Ethanol and Biodiesel:
Few Benefits, Many Problems

By Linnea Lueken

"When one accounts for the decline in vehicle fuel economy from using biofuels and their various negative environmental impacts, it seems reliance on biofuel may provide fewer benefits than claimed by its proponents. Accounting for its effects on fuel economy, air quality, and food prices, biofuels likely produce net harms on balance."

Ethanol and Biodiesel 101

Ethanol is a simple alcohol that can be used as fuel. Due to recent federal mandates, it is increasingly being blended into gasoline. For the context of this paper, it is a manufactured biofuel, usually made from corn, sugarcane, or other agricultural products.[1] In the United States, almost all ethanol for fuel use is made from corn.[2]

Biodiesel is made from vegetable oil, palm oil, or similar products, including leftover cooking grease. In the United States, the majority of biodiesel is made from soybean oil.[3]

Biofuels vs. Gasoline

Ethanol has a lower energy density than gasoline, at about 20 megajoules per liter compared to gasoline's 33.[4] Ethanol does have a higher average octane value, meaning it can burn more slowly, which slightly increases energy efficiency. However, ethanol's higher octane does not make up for its lower energy density. Essentially, when ethanol is added to fuel, vehicle fuel economy declines. In fact, it takes 1.5 times more fuel to travel the same distance on ethanol than with a purely gasoline-fueled vehicle.

Ethanol also attracts water, which can separate and cause mechanical issues. Fuel blended with ethanol corrodes rubber components in older vehicles, older fuel storage tanks, and can badly damage small engines such as those used in lawnmowers and boats. Indeed, the U.S. Coast Guard warns boaters not to use gasoline containing ethanol in their boats.

Quick Bullets

- Ethanol and biodiesel are biofuels made from agricultural products.
- Ethanol has a lower energy density than gasoline, which means vehicles get fewer miles per gallon.
- Per unit of equivalent energy, ethanol produces more carbon dioxide than normal gasoline.
- Ethanol use in gasoline spiked after the banning of methyl tert-butyl ether (MTBE) and the passage of the 2005 Renewable Fuel Standard program, from 1.5 percent of gasoline consumption in 2002 to 10.3 percent in 2020.
- Ethanol fuels produce more nitrogen oxides (NOx) and other air pollutants, which contribute to worsening air pollution, especially in summer months.

Ethanol should not be not shipped via pipeline because it attracts too much water, which is often present inside pipelines.[5] Because ethanol is also more corrosive, it is likely to shorten the life of

[1] U.S. Department of Energy. "Ethanol Fuel Basics," Alternative Fuels Data Center, Retrieved July 11, 2022 from https://afdc.energy.gov/fuels/ethanol_fuel_basics.html

[2] U.S. Energy Information Administration (EIA), "Biofuels explained: Ethanol," Retrieved July 11, 2022 from https://www.eia.gov/energyexplained/biofuels/ethanol.php

[3] U.S. EIA, "Biofuels explained: biodiesel, renewable diesel, and other biofuels," Retrieved July 11, 2022 from https://www.eia.gov/energyexplained/biofuels/biodiesel-rd-other-basics.php

[4] Biofuel.org.uk, "Bioalcohols," Retrieved July 11, 2022, from http://biofuel.org.uk/bioalcohols.html

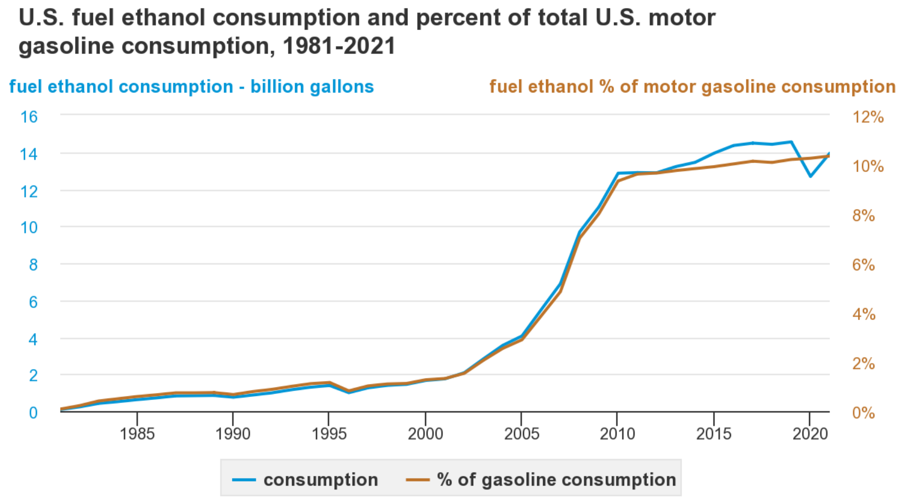
[5] U.S. Department of Transportation, "Ethanol," Pipeline and Hazardous Materials Safety Administration, Retrieved July 11, 2022 from https://primis.phmsa.dot.gov/comm/Ethanol.htm

any pipelines used to ship it. This being the case, ethanol is usually shipped by truck, rail, and barge.

Biodiesel is also less energy dense than its petroleum counterpart, by about nine percent. It has the same problem as ethanol in that it is corrosive to rubber parts in some vehicles.

Also, like ethanol, biodiesel has a better cetane rating than regular diesel. The cetane rating for diesel vehicles is the measurement of how well fuel combusts under the compression ignition of a diesel engine.

One major drawback for biodiesel when compared to regular diesel fuel is the temperature at which the fuel gels—or begins to form small ice crystals. Regular diesel begins to gel at 5°F to -2°F. Biodiesel gels more readily—at temperatures as high as 60° F in extreme cases—and the best cold-weather biodiesel (made from canola oil) gels at 14° F. This makes using biodiesel in heavy equipment and diesel big rig trucks in regions that experience regularly cold winters and summers problematic. The effect can be mitigated with special petroleum-based additives and winter biodiesel blends.



Data source: U.S. Energy Information Administration, *Monthly Energy Review* and *Petroleum Supply Monthly*, March 2022, preliminary data for 2021
Note: Motor gasoline is finished motor gasoline.

Emissions

Considering emissions at the source of combustion, carbon dioxide emissions from ethanol are about 1.91 kg CO2 per kilogram fuel burned. Gasoline emits 3.3 kg per kg. So, at first glance, ethanol seems to be the "cleaner" fuel burned. However, fuel economy must be taken into account. Since the energy density of gasoline is significantly higher, the end result is that using ethanol results in higher carbon dioxide emissions per unit used than gasoline. In kilograms of CO2 per energy output equivalent, ethanol comes in at 4.05 kg CO2 and gasoline at 3.30 kg CO2.

A study from the Environmental Protection Agency (EPA) confirms the findings of a National Academy of Sciences report on biofuel policy, stating, "air quality modeling suggests that production and use of ethanol as fuel to displace gasoline is likely to increase such air pollutants as PM2.5, ozone, and SOx in some locations."[6]

The EPA's report goes on to say that "ethanol increased NOx emissions, even though modern technology vehicles have near instantaneous control of the air/fuel ratio, as most emissions occur in these systems during times when the vehicle catalyst is not yet warmed up or air/fuel ratio is not perfectly controlled."

Another study, "Effects of Ethanol (E85) versus Gasoline Vehicles on Cancer and Mortality in the United States," notes that using higher ethanol concentrations has led to the production of ozone at ground level, contributed to smog, and caused greater "ozone-related mortality, hospitalization, and asthma by about 9% in Los Angeles and 4% in the United States as a whole relative to 100% gasoline."[7]

Policy Background

The oil embargo of 1973 encouraged the U.S. government to find alternative fuels, or fuel additives, to reduce America's need for foreign fuel sources.

In 2002, a gasoline additive called methyl tert-butyl ether (MTBE), which until that point was commonly used as a gasoline octane booster, was banned by multiple states because of groundwater contamination concerns. Ethanol then replaced MTBE as a gasoline oxygenate.

Then, under the Energy Policy Act of 2005, Congress passed the Renewable Fuel Standard (RFS) program, which requires the increased use of renewable fuels over time, primarily ethanol and biodiesel.[8] These factors led to the significant rise in ethanol blend use seen in the Energy Information Administration chart above.

[6] Environmental Protection Agency, "Biofuels and the Environment: Second Triennial Report to Congress (Final report, 2018)," Retrieved July 11, 2022 from https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=IO&dirEntryId=341491

[7] Mark Jacobson, "Effects of Ethanol (E85) versus Gasoline Vehicles on Cancer and Mortality in the United States," *Environmental Science & Technology*, Vol. 41, No. 11, April 18, 2007, pp. 4150–4157.

[8] Environmental Protection Agency, "Renewable Fuel Standard Program," Retrieved July 11, 2022, from https://www.epa.gov/renewable-fuel-standard-program

Food Prices and Land Impacts

A study from the University of Wisconsin-Madison found the impact of RFS on food supplies, prices, and the environment was likely a net harm.[9] For example, after the mandate, the price of corn increased by 30 percent. Emissions from the entire ethanol production process, from growing the corn to burning the fuel, were possibly 24 percent higher than gasoline alone.

According to the study:

> "We find that the RFS increased corn prices by 30% and the prices of other crops by 20%, which, in turn, expanded US corn cultivation by 2.8 Mha (8.7%) and total cropland by 2.1 Mha (2.4%) in the years following policy enactment (2008 to 2016). These changes increased annual nationwide fertilizer use by 3 to 8%, increased water quality degradants by 3 to 5%, and caused enough domestic land use change emissions such that the carbon intensity of corn ethanol produced under the RFS is no less than gasoline and likely at least 24% higher."

Though there are some countries that use much more ethanol than the United States, like Brazil's sugarcane ethanol, the land use issue persists. In Brazil, environmental scientists are alarmed at the expansion of sugarcane plantations and related deforestation of the Amazon and other fragile ecosystems. One study suggests that the expanded land use related to ethanol production could offset any carbon emissions savings from the biofuel use.[10]

Ethanol never displaced significant amounts of foreign oil and therefore did not reduce U.S. dependence on foreign suppliers. By contrast, the fracking revolution and other advancements in oil discovery and production made the United States energy independent less than two years ago. When one accounts for the decline in vehicle fuel economy from using biofuels and their various negative environmental impacts, it seems reliance on biofuel may provide fewer benefits than claimed by its proponents. Accounting for its effects on fuel economy, air quality, and food prices, biofuels likely produce net harms on balance.

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[9] Tyler Lark *et al.,* "Environmental outcomes of the US Renewable Fuel Standard," Proceedings of the National Academy of Sciences, Vol. 119, No. 9, February 14, 2022.

[10] David Lapola *et al.,* "Indirect land-use changes can overcome carbon savings from biofuels in Brazil," Proceedings of the National Academy of Sciences, Vol. 107, No. 8, February 23, 2010, pp. 3388–3393.