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The Biofuels Conundrum

Their Potential for Good or Ill is Enormous; Getting the Rules Right is Critical

Climate change has risen to the forefront of the international agenda, and not just as an environmental issue—for its economic, political, and security implications as well. Preventing catastrophic climate change is the challenge of this generation. To succeed, we must foster a new energy economy in the United States and around the world, with special emphasis on two economic sectors—power generation and transportation—and their dominant fuel sources, coal and oil. Both areas pose very large challenges, but transportation may be the more difficult because the sector depends almost completely on a single fuel.

Recently, much attention has been paid to the potential of ethanol—and biofuels more broadly—to substitute for gasoline at large scale. Ethanol, particularly from corn, is no panacea, but over time biofuels—especially "second-generation" biofuels from non-food crops—could make a substantial positive contribution. Their development could also come at great environmental cost. Sensible policies are needed that consider the long-term consequences of our actions.

Long-term thinking, unfortunately, is not a leading American virtue. Corporations seek short-term profits over long-term gains, driven by the pressure to report to investors each quarter. Public officials rarely rise above the perceived demands of the next election cycle in shaping policy. Even high-minded interest

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groups often have difficulty seeing the forest from the trees. Yet long-term thinking will be essential to preserving a livable climate on Earth.

To avoid catastrophic consequences for our planet, there is broad scientific consensus that we should hold global temperature increases to 2 degrees Centigrade, and to do that the U.S. must join other industrialized countries in reducing emissions of carbon dioxide and other greenhouse gases by roughly 80 percent by 2050. That means we must start moving immediately and aggressively towards a low-carbon economy. Along the way, we must pay careful attention to the effects that our actions have on the environmental life cycle and human health, and make mid-term corrections as needed.

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Transportation is a critical area to address, as the consumption of petroleum-based fuels is expected to double worldwide by 2050 if we simply stay on the track we are on. In addition, the history of our relationship with automobiles and petroleum provides many examples of unintended consequences—choices that seemed right at the time and turned out badly over the long run. Gasoline, to take but one example, is a highly useful fuel –compact, dense, and readily portable—but we experience the adverse health effects of gasoline emissions through the air we breathe every day. Abundant fossil fuels have led to unprecedented global prosperity—but their emissions are upsetting the delicate balance of the global climate. Petroleum has made possible cheap transportation of people, goods and services—but our dependence on oil has had disastrous consequences for our national security, trade balance, and the purchasing power of the dollar.

Would biofuels be any better? They could be much better—and in December the U.S. Congress placed a big bet on them in the Energy Independence and Security Act of 2007, amending the so-called "renewable fuels standard" to require the use of 36 billion gallons of biofuels by 2022—more than a sixfold increase from today's consumption. This certainty of explosive growth means that we must think through all its implications and govern the transition to new fuels with sensible long-term policies. Energy is a rules-based business, and to get the outcome we want, we have to get the rules right.

Toward that end, the Institute of Medicine of the National Academies in Washington, with support from the United Nations Foundation, convened a scientific roundtable in November 2007 to explore the health and environmental impacts of today's fuels and identify research needs related to increased use of biofuels—not just in the U.S., but globally.[1] The purpose was to anticipate and avoid any adverse consequences of new fuel choices—and in that way break with the past.

UNINTENDED CONSEQUENCES

The following history lesson is instructive—with thanks to C. Boyden Gray, U.S. Ambassador to the European Union and a longtime student of this subject.[2] In Henry Ford's day, the nascent automobile industry needed octane to combat the problem of premature combustion—engine knock—so cars could climb hills and carry bigger loads. Ethanol is a high-octane fuel, and the vision of Henry Ford and other auto industry founders such as Charles Kettering of General Motors was that cars would run on ethanol, either alone or in combination with gasoline. Ford was concerned that autos would generate pollution, so he spent considerable time and money to study various sources of alcohol fuel.

But the federal government put a damper on what might have been the first ethanol boom. To help pay for the Civil War, Congress had placed an excise tax of $2 per gallon on alcohol and didn't repeal it until the early 20th century. That made ethanol too expensive for Ford. Then, during Prohibition, the IRS told Ford that it was illegal to distill alcohol, even to put into auto tanks.

The beneficiary of these barriers to ethanol was tetraethyl lead, which General Motors researcher Thomas Midgley discovered could boost octane when added to gasoline. Also helping its fortunes were a couple of other benefits: it was cheap to make, and unlike alcohol, it could be patented. Despite early evidence of lead's poisonous effects, the responsibility for researching its health impacts was left to the industry. By 1960, leaded gasoline had captured nearly 90 percent of the U.S. market for automotive fuels. And only in the 1960s did research start to show that leaded gasoline produces exhaust that harms everyone who breathes the air it pollutes—and that children are especially vulnerable.

When the severe health problems posed by lead pollution became known, the additive was phased out by the newly created Environmental Protection Agency after the Clean Air Act was passed in 1970. But again, unintended consequences prevailed. Refiners had two basic choices for additives to boost octane: alcohol-based fuels such as ethanol, and chemicals known as aromatics—including the substances benzene, toluene, and xylene. The latter were already present in gasoline and were both inexpensive and within the control of the oil refiners, making them the clear choice. The harmful effects of these aromatic compounds were known at the time, but because they were already in gasoline, adding more to the mix did not fall afoul of EPA regulations.

The proportion of aromatics added to gasoline grew from about 22 percent of gasoline in the early 1970s to about a third by 1990. That year, major amendments to the Clean Air Act were signed into law, directing EPA to promulgate new regulations to lower the toxicity of air from auto emissions. EPA was instructed to study the need for and feasibility of controls on air toxics from mobile sources (MSATs) and to issue regulations seeking the "greatest degree of emission reduction achievable through the application of technology which will be available."[3] But in 2007, aromatics still compose roughly a quarter of most tanks of gas and present health risks, some of which we still don't fully understand.

THE RISKS OF AROMATICS

The cancer-causing properties of benzene are well accepted. Acute myelogenous leukemia is the primary cancer linked to benzene. EPA classifies benzene as a hazardous substance under the Safe Drinking Water Act and a hazardous air pollutant under the Clean Air Act. The World Health Organization has concluded that there is no safe level of benzene exposure.

Reductions in fine particulates would offer benefits worth tens of billions of dollars. Aromatics are considered the most significant gaseous precursors.

Toluene and xylene, other aromatic molecules, are also designated as hazardous air pollutants under the Clean Air Act. Benzene is a direct product of gasoline combustion and also is formed by the combustion of toluene and xylene. EPA estimates that non-benzene aromatics contribute about 30 percent of benzene emissions.[4]

Air pollution forms when the combustion of chemicals in gasoline leads to by-products that end up both in the air at ground level and higher up in the atmosphere. These by-products combine to form fine particulates, which are harmful to the lungs when inhaled.

Aromatics differ from other parts of gasoline because their carbon atoms are so tightly bonded to their neighbors in rings that they are harder to burn than any other kind of hydrocarbon. Incomplete combustion leads to more particulate emissions. Simpler chains of hydrocarbons, such as ethanol, burn more completely.

While scientists have known that high levels of particulates cause premature death, recent studies in the U.S. and Europe have found that much lower levels may also be associated with premature death, according to a report presented by Dan Greenbaum, President of the Health Effects Institute, at the Institute of Medicine roundtable. Finer-grained particles are more harmful than bigger specks of pollution because they lodge more deeply in human lungs.[5]

The EPA has estimated that approximately 60,000 excess deaths occur annually as a result of particulate air pollution, most of them from cardiovascular causes. In one major study, the strongest links to disease stemmed from particles of 2.5 microns or less. That study also established an association with lung cancer mortality.[6]

Reductions in fine particulates would offer benefits worth tens of billions of dollars, assuming the EPA's health risk estimates are correct. EPA stated in 2005 that aromatics are considered to be the most significant gaseous precursors of carbon-based fine particulates.[7] Gasoline aromatics are carbon-based, and carbon-based particulates appear to be more dangerous to public health than the sulfur and nitrogen aerosols associated with stationary sources and automobile emissions.

Other research has shown a link between the risk for heart attacks and living close to a road. One study found that living within 100 meters of a roadside raises the risk for acute myocardial infarction by 4 to 5 percent, which is a highly significant increase for nations, including the U.S., with that are urbanizing rapidly.[8]

University of Cincinnati environmental health professor Grace LeMasters reported at the Institute of Medicine roundtable that proximity to motor vehicle exhaust also appears to increase wheezing in infants, which may be linked to increased levels of childhood asthma.

THE ETHANOL ALTERNATIVE

Ethanol provides the same octane benefit as aromatics, but when the EPA tightened limits on benzene in gasoline in 2007 (after being sued by an environmental group), it declined to place limits on all aromatics. It failed to seek what the law required: the "greatest degree of emission reduction achievable" of these air toxics.

Ironically, ethanol use is surging as a result of another regulatory failure. The 1990 Clean Air Act amendments required the use of oxygenated fuels in the winter in areas where carbon monoxide pollution was the worst. The initial winner was a chemical compound called MTBE. However, leaks from underground tanks contaminated ground water and were hard to clean up, and when Congress refused to provide liability protection to MTBE producers, the compound was pulled from the market. Ethanol was the only remaining substitute.

A 10 percent ethanol blend can reduce the emissions of benzene by 25 percent compared to regular gasoline. The EPA, in this year's rule on benzene reductions, stated, "With ethanol use expected to more than double, we expect a significant reduction in aromatics levels…. [W]ith all of this ethanol, there will be excess octane in the gasoline pool. Thus, not only will increased ethanol use decrease aromatics concentrations through dilution, but refiners will make the economic decision to use ethanol to reduce or avoid producing aromatics for the purpose of increasing octane."[9]

Thus, the EPA expects that increased demand for ethanol will accomplish the reduction in aromatics that it failed to require by regulation. It would be wiser for federal policy makers to mandate the gradual phase out of toxic aromatic compounds in favor of ethanol as a gasoline additive.

This case study illustrates a failure to think through all the consequences of fuel choices. Just as important as the air pollution effects of transportation fuels, however, is their contribution to the world's greenhouse gas emissions—about one quarter now, and transportation is among the fastest-growing sources of emissions. To avoid catastrophic consequences from global warming, we need to move with great urgency away from petroleum products. At the same time, for the next decade or so, we have little choice but to continue using gasoline and diesel to run our fleets of vehicles.

Part of the solution will involve developing an international industry to produce biofuels, first as a fuel additive, and then as the industry ramps up, as a replacement fuel. Plant-based fuels offer a double benefit. In addition to creating new economic opportunities, they provide an alternative to gasoline with a much lower carbon footprint: because plants take carbon dioxide out of the air in order to grow, their carbon is part of the natural cycle. Fossil fuels, on the other hand, take long-buried carbon out of the earth and add it to the atmosphere. Yet we need to approach the development of this industry with a much more thoughtful approach than we have with fuels in the past.

The early research on ethanol as a gasoline additive is largely positive. Alcohols added to fuels make them burn at lower temperatures and thus more completely. Thus, ethanol blends result in lower emissions of nitrogen oxide and particulate matter.

One study suggests that the now-common 10% ethanol blends, known as E10, have been credited with reducing emissions of carbon monoxide by as much as 30% and particulates by 50%. The effects on ozone smog varies by atmospheric conditions. Mixing low levels of ethanol (2% to 10%) with gasoline increases the blend's tendency to evaporate and thus can contribute to low-level ozone, but this volatility can be reduced by changes in the blending process. Perhaps more significantly, the problem is reduced as the level of ethanol is increased. At blends of 25% and 45%, the fuel is about as evaporative as gasoline, and at higher blends it is less so.

In studies of high-level ethanol blends, known as E85, the impact on air quality is almost uniformly positive—with one exception: researchers have measured increased emissions of another class of pollutants known as aldehydes, including acetaldehyde. Better engine technology offers a potential solution: Conventional catalytic converters control these emissions in ethanol blends of up to 23%, and it is expected that they could be readily adapted to E85 blends.[10] 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%.[11] However, additional research is needed.

The recent Institute of Medicine roundtable identified a variety of research questions that need to be addressed with regard to new fuel strategies and the rapid ramp up of biofuels. They include: What are the effects of emissions of acetaldehydes and formaldehydes on health? What pollution mixes enter the air in what amounts as ethanol is added in varying amounts to gasoline? What are the synergistic effects on combustion of ethanol and gasoline mixtures? What are the effects of small particles on health, especially in the increasingly diesel-dependent European Union? This is an important research agenda, and it is consistent with thinking seriously about the transition to new transportation fuels.

It is likely that biofuels can be produced at very large scale globally. This new industry can be developed in a way that is beneficial for farmers and rural economies, for the environment, and for public health. However, the opposite is also true, and many alarmists have warned of the dangers—usually based on projections of uncontrolled expansion of corn ethanol.

Corn ethanol is relatively easy to produce—the process is little different from the way alcohol has been made for the last five millennia. But converting the starch contained in corn kernels and ignoring the rest of the plant is hardly a recipe for efficient use of a feedstock. Sugarcane grown in Brazil is much more productive per acre: its fermentable sugars can be accessed directly, and it produces an abundance of waste material that can be burned in industrial boilers to generate electricity and run the process. That is a better model.

"SECOND GENERATION" BIOFUELS

So-called "second generation" biofuels are headed for commercial production in the next 2 to 3 years and will be based on cellulose, the fibrous material in plants that is not used for food. Dedicated energy crops—e.g., native prairie grasses and fast-growing trees—and waste materials from food crops will be the long-term source of biofuels, not corn. Similarly, the term "biofuels" is intentionally vague because it is impossible to know whether ethanol, butanol, bio-gasoline, or another fuel will ultimately be preferred.

Biofuels cannot all be painted with one brush, whether the brush is black or white. What matters is how the crops and fuels are produced. Cutting down tropical forests in Indonesia to make palm oil-based biodiesel is a bad idea. Revegetating degraded land in India or Africa with the drought-tolerant jatropha bush is a good one. In the U.S. farmers have quite a broad array of choices for growing corn. To take but one example, no-till farming, gaining increasing acceptance in the corn belt, greatly reduces the environmental impact of production by reducing the need for fertilizer and herbicides, thereby minimizing chemical runoff. But we will need policies to encourage such sustainable production.

Some observers worry about the potential competition for farmland between "food and fuel." Increased demand for agricultural resources will tend to increase crop prices; whether that is good or bad depends on one's perspective. The surging popularity of corn ethanol has brought new life to rural Midwestern communities and given farmers what they see as the first fair price for their product in a generation. Higher grain prices benefit farmers worldwide. Indeed, these higher prices have partially accomplished the principal objective of the Doha development trade round: to eliminate the depressing effect that Western farm subsidies have on world grain prices and improve the ability of the rural poor to earn a living from their land.

Global malnutrition is caused not by a lack of food but by a lack of money to pay for it, and by a failure to distribute it effectively. Higher crop prices result in higher food prices (albeit not on a 1-for-1 basis), increasing the cost of feeding the poor—but that is morally and economically preferable to subsidizing rich and poor alike by keeping crop prices low and impoverishing farmers. Higher oil prices, which biofuels seek to restrain, have at least as large an impact on the price of food. In the U.S., processing, packaging, distribution and marketing—each directly impacted by rising energy costs—consume about 80 cents of every retail food dollar.[12]

The world's farmers are capable of increasing the amount of crops they grow if they have a market for them, and many developing countries have land that is well-suited to growing crops that depend on rain—i.e., that do not need supplemental water. An estimated 1.7 billion acres globally could be planted sustainably if there were demand.[13] Increased demand would also justify increased investment, bringing fertilizer and mechanized equipment to land that has never seen them and increasing the production of both food and fiber. The recent introduction of fertilizer subsidies in Malawi, for example, led to increased crop production, lower food prices, and higher wages for farm workers.[14] Planting energy crops and producing biofuels would mean more income and less poverty as well as other benefits: more rural economic development, less migration to crowded cities, and the availability of clean fuels to replace smoky wood fires whose air pollution now kills 1.6 million people every year, mostly women and children.[15] Getting appropriate policies in place to achieve these outcomes, however, is a formidable challenge; land tenure policy that protects indigenous farmers is just one thorny example.

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While agricultural goods account for only 8 percent of total global trade, primary energy commodities represent 52 percent of the total—and thus offer tremendous opportunities for international economic development. The transformation is possible, as Brazil has demonstrated: after 30 years of effort, renewable energy supplies 44.5 percent of the nation's energy needs.[16] We need to help developing nations assess their biofuels potential, quantifying the real-world costs and benefits of these policies compared to the status quo.

Biofuels have great potential—for good or ill. We still have time to make the right choices on developing biofuels globally and to move rapidly to second-generation feedstocks to produce fuels from cellulosic sources. We still have time to make choices that consider the long-term consequences of our actions. But we must do so with thoughtful consideration of a complex array of issues, and we must start now.

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