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Fuel Ethanol

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As energy prices reach historic highs, there is a broad interest across the state in utilizing and producing renewable bioenergy from domestic agricultural products. Nationwide, it is expected that a 20 percent replacement of petroleum usage will happen over the next ten years. This is equivalent to 35 billion gallons of alternative fuel use by 2017, with fuel ethanol playing an important role in this transition. Fuel ethanol can be blended with gasoline (from 10 percent to 85 percent), and thus reduce the amount of gasoline used. In the United States, corn kernels are commonly used for producing fuel ethanol, and thus reduce the nation's dependence on foreign oils. The purpose of this publication is to introduce the basics of fuel ethanol and answer questions regarding fuel ethanol.

Glossary

Gasohol – A mixture of gasoline and ethanol.

E10 – A gasohol blend of 10 percent ethanol and 90 percent gasoline, by volume

E85 – A gasohol blend of 85 percent ethanol and 10 percent gasoline, by volume

FFV (Flexible Fuel Vehicle) – A vehicle that can operate on any blend of up to 85 percent ethanol. If E85 is not available, the vehicle can operate on straight unleaded gasoline or any percentage of ethanol up to 85 percent.

VEETC (Volumetric Ethanol Excise Tax Credit) – A federal excise tax credit that was signed on American Job Creation Act of 2004 (JOBS Act) by President Bush.

DDGS – Corn Distillers Dried Grains with Solubles

Octane number – A measure of how well a fuel resists premature combustion (autoignition) or "knocking" in spark-ignition in internal combustion engines. Gasoline with too low of an octane rating converts fuel to heat rather than power, making for less efficient fuel usage and reduced engine life.

Oxygenate – A chemical that adds oxygen to the gasoline.

Engine warranty

Automobiles: Currently, all major automakers (General Motors, Ford Motor, DaimlerChrysler, Acura/Honda, Audi, BMW, Hyundai, Infinti/Nissan, Isuzu, Jaguar, Kia, Land Rover, Lexus/Toyota, Mercedes-Benz, Mazda, Mitsubishi, Porsche, Roll Royce/Bentley, Saab, Saturn, Subaru, Suzuki, Volkswagen, and Volvo) approve the use of gasohol up to E10 under warranty for the vehicles they produce. The most recent automakers' fuel recommendations are for their 2006 model vehicles, and the information can be accessed at *http://www.ethanolrfa.org/resource/facts/engine/documents/2006AutoManufacturerFuelRecommendations04-18-06.pdf.*

Motorcycles: Major manufacturers of motorcycles (Harley-Davidson, Honda, Kawasaki, Suzuki, and Yamaha) approve the use of E10.

Small Engines: All mainstream manufactures of power equipment, snowmobiles, motorboats, and lawnmowers permit the use of ethanol blends up to E10 in their products. Generally, E10 unleaded can be used anywhere that ordinary unleaded gasoline is used. However, due to the widely diversified products, always check the owner's manual for specific information regarding the equipment.

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FFV: FFVs produced from major automakers are guaranteed using ethanol blend up to E85. FFV owners do not have to fill up with E85 all the time because the vehicles can also run on regular gasoline, E10, or an ethanol blend between E10 to E85. To determine if your vehicle is an FFV, review *http://www.e85fuel.com/e85101/flexfuelvehicles.php*.

Performance

Engine runs smoothly: Ethanol has a higher octane number (113) than regular unleaded gasoline (87) and premium unleaded gasoline (93). A higher octane number reduces the tendency for an engine to pre-ignite and knock; it runs more smoothly.

Complete combustion*:* Ethanol molecules contain 35 percent oxygen, and serve as an "oxygenate" to raise the oxygen content of gasoline fuel. Thus, it helps gasoline burn completely and reduces the build up of gummy deposits in the engine.

Prevent overheating: Ethanol burns cooler than gasoline, preventing engine valves from burning.

Antifreeze function: Ethanol has the ability to absorb water. Therefore, condensation in the fuel system is absorbed and does not have the opportunity to collect and freeze. Gas-line antifreeze is alcohol – usually methanol, ethanol, or isopropyl, which may be used at up to a 0.3 percent level in the car's fuel tank. When E10 is used, it is able to absorb more water than a small bottle of methyl or isopropyl alcohol, therefore eliminating the need and expense of adding a gas line anti-freeze.

Energy content: As shown in Table 1, fuel ethanol contains around 33 percent less energy content than regular gasoline. The energy content of gasohol blends (E10 or E85) is determined by the energy content of ethanol and gasoline, and their ratio.

Engine power and fuel economy: The engine power and fuel economy are determined by the engine configuration, the efficiency of an engine, and volumetric energy content of the fuel used by the engine. For the same engine type and efficiency, the difference in fuel economy depends entirely on the volumetric content of the fuels. Due to the low energy content of ethanol (Table 1), E10 has approximately 2 percent lower mileage than regular gasoline. For example, a car averaging 30 miles per gallon (mpg) on gasoline would average 29.4 mpg when using E10. However, when using FFV running on E85, the mileage will drop significantly (10 percent to 15 percent lower than gasoline). A *Consumer Reports* article in the October 2006 issue reported on the poor fuel economy of FFVs fueled by E85. Currently, major automakers are optimizing their FFVs to run E85 more efficiently.

Table 2. Fuel economy test of 2007 Chevrolet Tahoe [a]

E85	Fuel economy, mpg	Gasoline
7	City	9
15	Highway	21
13	150-mile trip	18
10	overall	14

[a] *Consumer Reports* (October 2006, ISSN: 0010-7174)

Volatility: Ethanol has a higher volatility than regular gasoline; therefore, its emissions increase slightly in warm weather due to evaporation.

Environmental benefits

Reducing tailpipe emissions: Fuel ethanol contains 35 percent oxygen; this assists gasoline in burning completely and significantly reduces smog and greenhouse gas emissions. Scientists at the U.S. Department of

Table 1. Energy content of different fuels [a,b]

Fuel type	Ethanol	Regular gasoline	Premium gasoline	E10 gasohol	E85 gasohol
Energy content (BTU/gallon)	84,600	125,000	131,200	120,900	90,660

[a] BTU: British Thermal Unit

[b] Reference: *Transportation Energy Data Book from Oak Ridge National Laboratory http://cta.ornl.gov/data/appendix_b.shtml.*

Energy Argonne National Laboratory have estimated a 12 percent to 19 percent reduction of greenhouse gas emissions carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) when using an E10 blend (*http://www.ipd.anl.gov/anlpubs/1999/02/31961.pdf*). Also, an E10 blend can reduce the emission of carbon monoxide (CO) by 30 percent, fine particle matter (PM) by 50 percent, toxins by 13 percent, and volatile organic compounds (VOC) by 12 percent (*http://www.ethanolrfa.org/objects/documents/69/nec_whitten.pdf; NGGA*)

It should be noted that ethanol increases the tendency of fuel to evaporate (be volatile) during warm weather. These slight increases in evaporative emissions from ethanol-blended fuel are more than offset by the greater reduction of CO, PM toxics, and VOC emissions due to the use of fuel ethanol. Additionally, reformulated gasoline in smog prone areas require refineries to manage the components in gasoline fuel to reduce the volatility of gasoline, specifically mandating that ethanol-blended fuels meet the same evaporative emissions standards as conventional gasoline.

Elimination of MTBE: MTBE (Methyl Tertiary Butyl Ether) is a compound derived from petroleum. It is an oxygenate additive for gasoline that causes it to burn completely. However, MTBE has serious problems, already having polluted ground water and possibly having carcinogenic properties. Ethanol can be used as an alternative oxygenate for MTBE and achieve the same combustion performance.

Safe in soils and ground water: Ethanol is nontoxic, water-soluble, and biodegradable; when spilled on land or in water, ethanol is quickly, safely, and naturally degraded. In addition, the presence of ethanol in gasoline proportionally reduces the presence of other toxic components originally contained in gasoline such as benzene and sulfur in the gasohol.

Energy balance

The energy balance for ethanol production refers to the energy used to grow and process the raw material into ethanol versus the energy contained in the ethanol itself. When cellulosic residues are used as raw materials, there is no doubt that ethanol production will have a strongly positive energy output. However, when cornstarch is used as a raw material, the energy balance is not conclusive. Since the early 1990s, a significant amount of research on the energy balance of corn-based fuel ethanol production has produced two opposing viewpoints, positive energy balance and negative energy balance.

Positive energy balance: The mainstream conclusion is that ethanol has a positive energy balance, indicating that ethanol contains more energy than it takes to produce. This conclusion is supported by U.S. Department of Agriculture (USDA), Office of Energy Policy and New Uses U.S. Department of Energy, Argonne National Laboratory; Michigan State University, Colorado School of Mine; and the Institute for Local Self-Reliance.

In 2002, the USDA concluded that the net energy balance production is 1.35 to 1; in 2004, USDA updated this ratio to 1.67 to 1. Michael Wang from Argonne National Laboratory reported a 35 percent net energy gain. A Michigan State University study in 2002 found that ethanol produced from corn provided 56 percent more energy than is consumed during production. All those studies take into account the entire life cycle of ethanol production; including the energy used to produce and transport corn, the energy used to produce ethanol, and the energy used to distribute ethanol to the gas station.

The reason behind the net energy balance of corn-derived ethanol is due to the fact that (1) the energy efficiency of agricultural production. U.S. agriculture uses about half the energy today to produce a bushel of corn today as was needed in the 1950s and (2) the increased production efficiency of an ethanol plant. Today's ethanol plant produces 15 percent more ethanol from a bushel of corn, and uses 20 percent less energy in the process than five years ago. In addition, the co-products (e.g. distiller grains, gluten feed, corn sweeteners, etc.) are also created in ethanol production. This means not all the energy used by an ethanol plant is directed at producing ethanol, further improving the net energy balance of ethanol production.

Negative energy balance: Negative energy balance of ethanol production from corn has also been reported. Two major advocates of this position are David Pimentel of Cornell University and Tad Padzek of University of California, Berkeley. Both professors reported a negative energy balance for producing ethanol from corn. For example, a July 5, 2005, news release from Cornell University states, "Cornell ecologist's study finds that ethanol and biodiesel from corn and other crops is not worth the energy." (*http://www.news.cornell.edu/stories/July05/ethanol.toocostly.ssl.htm*l). The website *http://petroleum.berkeley.edu/patzek/index.htm* also collects Professor Padzek's arguments on the negative energy balance of biofuels.

U.S. fuel ethanol production

Driving force: High oil prices and energy security concerns are the major driving forces for boosting U.S. ethanol production. The United States is increasingly dependent on imported oil to meet personal, transportation, and industrial needs. The increasing domestic demand, the growing demands from China and India, the ongoing violence in the Middle East, and the occasional hurricane-caused disruption of oil production in the Gulf region, sent the oil price to historic highs (~$74/barrel) during the summer of 2006. Currently, the U.S. imports 65 percent of its petroleum needs. The Energy Information Administration (EIA) estimates this ratio of imported petroleum will increase to 71 percent by 2025. Unfortunately, the Middle East owns two-thirds of the world's known oil reserve. According to a 1989 study by the General Accounting Office, the U.S. has spent approximately $150 billion since 1968 in government subsidies to the oil industry. This does not include the money spent on military protection of Middle East oil supplies, which is estimated roughly at $50 billion per year since the turn of the century. These factors create a need to diversify the U.S. energy infrastructure with domestic production of renewable fuels.

Historical production: Figure 1 shows the U.S. fuel ethanol production from 1980 to 2005. Before 1991, the U.S. ethanol production was below 1 billion gallons. Since then, the production was relatively stable, maintaining 1 to 1.5 billion gallons per year until 2000. Since 2000, the production has increased sharply. During the same period, the oil price also increased sharply.

Current production capacity: Based on the latest statistics (January 29, 2007) from the Renewable Fuel Association, ethanol production in 2006 was 4.9 billion gallons, the highest production in history. Currently, there are 111 ethanol refineries operated in 19 states, with a total 5.4-billion-gallon-per-year-production capacity. In addition to these existing plants, 76 new plants are under construction and the expansion of seven existing plants will add another 6 billion gallons of new capacity by the middle of 2009 (*http://www.ethanolrfa.org/media/press/rfa/view.php?id=930*). Figure 2 shows the locations of those refineries, the majority of those refineries are located in Midwest states.

World ethanol production: Brazil, the U.S., and China are the top three ethanol producers in the world. The ethanol production from these three countries accounts for 78 percent of worldwide ethanol production. Brazil was the biggest producer until 2005 when the U.S. exceeded Brazil and became the biggest producer. The top ten countries in terms of ethanol production are shown in Table 3.

Feedstock: Various sugar- and starch-based feedstock can be used for ethanol production, these include sugar cane, bagasse, miscanthus, sugar beet, sorghum, grain sorghum, switchgrass, barley, hemp, kenaf, potatoes, sweet potatoes, cassava, sunflower, molasses, whey or skim milk, corn, stover, grain,

Figure 1. Historic U.S. fuel ethanol production

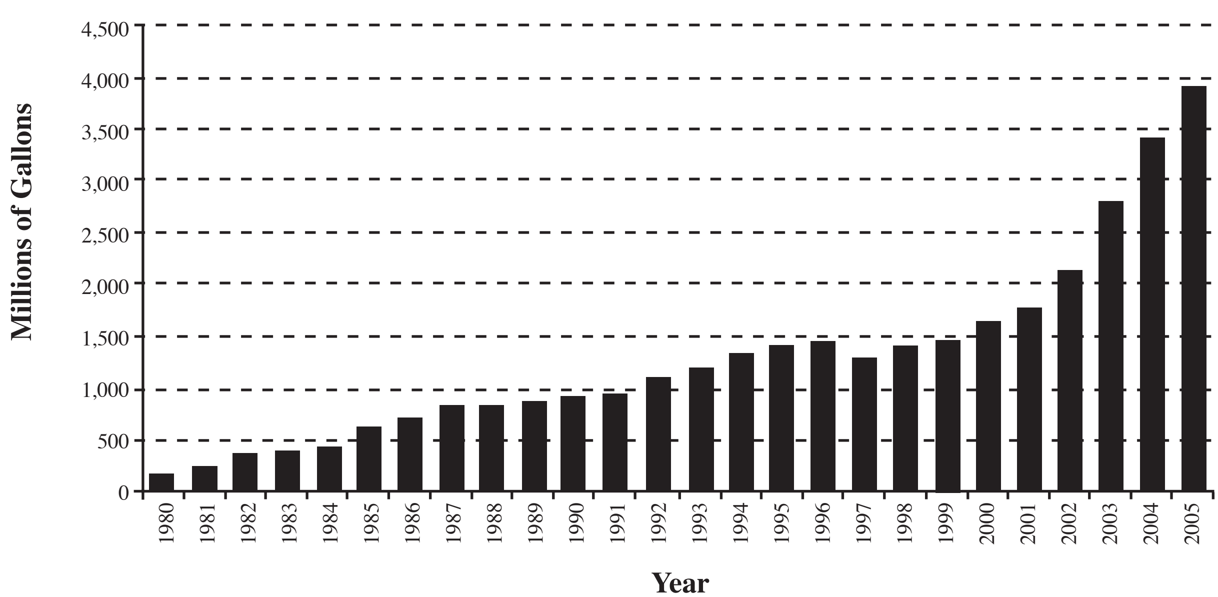
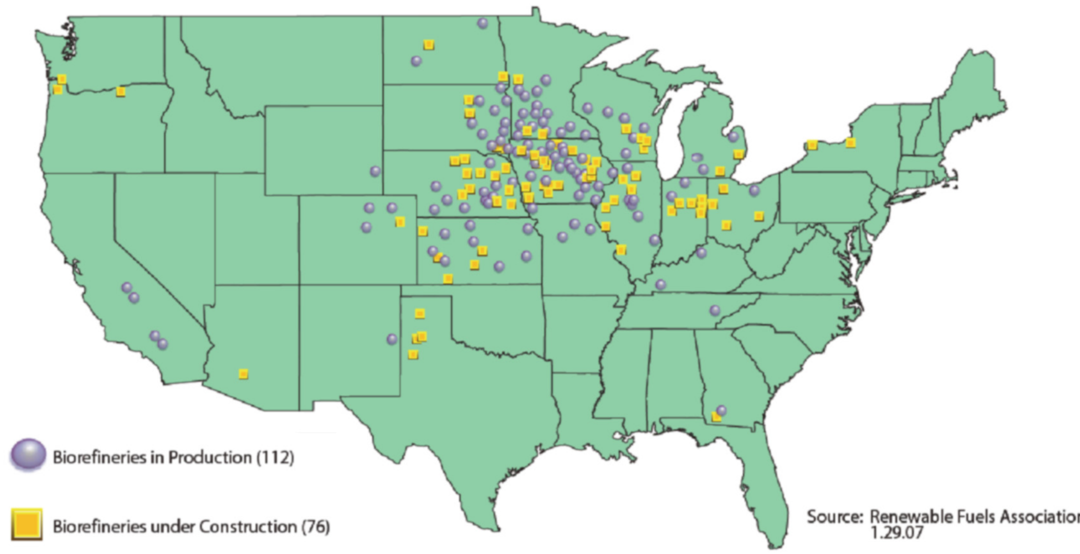


Figure 2. U.S. ethanol refinery locations



wheat, wood, paper, straw, and cotton. In the U.S., the primary feedstock is corn grain due to the favorable climate conditions for corn. In Brazil, sugar cane is the major feedstock.

Another group of feedstock which can be used for ethanol production is cellulosic materials, including various agricultural residues (e.g. corn stover, wheat straw), herbaceous materials (e.g., switchgrass) and woody materials (e.g., poplar wood).

Table 3. Annual ethanol production by top ten countries [a]

Country	2004	2005
Brazil	3,989	4,227
U.S.	3,535	4,264
China	964	1,004
India	462	449
France	219	240
Russia	198	198
South Africa	110	103
U.K.	106	92
Saudi Arabia	79	32
Spain	79	93
Thailand	74	79
Worldwide	10,770	12,150

[a] Unit: millions of gallons; all ethanol grades

Reference: *http://www.ethanolrfa.org/industry/statistics/#E*

Incentive/tax benefit:

Renewable Fuel Standard (RFS): The Energy Policy Act (EPAct) of 2005 is comprehensive energy legislation that includes a nationwide Renewable Fuels Standard (RFS) that will double the use of ethanol and biodiesel by 2012.

Under the RFS, a small percentage of the nation's fuel supply must be provided by renewable, domestic fuels including ethanol and biodiesel. EPAct ensures that the volume of renewable fuel blended into gasoline starts with 4.0 billion gallons in calendar year 2006 and nearly doubles to 7.5 billion gallons by 2012.

VEETC: The American Jobs Creation Act of 2004 (JOBS Act), which created the Volumetric Ethanol Excise Tax Credit (VEETC), replaces the previous federal ethanol excise tax credit. It allows a 51-cent refund for each gallon of ethanol blended with gasoline. For example, if ethanol is blended with gasoline at 10 percent (E10), blenders will receive 5.1 cents for each gallon of E10 sold.

Fuel ethanol in Virginia

Promotion program: Currently, the Virginia State Government provides the Biofuels Production Fund to producers of biofuels, specifically ethanol and biodiesel. A biofuels producer is eligible for a grant of $0.10 per gallon of pure biofuels sold in the Commonwealth from January 1, 2007 to January 1, 2017. To qualify, a biofuels producer must produce at least 10 million gallons of neat biofuels in the calendar year in which the incentive is taken. Each producer is only eligible for six calendar years of grants. The summary report can be accessed at *http://www.eere.energy.gov/afdc/progs/state_summary.cgi?afdc/VA*.

In addition, the Hampton Roads Clean Cities Coalition (HRCCC, *http://www.hrccc.org/*) and Blue Ridge Clean Fuel Inc. (BRCFI, *http://www.blueridgecleanfuels.org/*) are two non-profit organizations that promote biofuel usage in Virginia.

Commercial producers: Currently, there are no commercial fuel ethanol producers in Virginia.

Distributors and retailers: The location of gas stations selling E85 can be found at *http://www.e85refueling.com/*.

Where to find additional information

The website of the Renewable Fuels Association (RFA) (*http://www.ethanolrfa.org/*) provides detailed information from ethanol basics to the most recent updates on the ethanol industry. RFA is the national trade association; it promotes policies, regulations, and research and development initiatives that will lead to the increased production and use of fuel ethanol. The membership of RFA includes a broad cross-section of businesses, individuals, and organizations dedicated to the expansion of the U.S. fuel ethanol industry.

The National Corn Growers Association (NCGA, *http://www.ncga.com/)* is another advocate for fuel ethanol. The "renewable energy entities" on the NCGA website (*http://www.ncga.com/GrowersResources/RenewableEnergy/index.asp*) is another source for ethanol fuel information.

World Wide Web resources

American Coalition for Ethanol (*http://www.ethanol.org*)

Renewable Fuels Association (*http://www.ethanolrfa.org*)

National Corn Growers Association (*http://www.ncga.com*)

National Ethanol Vehicle Coalition (*http://www.e85fuel.com/index.php*)

Department of Energy E85 Fleet Tool Kit (*http://www.eere.energy.gov/afdc/e85toolkit*)

Department of Energy Alternative Fuels Data Center (*http://www.eere.energy.gov/afdc/index.html*)

General Motors E85 Page (*http://www.gm.com/company/gmability/environment/e85/index.html*)

Ford Motor Company Ethanol Vehicles Page (*http://www.ford.com/en/vehicles/specialtyVehicles/environmental/ethanol.htm*)

E10 Unleaded (*http://www.e10unleaded.com*)

Governors Ethanol Coalition (*http://www.ethanol-gec.org*)

Ethanol Promotion & Information Council (*http://www.drivingethanol.org*)

Department of Energy Clean Cities Program (*http://www.eere.energy.gov/cleancities*)

Department of Energy National Renewable Energy Laboratory (*http://www.nrel.gov*)

Oak Ridge National Laboratory (*http://www.ornl.gov*)

National Corn-to-Ethanol Research Center (*http://www.ethanolresearch.com*)

Argonne National Laboratory (*http://www.anl.gov*)

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