Should Corn Become Fuel?

Corn-based ethanol is big business—so big, in fact, that to offset demand for petroleum, U.S. policy calls for an increase in annual ethanol production from 34 billion liters (9 billion gallons) in 2008 to 57 billion liters (15 billion gallons) by 2015.

Ethanol proponents maintain that substituting ethanol for gasoline decreases air pollution, greenhouse gas emissions, and our dependence on foreign oil. Opponents counter that growing corn and converting it into ethanol uses more energy than we recover when we burn the ethanol for fuel. Perhaps more importantly, those energy inputs release additional carbon into the atmosphere. Are the policies that encourage corn ethanol production firmly grounded in science, or are they a concession to politically powerful farming interests?

Does ethanol reduce air pollution?

Ethanol (C_2H_6O) and gasoline (a mixture of several compounds, including heptane: C_7H_{16}) are both hydrocarbons. Under ideal conditions, in the presence of enough oxygen, burning hydrocarbons produces only water and carbon dioxide. In reality, however, gasoline-only vehicles always produce some carbon monoxide (CO) because there can be insufficient oxygen present at the time of combustion. Carbon monoxide has direct effects on human health and also contributes to the formation of photochemical smog (see Chapter 15 for more on CO and air pollution). Modern car engines regulate the fuel/oxygen mix to maximize the combustion of gasoline and minimize CO production. However, these regulatory systems are not fully operational until a car has "warmed up." As a result, whenever you start your engine, you release some CO. Many older cars do not have these regulators at all.

Because ethanol is an **oxygenated fuel**—a fuel with oxygen as part of the molecule—adding ethanol to a car's fuel mix should ensure that more oxygen is present, and thus that combustion is more complete, reducing CO production. However, an ethanol/gasoline blend evaporates more readily than pure gasoline. In the atmosphere, evaporated fuel produces photochemical smog in the same way that CO does. In other words, the fuel may burn more cleanly, but the extra evaporation may counteract some of this benefit.

Does ethanol reduce greenhouse gas emissions?

Biofuels are modern carbon, not fossil carbon. In theory, burning biofuels should not introduce additional carbon into the atmospheric reservoir because the carbon captured in growing the crops and the carbon released in burning the fuel should cancel each other out. However, agriculture in the United States depends heavily on inputs of fossil fuels to grow and process crops. Does the argument that ethanol use is carbon neutral hold up when we examine the entire ethanol production cycle from farm to filling station?

To analyze this question further, we need to examine ethanol's energy return on energy investment (EROEI), or how much energy we get out of ethanol for every unit of energy we put in.

Scientists at the U.S. Department of Agriculture have analyzed this problem, examining the energy it takes to grow corn and convert it into ethanol (the inputs) and the return on this energy investment (the outputs). Energy to run farm machinery, to produce chemicals (especially nitrogen fertilizer), and to dry the corn are inputs. Additional energy is required to transport the corn, convert it into ethanol, and ship it. Ethanol is the primary output, but in the course of growing and processing the corn, several by-products are produced, including distiller's grains, corn gluten,

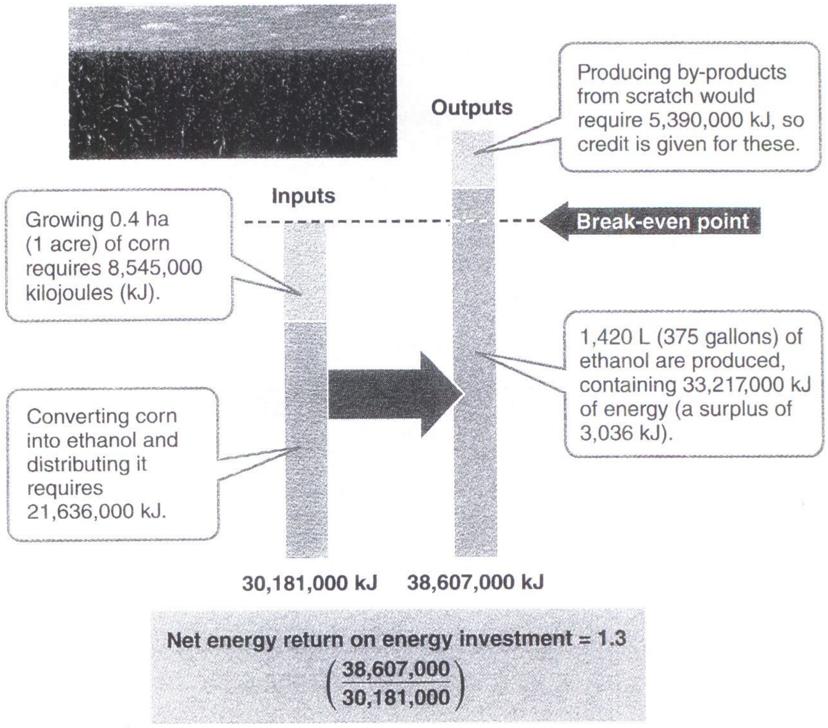

FIGURE SA6.1 Producing ethanol requires energy. An analysis of the energy costs of growing and converting 0.4 hectares (1 acre) of corn into ethanol shows a slight gain of usable energy when corn is converted into ethanol.

and corn oil. Each by-product would have required energy to produce, had they been manufactured independently of the ethanol manufacturing process, and so energy "credit" is assigned to these by-products. As FIGURE SA6.1 shows, there is a slight gain of usable energy when corn is converted into ethanol: for every unit of fossil fuel energy we put in, we produce about 1.3 units of ethanol. A land area of 0.4 hectares (1 acre) produces enough net energy to displace about 236 liters (62 gallons) of gasoline.

Our analysis indicates that replacing part of our gasoline needs with ethanol will displace some greenhouse gases. There will be a climate "benefit," but perhaps not to the extent that one would imagine, because we rely so heavily on fossil fuels to support agriculture. Moreover, in the United States, the ethanol production process currently uses more coal than natural gas. Because coal emits nearly twice as much CO_2 per joule of energy as natural gas (see Chapter 12), producing the ethanol may reverse many of the benefits of replacing the fossil carbon in gasoline with the modern carbon in ethanol. Quite possibly, producing ethanol with coal releases as much carbon into the atmosphere as simply burning gasoline in the first place.

Finally, we have to take into account the corn-growing process itself. Various aspects of corn production, such as plowing and tilling, may release additional CO_2 into the atmosphere from organic matter that otherwise would have remained undisturbed in the A and B horizons of the soil. Furthermore, greater demand for corn will increase pressure to convert land that is forest, grassland, or pasture into cropland. There is increasing evidence from recent studies that these conversions result in a net transfer of carbon from the soil to the atmosphere. This transfer leads to additional increases in atmospheric CO_2 concentrations.

Does ethanol reduce our dependence on gasoline?

If there is a positive energy return on energy investment, then using ethanol should reduce the amount of gasoline we use and therefore the amount of foreign oil we must import. However, if in order to use less gasoline we use more coal to produce ethanol, we might increase the release of greenhouse gases, so the overall benefit is questionable. Furthermore, if we create greater demand for a crop that until now has been primarily a food source, there are other implications as well.

Replacing a significant fraction of U.S. gasoline consumption with corn-based ethanol would involve the large-scale conversion of cropland from food to fuel production. Even if we converted every acre of potential cropland to ethanol production, we could not produce

FIGURE SA6.2 **Rising food prices.** Increased demand for corn-based ethanol accounted for about 10 to 15 percent of the rise in food prices from April 2007 to April 2008, according to the Congressional Budget Office.

enough ethanol to displace more than 20 percent of U.S. annual gasoline consumption. Furthermore, all agricultural products destined for the dinner table would have to be imported from other countries. Clearly this is not a practical solution.

What seems more likely is that we will be able to replace some smaller fraction of gasoline consumption with biofuels. Lester Brown of the Earth Policy Institute points out, however, that the 10 bushels of corn that it takes to produce enough ethanol to fill a 95-liter (25-gallon) SUV fuel tank contain the number of calories needed to feed a person for about a year. He argues that higher ethanol demand would increase corn and other grain prices and would thus make it harder for lower-income people around the world to afford food (FIGURE SA6.2).

Indeed, in the summer of 2007, corn prices in the United States rose to $4 per bushel, roughly double the price in prior years, primarily because of the increased demand for ethanol. Since then, prices have stayed above $3 per bushel. People in numerous countries have had difficulty obtaining food because of higher grain prices. In 2008, there were food riots in Afghanistan, Bangladesh, Egypt, and Haiti, among other places around the globe.

Our analysis indicates that corn-based ethanol has the potential to displace a small amount of total U.S. gasoline consumption, but that increasing corn ethanol consumption to the levels suggested by some politicians may require troublesome trade-offs between driving vehicles and feeding the world.

Are there alternatives to corn ethanol?

Stimulating demand for corn ethanol may spur the development of another ethanol technology: **cellulosic ethanol.** Cellulose is the material that makes up plant cell walls: grasses, trees, and plant stalks are made primarily of cellulose. If we were able to produce large quantities of ethanol from cellulose, we could replace fossil fuels with fuel made from a number of sources. Ethanol could be manufactured from fast-growing grasses such as switchgrass or *Miscanthus* (FIGURE SA6.3), tree species that require minimal energy input, and many waste products, including discarded paper and agricultural waste. It is also possible that algae could be used as the primary material for ethanol.

Producing cellulosic ethanol requires breaking cellulose into its component sugars before distillation. This is a difficult and expensive task because the bonds between the sugar molecules are very strong. One method of breaking down cellulose is to mix it with enzymes that sever these bonds. In 2007, the first commercial cellulosic ethanol plant was built in Iowa. At the moment, however, cellulosic ethanol is more expensive to produce than corn ethanol.

How much land would it take to produce significant amounts of cellulosic ethanol? Some scientists suggest that the impact of extensive cellulosic ethanol production would be very large, while others have calculated that, with foreseeable technological improvements, we could replace all of our current gasoline consumption without large increases in land under cultivation or significant losses in food production. Because the technology is so new, it is not yet clear who is correct. There will still be other considerations, such as the impact on biodiversity whenever land is dedicated to growing biofuels.

The good news is that many of the raw materials for cellulosic ethanol are perennial crops such as grasses. These crops do not require the high energy, fertilizer, and water inputs commonly used to grow annuals such as corn. Furthermore, the land used to grow grass

FIGURE SA6.3 A potential source of cellulosic ethanol. *Miscanthus,* a fast-growing tall grass, may be a source of ethanol in the future.

would not need to be plowed every year. Fertilizers and pesticides would also be unnecessary, eliminating the large inputs of energy needed to produce and apply them.

Algae may be an even more attractive raw material for cellulosic ethanol because its production would not need to utilize land that could otherwise be used for growing food crops or serve as a repository for carbon.

Many forms of ethanol are now being produced or are very close to being produced commercially. Production methods that use biomass grown with fewer fossil fuel inputs, at a lower level of intensity on agricultural land, or without the use of land at all are the most desirable from virtually all environmental perspectives.

Summarizing the science

Adding ethanol to gasoline reduces carbon monoxide formation and may reduce photochemical smog if evaporation can be controlled. When we look at the entire "life cycle" of ethanol, from farm to tank, it's not clear whether ethanol will reduce greenhouse gas emissions. Because its EROEI is fairly low, and because the amount of available agricultural land is limited, corn ethanol will not replace more than a small fraction of gasoline consumption. Cellulosic ethanol shows the potential to have a significant effect on fossil fuel use, at least in part because of lower energy inputs to obtain the raw material and convert it into a fuel. Corn should not be used for fuel to any great extent, but it may serve as a stepping-stone to other biofuels.

References

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