# Ethanol's Broken Promise:

## Using Less Corn Ethanol Reduces Greenhouse Gas Emissions

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# **Ethanol's Broken Promise:** Using Less Corn Ethanol Reduces Greenhouse Gas Emissions

## Summary

The Environmental Protection Agency's pending proposal to cut the amount of corn ethanol that must be blended into gasoline in 2014 by 1.39 billion gallons would lower U.S. greenhouse gas emissions by the equivalent of 3 million tons of carbon dioxide ($CO_2e$) – as much as taking 580,000 cars off the road for a year. It is now clear that the federal corn ethanol mandate has driven up food prices, strained agricultural markets, increased competition for arable land and promoted conversion of uncultivated land to grow crops. In addition, previous estimates have dramatically underestimated corn ethanol's greenhouse gas emissions by failing to account for changes in land use. In 2012, an Environmental Working Group study found that from 2008 to 2011, more than 8 million acres of grassland and wetlands were converted for corn alone.[1] EWG's new analysis shows that these land use changes resulted in annual emissions of 85 million to 236 million metric tons ($CO_{2e}$) of greenhouse gases. In light of these emissions, many scientists now question the environmental benefit of so-called biofuels produced by converting food crops. A few recent studies still claim that corn ethanol produces fewer emissions than gasoline, but a careful look reveals that their methods don't properly account for land use change. Studies that do factor in land use change show that using food crops to produce biofuels – once considered a promising climate change mitigation strategy – is worse for the climate than gasoline.

### Introduction

Transportation accounts for 28 percent of greenhouse gas emissions in the United States.[2] In an effort to reduce these emissions, Congress passed a law in 2005 requiring oil companies to blend so-called renewable fuels – produced by converting biological material (biomass) into ethanol, biodiesel or other liquid fuels – into vehicle fuels. Two years later, the Energy Independence and Security Act (EISA) dramatically increased the amount of biofuels required to be blended into gasoline. This mandate, formally known as the Renewable Fuel Standard (RFS), was intended to reduce U.S. dependence on foreign oil imports and reduce greenhouse gas emissions.

The Renewable Fuel Standard requires that annual biofuel use increase every year, from 9 billion gallons in 2008 to 36 billion gallons in 2022. Of the 36 billion gallons of biofuel required in 2022, up to 15 billion gallons can be produced from corn. The remaining 21 billion gallons (dubbed "advanced biofuels") would have to come from a biomass-based feedstock that is not corn. This requirement was intended to help get advanced fuels off the ground, but commercial production has fallen short of the mandated level every year since the law took effect in 2009. In reality, the law has produced a flood of corn ethanol and only a trickle of the advanced biofuels that were the goal of the act.

Every year, as required by the Renewable Fuel Standard, the EPA sets the mandate for the annual volumes of biofuels to be blended into gasoline, called the statutory Renewable Volume Obligations (or RVOs). The EPA sets the RVOs every year so that ethanol plants know how much to produce and oil refineries know how many gallons to blend into gasoline. In November 2013, EPA proposed to significantly reduce the 2014 required volumes of biofuels to be blended into gasoline.[3] In its proposal, EPA reduced the RVOs for advanced and cellulosic, and, for the first time since the Renewable Fuel Standard was implemented, also proposed to reduce the mandated volume of corn ethanol. Reducing the

corn ethanol mandate would reduce the demand for corn, thereby reducing the incentives for converting land to corn production.

## Emissions from Land-Use Change

Between 2008 and 2011, conversion of grasslands and wetlands to grow corn emitted millions of tons of greenhouse gases, and the Renewable Fuels Standard continues to spur production of corn ethanol rather than advanced biofuels. Although the RFS explicitly prohibits using converted land to produce ethanol, there is no regulatory framework to enforce this and the USDA has no way of knowing whether corn is being grown on converted land.

Overall, the proportion of the U.S. corn crop that goes to make ethanol soared from about 6 percent in 2000 to about 40 percent in 2013. Because the United States is the world's top corn producer, this radical shift roiled global markets not just for corn but for other agricultural commodities as well.

Increased competition for the corn crop that used to be grown mainly for human food and animal feed has put upward pressure on corn prices. National Research Council studies suggests that the ethanol mandate raised commodity prices by 20-to-40 percent from 2007 to 2009.[4] Farmers have responded to higher prices and increased demand by increasing production and seeking more land to plant, resulting in millions of acres of land-use change. In 2013, EWG documented that 23 million acres of grassland, shrub land and wetland had been plowed under for crop production between 2008 and 2011. Eight million acres were converted to grow corn and another 5.6 million to plant soybeans, because the ethanol mandate pushed up soybean prices as well.

Numerous studies have now shown that plowing up grasslands and cutting down rainforests to plant more commodity crops dramatically *increases* carbon emissions, releasing the carbon locked up in the trees and soil into to the atmosphere.[5] The extent of the emissions depends on the type of land being converted (Table 1). Wetlands store the most carbon, followed by forests and grasslands.

### TABLE 1
### CARBON EMISSIONS DEPEND ON THE TYPE OF LAND BEING CONVERTED.

| Emissions from land-use change | |
|---|---|
| Type of land | Emissions in metric tons of $CO_2$ per acre |
| Grassland | 30 - 81 |
| Forest | 142 - 263 |
| Wetland | 405 - 1215 |

Values modified from Plevin et al. [6]

EWG's research shows that roughly 306,000 acres of wetlands were converted to produce corn between 2008 and 2012. The emissions released by this conversion totaled 25-to-74 million tons of $CO_2$ equivalent per year for each of those five years. The additional 8 million acres of grasslands and shrub lands converted to corn from 2008 to 2011 added another 60-to-162 million tons of $CO_2$ equivalent emissions per year over the period, for a total of between 85 million and 236 million metric tons of $CO_2$ equivalent greenhouse gases.

## EPA's Emissions Assessment

The Energy Independence and Security Act of 2007 specified that in order to comply with the Renewable Fuel Standard, biofuels must meet greenhouse gas emissions reduction thresholds. EPA set these thresholds in March 2010 with its final rule, which ensures that an increasing volume of biofuels would be blended into fuels and those biofuels would meet emission reduction thresholds. Under the final rule corn ethanol must reduce emissions by 20 percent, and advanced biofuels must cut emissions by 50 percent.[7]

Also as part of the final rule, EPA released a Regulatory Impact Analysis that projected the greenhouse gas emission performance of various biofuels. This Analysis compared the projected life-cycle greenhouse gas emissions of corn ethanol and gasoline over three 30-year time periods with different starting points – 2012 to 2042, 2017 to 2047 and 2022 to 2052. The Analysis included life-cycle emissions of biofuels produced in plants using

different power sources and milling processes. Corn ethanol production results in a solid co-product called distiller's grains that is used as animal feed. These distiller's grains are produced either wet or dry, but dried distiller's grains require more energy for drying. Another factor that determines the life-cycle emissions of producing a biofuel is the power source. Most ethanol plants in 2014 use natural gas as the power source, but some still use coal. The life cycle greenhouse gas emissions projected for corn ethanol produced using natural gas, for wet and dry distiller's grains, are shown in Table 2.

Because of the expected amount of land use change, EPA's analysis predicted that corn ethanol's emissions would be 33 percent higher than gasoline's in 2012 but would be 17 percent lower by 2022. However, in its Regulatory Impact Analysis, EPA projected that overall corn ethanol would reduce emissions by 21 percent based on the assumption that by 2022 biomass would power ethanol plants, which would reduce overall ethanol emissions.

The assumption is questionable given the recent increase in natural gas production in the U.S. and consistently low natural gas prices. Unless ethanol plants are given financial incentives to use biomass, switching away from natural gas is unlikely. Moreover, EPA's projection for 2022 ignored emissions from land use conversion between 2007 and 2022, even though the climate damage from those emissions will continue for years to come. Carbon dioxide stays in the atmosphere for 30 to 95 years.[8]

## TABLE 2
## CUMULATIVE CORN ETHANOL GREENHOUSE GAS EMISSIONS COMPARED TO GASOLINE'S

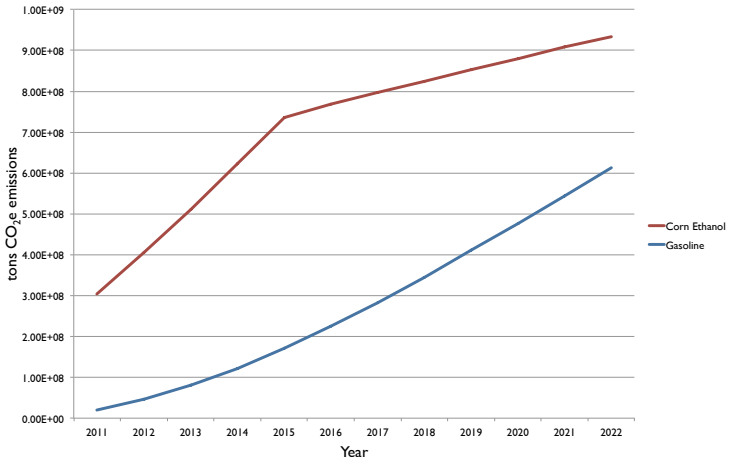
| Distillers Grains | 2012 | 2017 | 2022 |
|---|---|---|---|
| Dry | + 33% | + 10% | -17% |
| Wet | + 21% | -2% | -27% |

Positive values indicate higher emissions than gasoline, and negative values indicate lower emissions.
To determine life-cycle emissions for all corn ethanol, EPA estimates 63 percent of corn ethanol is produced by dry milling and 37 percent by wet milling.
Source: EPA's Regulatory Impact Analysis.[9]

In its Regulatory Impact Analysis, the EPA essentially ignored all land use change emissions before 2022 and evaluated corn ethanol based on emissions from 2022 to 2052 only. In other words, the EPA's accounting disregards the legacy of increased emissions from earlier land conversion. The agency started its analysis of projected emissions at 2022 because this is the year when the Renewable Fuel Standard requires the blending of the ultimate goal of 36 billion gallons of biofuels.

The agency's calculation was challenged in 2013 in a white paper by the Clean Air Task Force, an independent non-profit environmental organization, using EPA's own numbers. It found that if the EPA had taken into account emissions from the start of the Renewable Fuel Standard's implementation, corn ethanol's emissions would be much higher than those from an energy-equivalent amount of gasoline (Figure 1).

## FIGURE 1
## CUMULATIVE GREENHOUSE GAS EMISSIONS FROM CORN ETHANOL COMPARED TO GASOLINE




Source: EPA's Regulatory Impact Analysis,[10,11] analyzed by the Clean Air Task Force[12].

Clean Air Task Force's white paper points out that if the EPA had done its emissions accounting for RFS-mandated corn ethanol starting in 2010 and ending in 2044 (30 years after the corn ethanol mandate ramped up to 15 billion gallons), it would have found greenhouse gas emissions from corn ethanol were 28 percent higher than from an energy-equivalent amount of gasoline.[13]

## Cutting the ethanol mandate will reduce greenhouse gas emissions

In November 2013, EPA proposed reducing the Renewable Volume Obligations (RVOs) required by the Renewable Fuel Standard for both advanced biofuels and conventional corn ethanol. The proposal would cut the corn ethanol mandate from 14.4 billion to 13.01 billion gallons, and the advanced biofuels mandate from 3.75 billion to 2.2 billion gallons. The agency based its decision in part on the limited availability of advanced fuels. Production of cellulosic and other advanced fuels has fallen short of statutory volumes every year since the standard was implemented. In addition, the drop in gasoline demand that developed in 2013 meant that requiring larger amounts of corn ethanol would force gasoline refiners to exceed the so-called "E10 blend wall" that limits ethanol content to 10 percent of the fuel volume.

EPA's Regulatory Impact Analysis estimated that corn ethanol's greenhouse gas emissions for the year 2012 would be 33 percent higher than gasoline's with dry distiller's grains, and 21 percent higher with wet distiller's grains. EWG determined a composite estimate based on EPA's assumption that 63 percent of corn ethanol is produced using dry milling and 37 percent from wet milling (Table 3). EPA's numbers are expressed both in terms of performance compared to gasoline and also in grams of $CO_2$ equivalent emissions per the amount of energy produced (expressed in megajoules).

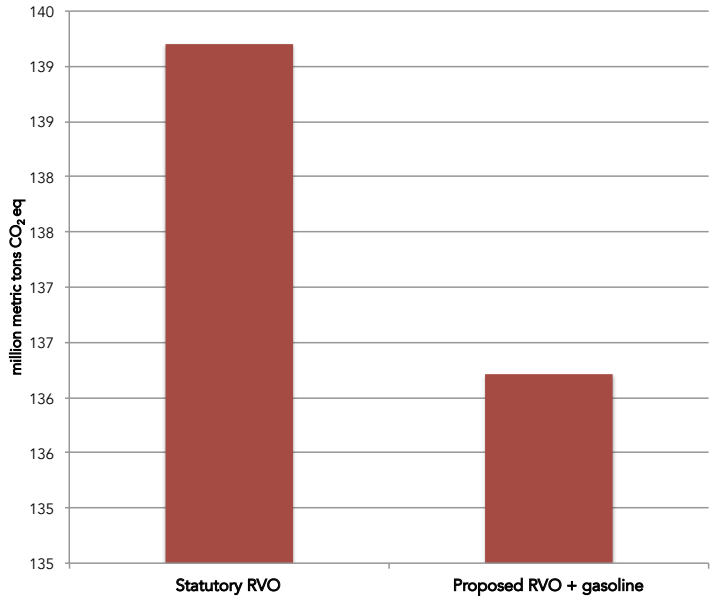
### TABLE 3
### CORN ETHANOL EMISSIONS FOR 2012
### POSITIVE PERCENTAGES MEAN HIGHER EMISSIONS THAN GASOLINE

| Corn Ethanol Emissions | | Compared to gasoline | in grams $CO_2e$ / MJ |
|---|---|---|---|
| EPA | Dry | + 33% | 125 |
| | Wet | + 21% | 113.7 |
| | Composite | + 29% | 120.8 |

Gasoline emits 94 grams of CO2e per megajoule.[14]
Source: EPA estimates from natural gas-powered base plants in the final impact analysis for 2012.15 Composite ethanol emissions are based on EPA assumption that 63 percent of corn ethanol is produced using dry milling and 37 percent from wet milling.

Using EPA's emissions estimates in Table 3, EWG compared the anticipated greenhouse gas emissions from the statutory corn ethanol mandate with the reduced volumes proposed in November 2013. We assumed that an energy-equivalent amount of gasoline would replace the lower volume of corn ethanol. The analysis shows that emissions would drop because of corn ethanol's greater emissions. The proposed cut of 1.39 billion gallons in the corn ethanol mandate would reduce emissions by 3 million metric tons of $CO_2$ equivalent (see Figure 2) – as much as taking more than 580,000 cars off the road for a year.[16]

## FIGURE 2
## GREENHOUSE GAS EMISSIONS FROM THE STATUTORY 2014 RVO VERSUS EPA'S PROPOSED 2014 RVO




## TABLE 4
## COMPARISON OF EMISSIONS ESTIMATES BY GREET AND THE EPA

| Corn Ethanol Emissions | | Compared to gasoline | Grams $CO_2$e / MJ |
|---|---|---|---|
| EPA | Dry | + 33% | 125 |
| | Wet | + 21% | 113.7 |
| | Composite | + 29% | 120.8 |
| GREET | Composite | - 31% | 65 |

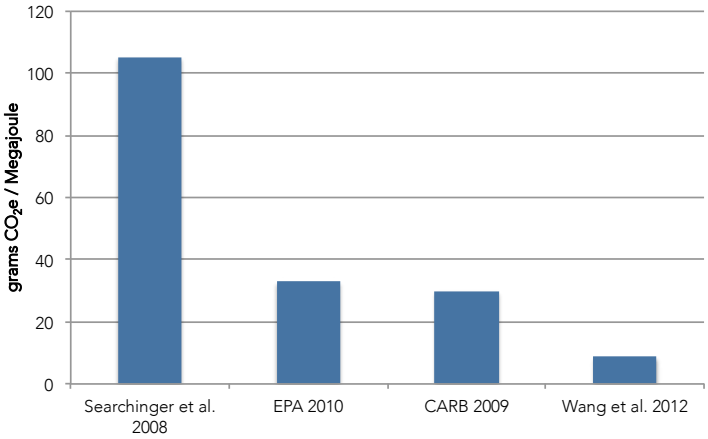
Corn ethanol emissions per megajoule of energy produced compared to gasoline and in terms of grams of CO2e. Positive percentages mean higher emissions than gasoline; negative percentage means lower than gasoline. Gasoline emits 94 grams of CO2e per megajoule.[18]

## Industry claims

In March 2013, the Biotechnology Industry Organization (known as BIO), the trade organization that represents biofuels manufacturers, published a study concluding that, contrary to EPA's findings, corn ethanol's emissions in 2012 were 31 percent lower than gasoline's.[17] The EPA had found that corn ethanol's emissions were 29 percent higher than gasoline's (Table 4). The BIO study also claimed that lowering the corn ethanol mandate would increase greenhouse gas emissions. However, a close examination shows that the BIO study greatly underestimated emissions from land use change because it used a model developed at Argonne National Laboratory, called GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) that relies on unrealistic assumptions.

The BIO study cited a paper by Michael Wang of Argonne National Laboratory and colleagues, published in December 2012 in Environmental Research Letters, that came up with an estimate of emissions from land-use change that is less than half of the low end of published ranges,[19] and about a third of EPA's estimate. Figure 3 compares Wang's estimates with those arrived of the EPA; Tim Searchinger, a research scholar at Princeton University; and the California Air Resources Board, which sets California's low-carbon fuel standard. Using an economic model called GTAP (Global Trade Analysis Project), developed at Purdue University, Wang and colleagues estimated land-use change emissions at just 9 grams of $CO_2$e per megajoule of energy which is much smaller than the 34 grams of $CO_2$e per megajoule estimated by the EPA. Results published by Wang and colleagues in 2012 are referenced in this report as the GREET model, but Wang and colleagues' results rely on GTAP to determine land use change emissions.

## FIGURE 3
## RECENT ESTIMATES OF LAND-USE CHANGE EMISSIONS FOR CORN ETHANOL




Wang et al. 2012 estimates are one-third of EPA's because of unrealistic assumptions about yield improvements, land conversions, and resource availabilities.

The GREET model underestimated land-use change emissions because it made several erroneous assumptions. It assumed that the increased demand for corn driven by the renewable fuels mandate would be met largely by increasing the yield of existing croplands, not by putting uncultivated land into production. Additionally, GREET's estimate did not account for the higher water requirements of increased crop yields.

GREET also made unrealistic assumptions about how yields respond to price. In economics, this is called the yield elasticity. For example, if the price of corn doubles from $2/bushel to $4/bushel (100 percent increase) and yield increases by 10 percent, that would be a yield elasticity of 0.10. GREET used a yield elasticity of 0.25, which means that every doubling of corn prices would result in a 25 percent increase in yield.[20] However, agricultural scientist David Lobell and colleagues at Stanford University showed in a 2009 paper that GREET's yield elasticity number is higher than most published values, which typically range from 0.10 to 0.20.[21]

Lobell also showed that yield elasticity is dependent on context. Yields may be easier to improve on underperforming farms but difficult to increase on already high-yielding operations. In addition, crop yields are typically limited by inputs such as fertilizer and water, which together explain 60-to-80 percent of global yield variability.[22] Many studies have found that increasing these inputs results in diminishing marginal returns, especially on croplands with high yields. In other words, for every additional unit of input such as fertilizer, the yield improvement gets smaller and smaller.[23,24] Farms at or near the "yield ceiling" will likely achieve less yield improvement per input than underperforming farms because it is uneconomical for farmers to keep adding more and more inputs for smaller and smaller returns. The GTAP model used with GREET by Wang and colleagues assumes the same high rate of yield elasticity across all farms and ignores yield ceilings and diminishing marginal returns.

In a regional analysis, the Lobell study estimated that yield elasticity in developed countries is much lower (0.14 for corn)[25] than the 0.25 value used by GREET, which overestimates yield improvements and underestimates the land required to meet crop demands.

Moreover, both the GREET and EPA calculations ignore water constraints. A 2013 analysis by agricultural economists Farzad Taheripour, Thomas Hertel and Jing Liu (Hertel was one of the developers of the GTAP model) at Purdue University also found that ignoring water constraints underestimates emissions from land-use change by 28 percent. Although irrigated croplands have much higher yields than those that rely only on rainwater, irrigation is limited in some regions by water scarcity and lack of infrastructure. The Taheripour study found that when water constraints were included in the GTAP analysis, the estimated emissions from land use change rose by 28 percent (from 35.6 grams $CO_2e$/MJ to 45.4 grams $CO_2e$/MJ).[26]

Accounting for resource constraints on corn production – which the GREET model ignored – is essential to get an accurate estimate of the emissions from land use change.

## Fertilizer and emissions

An accurate accounting of corn ethanol's life cycle emissions must also include the impact of nitrous oxide ($N_2O$), a greenhouse gas that is released from the fertilizers used to grow corn that has 298 times the global warming potential of carbon dioxide. More fertilizer is used on corn than on any other crop, an average of 138 pounds per acre. Nobel prize winning atmospheric chemist Paul Crutzen and colleagues found in a 2008 paper that nitrous oxide emissions from fertilizer could be up to five times greater than previous estimates, which assumed that on average 1 percent of fertilizer is emitted as nitrous oxide.[27] Crutzen found the emissions to be as high as 3-to-5 percent, which would negate any potential greenhouse gas reductions from corn ethanol.[28]

The corn ethanol mandate has also led a lot of farmers to grow more corn and to switch from rotating corn and soybeans to continuous production of corn, which requires more than eight times more fertilizer than soybeans.

## Conclusion

The proposed cut in the corn ethanol mandate would reduce greenhouse gas emissions by 3 million metric tons of carbon dioxide equivalent.

Studies that claim that corn ethanol reduces emissions do not properly account for the constraints on increasing crop yield and significantly underestimate the emissions from land use change driven by the corn ethanol mandate.

The intent of the Renewable Fuel Standard was to reduce greenhouse gas emissions, diminish America's dependence on foreign oil and promote development of advanced biofuels. Instead it has resulted in rapid expansion of corn ethanol production, increasing greenhouse gas emissions, worsening air and water pollution and driving up the price of food and feed.

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