

Biofuels

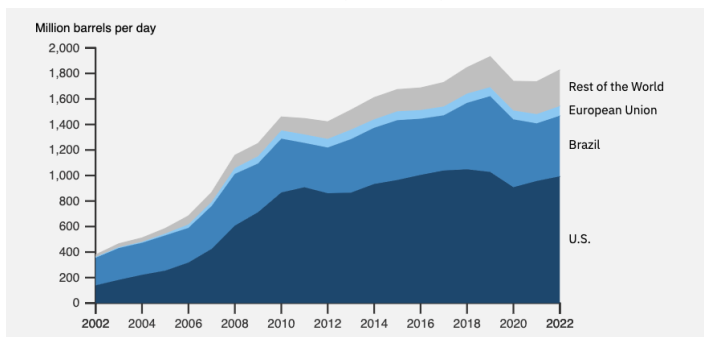
Biofuels, primarily ethanol and biodiesel, are liquid fuels produced from renewable biological sources, including plants, animal fat, and algae¹. Biofuels have the potential to reduce the energy and greenhouse gas emission intensities associated with transportation, but can have other significant effects on society and the environment. Depending on demand, crop growing conditions, and technology, they may require significant increases in cropland area and irrigation water use, and can affect food prices.

Patterns of Use

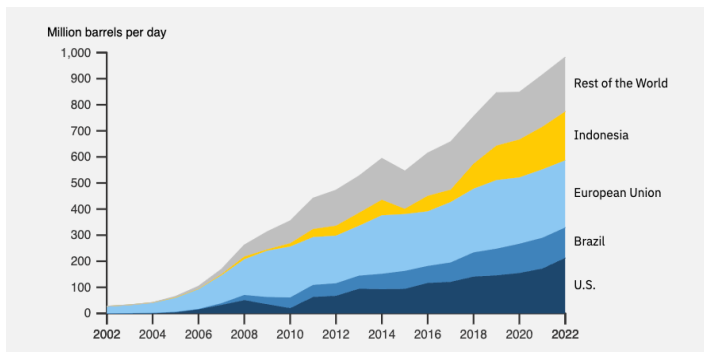
Production

- Ethanol, an alcohol blended with gasoline for vehicle fuel, is the most produced (82%) and used (75%) biofuel in the U.S.²
- The U.S. and Brazil produced 80% of the world’s ethanol in 2022.³ 94% of U.S. ethanol is derived from corn⁴, while Brazil uses sugarcane as feedstock⁴.
- In the 2023/24 season, 5.4B bushels of corn, 37% of the U.S. corn supply, were used as ethanol feedstock.⁵
- Cellulosic ethanol is made from feedstocks including corn stalks, plant residue, waste wood chips, and switchgrass. Making ethanol from these sources is more difficult because cellulose does not break down into sugars easily.⁶The U.S. had no commercial cellulosic ethanol production⁸ as of 2022.⁷
- Biodiesel accounted for 9% of U.S. biofuel production in 2022.² Biodiesel can be made from animal fats, grease,

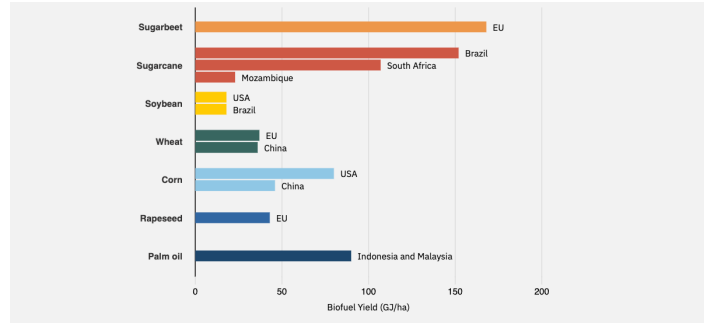
World Ethanol Production (M bbl/d)³



World Biodiesel Production (M bbl/d)³



Biofuel Yield by Region and Feedstock (GJ/ha)¹⁰



vegetable oils, and algae. In the U.S., soybean oil, corn oil, and recycled cooking oils are common feedstocks.⁸ Algae could potentially produce 10 to 100 times more fuel per acre than other crops.⁹ Biodiesel from algae is an area of ongoing research.⁹

- In 2022, the U.S. had 187 ethanol refineries¹¹ and 59 biodiesel production plants¹². Many biodiesel producers are reliant on federal tax credits and remain sensitive to feedstock (soybean oil) and energy (petroleum) prices. The Inflation Reduction Act (IRA) reinstated and extended several biofuel tax incentives through 2024.^{13, 14}

Consumption and Demand

- In 2023, over 98% of U.S. gasoline contained ethanol⁴, and 10% of U.S. vehicle fuel use (by volume) was ethanol¹⁵.
- E85, or flex fuel, sells for less than regular gasoline, but contains less energy per gallon, resulting in a 15-27% reduction in fuel economy.¹⁶
- The global demand for biofuels is expected to increase 11% from 2023 to 2024.¹⁵

Life Cycle Impact

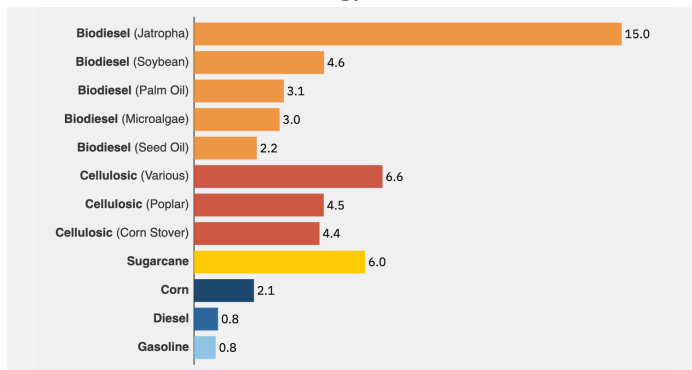
Energy

- The Fossil Energy Ratio (FER) is the ratio of energy output to nonrenewable energy inputs.¹⁷ Gasoline has a value of 0.8 (1.2 Btu of fossil fuel needed to supply 1 Btu of gas at the pump).²¹Recent estimate placed ethanol’s FER at about 1.5, though areas with highly efficient corn agriculture, such as Iowa and Minnesota, have FERs close to 4.²²
- From 1990-2006, the FER for soybean biodiesel improved from 3.2 to 5.5.²³ During the same period, ethanol transitioned from an energy sink to a net energy gain. Much of the improvement came from the reduction of fertilizer inputs to grow corn.²² In comparison, petrodiesel has a FER of 0.83.²⁴

Greenhouse Gases (GHGs)

- Globally, biofuels replaced the consumption of 2M bbl of oil equivalent per day in 2022, or 4% of the global transportation sector oil demand.¹⁵
- GHG emissions from corn ethanol average 39% lower than gasoline, and NG-fueled refineries achieve nearly a 43%

Fuel Return on Fossil Energy Investment^{17, 18, 19, 20}



reduction.²⁵ GHG emissions for cellulosic ethanol average 97% lower than gasoline when including land use change (LUC) emissions and 93% lower when excluding LUC emissions.²⁶

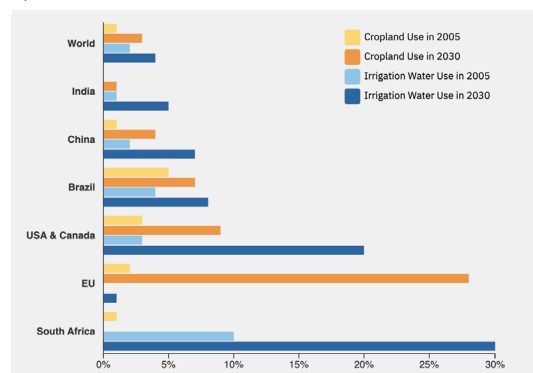
- The use of B20 (20% biodiesel, 80% petroleum diesel), a common blend in the U.S.²⁷, can reduce CO₂ emissions by 15% compared to petroleum diesel²⁸. The use of B100 (100% biodiesel) can reduce CO₂ emissions by 74%.²⁸
- Biodiesel CO₂ emissions are assumed to be taken up again by growth of new feedstock²⁹, thus, tailpipe CO₂ emissions from biofuels are excluded from emissions calculations³⁰.
- Multiple studies have suggested that increased biofuel production in the U.S. will increase global GHG emissions, due to higher crop prices motivating farmers in other countries to convert non-cropland to cropland. Clearing new cropland releases carbon stored in vegetation, preventing the future storage of carbon in those plants.³¹

Other Impacts

- Increasing corn ethanol acreage without changing cultivation techniques will result in increasing fertilizer runoff from Midwestern farms. Excess nutrients that travel down the Mississippi/Atchafalaya River fuel a large hypoxic region in the Gulf of Mexico each summer.³² This “dead zone” is an area of low to no oxygen that can kill fish and other marine life, and is forecast to be 5,827 mi² in 2024, similar to the size of Connecticut.³³
- Globally, arable land used for biofuels is predicted to rise from 2.5% today to 6% in 2050. The impacts of growing biofuel crops vary widely due to regional differences in climate and farmland availability.³⁴
- The water intensity of fuels is extremely variable but generally higher for biofuels than for fossil fuels. For example, irrigated soybean biodiesel ranges between 6.32 and 6,320 gal/GJ, while conventional oil is between 0.63 and 632 gal/GJ.³⁶
- The average surface and groundwater consumption of ethanol and biodiesel consumed in Europe is 972 gal/GJ and 502 gal/GJ respectively—this is 40 and 60 times higher compared to their respective fossil alternatives.³⁷

- Feedstock irrigation accounts for over 80% of water used in corn-ethanol production in most U.S. states. In Nebraska, which produced 12% of U.S. corn ethanol in 2013, 99% of water used for corn ethanol production was for irrigation.³⁸
- The majority of corn production for ethanol relies on substantial irrigation from groundwater.³⁹
- A review of studies found that the growth of biofuel feedstock contributes 20-50% to the price increase of corn in 2006-2008.⁴⁰
- Land use change resulting from an increase in biofuel demand is expected to increase global corn and wheat prices 1-2% and vegetable oil prices by around 10%.⁴⁰

Portion of Cropland and Irrigation Water Used for Biofuels, 2005 & 2030³⁵



Solutions and Sustainable Actions

- The latest renewable fuel standard set by the U.S. EPA requires production of 34B gal of biofuels in 2025, a 15% increase from 2022.⁴¹
- U.S. ethanol producers, blenders, and resellers have been supported by tax incentives, some of which were extended in 2022 by the IRA.¹⁴
- Fuel content standards are one policy option to encourage biofuel use. Regular gasoline sold in Brazil is required to contain 27% ethanol.⁴²
- There is concern that replacing gasoline with corn ethanol is unlikely to contribute significantly to climate change mitigation.^{43, 44} Advances in technology and policies are needed to realize the potential environmental benefits of biofuels.^{43, 45}
- Strategies to reduce the carbon intensity of corn ethanol production include adoption of precision agriculture systems, retention of soil carbon, use of alternative energy, and increased demand for ethanol production co-products.⁴⁶
- Public transportation, carpooling, biking, and telecommuting are excellent ways to reduce transportation energy use and related impacts. See the “[Personal Transportation Factsheet](#)” for more information.