DEEP DIVE: CARBON AS A COMMODITY

HOW ALTERNATIVE FUELS REDUCE THE CARBON EMISSIONS OF TRANSPORTATION

Carbon Intensity (CI) measures the carbon and greenhouse gas (GHG) emissions of an activity, such as performing a chemical process, generating electricity, or using gasoline in a vehicle. The unit for CI is grams CO_2 equivalent per megajoule (gCO_2e/MJ), or more simply, emissions per unit energy (g/MJ).

The lower the CI, the lower the carbon footprint of that activity.

Lifecycle Analysis (LCA) uses CI to understand the total emissions from all activities performed to bring a product to market. Results of LCA are used in government policy and carbon markets and are sometimes called **CI scores**.

An important example is gasoline. Petroleum-based fuels, such as gasoline, come from crude oil that is processed for consumer use. CI helps us understand the emissions of each individual step in the process to extract crude oil, refine it to gasoline, transport it to stations across the U.S., and burn it in vehicle engines.

LCA ties it all together by combining the steps into one CI score.

Performing LCA on products helps identify ways to reduce emissions. For instance, LCA demonstrates that one of the best methods to reduce the CI score of gasoline is to use higher blends of ethanol.

The LCA of ethanol is about 46% lower than gasoline. This is because ethanol is a renewable biofuel that burns cleaner in vehicle engines.

WHO CARES ABOUT LOWER CARBON INTENSITY SCORES?

FARMERS & RANCHERS

Emerging carbon markets provide monetization opportunities for farmers, ranchers, and landowners who implement climate-smart practices that lower their CI.

Supporting value-added ag industries that prioritize low-CI operation, such as ethanol production, secures a future for corn demand and valuable co-products like distillers grains, corn oil, and CO_2.

Scan the QR code for an introduction to carbon marketing for farmers.

Nebraska CornGrowers ASSOCIATION

ETHANOL PRODUCERS

Nebraska's ethanol industry positively impacts the state through an economic impact of $4.5B and employment of more than 6,200 full-time employees.

Various low-carbon fuel markets and regulations within the U.S. and Canada currently incentivize the use of low-carbon biofuels, with more in development. Nebraska producers are well positioned to capture much of this value, which stimulates rural economic growth.

Today, a Nebraska farmer who supplies grain to an ethanol bio-refinery sees an average benefit of $0.22 per bushel. This amount increases as ethanol producers deploy technologies that lower their CI score, including carbon capture and sequestration (CCS), biogas, and renewable energy.

CONSUMERS

Utilizing higher blends of ethanol lowers the CI of driving a vehicle by reducing both lifecycle and tailpipe emissions. With well over 250 million cars on the road in the U.S. using gasoline today, this equates to vast improvements in air quality by lowering greenhouse gases and particulate matter emissions.

In Nebraska, drivers that utilize a 10% blend of ethanol will routinely save at least $0.40 compared to gasoline with no ethanol. The savings are even greater when choosing higher blends like E15, E30, and E85. Find ethanol retailer locations near you at fueledbynebraska.com.

Fueled by NEBRASKA

Take a look at the LCAs performed on gasoline, battery electric vehicles (BEVs), and ethanol. Ethanol has a lower CI than gasoline made only with fossil fuels; and with proper scientific measures, the CI of ethanol is competitive, and it may even be lower than BEVs.

Lifecycle Analysis GHG Emissions for Gasoline

GRAMS CO_2-EQUIVALENT GHG PER MEGAJOULE ENERGY DELIVERED

OIL EXTRACTION, PRE-PROCESSING AND TRANSPORTATION TO REFINERY = 11 g/MJ

- Crude oil recovery
- Flaring excess/waste gas
- Initial processing and preparation
- Energy use in crude oil transport (pipelines, trains, barges)

OIL REFINING= 14 g/MJ

- Energy use (natural gas, electricity, etc.)

GASOLINE DISTRIBUTION = 0.5 g/MJ

- Energy use in finished product transport (pipelines, trains, barges, trucks)
- Energy use by fuel blenders and retailers

GASOLINE COMBUSTION = 73 g/MJ

- Tailpipe CO_2, CH_4, and N_2O emissions

Total emissions = 98.5

Land use change not currently included in LCA for petroleum fuels.

LCA DATA SOURCES

Argonne NATIONAL LABORATORY

RFA RENEWABLE FUELS ASSOCIATION

Lifecycle Analysis GHG Emissions for BEVs

GRAMS CO_2-EQUIVALENT GHG PER MEGAJOULE ENERGY DELIVERED

NATURAL GAS, OIL OR COAL EXTRACTION = 3-6 g/MJ

- Natural gas, oil, or coal recovery
- Initial processing and preparation

RARE MINERAL EXTRACTION = 3-9 g/MJ

- Energy use (natural gas, electricity, etc.) for mineral recovery
- Initial processing and preparation

FUEL & MINERAL TRANSPORT = 1-2 g/MJ

- Energy use (pipelines, trucks, trains, barges)

BATTERY MANUFACTURING = 2-5 g/MJ

- Energy use (natural gas, electricity, etc.)

ELECTRICITY GENERATION AND TRANSMISSION= 1-301 g/MJ

- Coal = 298 g/MJ
- Oil = 285 g/MJ
- Natural Gas = 122 g/MJ
- Nuclear = 0-10 g/MJ
- Wind/Solar/Hydro = 0-10 g/MJ
- Energy use for transmission
- Transmission losses

(U.S. GRID AVERAGE) = 130
(NEBRASKA GRID AVERAGE) = 185

ELECTRICITY USE IN VEHICLE = 0 g/MJ

- No tailpipe emissions
- Transmission losses

Total emissions:

(U.S. GRID AVERAGE) = 47 to 51
(NEBRASKA GRID AVERAGE) = 65 to 69

Land use change is currently not included in LCA.
Because EV drivetrain is 3x more efficient per unit of energy, total lifecycle emissions are divided by 3 to derive estimate.

Lifecycle Analysis
GHG Emissions for Ethanol

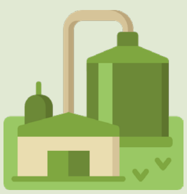
GRAMS CO_2-EQUIVALENT GHG PER MEGAJOULE ENERGY DELIVERED

CORN PRODUCTION = 22 g/MJ

- Seed production
- Fertilizer/chemical production & use
- Energy use (liquid fuels, electricity, etc.) in farm equipment
- Soil emissions (N_2O/CO_2)
- **Ethanol co-product credit (-12)**
- Land use change (7)

CORN TRANSPORT = 1.5 g/MJ

- Energy use (trucks, trains, barges)

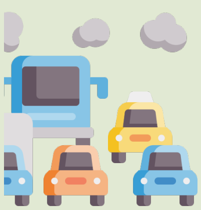


ETHANOL PRODUCTION = -2 to 28 g/MJ

- Energy use (natural gas, electricity, etc.)
- Addition of denaturant
- **Carbon capture & sequestration (CCS) of fermentation CO_2 (-25 to -30)**

ETHANOL DISTRIBUTION = 1.5 g/MJ

- Energy use in finished product transport (pipelines, trains, trucks, barges)
- Energy use by fuel blenders and retailers



ETHANOL COMBUSTION = 0.3 g/MJ

- ***Biogenic** CO_2 tailpipe emissions
- Other tailpipe emissions (N_2O, CH_4)

***Biogenic** is CO_2 sequestered from the atmosphere during crop growth and released in biofuels production and combustion.

Total emissions:

TOTAL EMISSIONS = 53.3

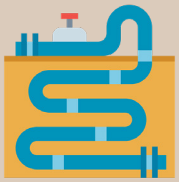
AVERAGE EMISSIONS WITH CCS= 23.3 to 28.3

As an already low-carbon fuel option, ethanol is a top commodity to states and countries focused on decarbonization (especially from Nebraska).

CO_2: POLLUTION TO SOLUTION

Numerous producers in the ethanol industry capture biogenic CO_2 released during ethanol production. The captured CO_2 is extremely pure, so it may be stored underground or used as a co-product. This practice is commonly referred to as **Carbon Capture, Utilization and Storage (CCUS).**

Roughly 25% of the ethanol industry already captures biogenic CO_2 to be used in water treatment, refrigeration (dry ice), fire extinguishers, carbonation, and creating fabrics and bioplastics. New, innovative pathways are emerging to transform CO_2 into fuels, chemicals, and building materials for sectors that are difficult to decarbonize.



The permanent storage of captured CO_2 underground is often called **Carbon Capture and Sequestration (CCS)**. Several U.S. ethanol producers have already implemented it over the last decade, and many more are able to today.

In CCS, Class VI wells are utilized to inject CO_2 into deep rock formations for permanent storage. In Nebraska, these wells are permitted by the Nebraska Oil and Gas Conservation Commission and U.S. Environmental Protection Agency. Requirements are extensive and designed to protect sources of drinking water.

The geology of Nebraska features many suitable formations for CCS, which allow for some ethanol biorefineries to perform CCS onsite.

Ethanol producers that are unable to perform CCS onsite may transport captured biogenic CO_2 via pipeline to a Class VI well located above suitable geology.

CCUS in the ethanol industry represents tremendous opportunity to increase investment and diversify markets for Nebraska grains. More specifically through CCS, ethanol biorefineries can lower production CI by a game-changing 25 to 30 gCO2e/MJ.

If all Nebraska ethanol producers were implementing CCS today, the immediate economic benefit could range from an additional $200M to $1B even before considering tax credits. This would create a ripple felt across rural communities by maintaining strong demand for corn, increasing capital investment, and generating employment opportunities.

Have questions about CCS? Scan the QR for FAQs.

CORN ETHANOL IS LEADING THE WAY TO NET-ZERO EMISSIONS

When the right technologies and methods are used throughout its lifecycle, ethanol has the potential to be the first net-zero, and even net-negative, lifecycle emissions fuel on the market.

This pathway begins on the farm, where utilizing carbon-efficient corn production practices (noted in the LSA to the right), can result in significant emissions reductions. Many farmers have already adopted these methods, and much work is being done to properly account for this in ethanol lifecycle analysis (LCA).

In addition to processing a low-carbon feedstock, ethanol biorefineries can utilize practical and proven technologies to lower emissions. CCS is an already well-established technology that captures CO_2 produced during fermentation, then injecting it underground for permanent storage. Several Nebraska ethanol plants already use CCS to reduce their carbon footprint and/or capture CO_2 for use as a co-product.

Biogas is another example of how to lower ethanol's CI. This natural gas is made from renewable raw materials like manure and waste, instead of fossil fuels. Renewable electricity (wind, solar, hydro, etc.) can also reduce CI.

Increased adoption of innovation is expected in the coming years among many of Nebraska's ethanol producers and farmers. This will continue to bring economic prosperity to Nebraska and transform the way ethanol is produced and used, all while increasing its positive environmental impact.

Lifecycle Analysis GHG Emissions for Ethanol

with climate-smart farming practices, CCS, biogas, and renewable energy

GRAMS CO_2-EQUIVALENT GHG PER MEGAJOULE ENERGY DELIVERED

CORN PRODUCTION = 0 to 5 g/MJ

- Seed production
- **Climate-smart** fertilizer/chemical production and use
- Energy use (**biofuels,** electricity, etc.) in farm equipment
- Soil emissions (N_2O/CO_2)
- **Soil carbon sequestration (-15)**
- **Ethanol co-product credit (-12)**
- Land use change (7)

CORN TRANSPORT = 1.5 g/MJ

- Energy use (trains, trucks, barges)

ETHANOL PRODUCTION = -15 to 5 g/MJ

- Energy use (natural gas, electricity, etc.)
- **Use of renewable activity**
- **Use of biogas (RNG)**
- Addition of denaturant
- **Capture and sequestration of fermentation CO_2 (-25 to -30)**

ETHANOL DISTRIBUTION = 1.5 g/MJ

- Energy use in finished product transport (pipelines, trains, trucks, barges)
- Energy use by fuel blenders and retailers

ETHANOL COMBUSTION = 0.3 g/MJ

- ***Biogenic** CO_2 tailpipe emissions
- Other tailpipe emissions (N_2O, CH_4)

***Biogenic** is CO_2 sequestered from the atmosphere during crop growth and released in biofuels production and combustion.

Total emissions = -12 to 13

FIND ETHANOL NEAR YOU

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