RENEWABLE FUELS ASSOCIATION

COMPARING THE CARBON INTENSITY OF CORN ETHANOL AND PETROLEUM: PAST, PRESENT, AND FUTURE

A comprehensive new study conducted by Life Cycle Associates found that the carbon footprint of corn ethanol continues to rapidly shrink, while the carbon impacts associated with crude oil production continue to worsen. According to the report, *"As the average carbon intensity of petroleum is gradually increasing, the carbon intensity of corn ethanol is declining. Corn ethanol producers are motivated by economics to reduce the energy inputs and improve product yields."* A number of key findings and recommendations from the study are summarized below.

2012-era corn ethanol reduced GHG emissions by 32% compared to gasoline—*including* emissions from hypothetical land use changes: Using the Department of Energy's GREET model and other resources, Life Cycle Associates estimated that average corn ethanol reduced greenhouse gas (GHG) emissions by **32%** compared to average petroleum in 2012. This estimate ***includes*** prospective emissions from indirect land use change (ILUC) for corn ethanol.

Table S.1. Advancements in corn ethanol in relation to petroleum gasoline GHG emissions.

	2005	2012	2022	2005 to 2012 Average
Avg. Crude Oil (or Gasoline)	96.46	96.87	96.95	96.64
Avg. Corn Starch Ethanol (w/ILUC)	76.34	65.54	55.53	71.54
% Baseline Reduction	-20.9%	-32.3%	-42.7%	-26.0%
Avg. Corn and Stover CRF Ethanol (w/ILUC)	76.23	65.18	38.49	71.40
% Baseline Reduction	-21.0%	-32.7%	-60.3%	-26.1%

Units are grams of CO2 equivalent per megajoule (g CO2e/MJ)

Average corn ethanol reduces GHG emissions by 37-40% compared to tight oil from fracking and oil sands: When compared to the marginal sources of crude oil that ethanol is actually replacing today, the GHG impacts are even more compelling. Average corn ethanol reduces GHG emissions by ***37% compared to tight oil*** from fracking, and ***40% when compared to tar sands***.

- *"The majority of unconventional fuel sources discussed here emit significantly more GHG emissions than both biofuels and conventional (primary and secondary) fossil fuel sources… the biggest future impacts on the U.S. oil slate are expected to come from oil sands and fracking production."*
- *"…significant quantities of marginal oil would be fed into U.S. refineries, generating corresponding emissions penalties that would be further aggravated in the absence of renewable fuel alternatives."*

Technology adoption and improved efficiency have enable dramatic reductions in corn ethanol's carbon intensity: The study describes how new technologies and innovation have reduced the carbon impacts of producing corn ethanol.

- *"Corn ethanol production technology evolves as new innovations are proven and then rapidly adopted. Most dry mill plants have improved their energy consumption, thermal integration, and they produce more diverse co-products."*
- *"Energy efficiency and fuel switching as well as an expansion of co-products reduce the CI of corn ethanol."*

- *"Wet mills today account for 10 to 12% of installed capacity, and less than 10% of the total number of plants."* The study shows that **only 13%** of U.S. ethanol production capacity used coal as a thermal energy source in 2012. Natural gas provides thermal energy for **more than 80%** of existing plants.

Average corn ethanol was already reducing GHG emissions by 21% compared to gasoline in 2005: Notably, the study found that average corn ethanol in **2005** reduced GHG emissions by **21%** compared to petroleum. Yet, the Environmental Protection Agency's GHG analysis for the Renewable Fuel Standard (RFS2) assumes corn ethanol GHG reductions won't reach 21% until 2022.

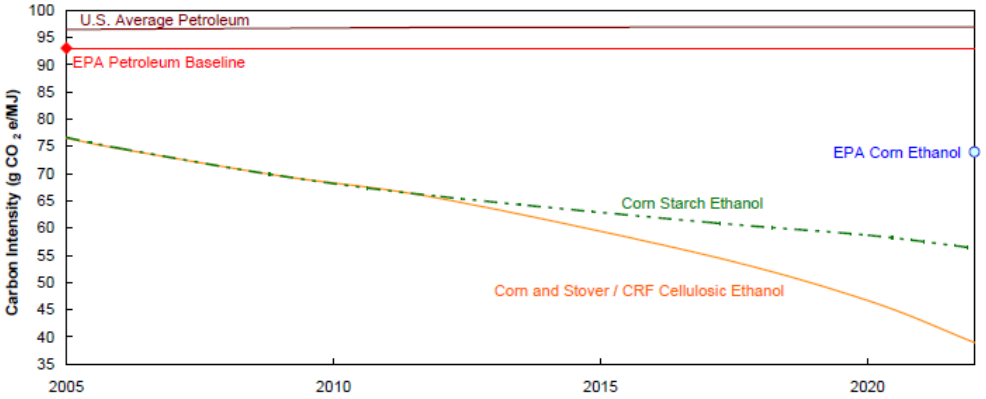

Figure S.1. Carbon intensity (g CO_2 e/MJ) of petroleum gasoline and corn ethanol consumed in the U.S. over time.

Estimates of land use change emissions have fallen by a factor of 10: The study describes the progression of land use change modeling, showing that the latest estimate is ***10 times lower*** than the emissions initially hypothesized by Timothy Searchinger in 2008 and ***three times lower*** than the current estimates used by EPA.

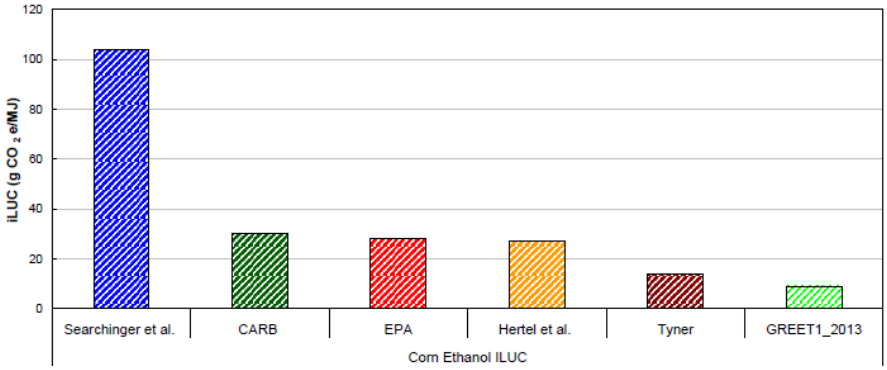

Figure 3.5. Comparison of ILUC from various sources

Ethanol's carbon footprint will continue to shrink, while oil's impacts worsen: Recent trends in the carbon intensity of corn ethanol and crude oil are expected to continue well into the future, as the environmental performance of ethanol continues to improve and oil's footprint gets even larger.

- *"Further significant incremental carbon intensity savings are expected in the near future with the advancements in fermentation technology and the use of stover as a feedstock."*

- Average corn ethanol is expected to reduce GHG emissions by **43%** compared to average petroleum in 2022. And if some amount of corn stover fed to livestock is appropriately treated as a co-product, the weighted average GHG emissions reduction for corn ethanol rises to **more than 60%.**

The RFS2 assumes the carbon intensity of crude oil will not get any worse than it was in 2005: Unfortunately, the study found, the current RFS2 regulations fail to account for worsening carbon intensity of crude oil and improvements in the corn ethanol lifecycle. The study found that today's average mix of crude oil is far more carbon intensive than the 2005 crude oil slate used in the EPA's 2008 lifecycle analysis, which is still used by the Agency today.

- *"As unconventional sources of crude oil have grown in recent years, the carbon intensity of petroleum fuels has increased above the baseline levels initially identified in the Renewable Fuel Standard..."*

Recommendations: The study offers a number of recommendations for future lifecycle analysis efforts related to corn ethanol and crude oil:

- *"Refine the GHG emissions from petroleum pathways."*
- *"Include indirect effects and co-products in petroleum GHG calculations."*
- *"Consider avoidance of marginal petroleum GHG emissions as an indirect effect of biofuels substitution."*
- *"Incorporate co-product effects of CRF and soy oil into RFS2 and LCFS ratings for corn ethanol."*
- *"Continue to monitor corn ethanol production by production technology."*
- *"Consider corn from starch and cellulose as a single feedstock/fuel pathway when assessing the national impact of renewable fuels."*

The report also suggests EPA should update its outmoded lifecycle analysis to better reflect the actual performance of corn ethanol and crude oil.

- *"The EPA has not updated its analysis of corn ethanol because it would have little or no impact on compliance with the RFS2 as the volumetric requirements are readily achievable. However, improvements to the analysis of corn ethanol would improve the understanding of the environmental impact of this fuel option."*

About Life Cycle Associates, LLC: Life Cycle Associates analyzes the energy and environmental impacts of fuels and energy systems. The firm's work focuses on the assessment of fuel production pathways on a well to wheel basis, economic analysis of energy systems, process engineering analysis of fuel production systems, and the development of GHG reduction strategies. Life Cycle Associates has completed numerous life cycle analysis studies, including those to establish fuel pathway carbon intensities (CI) for the California Low Carbon Fuel Standard (LCFS). The company conducts research in the area of biofuel production and the greenhouse gas (GHG) emissions impacts of biofuel production.

Clients include: Natural Resources Defense Council (NRDC), U.S. Department of Energy, U.S. Environmental Protection Agency, California Energy Commission, California Air Resources Board, the European Commission, Coordinating Research Council (CRC), Northeast States for Coordinated Air Use Management (NESCAUM), Federal Aviation Administration, New Fuels Alliance, Alberta Department of Energy, and many others. Learn more about Life Cycle Associates, LLC at www.lifecycleassociates.com.