Biofuels

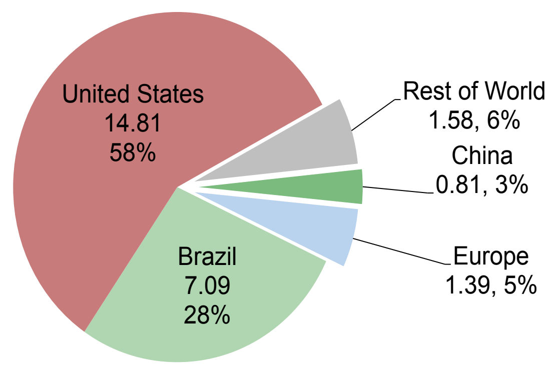
Biofuels have the potential to reduce the energy and greenhouse gas emission intensities associated with transportation but can have other significant effects on society and the environment. Depending on demand, crop growing conditions, and technology, they may require significant increases in cropland and irrigation water use. Also, biofuels may have already affected world food prices.

Patterns of Use

Production

- In the U.S., ethanol is primarily derived by processing and fermenting the starch in corn kernels into a high-purity alcohol—96% of ethanol was derived from corn in 2011. Brazil uses sugar cane as the primary feedstock for ethanol production.[1]
- The U.S. and Brazil produced about 85% of the world's ethanol in 2015.[2]
- In 2015, 5.2 billion bushels of corn, 38% of the U.S. supply, became ethanol feedstock.[3]
- Cellulosic ethanol feedstocks are abundant and include corn stalks, plant residue, waste wood chips, and switchgrass. Making ethanol from these sources is more difficult because the cellulose doesn't break down into usable sugars as easily.[1]
- Biodiesel can be made from animal fats, recycled grease, vegetable oils, and algae. In the U.S., soybean oil and recycled cooking oils are the most common feedstocks.[1]
- Biodiesel from algae is an area of ongoing research. Algae could potentially produce 10 to 300 times more fuel per acre than other crops.[4]

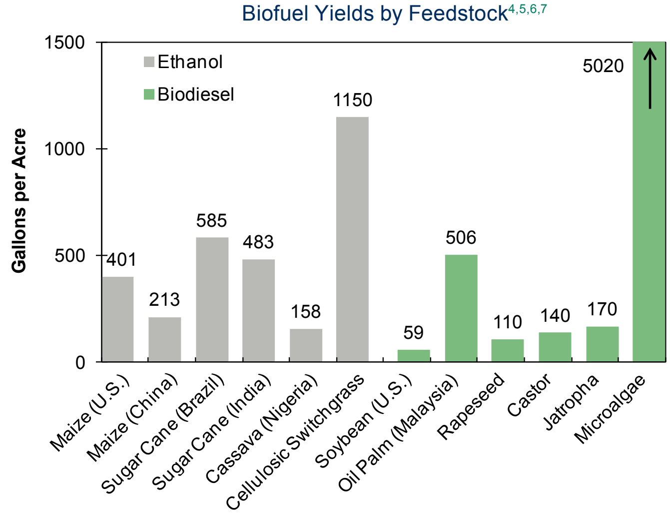
World Fuel Ethanol Production, 2015[2]
(billion gallons)



Consumption and Demand

- In 2015, U.S. petroleum consumption averaged 19 million barrels per day, of which 24% was imported.[8]
- In January 2016, there were 199 ethanol refineries in operation, 3 more under construction, and 100 biodiesel production plants in the U.S.[9,10]
- U.S. Biodiesel production facilities operated at ~55% capacity in 2015.[8,10]
- Many biodiesel producers are reliant on federal production tax credits and remain sensitive to volatile feedstock (soybean oil) and energy (petroleum) prices. The $1/gallon tax credit expired three times in five years and was retroactively reinstated in January of 2014 and extended to December 2016.[11,12]
- In 2015, nearly 10% of U.S. vehicle fuel consumption (by volume) was ethanol and over 96% of U.S. gasoline contains ethanol.[8,13]
- E85 may sell for less than regular gasoline, but contains less energy per gallon. Flex-fuel vehicles running on E85 typically see a 15-30% reduction in fuel economy.[14]

Biofuel Yields by Feedstock[4,5,6,7]

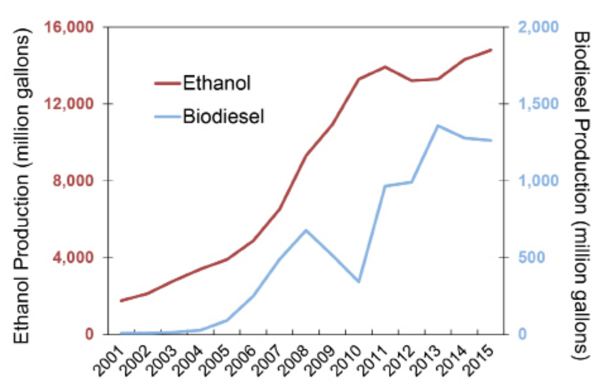


Life Cycle Impacts

Energy

- The Fossil Energy Ratio (FER) is the ratio of energy output to nonrenewable energy inputs.[15] Gasoline has a value of 0.81 (1.23 BTU of fossil fuel needed to supply 1 BTU of gas at the pump).[16] Some controversy exists about whether corn ethanol has a better ratio than gasoline. However, most recent studies find FERs of 1 to 1.6, with GREET weighing in at 1.3.[16,17]
- Cellulosic ethanol studies estimate potential FER's of 4.4 to 6.6; utilizing these fuels could significantly reduce fossil fuel use (FER range due to new technology and feedstock variation).[17]
- From 1990-2006, the FER for soybean biodiesel improved from around 3.2 to 5.5.[18] In comparison, petroleum-based diesel has an FER of 0.83.[19]

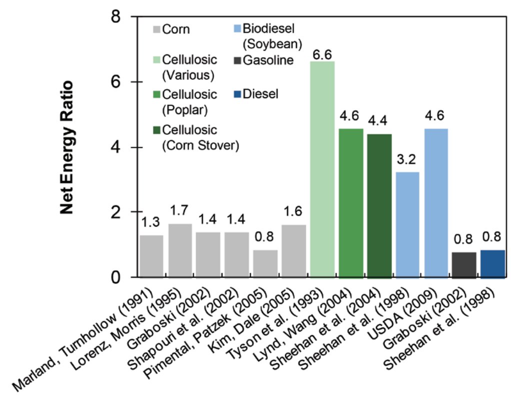
U.S. Biofuel Production, 2001-2015[8]



Greenhouse Gases (GHGs)

- On average, GHG emissions from corn ethanol are 34% lower than gasoline when including Land Use Change (LUC) emissions and 44% lower when excluding LUC emissions.[20]
- GHG emissions for cellulosic ethanol average around 97% lower than gasoline when including LUC emissions and 93% lower when excluding LUC emissions.[20]
- The use of B20 (20% biodiesel, 80% petroleum diesel), a common biodiesel blend in the U.S., can reduce CO_2 emissions by 15%, compared to petroleum diesel. The use of B100 (100% biodiesel) can reduce CO_2 emissions by more than 75%.[21,22]
- Biodiesel CO_2 emissions are assumed to be taken up again by growth of new feedstock, thus, tailpipe CO_2 emissions from biofuels are excluded in emissions calculations.[23,24]
- 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.[25]

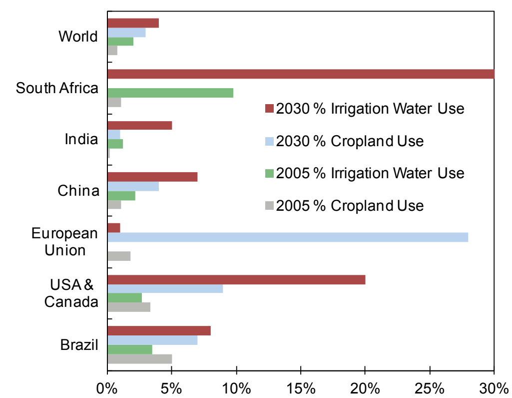
Fuel Return on Fossil Energy Investment[15,17]



Other Impacts

- A large hypoxic zone (with a long-term average of 5,000 square miles) occurs in the Gulf of Mexico each summer.[26] Excess nitrogen, primarily from fertilizer use in Midwest farms, causes algae blooms that decompose and deplete dissolved oxygen, injuring or killing aquatic life. Increasing corn ethanol acreage without changing cultivation techniques will make reducing the hypoxic zone more difficult.[27]
- Globally, average cropland and irrigation water use for biofuels is predicted to remain under 5% in 2030. However, the impacts of growing biofuel crops vary widely due to regional differences in climate and farmland availability.[28]
- The irrigation of feedstocks requires considerably more water resources than the manufacturing of biofuels. Although a typical biorefinery consumes 1 to 4 gallons of water per gallon of biofuel, corn grown in 2003 in Nebraska's dry climate required 780 gallons of irrigation water per gallon of ethanol.[29] The majority of corn production for ethanol occurs in highly irrigated areas, with substantial amounts from groundwater.[30]
- The World Bank attributes 70% of 2002-2008 global food price increases to biofuels and the rest to other factors such as high energy and fertilizer prices, and the declining value of the U.S. dollar.[31] In contrast, the USDA found that biofuel production caused ~10% of global food price increases from 2007-2008.[32]

Percentage of Cropland and Irrigation Water Required for Biofuels, 2005 vs 2030[28]



Solutions and Sustainable Actions

- Under the Energy Independence and Security Act of 2007, the Renewable Fuel Standard (RFS2) requires that 36 billion gallons per year (bg/y) of biofuels be produced by 2022: 16 bg/y from cellulosic sources, 5 bg/y from other advanced sources, and no more than 15 bg/y of corn ethanol. Life cycle GHG standards are also in place, to ensure the biofuels produce fewer emissions than their petroleum counterparts.[33]
- U.S. ethanol blenders and resellers were supported by a federal tax credit of $0.45/gallon of ethanol, which expired in December 2011.[34]
- Fuel content standards are one policy option to encourage biofuel use. Regular gasoline sold in Brazil is required to contain 27% ethanol.[35] Ethanol thus makes up 56% of transportation fuel in Brazil, compared to 8% in the U.S.[36]
- The U.S. EPA and the National Highway Traffic Safety Administration jointly issued rules in 2010 and 2012 establishing new GHG emissions and corporate average fuel economy (CAFE) standards. Vehicle manufacturers' new passenger car and light-duty truck fleets must average 250 g/mi of CO_2 and 34.1 mpg by model year 2016 and 163 g/mi of CO_2 and ~49 mpg by 2025.[37,38]
- Public transportation, carpooling, biking, and telecommuting are excellent ways to reduce transportation energy use and related impacts. See the Center for Sustainable Systems' "Personal Transportation Factsheet" for more information.

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