ISSUE BRIEF:

ENVIRONMENTAL BENEFITS OF ETHANOL

Nebraska Ethanol Board

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I. EXECUTIVE SUMMARY

This issue brief provides a two-pronged description of the environmental benefits of ethanol as a fuel. First the cleaner tailpipe emissions are explained via ethanol's role in reducing various harmful exhaust pollutants. Then the overall lifecycle emissions of ethanol are shown to be highly favorable compared to other liquid fuels, and how ethanol lifecycle emissions are declining over time. This approach will give a complete picture of how ethanol is providing a cleaner alternative to other fuels.

II. TAILPIPE EMISSIONS

Ethanol has long been known to burn cleaner in vehicle engines and produce less emissions than gasoline. There are several important hazardous pollutants that ethanol reduces the intensity of in vehicle emissions, and the more ethanol added to fuel, the greater the air-quality benefits.

A. CARBON EMISSIONS

Carbon emissions, which include greenhouse gases (GHGs) like carbon dioxide (CO_2), trap heat in the atmosphere and contribute to environmental damage. Ethanol in the fuel supply reduces the amount of these gases emitted through a vehicle's tailpipe, according to the U.S. Environmental Protection Agency (EPA), because it "has less carbon per gallon than gasoline."[1] Since 2008, ethanol blending has resulted in cumulative CO_2 savings of 1.336 billion tons,[2] the equivalent of taking 17 million vehicles off the road.

All blends of ethanol reduce CO_2 tailpipe emissions. The University of California-Riverside has found that mid-level blends, like E30, reduce CO_2 emission rates compared to E0,[3] and E15 does the same.[4] For higher blends, vehicles using E85 lower tailpipe CO_2 emissions by 12%.[5] Ethanol reduces emissions of other harmful GHGs as well. Carbon monoxide (CO) emissions are significantly reduced with higher blends, [6] due to ethanol's clean-burning properties. Simply by switching from E10 to E15, CO emissions are reduced by 17%.[7] And emissions of ozone (O_3), which harms plants and forms smog, trend lower for E15 compared to E10.[8]

B. OXIDES OF NITROGEN (NO_X)

NO_x is highly pollutant. The U.S. Department of Energy (DOE) says that it contributes to "numerous environmental problems such as acid rain [and] air toxics."[9] Ethanol reduces NO_x when blended with gasoline, and the effect only increases with greater ethanol content. NO_x emissions decrease by as much as 70% for midlevel blends like E20 and E30 compared to E0, according to the Ford Motor Company.[10] E27 has lower NOx emission rates than E10,[11] and even E15 provides reduction in NOx emissions compared to E10.[12]

C. PARTICULATE MATTER (PM)

Particulate matter is the mixture of solid particles and liquid droplets found in the air, and, DOE explains, "contributes to haze, pollutes fresh and

[1] U.S. Environmental Protection Agency. Tailpipe Greenhouse Gas Emissions from a Typical Passenger Vehicle.
[2] Unnasch, S. et al. (2023). GHG Emissions Reductions due to the RFS2-A 2022 Update. Life Cycle Associates.
[3] Yuan, W. et al. (2019). Comparison of real-world vehicle fuel use and tailpipe emissions for gasoline-ethanol fuel blends. *Fuel*.
[4] Karavalakis, G. et al. (2022). Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15. California Air Resources Board.
[5] Delavarrafiee, M. & Frey, H. C. (2018). Real-world fuel use and gaseous emission rates for flex fuel vehicles operated on E85 versus gasoline. *Journal of the Air & Waste Management Association.*
[6] Ibid. note 3.
[7] Tang, T. et al. (2023). Expanding the ethanol blend wall in California: emissions comparison between E10 and E15. *Fuel*.
[8] Ibid. note 4.
[9] Alternative Fuels Data Center. Pollutants and Health. U.S. Department of Energy.
[10] Hubbard, C. et al. (2013). Ethanol and Air Quality: Influence of Fuel Ethanol Content on Emissions and Fuel Economy of Flexible Fuel Vehicles. *Env. Sci. & Tech.*
[11] Ibid. note 3.
[12] Ibid note 7.

coastal waters, and contaminates farmland and natural ecosystems."[13] Increasing ethanol content results in lower PM emissions,[14] and the use of even E15 results in 18% PM emissions reductions compared to E10.[15]

III. LIFECYCLE EMISSIONS

As shown above, ethanol reduces several kinds of environmentally damaging emissions when burned in vehicle engines, but emission reductions also occur throughout the ethanol production process. Examining emissions reductions for ethanol's entire lifecycle from field to fuel will complete the picture of how ethanol is helping to clean the air and benefit the environment.

A. TOTAL EMISSIONS REDUCTIONS

The U.S. Department of Agriculture (USDA) has found that lifecycle GHG emissions of ethanol are 43% lower than those of gasoline.[16] A more recent study found that ethanol emissions are 46% lower than those of gasoline, reflecting improvements of technology and efficiency in the ethanol production process.[17] In real numbers, ethanol carbon emissions are about 53.3 grams of CO_2-equivalent per megajoule of energy (g/MJ), compared to gasoline's 98.5 g/MJ.[18] We examine three major components of the ethanol lifecycle below.

B. ON THE FARM

Farmers growing corn for ethanol have implemented new technologies to reduce GHG emissions. According to USDA, these practices include producing corn more efficiently, reducing tillage, utilizing cover crops, and improving nitrogen fertilizer management.[19] Farming energy use per bushel of corn has been drastically reduced since 2005,[20] and a recent USDA study found that nitrogen application per unit of crop yield has decreased.[21] Corn growers have also used more biofuels to power farm machinery over time, which has contributed to emissions reductions.[22]

C. AT THE BIOREFINERY

In the same way that farmers have become more efficient at growing corn, so too have ethanol facilities gotten more efficient at producing ethanol. Ethanol yield on a gallon per bushel basis has increased by 6.5% since 2005.[23] Additionally, ethanol plants are using less energy consumption during production than ever before,[24] which decreases GHG emissions generated from fossil fuels.

D. ON THE MOVE

Transporting feedstocks and ethanol requires trucks and trains, which contribute to emissions. Ethanol "transportation vehicles and systems have become more fuel and GHG efficient" over time for two reasons, according to USDA.[25] One is that as more ethanol plants are built, the average proximity to corn farms and fuel terminals shrinks.[26] The other reason is the transport containers' utilization of more environment-friendly fuels like biodiesel and renewable diesel.[27]

FOR FURTHER INFORMATION

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ethanol.nebraska.gov
402-471-2941

[13] Ibid. note 9.
[14] Stein, R. et al. (2013). An Overview of the Effects of Ethanol-Gasoline Blends on SI Engine Performance, Fuel Efficiency, and Emissions. *SAE Int. J. Engines.*
[15] Ibid note 7.
[16] Lewandrowski, J. et al. (2019). The greenhouse gas benefits of corn ethanol – assessing recent evidence. *Biofuels*.
[17] Scully, M. J. et al. (2021). Carbon intensity of corn ethanol in the United States: state of the science. *Environmental Research Letters.*
[18] Cooper, G. (2022). The Truth About Ethanol and Carbon Emissions. Renewable Fuels Association.
[19] United States Department of Agriculture. USDA Factsheet: Lifecycle Greenhouse Gas Emissions of Corn-Based Ethanol.
[20] Lee, U. et al. (2021). Retrospective analysis of the U.S. corn ethanol industry for 2005-2019: implications for greenhouse gas emission reductions. *Biofpr.*
[21] Rosenfeld, J. et al. (2018). A Life-Cycle Analysis of the Greenhouse Gas Emissions from Corn-Based Ethanol. U.S. Department of Agriculture.
[22] Ibid. note 17.
[23] Ibid. note 20.
[24] Ibid. note 20.
[25] Ibid. note 21.
[26] Ibid. note 17.
[27] Ibid. note 21.