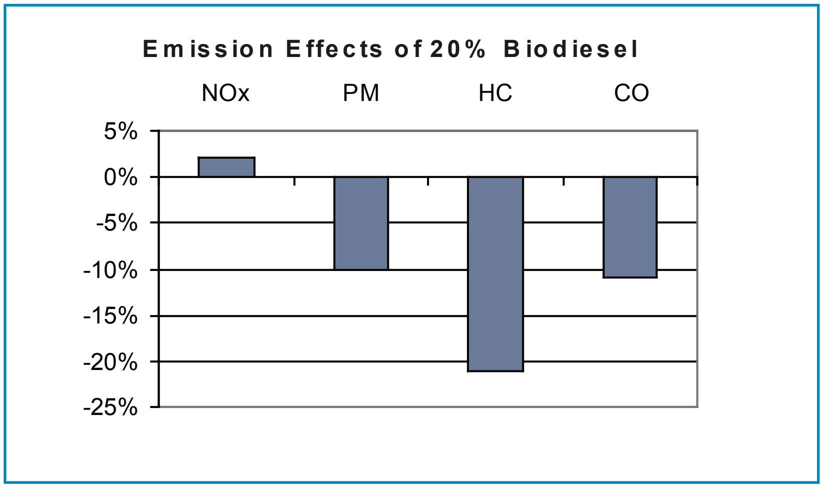
Verbatim:

"Cellulosic ethanol is at least as likely as hydrogen to be an energy carrier of choice for a sustainable transportation sector."

– Natural Resources Defense Council, Union of Concerned Scientists[204]

Are biofuels cleaner than gasoline and diesel?

Compared to conventional diesel fuel, the use of biodiesel results in an overall reduction of smog-forming emissions from particulate matter, unburned hydrocarbons, and carbon monoxide, as shown below. Biodiesel slightly increases nitrogen oxide emissions, by about 2% in a B20 blend.[205] Sulfur oxides and sulfates, which are major components of acid rain, are not present in biodiesel.



As for ethanol, the oxygen atom in the ethanol molecule leads to more complete fuel combustion and generally fewer emissions. E10 blends have been credited with reducing emissions of carbon monoxide by as much as 30% and particulates by 50%.[206] However, mixing low levels of ethanol (2% to 10%) with gasoline increases the blend's tendency to evaporate and contribute to low-level ozone unless the gasoline itself is adjusted.[207] This problem diminishes with higher levels of ethanol. At blends between 25% and 45%, the fuel is equivalent to gasoline, and at higher blends it is less evaporative. E85 has about half the volatility (tendency to evaporate) of gasoline.[208]

The effect of E85 on air quality is almost uniformly positive, with the exception of increased emissions of aldehydes, such as acetaldehyde. Conventional catalytic converters control these emissions in ethanol blends of up to 23%,[209] and it is expected that they could be readily adapted to E85 blends.[210] A test of advanced emission control systems in three conventional gasoline vehicles found that advanced systems reduced formaldehyde emissions by an average of 85% and acetaldehyde by an average of 58%.[211]

Even without advanced controls, the benefits of reducing other toxic emissions outweigh the effects of aldehydes. The National Renewable Energy Laboratory tested a 1998 Ford Taurus FFV running on E85 and reported: "Emissions of total potency weighted toxics (including benzene, 1,3-butadiene, formaldehyde, and acetaldehyde) for the FFV Taurus tested on E85 were 55% lower than that of the FFV tested on gasoline."[212]

Verbatim:

Emissions characteristics of E85*

Actual emissions will vary with engine design; these numbers reflect the potential reductions offered by ethanol (E85), relative to conventional gasoline.

- Fewer total toxics are produced.
- Reductions in ozone-forming volatile organic compounds of 15%.
- Reductions in carbon monoxide of 40%.
- Reductions in particulate emissions of 20%.
- Reductions in nitrogen oxide emissions of 10%.
- Reductions in sulfate emissions of 80%.
- Lower reactivity of hydrocarbon emissions.
- Higher ethanol and acetaldehyde emissions.

** Estimates based on ethanol's inherently "cleaner" chemical properties with an engine that takes full advantage of these fuel properties.*

– U.S. Environmental Protection Agency[213]

How can biofuels reduce toxic compounds in gasoline?

The principal contributor to toxic air pollution from gasoline is a class of chemical compounds called aromatics, which make up an average of 26% of every gallon of gasoline. Blended with gasoline to increase octane, aromatics have the potential to cause cancer, and they also result in emissions of fine particulates and smog-forming gases that harm lung function and worsen asthma.

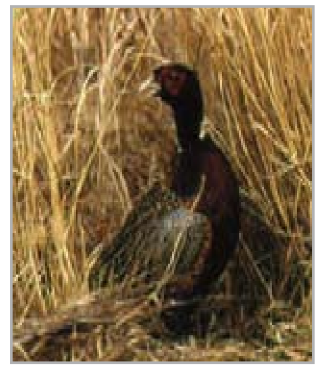
The EPA was required by the Clean Air Act Amendments of 1990 to seek "the greatest degree of emission reduction achievable" of air toxics in automobiles.[214] In response to recent litigation, the EPA issued a rule to reduce one of these hazardous air pollutants, benzene,[215] but the agency did not address the two other aromatic compounds, toluene and xylene, which form benzene during combustion. Using biofuels instead of aromatics to improve octane would result in public health benefits worth tens of billions of dollars from the reduction in emissions of small particles alone.[216]

What effect will the production of energy crops have on the land, water, and wildlife?

Native perennial grasses such as switchgrass had to be tough to survive on the prairie. They are deep-rooted and drought-resistant and require less water than food crops. They also need less fertilizer, herbicide, insecticide, and fungicide per ton of biomass than conventional crops.[217]

Switchgrass is an approved cover crop under the Conservation Reserve Program because it prevents soil erosion and filters runoff from fields planted with traditional row crops. Buffer strips of switchgrass, planted along stream banks and around wetlands, can remove soil particles, pesticides, and fertilizer residues from surface water before they reach ground water or streams.[218]

There are enough varieties of prairie grass and other sources of cellulosic biomass that farmers need not all rely on a single energy crop – so-called monocultures.[219] Indeed, recent research suggests that mixed prairie grasses may be more productive than monocultures. One study found that a diverse mixture of grasses grown on degraded land would yield 51% more energy per acre than ethanol from corn grown on fertile land.[220]



In general, perennial energy crops create more diverse habitats than annual row crops, attracting more species and supporting larger populations. Switchgrass fields are popular with hunters, as they provide habitat for many species of wildlife, including cover for deer and rabbits and a nesting place for wild turkey and quail[221] – and pheasants, as shown at right.[222] As long as farmers avoid work that would disturb the birds during nesting or breeding seasons, their fields will remain popular with wildlife.

The Benefits of Biofuels: International Development

What is the global potential for biofuels use?

Estimates of global potential for biomass that can be converted into fuels vary widely. One recent study concluded that by 2050, biomass theoretically could supply 65% of the world's current energy consumption, with sub-Saharan Africa, the Caribbean, and Latin America accounting for roughly half of this global potential.[223] In tropical countries, high crop yields and lower costs for land and labor provide an economic advantage that is hard for countries in temperate regions to match.[224]

The potential market demand for ethanol and biodiesel also varies widely. While gasoline commands a much larger share of the market in the U.S. than diesel, diesel dominates in Europe and is often the preferred fuel for vehicles in developing countries.[225]

Verbatim:

"The gradual move away from oil has begun. Over the next 15 to 20 years we may see biofuels providing a full 25% of the world's energy needs."

– Alexander Müller, Food and Agriculture Organization of the United Nations[226]

What does the biofuels opportunity mean for other countries?

Many countries, in both tropical and temperate regions, are capable of producing surplus biomass that can be used for energy. For example:

- Brazil and the U.S. are the world's leading producers of ethanol at more than four billion gallons a year each – Brazil from sugar cane, the U.S. from corn.[227] All Brazilian gasoline must contain at least 20% ethanol, which is distributed through a network of more than 25,000 filling stations.[228] Thanks to its oil, ethanol, and hydroelectric resources, Brazil expected to become self-sufficient in energy in 2006, and its ethanol producers say they can compete with oil at $30 a barrel.[229] Brazil is also rapidly developing its biodiesel industry and was a pioneer in introducing flexible-fuel cars, which can run on E100, gasoline, or any mix in between. In the first half of 2006, more than 80% of all new cars sold in Brazil were FFVs.[230] Roughly a million cars a year are sold in Brazil.

- Europe is the world's largest producer of biodiesel, which it makes principally from rapeseed (canola), soy, and sunflower seeds. In 2005, Europe produced nearly a billion gallons of biodiesel (a 65% increase from 2004), about half from Germany alone. Ethanol represented just 20% of the biofuels market.[231]

- China produced about 340 million gallons of ethanol in 2005, most of it from corn.[232] Several provinces have developed E10 blending and refueling infrastructure. The Chinese government is now encouraging ethanol production from non-grain sources such as cassava, sweet sorghum, and sweet potato, and it is supporting R&D into cellulosic ethanol.

- Plans for increased biofuels production are also advancing in Latin America (including Colombia and Peru), Asia (India, Thailand, Malaysia, and Australia), Africa (especially South Africa but possibly also Zimbabwe, Madagascar, Malawi, and Mozambique), and Eastern Europe (Romania, Ukraine, and Russia).[233] For example:
    - ♦ The Indian government has identified nearly 100 million acres of land where jatropha can be grown as a biofuel and hopes to replace 20% of diesel consumption in five years.[234]

- Malaysia, the world's top producer of palm oil, has approved licenses for 52 biodiesel plants with a combined capacity of 1.5 billion gallons a year.[235] (However, the destruction of tropical forests for palm cultivation is a major environmental concern.[236])
- The Australian government has set a target of producing nearly 100 million gallons of ethanol annually by 2010.[237]

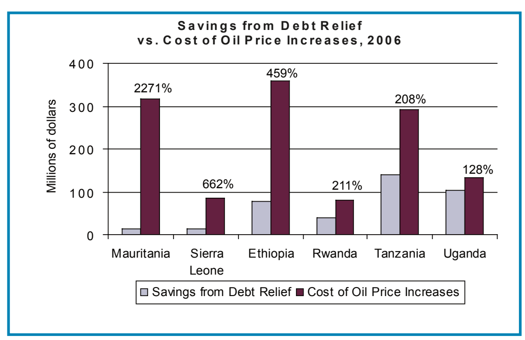
How is biomass used today?

Biomass provides a surprisingly large amount of the world's energy – 10% of total global primary energy consumption – but most of that is wood and charcoal gathered and used in the most primitive ways,[238] as shown at right.[239]

More than 2.4 billion people, generally among the world's poorest, rely directly on wood, crop residues, dung, and other biomass fuels for their heating and cooking needs.[240] In rural sub-Saharan Africa, women carry on average 11 pounds of wood 3 miles every day to meet their household needs for fuel.[241]

Burning this biomass in inefficient stoves or over open flames is in many cases the only way to stay warm or cook a meal – but such stoves are a health and safety hazard. The smoke inhaled while cooking is responsible for more than 1.6 million deaths annually, mostly among women and children.[242] More than half of these deaths occur among children under five years of age. In developing countries with high mortality rates overall, indoor air pollution ranks eighth in terms of the risk factors that contribute to disease and death.[243] Moving away from these dirty uses of biomass is a clear public health priority.

What role does oil play in developing countries?



Oil fuels the transportation sector everywhere, and in many parts of the world it is also used for space heating and power generation. As the price of oil has risen, this dependence has caused heavy economic burdens. Ten years ago, when the world agreed on debt relief for the poorest countries in sub-Saharan Africa, the price of oil was $22 a barrel. Over the last four years, the price has tripled. As shown at right, higher oil prices (calculated at $60 per barrel) now cost Ethiopia, for example, nearly five times as much as it is gaining from debt relief.[244]

What are the implications of biofuels for economic development?

Sustainable biofuel development can help bring modern energy services to more people, particularly in rural areas. It can also foster greater investment in agriculture, which employs 75% of the world's poor. It can create new job opportunities in rural areas and provide a major new source of income for farmers.[245] By producing transportation fuel, farmers will be entering a market with higher prices and rising demand. Growing energy crops is more likely to attract the kind of foreign investment that can modernize their agricultural practices – and increase their food production as well.

The Food and Agriculture Organization of the United Nations notes these benefits as well: "Energy plantations and crops (in particular perennial crops) can help to prevent soil erosion by providing a cover which reduces rainfall impact and sediment transport. Annual energy crops can also allow diversification and expansion of crop rotations. Deforested, degraded and marginal land could be rehabilitated as bioenergy plantations which could combat desertification and increase food production."[246]

Micro example: Biodiesel produced from jatropha nuts was used in Mali to provide affordable, decentralized energy services, fueling engines that could power other equipment or support a mini-grid for lighting, refrigeration, and electric pumps for small water distribution networks or irrigation systems. A jatropha hedge in Mali is shown at right.[247] This project increased annual income per participating woman from about $40 to $100 and freed two to six hours of her time per day. Villages experienced higher levels of schooling for girls, who were no longer pulled out of school to assist their mothers with household chores. The project also stimulated micro-level business activities for village men in blacksmithing, carpentry, and mechanics.[248]

Macro example: In Brazil ethanol production has created an estimated one million jobs and reduced the cost of oil imports by $43.5 billion between 1976 and 2000.[249]

What are the implications of biofuels for global trade?

If carried out on a large scale, the increased use of agricultural resources for energy will have the effect of raising the prices of most commodity crops and reducing the need for subsidies – with particular benefit for producers of commodity crops in developing countries. An analysis by researchers at the University of Tennessee found that increased demand for energy crops would all but eliminate the need for price-based support payments for most crops in the U.S.[250] In other words, an aggressive program of bioenergy development would lead to reductions in government support to farmers without any loss of income.

In the industrialized world, the problem in agriculture is not one of shortage but overproduction which is why there are perennial surpluses. Excess crops are shipped overseas, where they end up undercutting and impoverishing farmers in the developing world, who cannot compete with subsidized crops from abroad.

Negotiations in the Doha Development Round of the World Trade Organization broke down in 2006 because of disputes over agricultural subsidies. If governments took steps to raise biofuels production to 15% or more of global petroleum demand, the global market in agriculture could double or triple in volume and value. That would create a win-win situation for all involved, and the subsidy issue would diminish in importance.

As the world's population grows, won't we need all our farmland for food production?

According to the Food and Agriculture Organization of the United Nations (FAO), increased food production can keep pace with a growing global population. In a 2002 report, FAO observed:

> In recent years the growth rates of world agricultural production and crop yields have slowed. This has raised fears that the world may not be able to grow enough food and other commodities to ensure that future populations are adequately fed. However, the slowdown has occurred not because of shortages of land or water but rather because demand for agricultural products has also slowed. This is mainly because world population growth rates have been declining since the late 1960s, and fairly high levels of food consumption per person are now being reached in many countries, beyond which further rises will be limited. But it is also the case that a stubbornly high share of the world's population remains in absolute poverty and so lacks the necessary income to translate its needs into effective demand.[251]

On a global scale, malnutrition is caused not by a lack of food but by a failure to distribute it or a lack of money to pay for it. And certainly poverty, especially in urban areas, is exacerbated by rapid population growth.[252]

Agriculture remains the main activity in the developing world. The world's farmers are fully capable of increasing the amount they produce, but, in order for this to happen, demand must increase.[253] Poverty reduces global food demand and acts as a brake on food production. Most of the world's poorest people live in rural areas and work the land.[254]

Increased demand for agricultural products thus would mean more farm income and less poverty, more productive agriculture, more food, more rural economic development, and reduced migration to cities.

Many developing countries still have a significant quantity of land available that is well adapted to rain-fed crops – about as much as now is being farmed (over 1.7 billion acres). These lands do not include areas inhabited by human beings, forests, or protected areas.[255] If a country can produce and export biofuels, it will have a stronger economy and more resources to address the needs of the poor. Africa, with its significant sugar cane production potential, is often cited as a region that could profit from Brazil's experience and technology, although obstacles to realizing it (infrastructure, institutional, etc.) should not be underestimated.[256]

According to the FAO, in developing countries almost 70% of future increases in crop production will come from higher yields, around 20% from an expansion of arable land, and around 10% from multiple cropping and shorter fallow periods. Some regions will face serious water shortages, and they will need to use water more efficiently, as agriculture represents about 70% of all fresh water consumed by humans. Appropriately regulated genetically modified crop varieties could help to sustain farming in marginal areas and to restore degraded lands to production.[257]

Acknowledgements

This project was made possible through the generous support of **The Winslow Foundation.**

Reid Detchon was the lead author of this document.

Many thanks for helpful comments from:

Judy Adler, Turner Foundation

Frederick Anderson, McKenna Long & Aldridge

Bruce Arnold, Scott Paper Co. (retired)

John Ashworth, National Renewable Energy Laboratory

John Bonitz, Rural Advancement Foundation International – USA

David Bransby, Auburn University

Rebecca Cantwell, Rebecca Cantwell Communications

Wendy Clark, National Renewable Energy Laboratory

Ana Unruh Cohen, Center for American Progress

Bob Dinneen, Renewable Fuels Association

Joel Finkelstein, Fenton Communications

Ladeene Freimuth, The Freimuth Group

Richard Hamilton, Ceres, Inc.

Bill Holmberg, American Council on Renewable Energy

Suzanne Hunt, Worldwatch Institute

Mike Kessler, American BioFuels Development

Tom Konrad, Colorado Renewable Energy Society

Ron Larson, Ratepayers United of Colorado

Jason Masters, Northern Biodiesel

Bob Noun, National Renewable Energy Laboratory

George Sterzinger, Renewable Energy Policy Project

Charles Sweeney, TSD Communications

Bob Wallace, National Renewable Energy Laboratory

Michael Wang, Argonne National Laboratory

And to the team at the United Nations Foundation:

Matt Cordell

Naja Davis

Jana Gastellum

Daniel Laender

Phoebe Lee

Peper Long

Katherine Miller

Shannon Raybold

Endnotes

1. See below, "The Facts About Biofuels: Ethanol from Cellulose."

2. World of Molecules (http://www.worldofmolecules.com/fuels/ethanol.htm).

3. Alternatively, distillers dried grains with solubles (DDGS). National Corn Growers Association, "Killing the Myths of Ethanol" (http://www.ncga.com/ethanol/main/killing_myths.htm).

4. Iowa Beef Center, "Wet Distillers Grains for Feedlot Cattle," Aug. 2002 (http://www.extension.iastate.edu/Publications/IBC19.pdf).

5. Renewable Fuels Association, "Ethanol Biorefinery Locations," updated Feb. 12, 2007 (http://www.ethanolrfa.org/industry/locations/).

6. Renewable Fuels Association, "Ethanol Industry Overview" (http://www.ethanolrfa.org/industry/statistics/).

7. Bill Kovarik, "Henry Ford, Charles F. Kettering and the Fuel of the Future," Automotive History Review, Spring 1998, No. 32, p. 7-27 (http://www.radford.edu/~wkovarik/papers/fuel.html).

8. "Knock" is an engine sound that results from premature ignition of the compressed fuel-air mixture. U.S. Federal Trade Commission, "The Low Down on High Octane Gasoline," Oct. 2003 (http://www.ftc.gov/bcp/conline/pubs/autos/octane.htm).

9. "…nearly all RFG, which makes up about one-third of U.S. gasoline consumed, contains ethanol." U.S. Energy Information Administration, "This Week in Petroleum," May 10, 2006 (http://tonto.eia.doe.gov/oog/info/twip/twiparch/060510/twipprint.html).

10. Standards for fuel ethanol and E85 blends have been set by ASTM International: D4806-06a StandardSpecification for Denatured Fuel Ethanol and D5798-06 Standard Specification for Fuel Ethanol (Ed75-Ed85) (http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/REDLINE_PAGES/D6423.htm?E+mystore).

11. Ethanol Promotion and Information Council, IndyCar Series (http://www.drivingethanol.org/aspx/indy_car_series/default.aspx).

12. U.S. Energy Information Administration, "Petroleum Navigator: Product Supplied" (http://tonto.eia.doe.gov/dnav/pet/pet_cons_psup_dc_nus_mbblpd_a.htm).

13. Renewable Fuels Association, "Industry Statistics" (http://www.ethanolrfa.org/industry/statistics/).

14. Ethanol contains about two-thirds as much energy per gallon as gasoline. (http://www.nafa.org/Content/NavigationMenu/Resource_Center/Alternative_Fuels/Energy_Equivalents/Energy_Equivalents.htm)

15. Chief Economist Keith Collins, U.S. Department of Agriculture, statement before the Committee on Environment and Public Works, U.S. Senate, Sept. 6, 2006, p. 10 (http://www.usda.gov/agency/oce//newsroom/congressional_testimony/Biofuels%20Testimony%209-6-2006.doc).

16. Public Law 109-58, Aug. 8, 2005 – Sec. 1501, "Renewable Content of Gasoline" (http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ058.109.pdf).

17. Renewable Fuels Association, "Industry Statistics" (http://www.ethanolrfa.org/industry/statistics/). RFS data from the Energy Policy Act of 2005, "Title XV– Ethanol and Motor Fuels" (http://energycommerce.house.gov/108/0205_Energy/05policy_act/Title%2015%20-%20Ethanol%20and%20Motor%20FuelsL.PDF).

18. "… the President's Biofuels Initiative will accelerate research, development and demonstration aimed at bringing approximately 60 billion gallons of domestically produced biofuels to the market by 2030." U.S. Department of Energy, "Five Year Plan," Vol. 1, p. 24 (http://www.er.doe.gov/Budget_and_Planning/Five-Year%20Plan/FYP%20Vol%20I%20-%20final%20version.pdf).

19. State of the Union address, Jan. 23, 2007 (http://www.whitehouse.gov/news/releases/2007/01/20070123-2.html).

20. Andrew McAloon *et al.*, "Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks," U.S. Department of Agriculture and U.S. Department of Energy, Oct. 2000. Price estimate of 88 cents per gallon adjusted upward to account for higher natural gas prices. (http://devafdc.nrel.gov/pdfs/4898.pdf)

21. Rick Mullin, "Industrial Biotech," Chemical & Engineering News, Vol. 84, No. 31, July 31, 2006, pp. 34-35 (http://pubs.acs.org/cen/business/business.html - subscription required).

22. A bushel of corn produces about 2.8 gallons of ethanol: Renewable Fuels Association, "Ethanol Facts: Agriculture" (http://www.ethanolrfa.org/resource/facts/agriculture/).

23. U.S. Energy Information Administration, "Short-Term Energy Outlook," Monthly Price Data – comparing wholesale gasoline prices and West Texas Intermediate crude oil prices (http://tonto.eia.doe.gov/steo_query/app/pricepage.htm).

24. Oilnergy, "WTI Crude Oil Posted Price" (http://www.oilnergy.com/1opost.htm#year).

25. U.S. Energy Information Administration, "Petroleum Navigator: Refiner Gasoline Prices by Grade and Sales Type" (http://tonto.eia.doe.gov/dnav/pet/pet_pri_refmg_dcu_nus_m.htm).

26. U.S. Energy Information Administration, "Petroleum Navigator: U.S. All Grades All Formulations Retail Gasoline Prices (Cents per Gallon)" (http://tonto.eia.doe.gov/dnav/pet/hist/mg_tt_usw.htm).

27. U.S. Energy Information Administration, *Annual Energy Outlook 2006*, Feb. 2006 (http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2006).pdf), Figure 10: World Oil Prices in the AEO2005 and AEO 2006 Reference Cases (http://www.eia.doe.gov/oiaf/aeo/excel/figure10_data.xls).

28. U.S. Energy Information Administration, *Annual Energy Outlook 2007 (Early Release)*, Dec. 2006 (http://www.eia.doe.gov/oiaf/aeo/index.html), Table 12, Petroleum Product Prices (http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_12.xls).

29. Spot market prices nearly tripled in 2006, exceeding $3 a gallon (http://www.energy.ca.gov/gasoline/graphs/ethanol_10-year.html).

30. "Most ethanol is sold under long-term contract. These contracts are private agreements between ethanol producers/marketers and petroleum companies. According to industry observers, roughly 90 to 95% of ethanol is sold under these long-term contracts (6 to 12 months). Many of these contracts are 'fixed price.' In other words, the price a petroleum company pays for the ethanol doesn't change, regardless of changes in the spot (wholesale) market price. … The remaining small amount of ethanol is sold on the 'spot' market. Prices fluctuate daily according to market conditions." Renewable Fuels Association, "Industry Statistics" (http://www.ethanolrfa.org/industry/statistics/).

31. Clean Fuels Development Coalition *et al.*, "Changes in Tax Incentives for Ethanol and Biodiesel" (http://www.e85fuel.com/forretailers/ethanoltaxbrochure2005.pdf).

32. Keith Collins, Chief Economist, U.S. Department of Agriculture, oral testimony before the U.S. Senate Committee on Agriculture, Nutrition and Forestry, Jan. 10, 2007.

33. U.S. Energy Information Administration, "Petroleum Navigator: U.S. Oxygenates, Fuel Ethanol Imports" (http://tonto.eia.doe.gov/dnav/pet/hist/mfeimus1M.htm).

34. Vernon R. Eidman, "Renewable Liquid Fuels: Current Situation and Prospects," Choices, Vol. 21(1), First Quarter 2006, American Agricultural Economics Association (http://www.choicesmagazine.org/2006-1/biofuels/2006-1-03.htm).

35. The subject of agricultural support payments is complex. For an introductory overview, see "Government Payments and the Farm Sector: Who Benefits and How Much?" Economic Research Service, U.S. Department of Agriculture (http://www.ers.usda.gov/Briefing/FarmPolicy/gov-pay.htm).

36. Allen Baker and Edward Allen, "2006/07 Feed Grain Supplies To Decline and Use To Increase," Feed Outlook, Economic Research Service, U.S. Department of Agriculture, May 16, 2006 (http://usda.mannlib.cornell.edu/usda/ers/FDS//2000s/2006/FDS-05-16-2006.pdf).

37. M. Wu *et al.*, "Fuel-Cycle Assessment of Selected Bioethanol Production Pathways in the United States, Argonne National Laboratory, Nov. 7, 2006, p. 33 (http://www.transportation.anl.gov/pdfs/TA/377.pdf).

38. Also: Alexander E. Farrell *et al.*, "Ethanol Can Contribute to Energy and Environmental Goals," Science, Vol. 311, pp. 506-7, Jan. 27, 2006 (http://www.sciencemag.org/cgi/data/311/5760/506/ - subscription required).

39. The Second Law of Thermodynamics

40. For a thorough discussion of this subject, see Bruce E. Dale, "Impacts of Cellulosic Ethanol on the Farm Economy," in *A High-Growth Strategy for Ethanol*, Report of an Aspen Institute Policy Dialogue, pp. 37-39 (http://www.aspeninstitute.org/atf/cf/%7BDEB6F227-659B-4EC8-8F84-8DF23CA704F5%7D/FINALEthanolText.pdf).

41. M. Wu *et al.*, "Fuel-Cycle Assessment of Selected Bioethanol Production Pathways in the United States, Argonne National Laboratory, Nov. 7, 2006, p. 33 (http://www.transportation.anl.gov/pdfs/TA/377.pdf).

42. Several factors influence the energy balance of ethanol: the corn yield per acre; the energy consumed in corn production, including the amount of fertilizer and fuel used in cultivation and harvest; the energy efficiency of the conversion process; and the energy balance of any byproducts. See Hosein Shapouri, "USDA researcher explains decision to update 'The Energy Balance of Corn Ethanol'" (interview), 2006 (http://www.ethanolproducer.com/article-print.jsp?article_id=1727).

43. The assertions contained in articles by David Pimentel and Tad Patzek have been explicitly rejected by studies in two prestigious scientific journals, *Science* and the *Proceedings of the National Academy of Sciences*: Alexander E. Farrell *et al.*, "Ethanol Can Contribute to Energy and Environmental Goals," Science, Vol. 311, pp. 506-7, Jan. 27, 2006, and supporting material on line at http://www.sciencemag.org/cgi/data/311/5760/506/DC1/2 (subscription required). Also, Jason Hill *et al.*, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," Proceedings of the National Academy of Sciences, Vol. 103, No. 30, July 25, 2006, pp. 11206-10 (http://www.pnas.org/cgi/content/abstract/103/30/11206) (subscription required for access to full text). The analytical defects include a failure to credit the energy content of byproducts, such as animal feed, out-of-date data, and unusual system boundaries: Pimentel includes "food intake by farmers, ethanol plant construction materials, and farming equipment materials and manufacture. Patzek (2003) further includes the solar energy embedded in corn kernels." – Michael Wang, "Updated Energy and Greenhouse Gas Emissions Results of Fuel Ethanol," Argonne National Laboratory, Sept. 26-28, 2005, p. 19 (http://www.eri.ucr.edu/ISAFXVCD/ISAFXVAF/UGEEERF.pdf).

44. Suani Coelho, "Brazilian Sugarcane Ethanol: Lessons Learned," presentation to the Scientific and Technical Advisory Panel of the Global Environment Facility, workshop on liquid biofuels, New Delhi, India, Aug. 29-Sept. 1, 2005 (http://www.unep.org/stapgef/documents/Wshop_docs/liquid_biofuels_2005/Presentations%20on%2029th%20Aug%202005/Session%20-1%20%20Chaired%20by%20Sh.%20Vinay%20Shankar%20GOI/Prof%20Suani%20Teixeira%20Coelho%20Brazil/STCEthanolBR-290805final.ppt).

45. M. Wu *et al.*, "Fuel-Cycle Assessment of Selected Bioethanol Production Pathways in the United States, Argonne National Laboratory, Nov. 7, 2006, p. 33 (http://www.transportation.anl.gov/pdfs/TA/377.pdf).

46. See also Natural Resources Defense Council and Climate Solutions, "Ethanol: Energy Well Spent – A Survey of Studies Published Since 1990," Feb. 2006 (http://www.nrdc.org/air/transportation/ethanol/ethanol.pdf).

47. Association of Oil Pipe Lines, "Increased Ethanol Use Creates Challenges," *In the Pipe*, Vol. 4, Issue 4, Apr. 2006 (http://www.enewsbuilder.net/aopl/e_article000570935.cfm).

48. John Whims, "Pipeline Considerations for Ethanol," Agricultural Marketing Resource Center, Department of Agricultural Economics, Kansas State University, Aug. 2002 (http://www.agmrc.org/NR/rdonlyres/4EE0E81C-C607-4C3F-BBCF-B75B7395C881/0/ksupipelineethl.pdf).

49. A good discussion of pipeline issues can be found in C. Hammel-Smith *et al.*, "Issues Associated with the Use of Higher Ethanol Blends (E17-E24), National Renewable Energy Laboratory, NREL/TP-510-32206, Oct. 2002, pp. 23-28 (http://www.nrel.gov/docs/fy03osti/32206.pdf). Brazil's experience is discussed at p. 10, quoting P.M. Nastari, *Fuel Ethanol in the 21st Century Seminar*, "The Brazilian Fuel Ethanol Experience."

50. Brazil's state oil company, Petrobras is studying construction of a $225 million pipeline that would transport ethanol from sugarcane-growing areas to an export terminal in the state of São Paulo by 2008. David Adams, "The Saudis of the Southern Hemisphere," *Forbes*, Oct. 9, 2006 (http://www.forbes.com/energy/2006/10/06/ethanol-brazil-biz-energy_cx_da_1009latin_energy06.html).

51. Encyclopedia Britannica, "Cellulose" (http://www.britannica.com/eb/article-9022028).

52. Lance Gay, "Enzymes emerge to speed ethanol production," Scripps Howard News Service, Mar. 3, 2006 (http://www.shns.com/shns/g_index2.cfm?action=detail&pk=ETHANOL-03-03-06).

53. "'Termite guts can save the planet,' says Nobel laureate," posted Apr. 13, 2006 (http://www.physorg.com/news3700.html).

54. "Novozymes and NREL Achieve 30-fold Reduction in Enzyme Cost and Conclude Biomass-to-Ethanol Project," press release (http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/04-14-2005/0003393267&EDATE=).

55. See, for example, U.S. Department of Energy, Biomass Program – Technologies (http://www1.eere.energy.gov/biomass/technologies.html).

56. Kara Platoni, “Bug Juice: Could termite guts hold the key to the world’s energy problems? Don’t laugh.” East Bay Express, Sept. 7, 2005 (http://www.eastbayexpress.com/Issues/2005-09-07/news/feature_full.html).

57. “Termites may hold the secret to the production of cellulosic ethanol,” Diversa Corp. (http://www.diversa.com/Pages/Products/AlternativeFuels/AltFuelsTermites.html).

58. “Lonnie Ingram, Distinguished Professor of Microbiology” (http://www.ufl.edu/spotlight/ingram.html).

59. U.S. Department of Energy, Office of Science, “Fact Sheet: A Scientific Roadmap for Making Cellulosic Ethanol A Practical Alternative to Gasoline” (http://www.er.doe.gov/News_Information/News_Room/2006/Biofuels/factsheet.htm).

60. John J. Fialka and Scott Kilman, “Big Players Join Race to Put Farm Waste Into Your Gas Tank,” *The Wall Street Journal*, June 29, 2006 (http://www.iogen.ca/news_events/cellulose_ethanol_news/2006_06_29.html).

61. Dave Nilles, “Broin and Novozymes to continue collaboration,” *Ethanol Producer Magazine*, Oct. 26, 2006 (http://www.ethanolproducer.com/article-web.jsp?article_id=2406).

62. “Spain to Open World’s First Cellulosic Ethanol Plant,” Dow Jones News Service, Feb. 9, 2006 (http://www.evworld.com/view.cfm?section=communique&newsid=10986).

63. Abengoa Bioenergy, “DOE Project” (http://www.abengoabioenergy.com/research/index.cfm?page=10).

64. Nathanael Greene *et al.*, “Growing Energy: How Biofuels Can Help End America’s Oil Dependence,” Executive Summary, Natural Resources Defense Council, Dec. 2004, pp. v-vi (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf).

65. Richard E. Dickerson and Irving Geis, *Chemistry, Matter and the Universe*, chapter 21, “Lipids and Carbohydrates,” excerpted on Virtual Chemistry, University of Oxford (http://www.chem.ox.ac.uk/vrchemistry/chapter21/page01.html).

66. National Corn Growers Association, “How Much Ethanol Can Come From Corn?” May 24, 2006 (http://www.ncga.com/ethanol/pdfs/2006/HowMuchEthanolCan%20ComeFromCorn.v.2.pdf).

67. http://www.nrel.gov/biomass/photos.html. Auburn professor David Bransby is pictured.

68. David Bransby, “Switchgrass Profile” (http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html).

69. State of the Union address, Jan. 31, 2006 (http://www.whitehouse.gov/stateoftheunion/2006/).

70. David Bransby, “Switchgrass Profile” (http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html).

71. Daniel De La Torre Ugarte and Chad Hellwinckel, University of Tennessee, “The Impacts on U.S. Agriculture of Large-Scale Bioenergy Crop Production,” paper prepared for the William and Flora Hewlett Foundation, July 2005.

72. http://www.aces.uiuc.edu/news/News%20Photos/miscanthus/pages/miscanthus.htm.

73. LeAnn Ormsby, “Miscanthus: New Crop for U.S. Farmers?” *Agro-Ecology*, Vol. 12, No. 2, Summer 2003, pp. 6-7 (http://asap.aces.uiuc.edu//news/v12n2.pdf).

74. National Science Foundation, “Mixed Prairie Grasses Better Source of Biofuel Than Corn Ethanol and Soybean Biodiesel,” press release, Dec. 7, 2006 (http://www.nsf.gov/news/news_images.jsp?cntn_id=108206&org=NSF).

75. For a discussion of land requirements, see below, “The Benefits of Biofuels: Agriculture and Rural Economic Development.”

76. G.S. Augustus *et al.*, “Evaluation and Bioinduction of Energy Components of Jatropha Curcas” (summary), *Biomass* and *Bioenergy*, 23:161-164, Dec. 31, 2002 (http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=142316).

77. http://cropwatch.unl.edu/archives/agnews01/an01-7-20.htm

78. http://www.canola.okstate.edu/ptguides/index.htm

79. http://www.banana-tree.com/Product_Detail~Category~22~Product_ID~193.cfm

80. http://homepage.virgin.net/himal.proj/galleryhimal.htm

81. Randy Schnepf, "Agriculture-Based Renewable Energy Production," Congressional Research Service report RL32712, Jan. 4, 2005, p. 19 (http://ncseonline.org/NLE/CRSreports/05Jan/RL32712.pdf).

82. Chief Economist Keith Collins, U.S. Department of Agriculture, statement before the Committee on Environment and Public Works, U.S. Senate, Sept. 6, 2006, p. 10 (http://www.usda.gov/agency/oce//newsroom/congressional_testimony/Biofuels%20Testimony%209-6-2006.doc).

83. European Biodiesel Board, "EU biodiesel production growth hits record high in 2005," press release, Apr. 25, 2005 (http://www.ebb-eu.org/EBBpressreleases/EBB%20press%20release%202005%20statistics%20(final).pdf).

84. Chief Economist Keith Collins, U.S. Department of Agriculture, statement before the Committee on Environment and Public Works, U.S. Senate, Sept. 6, 2006, p. 10 (http://www.usda.gov/agency/oce//newsroom/congressional_testimony/Biofuels%20Testimony%209-6-2006.doc).

85. Methanol Institute and International Fuel Quality Center, "A Biodiesel Primer," Apr. 2006, p. 5 (http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20060401-GEN369.pdf).

86. "Dr. Rudolf Christian Karl Diesel (1858-1913)," Doxford Engine Friends Association (http://www.doxford-engine.com/diesel.htm).

87. National Biodiesel Board, "Biodiesel Myths and Facts" (http://www.biodiesel.org/pdf_files/fuelfactsheets/Myths_Facts.pdf).

88. National Biodiesel Board, "Lubricity Benefits" (http://www.biodiesel.org/pdf_files/fuelfactsheets/Lubricity.PDF).

89. Anthony Radich, "Biodiesel Performance, Costs, and Use," U.S. Energy Information Administration, June 8, 2004 (http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/).

90. K. Shaine Tyson, "Biodiesel Handling and Use Guidelines," National Renewable Energy Laboratory, Sept. 2001, pp. 1-2 (http://www.eere.energy.gov/cleancities/blends/pdfs/5845.pdf).

91. Wayne Hettler, garage foreman and head mechanic for St. John's Public Schools (MI), quoted in Michigan Soybean Promotion Committee news release, "St. Johns School Buses Rolling 1 Million Miles on Biodiesel," Apr. 27, 2004 (http://www.biodiesel.org/resources/users/stories/2004_0503_michigan_buses.pdf).

92. Jason Hill *et al.*, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," *Proceedings of the National Academy of Sciences*, Vol. 103, No. 30, July 25, 2006, pp. 11206-10 (http://www.pnas.org/cgi/content/abstract/103/30/11206) (subscription required for access to full text).

93. John Sheehan *et al.*, "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus," joint study for the U.S. Departments of Agriculture and Energy, May 1998, p. V (http://www.nrel.gov/docs/legosti/fy98/24089.pdf).

94. Bob McCormick, National Renewable Energy Laboratory, "Effects of Biodiesel on NOx Emissions," presentation to ARB Biodiesel Workgroup, June 8, 2005 (http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/38296.pdf).

95. Anthony Radich, "Biodiesel Performance, Costs, and Use," U.S. Energy Information Administration, June 8, 2004 (http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/).

96. Renewable Fuels Association, "Federal Regulations: Biodiesel Tax Credits" (http://www.ethanolrfa.org/policy/regulations/federal/biodiesel/).

97. Randy Schnepf, "Agriculture-Based Renewable Energy Production," Congressional Research Service report RL32712, Jan. 4, 2005, p. 18 (http://ncseonline.org/NLE/CRSreports/05Jan/RL32712.pdf).

98. Vernon R. Eidman, "Renewable Liquid Fuels: Current Situation and Prospects," *Choices*, Vol. 21(1), First Quarter 2006, American Agricultural Economics Association (http://www.choicesmagazine.org/2006-1/biofuels/2006-1-03.htm).

99. Anthony Radich, "Biodiesel Performance, Costs, and Use," U.S. Energy Information Administration, June 8, 2004 (http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/).

100. Jonathan Blundell, "Fuel from the farm," *The Daily Light*, Apr. 7, 2006 (http://www.biodiesel.com/News%20Archives/pacbionelson.pdf).

101. http://www4.law.cornell.edu/uscode/html/uscode26/usc_sec_26_00000040---A000-.html

102. California Energy Commission, "Synthetic Diesel Fuel," Gas-to-Liquids (GTL) Fuel Fact Sheet (http://www.energy.ca.gov/afvs/synthetic_diesel.html).

103. U.S. Environmental Protection Agency, "Clean Alternative Fuels: Fischer-Tropsch," fact sheet, Mar. 2002 (http://www.epa.gov/oms/consumer/fuels/altfuels/420f00036.pdf).

104. U.S. Energy Information Administration, "Issues in Focus – Synthetic Fuels," *Annual Energy Outlook 2006*, pp. 54 (http://www.eia.doe.gov/oiaf/aeo/pdf/issues.pdf).

105. U.S. Energy Information Administration, "Issues in Focus – Synthetic Fuels," *Annual Energy Outlook 2006*, pp. 56 (http://www.eia.doe.gov/oiaf/aeo/pdf/issues.pdf).

106. http://www.engin.umich.edu/dept/che/kinetics/01chap/html/reactors/sasol.htm.

107. Tracy Staedter, "Garbage into Oil," *Technology Review*, Massachusetts Institute of Technology, June 2003, p. 73 (http://www.whizkid.com/stuff/mittdp.pdf).

108. Brad Lemley, "Anything into Oil," *Discover* (Vol. 27, No. 4), Apr. 2006 (http://www.discover.com/issues/apr-06/features/anything-oil/).

109. "Pollute Not…Profit More," white paper, GreenFuel Technologies Corp. (http://www.greenfuelonline.com/gf_files/GreenFuelWhitePapers.pdf).

110. Hal Bernton, William Kovarik, and Scott Sklar, *The Forbidden Fuel* (New York: Boyd Griffin, 1982), p. 132.

111. BP DuPont Biofuels, "Biobutanol" (http://www2.dupont.com/Biofuels/en_US/news/index.html).

112. Gregory A. Dolan, "Methanol Transportation Fuels: A Look Back and a Look Forward," Methanol Institute, International Symposia on Alcohol Fuels, San Diego, Calif., Sept. 2005 (http://www.methanol.org/pdf/MIPaperforISAF.pdf).

113. Mark Ward, "Fuel cells to change laptop use," *BBC News*, Mar. 10, 2006 (http://news.bbc.co.uk/1/hi/technology/4794920.stm).

114. European Fuel Oxygenates Association, "Alcohols vs. ethers" (http://www.efoa.org/EFOA_Pages/02_What/02b2_AlcoholsTXT.html).

115. Governors' Ethanol Coalition, "Ethyl Tertiary Butyl Ether" (http://www.ethanol-gec.org/clean/cf04.htm).

116. American Petroleum Institute, "Ten Frequently Asked Questions About MTBE in Water," API Soil & Groundwater Research Bulletin, No. 3, Mar. 1998 (http://api.org/ehs/groundwater/upload/03_Bull.pdf).

117. U.S. Environmental Protection Agency, "MTBE in Fuels" (http://www.epa.gov/mtbe/gas.htm).

118. U.S. Energy Information Administration, "MTBE, Oxygenates, and Motor Gasoline," Mar. 6, 2000 (http://www.eia.doe.gov/emeu/steo/pub/special/mtbe.html).

119. "Achieving Clean Air and Clean Water," Report of the Blue Ribbon Panel on Oxygenates in Gasoline, EPA420-R-99-021, Sept. 15, 1999 (http://www.epa.gov/oms/consumer/fuels/oxypanel/r99021.pdf).

120. U.S. Department of Energy, "Fuel Blends – Ethanol" (http://www.eere.energy.gov/cleancities/blends/ethanol.html).

121. U.S. Department of Energy, "Fuel Blends – Biodiesel" (http://www.eere.energy.gov/cleancities/blends/biodiesel.html).

122. "DaimlerChrysler Expands Use of Biodiesel Fuel in Dodge Ram Pickup Trucks," DaimlerChrysler press release, Jan. 20, 2006 (http://sev.prnewswire.com/auto/20060120/DEF01220012006-1.html).

123. ANFAVEA (National Association of Automakers [of Brazil]), "Domestic Auto Sales 2006" (*"Tabela 11 – Vendas Atacado Mercado Interna por Tipo e Combustivel"*), Oct. 20, 2006 (http://www.anfavea.com.br/tabelas/autoveiculos/tabela11_vendas.pdf).

124. “Volkswagen Goes All Flex Fuel in Brazil,” *Inside Line*, Mar. 25, 2006 (http://www.edmunds.com/insideline/do/News/articleId=109766).

125. Worldwatch Institute, “Biofuels for Transportation: Selected Trends and Facts” (http://www.worldwatch.org/node/4081).

126. Tom LaSorda, President and CEO, Chrysler Group, remarks to Renewable Fuels Association, Apr. 25, 2006, p. 3 (http://www.ethanolrfa.org/objects/pdf/summit/20060501_TWL_RFA_Handouts.pdf).

127. Harris Interactive Reports, “Two-Thirds of Adult Vehicle Owners are Familiar with Flexible Fuel Vehicles and More than Half are Interested in Purchasing One,” July 26, 2006 (http://www.harrisinteractive.com/news/allnewsbydate.asp?NewsID=1074).

128. “Ethanol-fueled Saab 9-5 Bio-Power honored with Popular Science ‘Best of what’s new’ award,” press release, Nov. 9, 2005 (http://www.saabusa.com/saabjsp/about/pr_051109.jsp).

129. U.S. Department of Energy, “Flexible Fuel Vehicles: Powered by an American Fuel,” fact sheet, DOE/GO-102006-2291, Feb. 2006 (http://www.nrel.gov/docs/fy06osti/39407.pdf).

130. National Ethanol Vehicle Coalition, “Frequently Asked Questions” (http://www.e85fuel.com/e85101/faqs/number_ffvs.php).

131. FFV models are listed on the web site of the National Ethanol Vehicle Coalition (http://www.e85fuel.com/e85101/flexfuelvehicles.php).

132. Maya Jackson Randall and John D. Stoll, “Toyota mulls plug-in hybrids, ethanol cars for US,” *MarketWatch*, July 18, 2006 (http://www.marketwatch.com/News/Story/Story.aspx?dist=newsfinder&siteid=google&guid=%7B4A49593E%2D1991%2D4EEC%2D853A%2DC32ED22BC002%7D&link=&keyword=toyota).

133. http://www.shoplynch.com/index1.html.

134. For example, E85 refueling locations are listed on the web site of the National Ethanol Vehicle Coalition (http://www.e85fuel.com/database/search.php). A station locator is offered by the Alternative Fuels Data Center of the U.S. Department of Energy (http://afdcmap2.nrel.gov/locator/).

135. National Ethanol Vehicle Coalition, “E85 Stations Exceed 1,000,” news release, Oct. 6, 2006 (http://www.e85fuel.com/news/100606_1000_station_release.htm).

136. Biodiesel refueling locations are listed on the web site of the National Biodiesel Board (http://www.biodiesel.org/buyingbiodiesel/retailfuelingsites/).

137. http://www.nrel.gov/data/pix/searchpix.cgi.

138. For more information, see “Can a Vehicle Be Converted to Operate on E85?” (http://www.e85fuel.com/e85101/faqs/conversion.php).

139. MSNBC, “Ethanol hybrid? Ford unveils prototype,” Jan. 25, 2006 (http://www.msnbc.msn.com/id/11020257/).

140. *How to calculate*: A gallon of E85 would seem to contain 0.85 gallons of fuel ethanol and 0.15 gallons of gasoline – but ethanol typically contains up to 5% gasoline as a denaturant. Thus, a gallon of E85 actually contains 0.8075 gallons of ethanol and 0.1925 gallons of gasoline. Put another way, 1 gallon of gasoline plus 4.195 gallons of ethanol makes up 5.195 gallons of E85. Because ethanol has two-thirds of the energy content of gasoline, an Escape that averages 30 miles per gallon of gas would travel 83.9 miles on the ethanol in that blend (4.195 x 30 x 2/3) and 30 miles on the gas, for a total of 113.9 miles per gallon of gasoline consumed. A Prius that averages 50 miles per gallon would do better by two-thirds, or 189.8 miles per gallon of gasoline consumed. The same ratio would apply to any flexible-fuel vehicle – multiply its standard fuel economy rating by 3.8 to determine how far it would travel on a gallon of gasoline, if using an E85 blend.

141. “DaimlerChrysler Expands Use of Biodiesel Fuel in Dodge Ram Pickup Trucks,” DaimlerChrysler press release, Jan. 20, 2006 (http://sev.prnewswire.com/auto/20060120/DEF01220012006-1.html).

142. “GM ready for E85 with full-size SUVs,” *Houston Chronicle*, Feb. 1, 2006 (http://www.chron.com/class/cars/featuredvehicle/020106.html).

143. *Associated Press*, “Leaders of Big Three meet on Capitol Hill,” May 18, 2006 (http://www.msnbc.msn.com/id/12855704/).

144. Statistical Review of World Energy 2006, BP, “World Oil Consumption” (http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/publications/energy_reviews_2006/STAGING/local_assets/downloads/pdf/table_of_world_oil_consumption_2006.pdf).

145. Statistical Review of World Energy 2006, BP, “Proved Oil Reserves” (http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/publications/energy_reviews_2006/STAGING/local_assets/downloads/pdf/table_of_proved_oil_reserves_2006.pdf).

146. Statistical Review of World Energy 2006, BP, “Oil Reserves” (http://www.bp.com/sectiongenericarticle.do?categoryId=9009492&contentId=7017959).

147. State of the Union address, Jan. 31, 2006 (http://www.whitehouse.gov/stateoftheunion/2006/).

148. U.S. Energy Information Administration, “Energy in the United States, 1635-2000” (http://www.eia.doe.gov/emeu/aer/eh/petro.html).

149. U.S. Energy Information Administration, Weekly Petroleum Status Report, Table H1, Petroleum Supply Summary, June 2006 (http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/weekly_petroleum_status_report/current/pdf/tableh1.pdf).

150. U.S. Energy Information Administration, “Monthly Energy Review,” Mar. 2006, as cited in Stacy C. Davis and Susan W. Diegel, *Transportation Energy Data Book*, Edition 25 – 2006, Oak Ridge National Laboratory, ORNL-6974 (http://cta.ornl.gov/data/tedb25/Spreadsheets/Table1_13.xls).

151. U.S. Energy Information Administration, “Monthly Energy Review,” Mar. 2006, as cited in Stacy C. Davis and Susan W. Diegel, *Transportation Energy Data Book*, Edition 25 – 2006, Oak Ridge National Laboratory, ORNL-6974 (http://cta.ornl.gov/data/tedb25/Spreadsheets/Table2_02.xls).

152. State of the Union address, Jan. 23, 1980 (http://www.jimmycarterlibrary.org/documents/speeches/su80jec.phtml).

153. “President Discusses Energy Policy,” White House transcript, Apr. 25, 2006 (http://www.whitehouse.gov/news/releases/2006/04/20060425.html).

154. “The New Middle East Oil Bonanza,” *Business Week*, Mar. 13, 2006 (http://www.businessweek.com/magazine/content/06_11/b3975001.htm).

155. Tom Friedman, *Foreign Policy* special event, “Curing the Oil Addiction” (transcript), May 15, 2006 (http://www.foreignpolicy.com/files/060516_Transcript.doc).

156. Reid Detchon, “Over a Barrel? Myths and Facts about U.S. Dependence on Foreign Oil,” Century Foundation (http://www.tcf.org/Publications/InternationalAffairs/oildep_detchon.pdf).

157. Nathanael Greene and Yerina Mugica, “Bringing Biofuels to the Pump,” issue paper, Natural Resources Defense Council, July 2005 (http://www.nrdc.org/air/energy/pump/pump.pdf).

158. National Corn Growers Association, “How Much Ethanol Can Come From Corn?” May 24, 2006 (http://www.ncga.com/ethanol/pdfs/2006/HowMuchEthanolCan%20ComeFromCorn.v.2.pdf).

159. U.S. Department of Energy, “DOE Publishes Roadmap for Developing Cleaner Fuels,” press release, July 7, 2006 (http://www.doe.gov/news/3804.htm).

160. Robert D. Perlack *et al.*, “Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,” Oak Ridge National Laboratory, ORNL/TM-2005/66, Apr. 2005 (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf). See also below, “The Benefits of Biofuels: Agriculture and Rural Economic Development.”

161. “A High Growth Strategy for Ethanol,” Report of an Aspen Institute Policy Dialogue, 2006, pp. 1-2 (http://www.aspeninstitute.org/atf/cf/{DEB6F227-659B-4EC8-8F84-8DF23CA704F5}/EEEethanol1.pdf).

162. See, for example, Nathanael Greene *et al.*, “Growing Energy,” Natural Resources Defense Council, Dec. 2004 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf), and Amory B. Lovins *et al.*, “Winning the Oil Endgame,” Rocky Mountain Institute, 2004 (http://www.oilendgame.com/ReadTheBook.html).

163. See below, "The Benefits of Biofuels: Agriculture and Rural Economic Development."

164. John M. Urbanchuk, "Contribution of the Ethanol Industry to the Economy of the United States," Feb. 21, 2006, p. 6 (http://www.ethanolrfa.org/objects/documents/576/economic_contribution_2006.pdf).

165. For example, the U.S. Department of Agriculture estimated that a 100-million-gallon/year ethanol production facility would create 2,250 local jobs for a single community: Cited in "Biofuels and Agriculture: A Factsheet for Farmers," Oak Ridge National Laboratory, Sept. 2001 (http://www1.eere.energy.gov/biomass/pdfs/farmerfactsheet.pdf). A team at the University of Missouri concluded that 5,613 in-state jobs would be created from producing 350 million gallons of ethanol a year (1,600 per 100 million gallons): "Employment and Economic Benefits of Ethanol Production in Missouri," Missouri Corn Growers Association, Jan. 2006, p. 17 (http://agebb.missouri.edu/commag/ethanolreport.pdf).

166. Renewable Fuels Association, "Ethanol Biorefinery Locations," updated Feb. 12, 2007 (http://www.ethanolrfa.org/industry/locations/).

167. John M. Urbanchuk, "Contribution of the Biodiesel Industry to the Economy of the United States," June 19, 2006 (http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20060720_gen-372.pdf).

168. Additional information available at http://www.25x25.org/.

169. "Former President Bill Clinton and Ted Turner Discuss the Future of Energy Policy," Democratic Leadership Council event, June 29, 2005 (transcript) (http://www.ppionline.org/ndol/print.cfm?contentid=253507).

170. "A Conversation: President Bill Clinton speaks with Aspen Institute President and CEO Walter Isaacson at the Aspen Ideas Festival," Aspen Institute event, July 8, 2005 (http://www.aspeninstitute.org/site/c.huLWJeMRKpH/b.1105487/k.6E45/President_Bill_Clinton_at_Ideas_Fest.htm).

171. Bureau of Economic Analysis, U.S. Department of Commerce, "U.S. International Transactions Accounts Data," Table 2b, U.S. Trade in Goods (1986-2005 data) (http://www.bea.gov/bea/international/bp_web/list.cfm?anon=302&registered=0). 2006 data extrapolated from Jan.-June data, "U.S. International Trade in Goods and Services, June 2006," Exhibit 9, Exports, Imports, and Balance of Goods, Petroleum and Non-Petroleum End-Use Category Totals (http://www.bea.gov/bea/newsrelarchive/2006/trad0606.xls).

172. Bureau of Economic Analysis, U.S. Department of Commerce, "U.S. International Trade in Goods and Services, June 2006," Exhibit 1 (Seasonally Adjusted) (http://www.bea.gov/bea/newsrelarchive/2006/trad0606.xls).

173. Crude oil data from U.S. Energy Information Administration, "Petroleum Navigator: U.S. Total Crude Oil and Petroleum Products Product Supplied (Thousand Barrels)" (http://tonto.eia.doe.gov/dnav/pet/xls/pet_cons_psup_dc_nus_mbbl_a.xls#'1-Products Supplied'!A1). GDP data from U.S. Department of Commerce, Bureau of Economic Analysis, "Current-Dollar and 'Real' Gross Domestic Product," Aug. 30, 2006 (https://bea.gov/bea/dn/gdplev.xls).

174. U.S. Energy Information Administration, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006), Feb. 2006 (http://www.eia.doe.gov/oiaf/aeo/economic.html), Figure 28, Energy Expenditures as Share of Gross Domestic Product, 1970-2030 (http://www.eia.doe.gov/oiaf/aeo/excel/figure28_data.xls).

175. David L. Greene and Nataliya I. Tishchishyna, "Costs of Oil Dependence: A 2000 Update," Oak Ridge National Laboratory, May 2000, ORNL/TM-2000/152, p. 27 (http://www.ornl.gov/~webworks/cpr/v823/rpt/107319.pdf).

176. U.S. Sen. Richard Lugar and Vinod Khosla, "We can end oil addiction," *The Washington Times*, Aug. 3, 2006 (http://washingtontimes.com/commentary/20060802-095213-8630r.htm). In a speech on Aug. 29, 2006, Sen. Lugar recommended "setting a price floor for crude oil at about $45 a barrel through a variable ethanol tax credit that would rise as the price of oil dropped" (http://news.uns.purdue.edu/html3month/2006/060829.SP-Lugar.energy.html).

177. Robert D. Perlack *et al.*, "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply," Oak Ridge National Laboratory, ORNL/TM-2005/66, Apr. 2005 (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf).

178. U.S. Department of Agriculture, "USDA Announces Results of CRP General Sign-Up and Contract Re-Enrollments and Extensions," press release, June 5, 2006 (http://www.fsa.usda.gov/pas/FullStory.asp?StoryID=2318).

179. These calculations assume a conversion rate of 100 gallons per ton. A fuller discussion of these tradeoffs can be found in Nathanael Greene *et al.*, "Growing Energy: How Biofuels Can Help End America's Oil Dependence," Natural Resources Defense Council, Dec. 2004, pp. 32-35 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf).

180. Nathanael Greene *et al.*, “Growing Energy: How Biofuels Can Help End America’s Oil Dependence,” Natural Resources Defense Council, Dec. 2004, p. 39 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf).

181. See, for example, Nathanael Greene *et al.*, “Growing Energy,” Natural Resources Defense Council, Dec. 2004 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf), and Amory B. Lovins et al., “Winning the Oil Endgame,” Rocky Mountain Institute, 2004 (http://www.oilendgame.com/ReadTheBook.html).

182. Robert D. Perlack *et al.*, “Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,” Oak Ridge National Laboratory, ORNL/TM-2005/66, Apr. 2005, p. 3 (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf).

183. Based on the projected availability of 428 million dry tons of annual crop residues, in Robert D. Perlack *et al.*, “Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,” Oak Ridge National Laboratory, ORNL/TM-2005/66, Apr. 2005 (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf).

184. American Farm Bureau Federation, “Fast Facts” (http://www.fb.org/index.php?fuseaction=newsroom.fastfacts).

185. Economic Research Service, U.S. Department of Agriculture, “Food Marketing and Price Spreads,” updated July 28, 2006 (http://www.ers.usda.gov/briefing/foodpricespreads/spreads/table1a.htm).

186. National Corn Growers Association, “How Much Ethanol Can Come From Corn?” May 24, 2006 (http://www.ncga.com/ethanol/pdfs/2006/HowMuchEthanolCan%20ComeFromCorn.v.2.pdf).

187. Robert D. Perlack *et al.*, “Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,” Oak Ridge National Laboratory, ORNL/TM-2005/66, Apr. 2005 (http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf).

188. Jason Clay, “Introduction: A Global View,” in *Resources for Global Growth: Agriculture, Energy and Trade in the 21st Century*, Center for American Progress, Washington, D.C., 2005, p. iv (http://www.americanprogress.org/atf/cf/%7BE9245FE4-9A2B-43C7-A521-5D6FF2E06E03%7D/RGGBOOK.PDF).

189. Lee A. Christensen, “Soil, Nutrient, and Water Management Systems Used in U.S. Corn Production,” U.S. Department of Agriculture, Agriculture Information Bulletin No. 774, Apr. 2002, p. 31 (http://151.121.68.30/publications/aib774/aib774.pdf).

190. See also below, “The Benefits of Biofuels: Environment and Public Health – What effect will the production of energy crops have on the land and water and wildlife?”

191. Bryan & Bryan, Inc., “Iowa Ethanol Plant Pre-Feasibility Study,” Jan. 2000, p. 42 (http://www.ethanolrfa.org/objects/pdf/ethanol_resource_manual.pdf).

192. U.S. Department of Agriculture, “Energy and Agriculture – 2007 Farm Bill Theme Paper,” Aug. 2006, p. 17 (http://www.usda.gov/documents/Farmbill07energy.doc).

193. Keith Collins, Chief Economist, U.S. Department of Agriculture, oral testimony before the U.S. Senate Committee on Agriculture, Nutrition and Forestry, Jan. 10, 2007.

194. Marie E. Walsh *et al.*, “The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture,” Oak Ridge National Laboratory (http://bioenergy.ornl.gov/papers/wagin/index.html).

195. Daniel De La Torre Ugarte and Chad Hellwinckel, University of Tennessee, “The Impacts on U.S. Agriculture of Large-Scale Bioenergy Crop Production,” paper prepared for the William and Flora Hewlett Foundation, July 2005.

196. This estimate assumes a plant size of 50 million gallons per year.

197. John M. Urbanchuk, “Contribution of the Ethanol Industry to the Economy of the United States,” Feb. 21, 2006, p. 2 (http://www.ethanolrfa.org/objects/documents/576/economic_contribution_2006.pdf).

198. Remarks to the American Council on Renewable Energy, Washington, D.C., Oct. 17, 2005.

199. Derived from Michael Wang *et al.*, “Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – North American Analysis,” Argonne National Laboratory, June 2001 (http://www.transportation.anl.gov/pdfs/TA/163.pdf).

200. M. Wu *et al.*, "Fuel-Cycle Assessment of Selected Bioethanol Production Pathways in the United States, Argonne National Laboratory, Nov. 7, 2006, p. 35 (http://www.transportation.anl.gov/pdfs/TA/377.pdf).

201. Michael Wang, "The Debate on Energy and Greenhouse Gas Emissions Impacts of Fuel Ethanol," presentation, Argonne National Laboratory, Aug. 3, 2005 (http://www.transportation.anl.gov/pdfs/TA/347.pdf).

202. Jason Hill *et al.*, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," *Proceedings of the National Academy of Sciences*, Vol. 103, No. 30, July 25, 2006, pp. 11206-10 (http://www.pnas.org/cgi/content/abstract/103/30/11206) (subscription required for access to full text).

203. David Bransby, "Switchgrass Profile," Auburn University (http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html).

204. Joint statement, Feb. 2004, cited by Lee R. Lynd, testimony before the Senate Committee on Agriculture, Nutrition and Forestry, May 6, 2004 (http://agriculture.senate.gov/Hearings/hearings.cfm?hearingid=1161&witnessId=3320).

205. U.S. Environmental Protection Agency, Office of Mobile Sources, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions," Oct. 2002, p. iii (http://www.epa.gov/OMS/models/analysis/biodsl/p02001.pdf).

206. Gary Z. Whitten, "Air Quality and Ethanol in Gasoline," Smog Reyes, Feb. 2004 (http://www.ethanolrfa.org/objects/documents/69/nec_whitten.pdf).

207. Natural Resources Defense Council, "Unlocking the Promise of Ethanol: Promoting ethanol while protecting air quality," fact sheet, Feb. 2006 (http://www.nrdc.org/air/transportation/biofuels/air.pdf).

208. Orbital Engine Company, "A Literature Review Based Assessment on the Impacts of a 20% Ethanol Gasoline Fuel Blend on the Australian Vehicle Fleet," Nov. 2002, pp. 33-34 (http://www.nmma.org/lib/docs/nmma/gr/environmental/ethanol-report.pdf).

209. Ngo Anh-Thu and Gale West, "Advantages and Disadvantages of Using Ethanol: The Consumer Viewpoint," Laval University, Aug. 24, 2004 (http://www.nmma.org/lib/docs/nmma/gr/environmental/Ethanol_advantages_and_Disadvantages.ppt).

210. Nathanael Greene *et al.*, "Growing Energy: How Biofuels Can Help End America's Oil Dependence," Natural Resources Defense Council, Dec. 2004, pp. 50-51 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf).

211. The Manufacturers of Emission Controls Association, "MECA Demonstration Program of Advanced Emission Control Systems for Light-Duty Vehicles," May 1999, pp. 10-11 (http://www.meca.org/galleries/default-file/LDVdemo.pdf).

212. U.S. Department of Energy, Office of Transportation Technologies, "Ford Taurus Ethanol-Fueled Sedan," fact sheet, 1999 (http://www.eere.energy.gov/afdc/pdfs/taurus.pdf).

213. Transportation and Regional Programs Division, "Clean Alternative Fuels: Ethanol," fact sheet, Mar. 2002 (http://www.epa.gov/OMS/consumer/fuels/altfuels/420f00035.pdf).

214. 42 U.S.C. § 7521, Emission standards for new motor vehicles or new motor vehicle engines, subsection (l)(2): Mobile source-related air toxics - Standards (http://www.washingtonwatchdog.org/documents/usc/ttl42/ch85/subchII/ptA/sec7521.html).

215. U.S. Environmental Protection Agency, "Control of Hazardous Air Pollutants from Mobile Sources," Feb. 28, 2006, published Mar. 29, 2006 (70 Fed. Reg. 15804) (http://www.epa.gov/OMS/regs/toxics/msat-nprm-fr.pdf).

216. Energy Future Coalition, "Comments," May 30, 2006, p. 3 (Docket EPA-HQ-OAR-2005-0036, item 0949.1) (http://www.regulations.gov/fdmspublic/component/main - under Advanced Search, enter docket number; item can be found at p. 50).

217. Nathanael Greene *et al.*, "Growing Energy: How Biofuels Can Help End America's Oil Dependence," Natural Resources Defense Council, Dec. 2004, pp. 27-29 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf).

218. U.S. Department of Energy, Office of Transportation Technologies, "Biofuels from Switchgrass: Greener Energy Pastures" (http://bioenergy.ornl.gov/papers/misc/switgrs.html).

219. Nathanael Greene *et al.*, "Growing Energy: How Biofuels Can Help End America's Oil Dependence," Natural Resources Defense Council, Dec. 2004, p. 30 (http://www.nrdc.org/air/energy/biofuels/biofuels.pdf).

220. National Science Foundation, “Mixed Prairie Grasses Better Source of Biofuel Than Corn Ethanol and Soybean Biodiesel,” press release, Dec. 7, 2006 (http://www.nsf.gov/news/news_images.jsp?cntn_id=108206&org=NSF).

221. David Bransby, “Switchgrass Profile” (http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html).

222. Wind Erosion Research Unit, multimedia archive (http://www.weru.ksu.edu/new_weru/multimedia/general/general1.html).

223. Edward Smeets *et al.*, “A quickscan of global bio-energy potentials to 2050,” Copernicus Institute, Mar. 2004, p. 2 (http://www.chem.uu.nl/nws/www/publica/e2004-109.pdf).

224. Worldwatch Institute, “Biofuels for Transportation,” extended summary, June 7, 2006, p. 6 (http://www.worldwatch.org/taxonomy/term/445).

225. U.S. Energy Information Administration, “International Energy Outlook 2006,” chapter 2, “Energy Consumption by End-Use Sector,” pp. 7-8 (http://www.eia.doe.gov/oiaf/ieo/pdf/enduse.pdf).

226. Alexander Müller, Assistant Director-General for Sustainable Development, quoted in “FAO sees major shift to bioenergy,” FAO news release, Apr. 25, 2006 (http://www.fao.org/newsroom/en/news/2006/1000282/index.html).

227. UNICA (São Paulo Sugar Cane Agroindustry Union), “Statistics: Production Brazil, 1990-2005” (http://www.portalunica.com.br/portalunicaenglish/files/statistics_productionbrazil-1-Arquivo.xls).

228. UNICA (São Paulo Sugar Cane Agroindustry Union), “A clean and renewable fuel” (http://www.portalunica.com.br/portalunicaenglish/index.php?Secao=ethanol).

229. Larry Rohter, “With Big Boost From Sugar Cane, Brazil Is Satisfying Its Fuel Needs,” *The New York Times*, Apr. 10, 2006 (http://www.nytimes.com/2006/04/10/world/americas/10brazil.html?ex=1302321600&en=03adc82c67600388&ei=5088&partner=rssnyt).

230. ANFAVEA (National Association of Automakers [of Brazil]), “Domestic Auto Sales (Jan.-June 2006),” July 19, 2006 (http://www.anfavea.com.br/Tabelas2006/TAB4VEN.doc).

231. European Biodiesel Board, “EU biodiesel production growth hits record high in 2005,” press release, Apr. 25, 2005 (http://www.ebb-eu.org/EBBpressreleases/EBB%20press%20release%202005%20statistics%20(final).pdf).

232. Michael Wang, “Energy and Greenhouse Gas Emission Impacts of Fuel Ethanol,” Argonne National Laboratory, Apr. 14, 2006 (http://www.sustainablebioenergy.uiuc.edu/Presentations/Wang.pdf).

233. Edward Smeets *et al.*, “Supportive study for the OECD on alternative developments in biofuel production across the world,” Copernicus Institute, Dec. 2005 (http://www.chem.uu.nl/nws/www/publica/Publicaties2005/E2005-141.pdf).

234. Michael Casey, “Across Asia, Governments Look to Crops to Offset Oil Dependence,” Associated Press, May 1, 2006 (http://www.enn.com/today.html?id=10367).

235. “Malaysia Approves 52 Biodiesel Plants So Far,” Reuters, Aug. 16, 2006 (http://www.planetark.com/dailynewsstory.cfm/newsid/37685/newsDate/16-Aug-2006/story.htm).

236. Friends of the Earth International, “Greasy palms – palm oil, the environment and big business,” Mar. 2004 (http://www.foe.co.uk/resource/reports/palm_oil_summary.pdf).

237. Sen. Fiona Nash, “Submission to Biofuels Taskforce,” July 1, 2005 (http://www.dpmc.gov.au/biofuels/submissions/submission54.pdf).

238. Food and Agriculture Organization of the United Nations, “Bioenergy,” paper presented to the Committee on Agriculture, Apr. 2005 (http://www.fao.org/docrep/meeting/009/j4313e.htm).

239. Ugandan women carry fuelwood home for cooking (http://www.radford.edu/~wkovarik/envhist/RenHist/1.wood.html).

240. International Energy Agency, “World Energy Outlook 2004,” Executive Summary, p. 36 (http://www.iea.org/Textbase/npsum/WEO2004SUM.pdf).

241. Food and Agriculture Organization of the United Nations, “Bioenergy,” paper presented to the Committee on Agriculture, Apr. 2005 (http://www.fao.org/docrep/meeting/009/j4313e.htm).

242. United Nations Statistics Division, “Progress towards the Millennium Development Goals, 1990-2005,” UN Department of Economic and Social Affairs, June 13, 2005 (http://mdgs.un.org/unsd/mdg/Host.aspx?Content=Products/Progress2005.htm).

243. The Health and Environmental Linkages Initiative, “Policy Brief – Indoor air pollution: environment and health linkages,” World Health Organization and United Nations Environment Program (http://www.who.int/heli/risks/indoorair/indoorair/en/index.html).

244. Derived from “Africa’s Oil Emergency,” Center for American Progress, June 2006 (http://www.americanprogress.org/atf/cf/{E9245FE4-9A2B-43C7-A521-5D6FF2E06E03}/HIPC_ENERGYPOVERTY_CHART.PDF).

245. Kathy Roche and Teresita Perez, “Our Addiction to Oil is Fueling World Poverty,” Center for American Progress, Apr. 6, 2006 (http://www.americanprogress.org/site/pp.asp?c=biJRJ8OVF&b=1533171).

246. Food and Agriculture Organization of the United Nations, “Bioenergy,” paper presented to the Committee on Agriculture, Apr. 2005 (http://www.fao.org/docrep/meeting/009/j4313e.htm).

247. http://www.jatropha.de/mali/jatropha-hedge-in-village.htm.

248. Ines Havet, United Nations Development Program, “Linking women and energy at the local level to global goals and targets,” *Energy for Sustainable Development*, Volume VII, No. 3, Sept. 2003, pp. 76-79 (http://www.undp.org/energy/docs2/link-womengmdg.pdf).

249. Mark Langevin, “Fueling Sustainable Globalization: Brazil and the Ethanol Alternative,” *InfoBrazil*, Sept. 17, 2005 (http://www.infobrazil.com/busca/conteudo.asp?Arquivo=/conteudo/front_page/opinion/vb6309.htm).

250. Daniel De La Torre Ugarte and Chad Hellwinckel, University of Tennessee, “The Impacts on U.S. Agriculture of Large-Scale Bioenergy Crop Production,” paper prepared for the William and Flora Hewlett Foundation, July 2005.

251. Food and Agriculture Organization of the United Nations (FAO), *World agriculture: towards 2015/2030 – Summary report* (2002) (http://www.fao.org/docrep/004/y3557e/y3557e03.htm#c).

252. Food and Agriculture Organization of the United Nations (FAO), “Food requirements and population growth,” technical background document prepared for the 1996 World Food Summit, Vol. 1, Sec. 2.68, (http://www.fao.org/docrep/003/w2612e/w2612e04a.htm).

253. Food and Agriculture Organization of the United Nations (FAO), “Food requirements and population growth,” technical background document prepared for the 1996 World Food Summit, Vol. 1, Sec. 3.121, (http://www.fao.org/docrep/003/w2612e/w2612e04a.htm).

254. Food and Agriculture Organization of the United Nations (FAO), “Food requirements and population growth,” technical background document prepared for the 1996 World Food Summit, Vol. 1, Secs. 3.124-3.126, (http://www.fao.org/docrep/003/w2612e/w2612e04a.htm).

255. Food and Agriculture Organization of the United Nations (FAO), “Food requirements and population growth,” technical background document prepared for the 1996 World Food Summit, Vol. 1, Sec. 3.133, (http://www.fao.org/docrep/003/w2612e/w2612e04a.htm).

256. Food and Agriculture Organization of the United Nations (FAO), *World agriculture: towards 2030/2050 - Interim report*, “Conclusions” (June 2006), pp. 7 (http://www.fao.org/es/esd/AT2050web.pdf).

257. Food and Agriculture Organization of the United Nations (FAO), *World agriculture 2030*, “Main findings” (http://www.fao.org/english/newsroom/news/2002/7833-en.html).

Glossary

Alcohol: Colorless volatile liquid created through the fermentation of sugars or starches

Aromatics: Petroleum-based chemical compounds blended with gasoline to improve octane – principally benzene, toluene, and xylene

Bagasse: Sugar cane waste

Biobutanol: Alcohol containing four carbon atoms per molecule, produced from the same feedstocks as ethanol, but with a modified fermentation and distillation process. Less water-soluble than ethanol, biobutanol has a higher energy density and can be transported by pipeline more easily

Biodiesel: Biofuel (technically, methyl esters) produced from oilseed crops – including soy, canola, palm, and jatropha – that can be used in diesel engines

Biofuel: Fuel produced from biomass

Biomass: Biological material – including corn, switchgrass, and oilseed crops – that can be converted into fuel

Cellulose: Fiber contained in leaves, stems, and stalks of plants and trees. It is the most abundant organic compound on earth

Cetane Rating: Measure of diesel's combustion quality

Distillers Grains: Byproduct of ethanol production that can be used to feed livestock; alternatively, distillers dried grains with solubles (DDGS)

E10: Blend of 10% ethanol and 90% gasoline

E85: Blend of 85% ethanol and 15% gasoline

Energy Balance: Difference between the fossil energy needed to produce a fuel and the energy the fuel contains

ETBE: See 'Ethyl Tertiary Butyl Ether'

Ethanol: Alcohol containing four carbon atoms per molecule with about two-thirds the energy density of gasoline, mostly fermented from corn starch or sugar cane, also known as 'grain alcohol'

Ethers: Liquid fuel made from a blending an alcohol with isobutylene

Ethyl Tertiary Butyl Ether: Ether created from ethanol that can increase octane and reduce the volatility of gasoline, decreasing evaporation and smog formation

Feedstock: Raw material used in an industrial process, like the production of biofuel

FFV: See 'Flexible Fuel Vehicle'

Fischer-Tropsch Process: Method of producing liquid fuels, usually diesel fuel, from natural gas or synthetic gas from gasified coal or biomass

Flexible Fuel Vehicle: Automobile capable of running on gasoline and high-ethanol blends interchangeably

Gasohol: Fuel blend of 10% ethanol and 90% gasoline (E10)

Grain Alcohol: See ‘Ethanol’

Knock: Engine sound that results from ignition of the compressed fuel-air mixture prior to the optimal moment

Lignin: Energy-rich material contained in biomass that can be used for boiler fuel

Methanol: Alcohol containing one carbon atom per molecule, generally made from natural gas, with about half the energy density of gasoline, also known as ‘wood alcohol’

Methyl Esters: See ‘Biodiesel’

MTBE (Methyl Tertiary Butyl Ether): Ether created from methanol that can increase octane and decrease the volatility of gasoline, decreasing evaporation and smog formation

Octane: Measure of a fuel’s resistance to self-ignition (see ‘Knock’)

Perennial: Plant that doesn’t have to be planted every year like traditional row crops

Renewable Fuels Standard (RFS): Legislation enacted by Congress as part of the Energy Policy Act of 2005, requiring an increasing level of biofuels be used every year, rising to 7.5 billion gallons by 2012.

Switchgrass: Prairie grass native to the United States and known for its hardiness and rapid growth, often cited as a potentially abundant feedstock for ethanol

Thermal Conversion: Process that uses heat and pressure to break apart the molecular structure of organic solids

Transesterification: Chemical process that transforms raw vegetable oil into biodiesel by separating out glycerin, which is used in soaps and other products

Volatility: Propensity of a fuel to evaporate

Wood Alcohol: See ‘Methanol’