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Ethanol vs. Petroleum-Based Fuel Carbon Emissions

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Biofuels have been proven to emit significantly lower greenhouse gas (GHG) emissions than petroleum-based fuels, and recent scientific studies indicate that net-zero emission biofuels are not only possible, but achievable.

Corn ethanol and other biofuels are essential in America's transition to a clean energy economy that creates good-paying jobs, increases energy independence, and supports the Biden Administration's climate goals. However, not all biofuels are created equal. The GHG emissions of a biofuel depend on what it's made from, how and where it's made, and how it's used—the full life cycle of the biomass, biofuel production, and use.

As the world's largest producer and consumer of biofuels, the United States is a critical leader in biofuel science, technology, and policy, and the U.S. Department of Energy (DOE) has spent decades advancing the science behind biofuel emissions life cycle analysis (LCA).

Life Cycle Emissions Assessments of Corn Ethanol Over Time

Most U.S. biofuel comes in the form of ethanol, which is made from corn starch and then blended into gasoline. An estimated 98% of all gasoline sold in the United States contains 10% ethanol.

In the early 2000s, U.S. energy policy helped drive a significant increase in domestic ethanol production, largely to increase energy independence. U.S. corn ethanol production rose from about 1.5 billion gallons in 2000 to 16 billion gallons in 2018. LCAs in the early 2000s relied on computer models and assumptions, which estimated that U.S. corn ethanol would produce 20% lower GHG emissions than gasoline.

Scientific research completed over the past two decades using improved LCA

methods has identified several key trends that were difficult to predict in earlier studies, rendering those previous findings and forecasts inaccurate.

The most recent DOE study, published by Argonne National Laboratory in 2021, found that U.S. corn ethanol has 44%–52% lower GHG emissions than gasoline. Argonne National Laboratory is recognized globally as one of the leading experts in this type of LCA research and other credible studies have found similar results.

Argonne's analysis found that carbon emissions from U.S. corn ethanol have fallen 20% between 2005 and 2019 due to increased corn yields per acre, decreased fertilizer use, and improved ethanol production processes.

Existing Techniques for Driving Down Corn Ethanol Emissions

Evidence suggests that additional improvements can further reduce corn ethanol GHG emissions.

Existing technologies and agricultural practices have the potential to make further, significant improvements in the reduction of LCA GHG emissions of ethanol from approximately 40% today to over 70% as compared to a petroleum baseline.[1]

Further Argonne analysis on jet fuel applications concluded that smart farming practices and other existing technologies can reduce ethanol-to-jet fuel emissions to 153% lower than petroleum jet fuel. This means that biofuels could be not just net-zero, but net-*negative* carbon emissions. Because biomass removes carbon dioxide from the atmosphere throughout its lifetime via photosynthesis, net-negative emissions biofuels are possible when measures are taken to lower the emissions from biofuel production. These measures can include capturing and sequestering carbon dioxide emissions that occur during biomass fermentation. Carbon capture and sequestration technology and its application on biorefineries have been demonstrated with DOE funding.

Land Use Data Reflects Real Impact on LCA

The largest discrepancy among biofuel LCA over the last several years stems from the idea that the benefits of lower emission fuels are offset by the environmental harm caused by their production. Early critics of biofuels contended that rainforests, wetlands, grasslands, and other natural ecosystems (carbon sinks) that remove carbon from the atmosphere would be destroyed either directly or indirectly to produce biofuels.

The early LCA studies of the 2000s projected that U.S. landowners would convert large swaths of forests and wetlands for agricultural production in response to higher demand and prices for corn, which in turn would increase climate emissions.

Land use change analysis relies on complex models and the findings are heavily influenced by the underlying assumptions that researchers apply. Rigorous scientific study, debate, and the increased availability of real-world data from growing U.S. biofuels industry have allowed for a more accurate understanding of the impacts of biofuel production.

Recent studies based on actual data and not modeling indicate initial projections significantly overestimated land use change impacts.

The Future of U.S. Biofuels

While studies conducted by Argonne and other respected labs include the most recent scientific data, other scientific papers on biofuel LCA continue to use old, disproven data. Such papers present provocative findings about potential—but demonstrably avoidable—pitfalls of biofuels, while failing to consider public and private efforts to ensure biofuels are sustainably produced at a large scale.

DOE's Bioenergy Technologies Office (BETO) is committed to ensuring that future domestic biofuel production adheres to rigorous sustainability metrics, including

those for substantially reduced GHG emissions. BETO is currently examining strategies to lower GHG emissions and carbon intensity within the existing corn ethanol industry, including:

- Implementing low-carbon agricultural practices
- Switching to renewable process heat and power (e.g., wind, solar, renewable natural gas, or biomass)
- Developing new productivity and conversion efficiency measures in biorefinery processes
- Using or sequestering of biorefinery CO_2 emissions.

The U.S. Ethanol Industry Supports Surrounding Communities and Rural Partners

The U.S. ethanol industry has sufficient capacity to produce more than 17 billion gallons of ethanol and reduce GHG emissions by an estimated 42.7 million metric tons (CO_2-eq) per year, which is approximately 2% of total U.S. transportation emissions. The United States has more than 200 ethanol plants supporting nearly 70,000 jobs, many in rural areas.

Because biomass cannot be economically transported long distances, biofuel production facilities rely on feedstocks produced within a short radius of the refinery. Biorefinery owners and operators have a natural incentive to ensure long-term sustainability through the feedstocks they use, the way they're grown and replenished, and how their projects support—and are supported by—their surrounding communities. Low-GHG liquid transportation fuel production can provide jobs to rural economies and help decarbonize remote communities without near-term access to electric vehicle charging stations and thus reliant on existing fueling infrastructure.

Investment in low-GHG fuels will help to address issues of environmental justice in rural and underserved communities to ensure they are not left behind in the clean energy transition.

BETO Research, Development, and

Demonstration of Biofuel Technologies for Greater GHG Emissions Reduction

BETO is funding research, development, and demonstration of next generation biorefineries which will leverage a variety of sustainable biomass and waste feedstock sources. These include:

- Agricultural residues (e.g., corn stover)
- Forestry residues (e.g., logging residues and forest thinning)
- Dedicated energy crops (e.g., switchgrass, miscanthus, energy cane, sweet sorghum, high-biomass sorghum, hybrid poplars, and shrub willows)
- Algae
- Waste streams and reusable carbon sources (e.g., the non-recyclable portions of municipal solid waste; wastewater treatment sludges, and manure slurries; food waste; and carbon dioxide and industrial waste gases).

These abundant U.S.-based biomass and waste resources can offer the necessary sustainable feedstocks to support a growing low-carbon biofuel industry. These same renewable feedstocks can realize greater than 70% GHG emissions reductions for a variety of end-use fuels.

Transitioning to a sustainable, net-zero GHG emissions economy in America will only be possible by embracing the clean energy biofuels provide. With science as a guide, DOE and partners have spent decades researching, studying, and testing ethanol and ethanol technologies, as well as second generation biofuels to best understand the potential for this essential, sustainable energy source.

[1] Lewandrowski, J, J. Rosenfeld, D. Pape, T. Hendrickson, K. Jaglo, & K. Moffroid. 2020. The greenhouse gas benefits of corn ethanol – assessing recent evidence. Biofuels, 11:3, 361-375

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