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Ethanol and the Environment

By Kenneth P. Green

Contrary to popular belief, ethanol fuel will do little or nothing to increase our energy security or stabilize fuel prices. Instead, it will increase greenhouse gas emissions, local air pollutant emissions, fresh water scarcity, water pollution (both riparian and oceanic), land and ecosystem consumption, and food prices.

Ethanol has been a critically important chemical for a very long time. In fact, it has been used for eight thousand years or so—going back to the Paleolithic era—and some research suggests that Stone Age people recognized the value of a good tipple.[1] As commentator George Will recently pointed out, some have even argued that ethanol, in the form of beer and wine, was an evolutionary driver in helping humanity transcend its original hunter-gatherer lifestyle and begin living in denser population clusters.[2]

Automobile designers have long recognized ethanol's potential as motor vehicle fuel. The first American internal combustion prototype made by Samuel Morey in 1826 ran on ethanol, and it remained the dominant automotive fuel until 1908, when a combination of rapidly dropping gasoline prices and rapidly increasing ethanol prices led the Ford Motor Company to introduce the Model T, an early "flex-fuel" vehicle that could use either gasoline or ethanol. Gasoline/ethanol blends were used until the 1920s in the United States and the 1930s in Europe but were finally replaced by gasoline with lead additives, which was discovered to stop engine knocking. Ethanol blends were essentially off the market by 1940.[3]

Ethanol languished in niche uses for the next thirty years, until the 1973 oil embargo made ethanol look attractive again as a replacement for gasoline and rekindled an interest in building ethanol distilleries. Gas lines and shortages in the 1970s even had people thinking about fermenting local fruit and vegetable waste and surplus to stretch their supplies of gasoline.[4] (I also tried to do this, around 1978, but as a seventeen-year-old was not able to get through the paperwork of the Bureau of Alcohol, Tobacco, and Firearms!) When the price of gasoline started dropping in the 1980s,[5] interest in ethanol dropped with it, but ethanol fuel was given another look in 1989 when air pollution regulators mandated the use of fuel oxygenates (including ethanol) to reduce summertime pollution. This delighted the farm lobby, which was happy to take taxpayer subsidies to turn a crop surplus (usually a bad thing) into fuel supplements demanded by air quality laws. Later discovery of the groundwater-polluting effects of methyl tertiary butyl ether (MTBE)—the oxygenate that was ethanol's main competitor—led several states to switch from MTBE to ethanol as a fuel oxygenate.[6]

Recent events have sent the fortunes of ethanol producers skyrocketing, as ethanol fuel has come back with a subsidy-powered roar. In a speech on April 25, 2006, President George W. Bush, known to abstain from drinking the stuff, was nearly rhapsodic about ethanol as fuel:

> Ethanol is a versatile fuel. And the benefits are easy to recognize when you think

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> about it. . . . Ethanol is good for our rural communities. It's good economic development for rural America. . . . Ethanol is good for the environment. . . . [E]thanol's good for drivers. . . . Ethanol's good for the whole country.[7]

And Bush was excited about our ability to make ethanol as well:

> The ethanol industry is booming. . . . There are now ninety-seven ethanol refineries in our country, and nine of those are expanding, and thirty-five more are under construction. . . . But what's really interesting, there are new plants springing up in unexpected areas, like the Central Valley of California, or Arizona, or, of course, in the sugar fields of Hawaii.[8]

Finally, Bush assured us, more ethanol is on the way:

> I am committed to furthering technological research to find other ways, other sources for ethanol. We're working on research—strong research to figure out cellulosic ethanol that can be made from wood chips or stalks or switch grass. These materials are sometimes waste products that are just simply thrown away.[9]

When a president of the United States starts talking about wood chips and switch grass, you know that a substance has reached front and center in the national discourse. Both of our current presidential candidates, John McCain and Barack Obama, support ethanol as well, though McCain's support for ethanol seems to have been an epiphany on the eve of the Republican primary in Iowa and the corn belt.[10]

But ethanol also has its detractors, who claim that it has the potential to do great economic, ecologic, and gastronomic harm while doing little good. Before examining the implications of the use of ethanol as fuel, let us review some of the basics of ethanol: what it is and where it comes from.

What Is Ethanol and How Is It Made?

Most people probably remember from high-school biology that ethanol is a chemical made when yeast breaks down sugar molecules in a process called fermentation. Ethanol has two carbon atoms, six hydrogen atoms, and one oxygen atom. There are various kinds of alcohol, but ethanol is the one found in your beer, wine, and spirits. It is also combustible, which is well known to anyone who has set brandy on fire while cooking—think Cherries Jubilee.

Alcohols like ethanol and its chemical cousins make effective fuels because they give off a lot of energy when burned, just as liquid fossil fuels do. The advantage of alcohol is that it is liquid at room temperature, which makes it easy to transport and handle.

Ethanol can be made in a variety of ways, but the usual way is still the most common: yeast is fed sugar molecules isolated from fruits or vegetables, and it produces ethanol as a byproduct. The ethanol is then distilled from a dilute solution by controlled heating in order to drive off ethanol vapor. In the United States, the primary raw material for producing fuel ethanol is corn, while in other countries, such as Brazil, the primary source is sugar cane.

The Many Downsides of Ethanol

While ethanol promoters make it sound as if ethanol is the solution to all our energy woes—dependence on foreign oil, diminishing oil stocks, the environmental consequences of energy use, the decline of the family farm, and so on—a considerable amount of research has shown that ethanol has far more peril than it does promise.

Ethanol and Greenhouse Gas Emissions. Though ethanol is often pitched as a good solution to climate change because it simply recirculates carbon in the atmosphere, there is more than one kind of greenhouse gas to consider. Ethanol, blended with gasoline, actually turns out to increase the formation of potent greenhouse gases more than gasoline does by itself. As far back as 1997, the U.S. Government Accountability Office determined that the ethanol production process produces

> relatively more nitrous oxide and other potent greenhouse gases than does gasoline. In contrast, the greenhouse gases released during the conventional gasoline fuel cycle contain relatively more of the less potent type, namely, carbon dioxide.[11]

Last fall, Paul Crutzen, a Nobel-prize-winning chemist, confirmed these findings. Crutzen and his coauthors found that

> [w]hen the extra N_2O emission from biofuel production is calculated in "CO_2-equivalent" global warming terms, and compared with the quasi-cooling effect of "saving" emissions of fossil fuel derived CO_2, the outcome is that the production of commonly used biofuels, such as biodiesel from rapeseed and bioethanol from corn (maize), depending on N fertilizer uptake efficiency by the plants, can contribute as much or more to global warming by N_2O emissions than cooling by fossil fuel savings.[12]

In June 2007, two Colorado scientists, Jan F. Kreider, an engineering professor at the University of Colorado, and Peter S. Curtiss, a Boulder-based engineering consultant, determined that carbon dioxide emissions from corn-based ethanol are worse than those of conventional gasoline and diesel fuel. They concluded that carbon emissions in the life-cycle sense are about 50 percent higher for ethanols than for traditional fossil fuels; such fuels are not the answer to global warming—they make it worse.[13]

In February 2008, researcher Timothy Searchinger and colleagues calculated that

> "corn-based" ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50%.[14]

Ethanol and Air Pollution. Although the U.S. Environmental Protection Agency (EPA) claims a net decrease in greenhouse gas emissions from using ethanol, they recognize that ethanol use is a problem for conventional air pollutants. Ethanol use, according to the EPA, will increase the emission of chemicals that lead to the production of ozone, one of the nation's most challenging local air pollutants.

> At the same time, other vehicle emissions may increase as a result of greater renewable fuel use. Nationwide, EPA estimates an increase in total emissions of volatile organic compounds and nitrogen oxides (VOC + NOx) between 41,000 and 83,000 tons [due to increased use of ethanol]. . . . Areas that experience a substantial increase in ethanol may see an increase in VOC emissions between 4 and 5 percent and an increase in NOx emissions between 6 and 7 percent from gasoline powered vehicles and equipment.[15]

Producing enough ethanol from switch grass to displace 1 million barrels of oil per day would require that 25 million acres of land be planted in switch grass. That is an area about the size of Kentucky.

Increases in pollutants have also been shown at the state and local level. In 2004, the California Air Resources Board released a study that found that gasoline containing ethanol caused VOC emissions to increase by 45 percent when compared to gasoline containing no oxygenates. And in mid-2006, California's South Coast Air Quality Management District determined that gasoline containing 5.7 percent ethanol may add as much as seventy tons of VOCs per day into the state's air.[16] For a sense of scale, consider that an air quality regulator in the region around Los Angeles can become employee of the month by coming up with a way of reducing emissions by one-tenth of a ton per day.[17] More recently, Mark Z. Jacobson, a researcher at Stanford University, estimated that switching to a blend of 85 percent ethanol and 15 percent gasoline—relative to 100 percent gasoline—may increase ozone-related mortality, hospitalization, and asthma by about 9 percent in Los Angeles and 4 percent in the United States as a whole.[18]

Ethanol and Fresh Water Consumption. What may surprise many people is how much fresh water it takes to produce ethanol. In December 2006, scientists at Sandia National Laboratory in New Mexico issued a report, *Energy Demands on Water Resources*, explaining that virtually all forms of energy production consume a lot of water. Petroleum refining, for example, consumes 1–2.5 gallons of water per gallon of refined product. Colorado scientists Kreider and Curtiss estimate that refining a gallon of corn ethanol today requires thirty-five gallons of water. But that is only the beginning. Kreider and Curtiss estimate that three times as much water is needed to grow the corn that yields a gallon of ethanol. That brings the tally to 140 gallons of water per gallon of corn ethanol produced.[19] If their calculation is correct, the 5.4 million gallons of corn ethanol used in America in 2006 required the use of 760 million gallons of fresh water.[20]

And things do not look much better for ethanol made from cellulose crops, such as switch grass. Kreider and Curtiss estimate that switch grass would require between 146 and 149 gallons of water per gallon of ethanol produced from cellulose depending on the scale of production. Thus, meeting the Bush administration's target of 35 billion gallons of renewable and alternative fuels production in the United States by 2017 with cellulosic ethanol would require about 5 trillion gallons of water per year. That is a bit more than the average annual flow of the Colorado River, which the Southern Nevada Water Authority lists at 15 million acre-feet, or a little under 5 trillion gallons.[21]

Ethanol will not bring us energy security, and it may well make us less secure because of the significant volatility in crop productivity from year to year.

Ethanol and Water Pollution. In *Water Implications of Biofuels Production in the United States*, the National Academy of Sciences (NAS) points out that if the United States continues to expand corn-based ethanol production without new environmental protection policies, "the increase in harm to water quality could be considerable."[22] Corn, according to the NAS, requires more fertilizers and pesticides than other food or biofuel crops. Pesticide contamination is highest in the corn belt, and nitrogen fertilizer runoff from corn already has the highest agricultural impact on the Mississippi River. In short, more corn raised for ethanol means more fertilizers, pesticides, and herbicides in waterways; more low-oxygen "dead zones" from fertilizer runoff; and more local shortages in water for drinking and irrigation.

Fertilizer runoff does not just pollute local waters; it creates other far-reaching environmental problems. Each summer, the loading of nitrogen fertilizers from the Mississippi via the corn belt hits the Gulf of Mexico, creating a large dead zone—a region of oxygen-deprived waters unable to support sea life that extends for more than ten thousand square kilometers. The same phenomenon occurs in the Chesapeake Bay, in some summers affecting most of the waters in the mainstern bay.[23] A recent study by researchers at the University of British Columbia shows that if the United States were to meet its proposed ethanol production goals—15–36 billion gallons of corn and cellulosic ethanol by 2022—nitrogen flows to the Gulf of Mexico would increase by 10–34 percent.[24]

Ethanol and Land Consumption. In a February 2008 *Science* article, researchers calculated that producing 15 billion gallons of corn ethanol to meet U.S. ethanol goals would require the diversion of corn from 12.8 million hectares of U.S. cropland and would, in turn, bring 10.8 million hectares of additional land into cultivation. Locations would include 2.8 million hectares in Brazil, 2.3 million in China and India, and 2.2 million here in the United States.[25]

Projected corn ethanol production in 2016 would use 43 percent of the U.S. corn land harvested for grain in 2004 that would otherwise be primarily used to feed livestock, requiring big land-use changes to replace that grain or causing sharp price hikes due to scarcity of grain raised for human and livestock consumption.[26] And this does not include infrastructure requirements. As a low-density feedstock, corn or switch grass would be required in massive quantities to produce enough ethanol to slake the thirst of America's transportation fleets. Bringing that heavy, woody biomass to an ethanol processing plant would require an extensive transportation infrastructure, most likely both truck and train. And since ethanol cannot be run through pipelines—it is both corrosive and strongly attracts water molecules from soil outside the pipeline at seams or pipeline cracks, leading to dilution of the ethanol—it will have to be moved again by tanker truck to the blending stations, where it will be mixed with gasoline, or to fueling stations directly if we ever run vehicles on pure ethanol.

Ethanol and Energy Security. The fundamental thermodynamic limitations of biofuels will render them little more than niche sources barring massive technological breakthroughs. These limitations undercut claims that biofuels and renewables will increase America's military or energy security.

The problem is one of time and energy density: while nature spent millions of years concentrating solar energy in the forms of peat, coal, oil, and natural gas, all of the biofuels rely on sunlight to grow crops. Because such energy is extremely diffuse, the scale of land consumption and the labor required to gather massive quantities of low-density fuel quickly leads to diminishing returns.

As Rockefeller University researcher Jesse Ausubel points out, it would take one thousand square miles of

prime Iowa farmland to produce as much electricity from biomass as from a single nuclear power plant.[27] And cellulosic ethanol is not the solution. In May 2006, John Deutch, a chemistry professor at the Massachusetts Institute of Technology, concluded that producing enough ethanol from switch grass to displace 1 million barrels of oil per day would require that 25 million acres of land—about thirty-nine thousand square miles—be planted in switch grass. That is an area about the size of Kentucky. He concluded that we can produce ethanol from cellulosic biomass sufficient to displace 1–2 million barrels of oil per day in the next couple of decades, but not much more than that.[28] Even cellulosic ethanol cannot provide enough liquid fuel for us to be able to stop importing foreign oil and being dependent on foreign governments.

What ethanol is likely to do is lead to sharply higher food prices as less land is used to raise low-profit foods and more is used to raise high-profit biofuel crops. It is likely to increase local air pollution, water pollution, and, ironically, greenhouse gas emissions.

Biofuels cannot displace enough of the world oil market to cause economic hardship to enemy regimes (we are actually allies with most of our major suppliers), nor will renewables put a dent in the pocketbook of terrorists. As terrorism expert Colonel G. I. Wilson points out, "most insurgencies are low-tech in nature. Terrorists don't need oil money. For terrorists, the money flow doesn't come from oil, it comes from drugs, crime, human trafficking and the weapons trade."[29] That should be self-evident, as many terrorist groups exist in countries that do not have oil wealth. The Tamil Tigers have used terror in Sri Lanka, the Basque separatist group Euskadi Ta Askatasuna has used it in Spain, and the IRA has used it in Ireland—and none of them needed petrodollars for their actions. Nor for that matter do the Taliban or the Palestinians. Osama bin Laden's family wealth was made in the construction industry.[30]

Drink It, Don't Drive It

There is little question that high gasoline and oil prices are harmful to the national economy and the personal economies of individual Americans. But putting our hope in ethanol (whether from corn, switch grass, or other cellulosic crops) is not a rational policy response, however attractive it is to the corn lobby. Ethanol will not bring us energy security, and it may well make us less secure because of the significant volatility in crop productivity from year to year. Ethanol will not bring us energy independence because we cannot make enough of it to replace a significant fraction of motor fuel. Ethanol will not shield us from high gasoline prices because, in a free market, the price of ethanol will be the same as gasoline, on an energy-equivalent basis—that is, the price of a gallon of ethanol should be around 66 percent of a gallon of gasoline, as it will take you the same distance when you drive on it. And switching from oil to ethanol will not defund America's enemies—growing global demand for all forms of energy ensures that every barrel of oil pulled out of the ground will find a customer.

What ethanol is likely to do is lead to sharply higher food prices as less land is used to raise low-profit foods and more is used to raise high-profit biofuel crops. It is likely to increase local air pollution, water pollution, and, ironically, greenhouse gas emissions.

Though it is rare for anyone to recommend that lawmakers hit the bottle, in the case of ethanol, the balance of virtue and vice is fairly clear. America's motto should not be "Ethanol for Energy Independence." It should be "Ethanol: Drink It, Don't Drive It."

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Notes

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8. Ibid.

9. Ibid. Cellulose is a chemical compound that plants produce as cell walls, giving plants their characteristic rigidity. Cellulose molecules are long chains of connected sugar molecules (glucose) that bind to other long chains in a parallel fashion to form extensive sheets. Cellulose is a highly durable substance and the most common biomolecule on earth.

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