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factsheets

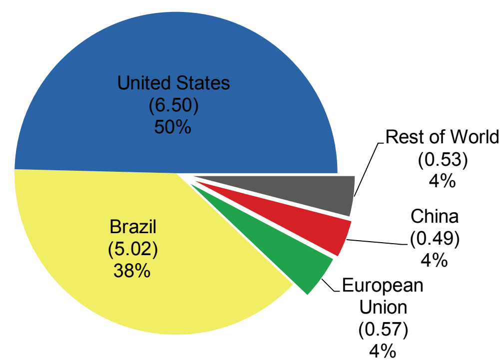
Biofuels

Biofuels have the potential to reduce the energy and greenhouse gas emission intensities associated with transportation, but can have other significant effects on the environment and society. 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.

Production

- Currently in the U.S., ethanol is commonly derived by processing and fermenting the starch in corn kernels into a high-purity alcohol.[1]
- 93% of the ethanol produced in the U.S. in 2006 came from corn (as sole feedstock).[1] This required over 2 billion bushels - about 17% of the total corn supply.[2]
- Cellulosic ethanol feedstocks are very abundant, and include corn stalks, plant residue, waste wood chips, and switchgrass. Making ethanol from these sources is more difficult, compared to corn, because the cellulose doesn't break down into usable sugars as easily.[3]
- Brazil uses sugar cane as their primary ethanol feedstock.[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]
- Algae could eventually become a major biodiesel feedstock, but growing and processing it is currently too expensive. Compared to other biodiesel crops, algae could produce 10 to 300 times more fuel per acre.[4]

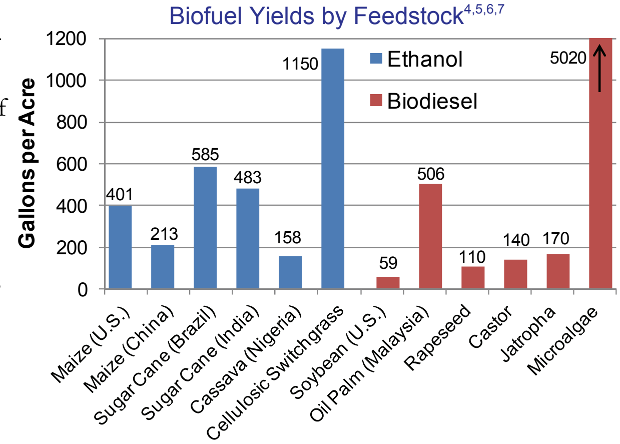
World Fuel Ethanol Production, 2007 (billion gallons)[3]



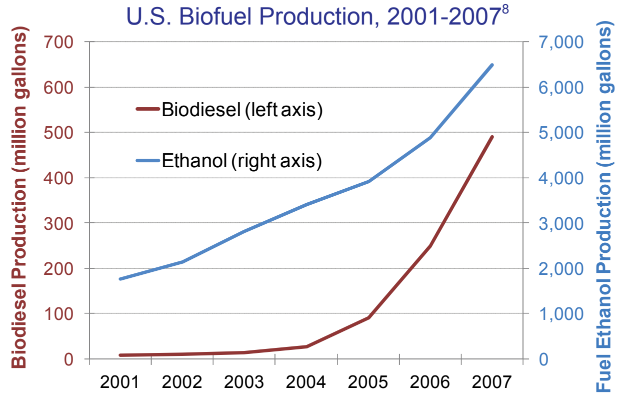
Consumption and Demand

- In 2007, U.S. petroleum consumption averaged 20.7 million barrels per day, of which 65% was imported.[8]
- Average gasoline prices increased from $1.56 in 2000 to a peak price in 2008 of $4.14 (July 2008) - a 265% price increase.[8]
- In early 2008 there were 139 ethanol refineries in operation, 62 more under construction, and 171 biodiesel production plants in operation.[3,9]
- E85 (85% ethanol, 15% gasoline) is available at over 1,400 locations nationwide, which is less than 1% of the total gas stations.[10]
- In 2006, under 4% of U.S. vehicle fuel consumption (by volume) was ethanol.[8]
- E85 is typically cheaper but contains less energy per gallon than regular gasoline. Flex-fuel vehicles running on E85 will see a 25-30% reduction in fuel economy; when gas costs $3 per gallon and E85 costs $2.60 per gallon, the average driver who uses E85 will spend an additional $400-$600 each year.[11]
- MTBE (methyl tertiary-butyl ether) replaced lead as a gasoline octane booster in the U.S. in 1979. It helps the fuel burn more thoroughly to reduce tailpipe emissions. However, due to recent health concerns over MTBE groundwater contamination and its potential carcinogenic effects, 25 States have banned or limited its use.[12]
- Ethanol is filling the void – in low concentrations it also boosts fuel octane rating and can be used in non flex-fuel vehicles. In 1996 only 11% of gasoline contained ethanol and 89% used MTBE as an additive; by 2005, ethanol had a 53% market share. [13]

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



U.S. Biofuel Production, 2001-2007[8]



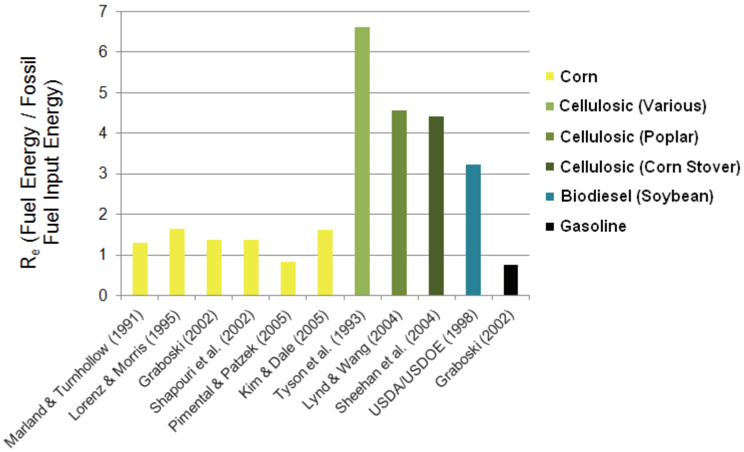
[1] U.S. DOE / EERE (2006) *Biomass Energy Data Book: Edition 1.*
[2] U.S. Department of Agriculture (2008) "USDA Long-Term Agricultural Projection Tables: Table 08 U.S. Corn"
[3] Renewable Fuels Association (2008) http://www.ethanolrfa.org/
[4] Chisti, Yusuf.(2007) "Biodiesel from microalgae." Biotechnology Advances 25: 294-306.
[5] United Nations Food and Agriculture Organization (2008) "The State of Food and Agriculture."
[6] Oak Ridge National Laboratory (2005) "Biofuels from Switchgrass: Greener Energy Pastures."
[7] Fulton, Lew. (2006) "Biodiesel: technology perspectives" Geneva UNCTAD Conference.
[8] EIA (2008) *Annual Energy Review 2007* and *Monthly Energy Review.*
[9] National Biodiesel Board (2008) http://www.biodiesel.org/
[10] EERE (2008) "E85 Fueling Station Locations" and EIA (2008) "Frequently Asked Questions – Gasoline."
[11] U.S. DOE / EERE (2008) *Clean Cities Alternative Fuel Price Report* and www.fueleconomy.gov and CSS calculation.
[12] U.S. EPA (2007) *MTBE faq* and *MTBE Bans and Phaseout Dates in the U.S.* http://www.epa.gov/mtbe/faq.htm
[13] U.S. EPA (2008) *Fuel Trends Report: Gasoline 1995-2005.*

Life Cycle Impacts

Energy

- The ratio of energy output to nonrenewable energy inputs is a useful way to compare fuels from different feedstocks and production methods. Gasoline has a value of 0.76 (the final product contains 24% less energy than the fossil fuel energy invested in producing it), while most corn ethanol studies have shown net energy benefits of 20-65%. [15,16]
- Cellulosic ethanol studies estimate benefits of 4.4 to 6.6 times more energy in the fuel than fossil fuel energy required for production. The wide range in the estimates is due to the immaturity of the technology and the feedstock type.[16]
- Ethanol derived from municipal solid waste (MSW) would require less fossil fuel energy than corn or cellulosic-based ethanol, but could only replace less than 3% of U.S. gasoline.[17]

Fuel Return on Fossil Energy Investment[14,16]



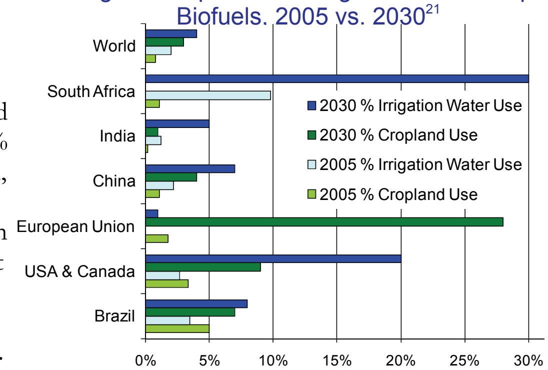
Greenhouse Gases (GHGs)

- According to a model developed by Argonne National Laboratory (GREET model), replacing gasoline with ethanol from corn can reduce lifecycle GHG emissions by about 15-30%, while using cellulosic ethanol could reduce emissions by nearly 90%.[15]
- Using MSW to create ethanol could result in 65% lower GHG emissions compared to gasoline.[17]
- A joint study by the U.S. Department of Energy and Department of Agriculture found that B100 (100% biodiesel) from soybeans can reduce CO_2 emissions by 80%, compared to petroleum diesel.[18]
- A study published in Science, which also used GREET and considered the effects of land-use changes in detail (i.e. converting forests and non-croplands to croplands), found that replacing gasoline with corn-based ethanol will increase lifecycle GHG emissions by 93%. Clearing new cropland releases carbon stored in plants and prevents them from sequestering more atmospheric carbon in the future.[19]

Other Impacts

- When nitrogen fertilizer runoff from farm fields gets into lakes and rivers it can cause algae blooms that deplete the oxygen content, creating a "hypoxic dead zone" which injures and kills aquatic life. A large hypoxic zone (about 7,700 square miles) occurs in the Gulf of Mexico each summer, primarily caused by runoff from Midwestern farm fields. The goal of decreasing the zone by 75% will become practically impossible if ethanol corn acreage increases as projected, without major changes in food production and management.[20]
- Total global cropland and irrigation water use for biofuels is predicted to remain under 5% in 2030, according to a study by the International Water Management Institute. However, regional impacts may be very high. [21]
- Biofuel refinery water consumption is relatively low per gallon of biofuel produced, compared to agricultural irrigation water where rainfall is insufficient. For example, corn in Nebraska in 2003 required 780 gallons of irrigation water per gallon of ethanol produced, while a typical refinery consumes (gallons water per gallon of fuel produced): biodiesel – 1, bioethanol – 4, petroleum – 1.5. [22]
- The effect of biofuels on food prices is controversial. According to a World Bank report, global food prices increased by 130% from 2002-2008. Higher energy and fertilizer prices, the drought in Australia, and the decline of the U.S. dollar can only account for about 30% of the increase – the remaining 70% is attributed to biofuels.[23] In contrast, a short-term evaluation by the USDA found that the increase in biofuel production between 2007 and 2008 only caused global food prices to increase by less than 5% over this period.[24]

Percentage of Cropland and Irrigation Water Required for Biofuels, 2005 vs. 2030[21]



Policy and Consumer Options

- The Energy Independence and Security Act of 2007 requires that 36 billion gallons per year (bg/y) of biofuels be produced by 2022, with corn ethanol limited to 15 bg/y. The Act also specifies that 16 bg/y come from cellulosic sources and 5 bg/y come from other advanced sources, both of which have at least 50% lower lifecycle greenhouse gas emissions than those of petroleum fuels in 2005.[25]
- U.S. ethanol blenders and resellers are supported by a $0.51/gallon of ethanol federal tax credit, which expires in December 2010.[1]
- Gasoline sold in Brazil is required to contain 25% ethanol.[26]

Personal Choices

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: <http://css.snre.umich.edu/facts/factsheets.html>

[14] USDA / US DOE (1998) "An Overview of Biodiesel and Petroleum Diesel Life Cycles"
[15] EERE (2007) *Ethanol: The Complete Lifecycle Energy Picture.*
[16] Hammerschlag, Roel. (2006) "Ethanol's Energy Return on Investment: A Survey of the Literature 1990-present" Environmental Science & Technology 40: 1744-1750.
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[18] USDA / US DOE (1998) "An Overview of Biodiesel and Petroleum Diesel Life Cycles"
[19] Searchinger, Timothy et al. (2008) "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change." Science 319: 1238-1240.
[20] Donner, Simon D., and Christopher J. Kucharik. (2008) "Corn-based ethanol production compromises goal of reducing nitrogen export by the Mississippi River." Proceedings of the National Academies of Sciences
[21] de Fraiture, Charlotte et al. (2008) "Biofuels and Implications for agricultural water use: blue impacts of green energy." Water Policy 10: 67-81.
[22] National Academy of Sciences (2008) "Water Implications of Biofuels Production in the United States."
[23] Mitchell, Donald. (2008) "A Note on Rising Food Prices." Working paperNo. 4682. Development Prospects Group, World Bank.
[24] Glauber, Joseph (2008) Statement before the Committee on Energy and Natural Resources, US Senate.
[25] Congressional Research Service (2007) *Energy Independence and Security Act of 2007: A Summary of Major Provisions.*
[26] Perkins, Morgan. (2006) Brazil Sugar Ethanol Update - February 2006. Rep.No. BR6001. USDA.