Is Corn Ethanol a Low-Carbon Fuel?

Bruce A. Babcock
Iowa State University, babcock@iastate.edu

Ofir Rubin
Iowa State University, rubino@iastate.edu

Hongli Feng
Iowa State University, hfeng@iastate.edu

Follow this and additional works at: http://lib.dr.iastate.edu/iowaagreview

Part of the Agricultural and Resource Economics Commons, Agricultural Economics Commons, Economics Commons, Energy Policy Commons, and the Oil, Gas, and Energy Commons

Recommended Citation
Babcock, Bruce A.; Rubin, Ofir; and Feng, Hongli (2015) "Is Corn Ethanol a Low-Carbon Fuel?," Iowa Ag Review: Vol. 13 : Iss. 4 , Article 1. Available at: http://lib.dr.iastate.edu/iowaagreview/vol13/iss4/1

This Article is brought to you for free and open access by the Center for Agricultural and Rural Development at Iowa State University Digital Repository. It has been accepted for inclusion in Iowa Ag Review by an authorized editor of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
Reports of disappearing glaciers, shrinking arctic ice, rising sea levels, stronger hurricanes, and unprecedented European heat waves combined with an inexorable buildup in atmospheric carbon dioxide levels is increasing pressure on governments to respond with new greenhouse gas initiatives. California and other states are providing policy leadership in the United States.

Of particular interest to the biofuels industry is Governor Arnold Schwarzenegger's January 2007 executive order that requires a 10 percent reduction in the carbon content of California's transportation fuels by 2020. In contrast to federal renewable fuel standards, which mandate levels of use of biofuels, California's fuel standard does not tell fuel suppliers (oil companies) how they should meet the new requirements. Alternative fuels will have to compete in terms of cost and carbon content. Only those fuels that can reduce carbon content at reasonable cost will be included in California fuel blends. Given that ethanol from corn comprises more than 90 percent of U.S. alternative fuels, a key determinant of the feasibility of meeting California's ambitious goals is the extent to which corn ethanol reduces greenhouse gas emissions.

To answer this question requires careful accounting of the differences in production and consumption that lead to changes in greenhouse gas emissions. The method commonly used to estimate greenhouse gas emissions is to conduct a life cycle analysis of the feedstock used to make biofuels. We present results of a life cycle analysis for Iowa corn from planting to refining to burning as fuel. In addition, we also consider changes in emissions caused by land use changes that are attributable to expansion of corn production. These land use changes can occur both domestically and overseas.

**Fuel Consumption**

Energy content is typically measured by megajoules (MJ). Gasoline contains approximately 121 MJ per gallon. A gallon of ethanol contains 67.4 percent of the energy content of gasoline so it takes 1.48 gallons of ethanol to replace the energy content of a gallon of gasoline. Greenhouse gas emissions, whether from methane, nitrous oxide, or carbon dioxide, are all measured in units of carbon dioxide equivalent (CO₂eq). Life cycle analyses of gasoline suggest that transportation of oil, refining oils into gasoline, and burning the gasoline in cars releases 94 grams of CO₂eq per megajoule. This is the carbon content of gasoline. If corn growth required only photosynthesis, if ethanol were produced using solar power, if corn were instantly transported to ethanol plants, and if no land use changes were needed to grow the corn, then displacing a gallon of gasoline with ethanol would reduce greenhouse gas emissions by approximately 11.2 kilograms (kg) of CO₂eq.

---

**Accounting for Corn Ethanol’s Greenhouse Gas Emissions**

Whether corn ethanol reduces net greenhouse gas emissions has been studied by many, and many different answers have been found. Sometimes the difference in answers rests on assumptions. For example, Professor David Pimental from Cornell University attributes all greenhouse gas emissions from ethanol plants to ethanol rather than attributing a portion to distillers grains, which displace feed (more about this later). But sometimes the differences in answers are caused by researchers answering different questions. To illustrate the process that researchers follow to calculate greenhouse gas emissions we answer the following question: Does expansion of Iowa corn production to produce ethanol help reduce the buildup of greenhouse gases? If the answer is yes, then corn-based ethanol produced from Iowa corn may qualify as a low-carbon fuel. If not, then the future of the current ethanol industry may be threatened because it may not help California meet its fuel composition target.

---

**Bruce A. Babcock**
babcock@iastate.edu
515-294-6785

**Ofir Rubin**
rubino@iastate.edu
515-294-5452

**Hongli Feng**
hfeng@iastate.edu
515-294-6307
However, fossil fuels are used to grow corn and produce ethanol. In addition, using corn to produce ethanol means that fewer acres will be devoted to competing crops, more land will be brought into cultivation, and other uses of corn will decline. The greenhouse gas implications of all these factors need to be considered before we can determine if corn ethanol is a low-carbon fuel.

### Biorefinery Phase

Corn ethanol is produced in either a dry mill or a wet mill plant. Most new ethanol plants are dry mills, so that is what we focus on here. Converting corn to ethanol in a dry mill plant requires energy to transport corn to the plant, prepare the corn for fermentation, ferment the corn, and distill the ethanol from the fermented product. The two key factors that determine the greenhouse gas emissions from a dry mill plant are whether the plant dries the distillers grains or sells them wet and whether the plant’s energy source is coal or natural gas.

A dry mill plant that dries distillers grains requires about 38 MJ to produce a gallon of ethanol. If distillers grains are not dried, the energy is reduced to about 26 MJ per gallon. Coal-powered plants emit 62 percent more CO₂eq than plants that use natural gas.

The contribution of ethanol to reducing greenhouse gas buildup is reduced by biorefinery emissions. Not all the greenhouse gas emissions of a dry mill plant should be allocated to ethanol because the plant also produces distillers grains, which displace other sources of animal feed, thereby reducing the greenhouse gas emissions associate with the displaced feed. Table 1 shows the amount of emissions that occurs depending on the source of energy (coal or natural gas) and on whether distillers grains are dried or not.

### Direct Agricultural Phase

Accounting for the fossil fuel used to produce corn further reduces the net reduction in greenhouse gas emissions. Fossil fuels are used directly in the form of diesel fuel or indirectly to produce fertilizer, pesticides, and other agricultural inputs. The two most important determinants of greenhouse gas emissions per gallon of ethanol in the agricultural phase are the yield per acre of land and the amount of nitrogen fertilizer used. And both of these are influenced by whether corn is grown after soybeans or after corn.

If there were no ethanol demand, it is likely that Iowa farmers would plant most of their corn crop after a crop of soybeans. Yields are higher and nitrogen fertilizer costs are lower. The higher yields and lower nitrogen rates have a direct impact on carbon emissions. If yields of corn planted after corn are 10 percent lower than for corn planted after soybeans, then CO₂eq emissions per bushel for corn planted after corn would be 10 percent higher than corn planted after soybeans. But the difference in emission is greater than 10 percent because nitrogen fertilizer application rates are typically 50 pounds per acre higher for corn planted after corn. Each additional pound of applied nitrogen contributes an additional 5 kg in CO₂eq emissions. The reason for this high emission

### Table 1. CO₂ emitted (kg) per gallon of gasoline displaced at the biorefinery stage

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried distillers grains</td>
<td>5.12</td>
<td>2.88</td>
</tr>
<tr>
<td>Wet distillers grains</td>
<td>3.53</td>
<td>2.08</td>
</tr>
</tbody>
</table>
rate is that nitrous oxide has a global warming potential more than 300 times that of CO₂. The combination of a lower corn yield and a higher nitrogen rate (and accounting for some other small differences) increases emissions from this phase of ethanol production from 3.5 kg to 4.8 kg CO₂eq per gallon of gasoline displaced.

A reasonable presumption is that increased ethanol production in Iowa comes primarily from increased acreage of corn planted after corn. Figure 1 shows the resulting net greenhouse reductions. As shown, it appears that expansion of Iowa corn production for ethanol does indeed reduce net greenhouse gas emissions, even when the ethanol is produced in a coal-fired plant. However, before we can make a final conclusion, we need to consider possible changes in emissions caused by changes in land use.

### Induced Changes in Land Use

Increased production of corn for ethanol production will affect land use both domestically and overseas. Domestically, most of the increase in corn production will come about because farmers will switch their land from an alternative crop to corn. Most of the switching will involve soybean acreage because most of the corn is grown alongside soybeans. We have already accounted for the emissions from growing corn. When the additional corn is grown on what would have been a soybean acre, there is an emission credit equal to the amount of emissions associated with soybean production. Under Iowa conditions the amount of credit equals about 1.5 kg CO₂eq per gallon of gasoline displaced.

Some corn grown for expanded ethanol use could also come from conversion of land that would not have been cropped otherwise. Virgin land with a mature forest or grassland contains as much carbon as it is ever going to. In contrast, land that has been previously tilled but is currently not being cropped is gaining carbon in soil or trees. Therefore, tilling virgin land releases more immediate carbon than tilling land that is gaining carbon. But growing crops on previously tilled land results in the loss of the carbon that would have accumulated on the land in future years. The loss of the annual increase in carbon accumulation needs to be accounted for if previously tilled land is cropped.

An example of previously cultivated land is acreage that is enrolled in the Conservation Reserve Program (CRP). The Chicago Climate Exchange assumes that farmers who convert cropland to grassland will sequester 750 kg CO₂eq per acre per year. If we use this as the amount of lost sequestration and if we assume also that an equivalent annualized amount of soil carbon stocks will be lost from land conversion, then a debit of 5.3 kg CO₂eq per gallon of gasoline displaced needs to be subtracted from the Figure 1 numbers. This debit makes ethanol production from corn a net contributor to greenhouse gas in all cases. Although the actual debit on CRP land may be higher or lower than 5.3 kg, this example illustrates just how sensitive is the measure of ethanol’s net greenhouse gas contribution.

To date, expansion of U.S. corn production for ethanol has primarily involved substitution of corn for another crop and not conversion of land. Thus, we conclude that corn-based ethanol reduces greenhouse gas emissions. However, this conclusion may not hold if we extend our accounting boundary to include land use changes in other countries.

As explained earlier, expansion of U.S. corn production for ethanol will reduce U.S. soybean production. But world soybean demand will be unaffected. The result is an increase in world soybean prices and a signal for other countries to expand production. If this production takes place solely through switching from lower-value crops to soybeans, then only the difference in emission rates between the two crops can be attributable to U.S. ethanol production. Because a soybean crop is a low carbon emitter, such a difference would likely result in a credit being added to U.S. ethanol. However, if soybean expansion occurs through conversion of grassland or forestland, then the immediate loss in carbon might be attributable to U.S. ethanol. This latter case presents a potential hurdle that must be overcome before U.S. ethanol can be considered a low-carbon fuel.

**Figure 1. Life cycle emission reduction for corn ethanol in Iowa**

<table>
<thead>
<tr>
<th></th>
<th>Kg CO₂ Per Gallon Gasoline</th>
<th>Percent Reduction in Greenhouse Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal and Dry DG</td>
<td>11%</td>
<td>45%</td>
</tr>
<tr>
<td>Coal and Wet DG</td>
<td>26%</td>
<td>40%</td>
</tr>
<tr>
<td>Nat. Gas and Dry DG</td>
<td>31%</td>
<td>35%</td>
</tr>
<tr>
<td>Nat. Gas and Wet DG</td>
<td>39%</td>
<td>30%</td>
</tr>
</tbody>
</table>

*Continued on page 10*
If, as seems likely, we are entering a future where policy incentives will be skewed toward rewarding production activities that reduce greenhouse gas emissions, then it is important for the U.S. biofuels industry to take steps to ensure that they are providing low-carbon fuels.

The key factors determining carbon emissions for corn-based ethanol are (1) whether coal or natural gas is used to power the ethanol plant, (2) whether distillers grains are dried or sold wet, and (3) whether expansion of corn acreage comes mainly from reduced acreage of lower-value crops or if idled land is brought into production.

The first of these factors is largely under the control of ethanol plant owners. Not drying distillers grains is feasible only if large beef feedlots or dairies are located near the ethanol plants. State and local policies that encourage strategic siting of cattle operations can greatly enhance ethanol’s low-carbon credentials. The last factor is beyond the control of industry. Conversion rates of idled U.S. cropland can be reduced by increasing domestic conservation incentives, such as CRP rental rates. But this policy decision creates a dilemma: if U.S. land is kept idle through higher conservation payments, there will be a larger impact on crop prices and a greater incentive for farmers in other countries to expand production. If this overseas production were to involve conversion of substantial amounts of idle land that would otherwise never be brought into production, then U.S. corn ethanol likely would not be able to lay claim to the title of low-carbon fuel.

### Table 2. Blending economics

<table>
<thead>
<tr>
<th></th>
<th>January 2007</th>
<th>September 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular</td>
<td>E-10</td>
</tr>
<tr>
<td></td>
<td>Unleaded</td>
<td>E-10</td>
</tr>
<tr>
<td>($ per gallon)</td>
<td></td>
<td>($ per gallon)</td>
</tr>
<tr>
<td>Gasoline</td>
<td>1.490</td>
<td>1.341</td>
</tr>
<tr>
<td>Ethanol</td>
<td>0.226</td>
<td>0.193</td>
</tr>
<tr>
<td>Price before taxes</td>
<td>1.490</td>
<td>1.567</td>
</tr>
<tr>
<td>Federal gas tax</td>
<td>0.184</td>
<td>0.184</td>
</tr>
<tr>
<td>Ethanol tax credit</td>
<td>-0.051</td>
<td>-0.051</td>
</tr>
<tr>
<td>Price after federal taxes</td>
<td>1.674</td>
<td>1.700</td>
</tr>
</tbody>
</table>

Is Corn Ethanol a Low-Carbon Fuel?
Continued from page 3

Policy Choices
If, as seems likely, we are entering a future where policy incentives will be skewed toward rewarding production activities that reduce greenhouse gas emissions, then it is important for the U.S. biofuels industry to take steps to ensure that they are providing low-carbon fuels. The key factors determining carbon emissions for corn-based ethanol are (1) whether coal or natural gas is used to power the ethanol plant, (2) whether distillers grains are dried or sold wet, and (3) whether expansion of corn acreage comes mainly from reduced acreage of lower-value crops or if idled land is brought into production.

The first of these factors is largely under the control of ethanol plant owners. Not drying distillers grains is feasible only if large beef feedlots or dairies are located near the ethanol plants. State and local policies that encourage strategic siting of cattle operations can greatly enhance ethanol’s low-carbon credentials. The last factor is beyond the control of industry. Conversion rates of idled U.S. cropland can be reduced by increasing domestic conservation incentives, such as CRP rental rates. But this policy decision creates a dilemma: if U.S. land is kept idle through higher conservation payments, there will be a larger impact on crop prices and a greater incentive for farmers in other countries to expand production. If this overseas production were to involve conversion of substantial amounts of idle land that would otherwise never be brought into production, then U.S. corn ethanol likely would not be able to lay claim to the title of low-carbon fuel.