

Ethanol Basics

Ethanol is a widely used, domestically produced renewable fuel made from corn and other plant materials. More than 96% of gasoline sold in the United States contains ethanol. Fuel ethanol contains the same chemical compound as beverage alcohol, but it is denatured with a small amount of gasoline or other chemicals during the production process, making it unsafe for human consumption.

Ethanol's primary market drivers are the Federal Renewable Fuel Standard requiring its use and its ability to enhance octane. Gasoline and gasoline blendstocks shipped via pipelines need ethanol or another octane enhancer to bring octane levels up and meet consumer demand for a higher-octane fuel (this improves vehicle performance).

Using ethanol in fuel also helps the nation reduce petroleum consumption, thereby potentially reducing the amount of oil we import.

Ethanol Blends

Nearly all fuel-grade ethanol is sold as E10 (a blend of 10% ethanol and 90% gasoline). E85—a blend containing 51% – 83% ethanol (depending on geography and season) can only be used in flexible fuel vehicles (FFVs). In 2011, the Environmental Protection Agency (EPA) approved E15 (15% ethanol, 85% gasoline) for use in model year (MY) 2001 and newer vehicles. Few stations currently offer E15 due to concerns about consumers fueling incorrectly. However, these issues are being addressed by early marketers through consumer education, point of purchase signage, and other outreach initiatives. Because nearly all gasoline sold already contains 10% ethanol,



Ethanol may be labeled in a variety of ways at the pump. Photos, left to right, from Wiecek Media Services; by Heather Proc, NREL 19959; by Warren Gretz, NREL 07133

the United States is essentially at the “blend wall,” a point where the only available expansion opportunities for using ethanol as a vehicle fuel will be to sell more E15 and E85.

How can I find ethanol?

The Alternative Fuels Data Center (AFDC) has information about fueling sites across the country that offer E85. To find E85 stations in your area, use the Alternative Fueling Station Locator at afd.energy.gov/stations.



Production

How is ethanol produced?

According to the U.S. Energy Information Administration, annual production of ethanol in the United States totaled more than 13.2 billion gallons in 2013, and 98% was made from corn. As of January 2014, the country had an annual production capacity of more than 14.9 billion gallons.² Corn ethanol is produced using dry mill technology, which is a process that grinds corn into flour and ferments only the starch into ethanol. The remaining components of corn are made into co-products like corn oil and distillers grains, which are used as livestock feed.

1 *TPocket Guide to Ethanol 2014*, Renewable Fuels Association. Accessed May 1, 2014: ethanolrfa.org/pages/rfa-pocket-guide-to-ethanol

2 *Monthly Ethanol Production Report, February 2014 with Data for December 2013*, Washington, D.C.: U.S. Energy Information Administration. Accessed April 24, 2014: eia.gov/totalenergy/data/monthly/pdf/sec10_7.pdf

Ethanol is an alternative fuel made from a variety of plant-based feedstocks such as prairie grasses, wood chips, harvested corn, and wheat leftovers. Photo by Pat Corkery, NREL 15652

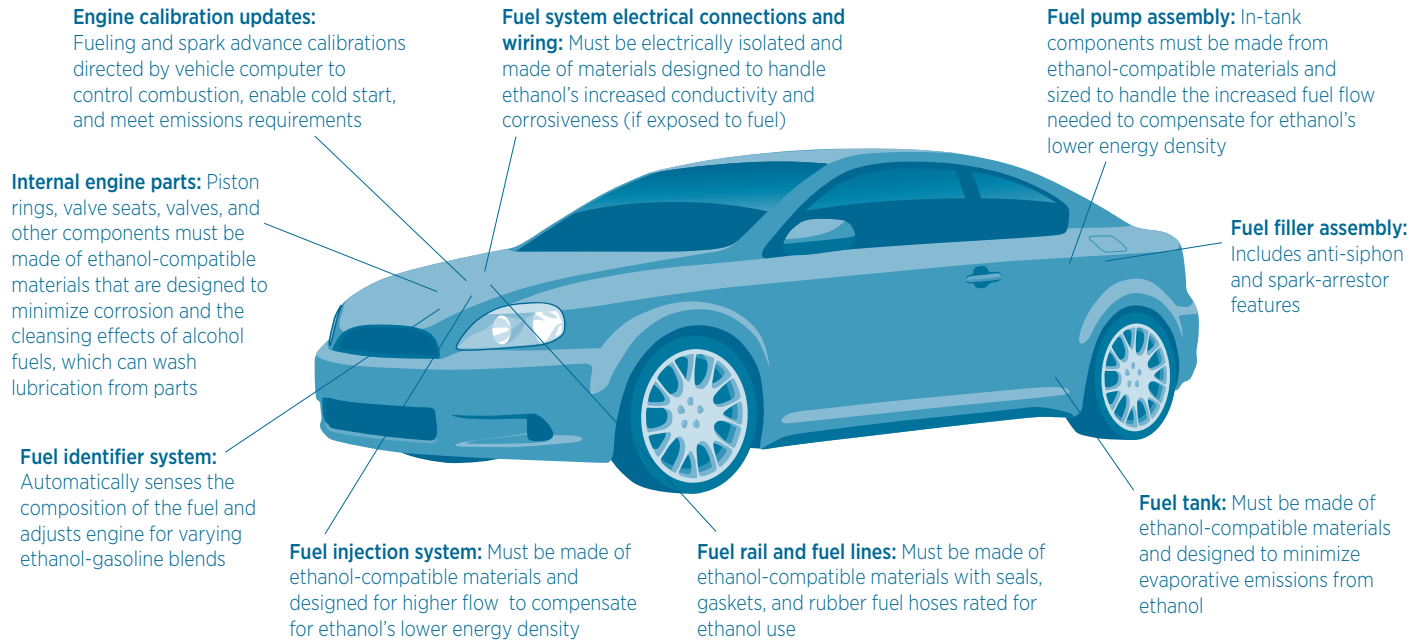


Figure 1. FFV Components. Illustration by Dean Armstrong, NREL

What is cellulosic ethanol?

Cellulosic ethanol is produced from non-food feedstocks such as crop residues, woody biomass, and dedicated energy crops. Both the U.S. Department of Energy (DOE) and industry have invested in the research and production of cellulosic ethanol, and it is being sold commercially in small volumes. To learn more, visit the AFDC ethanol production Web page at afdc.energy.gov/fuels/ethanol_production.html.

Vehicle Applications

Federal regulations allow all existing gasoline vehicles to use E10, while MY 2001 and newer vehicles are allowed to use up to E15. Approximately 65% of the more than 240 million registered gasoline vehicles in the U.S. are MY 2001 or newer.³ However, some manufacturers do not recommend using E15 in their vehicles.

What is an FFV?

An FFV, as its name implies, has the flexibility of running on more than one type of fuel. FFVs can be fueled with unleaded gasoline, E85, or any combination of the two. Like conventional gasoline vehicles, FFVs have a single tank and fuel system.



Flexible fuel vehicles (FFVs) are available in a wide range of models, such as sedans, pickup trucks, and minivans.

Photo from Mark Bentley, NREL 31747

They are available in a wide range of models, such as sedans, pickup trucks, and minivans. You can find many FFV models by using the AFDC Alternative Fuel and Advanced Vehicle Search at afdc.energy.gov/vehicles/search/. To learn more about FFVs and how to identify them, visit fuelconomy.gov.

How do FFVs differ from conventional vehicles?

There are several differences between FFVs and gasoline-powered vehicles. Unlike a gasoline-powered vehicle,

an FFV's fuel-system components are made from ethanol-compatible materials. Also, FFV control systems are designed to compensate for any fuel mixture variation, from unleaded gasoline to E85. Figure 1 illustrates the specialized components of an FFV.

Does fuel economy drop when using ethanol blends?

Ethanol contains less energy per gallon than gasoline contains—a gallon of pure ethanol (E100) has 76,330 British thermal units (Btu)

³ Vehicle populations were determined using 2012 Polk vehicle registration data purchased by NREL.

of energy while a gallon of gasoline typically contains 112,114 –116,090 Btu. The impact on fuel economy (miles per gallon) will depend on the ethanol content of the fuel, up to a maximum 25% reduction for E85 (assuming 83% ethanol content). The impacts of E10 or E15 are proportionally smaller; drivers will generally not notice a difference in a vehicle’s fuel economy or performance.

Greenhouse Gas Emissions

How do ethanol greenhouse gas (GHG) emissions compare to gasoline?

To determine a fuel’s GHG impact, its full “lifecycle” (which includes every step in the fuel’s production and use), is considered. To determine the impacts of ethanol, these steps include growing the feedstock (usually corn) and delivering it to the ethanol plant, and then producing, distributing, and using the fuel in vehicles. For gasoline, the lifecycle steps include crude oil extraction, transportation to a refinery, the oil’s conversion into gasoline, and finally distributing and using the fuel in vehicles.

An analysis conducted by Argonne National Laboratory found that, when entire lifecycles are considered, corn ethanol reduced GHG emissions by 19% – 52% when compared to gasoline (Figure 2). The amount of the reduction depends on the source of thermal energy used to produce the ethanol; the vast majority of ethanol plants use natural gas, which results in a 28% reduction compared to gasoline. Cellulosic ethanol, which intends to use wastes from agricultural, wood industry, or low-input dedicated energy crops, could result in an 86% reduction of GHG emissions compared to gasoline.

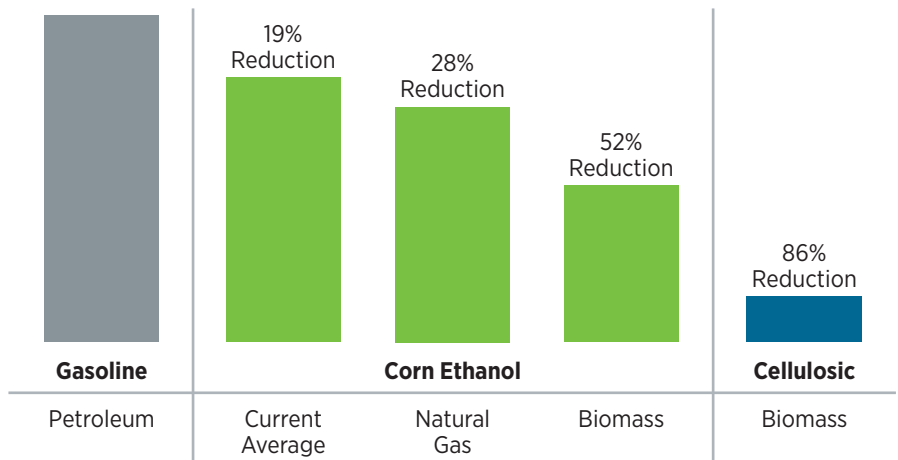


Figure 2. Lifecycle Greenhouse Gas Emissions, for gasoline, corn ethanol, and cellulosic ethanol as a function of each fuel’s thermal energy source. *Source: “Life-Cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types” (ANL). Figure by Dean Armstrong*

Online Resources

Take advantage of the following online resources to learn more about alternative fuels like ethanol and where to refuel.

Ethanol Handling and Use Guide: Use this handbook to learn basic information regarding the proper and safe use of E85 and other ethanol blends, with supporting technical and policy references included (afdc.energy.gov/uploads/publication/ethanol_handbook.pdf).

Alternative Fueling Station Locator:

Find fueling stations and electric vehicle charging locations in your area by visiting the website (afdc.energy.gov/stations) or downloading the iPhone App.

Clean Cities Technical Response Service:

Let seasoned experts answer your questions about alternative fuels, advanced vehicles, fuel economy, and idle reduction (technicalresponse@icfi.com; 800-254-6735).

An FFV is often distinguished by an emblem on the back of the vehicle, and many FFVs have yellow fuel caps.

Photo by Pat Corkery, NREL 18095



Case Study:

City of Chicago Program Encourages Petroleum Displacement and Collaboration Between Departments

Successfully transitioning a fleet to alternative fuels requires investment in fueling infrastructure and a strong commitment to modifying driver behavior. Motivated by energy security, economics, and emissions reduction goals, the City of Chicago fleet began its journey by acquiring FFVs in 1995. Today, it has more than 1,860 light-duty FFVs in law enforcement and municipal applications. The fleet displaces about 1.2 million gallons of gasoline per year by using E85, making the City of Chicago the largest user of E85 in the Chicago metropolitan area.

Fleet drivers expressed a genuine interest in E85 after the initial FFV roll-out. But with only six E85 fueling stations available to support more than 1,000 FFVs, the city quickly realized the need for E85 infrastructure expansion. Initially, the city lacked the funds to support such a project, but officials worked with the Chicago Area Clean Cities (CACC) to develop project goals, cost estimates, and timelines. Being prepared with these plans allowed the city to take advantage of a funding opportunity when it arose.

In 2009, CACC submitted a proposal for American Recovery and Reinvestment Act (ARRA) funding, including the city in the larger Chicago Area Alternative Fuels Deployment Program. The E85 infrastructure project secured approximately \$700,000, half funded by ARRA through DOE and the remainder matched by the city. By expanding the city's private E85 fueling infrastructure to a total of 11 stations, the Chicago Department of Fleet and Facility Management and the Chicago Department of Environment determined the city could achieve an 11-fold increase in E85 use.

With funding secured and planning complete, the city broke ground at five new E85 fueling sites in January 2010 and completed all work by March 2012. During this time, the city expanded the number of FFVs in its fleet to more than 1,500 vehicles.

To maximize petroleum displacement, the city developed a "lockout" policy for its FFVs: Using the existing fuel management system, the fleet required all city FFVs to fuel with E85 when at city fueling stations. Drivers enter vehicle identification numbers at the city's fueling kiosks, and the fuel management system directs FFV drivers to proceed to E85 dispensers.



The City of Chicago's police fleet includes several hundred FFVs, such as this Chevrolet Tahoe. *Photo from Walter S. Mitchell, courtesy of the City of Chicago, NREL 29548*

E85 consumption skyrocketed after the lockout policy was implemented, hitting approximately 600,000 gasoline gallon equivalents (GGEs) in the second quarter of 2012. The city was pleased with the policy's effectiveness, but challenges began to arise when E85 became significantly more expensive than gasoline on a GGE basis. "It's easy to get the vehicles. The tough part is the infrastructure. After that, the key is to keep an eye on the price and make sure it continues to be economically practical," said Samantha Bingham, CACC coordinator and environmental policy analyst at the Chicago Department of Transportation. The city had to find the right balance between environmental and financial sustainability. So it enacted a strategic plan to remove the blanket lockout policy and instead base its E85 fueling requirements on daily price differentials between gasoline and E85.

Under the new plan, the Chicago Department of Fleet and Facility Management re-institutes the lockout policy when E85 prices are equal to or less than gasoline prices. It places the fueling decision in the hands of individual drivers during the "policy-free" periods. Even with the policy modification, the fleet's E85 use is consistently higher than it was before the E85 infrastructure expansion. The city is also committed to working with fuel suppliers to find ways to keep the price of E85 below that of gasoline, and it is considering options to decouple the alternative fuel and conventional fuel contracts.

Looking ahead, the city plans to continue to increase the number of alternative fuel and advanced vehicles in the fleet by 10% per year, and CACC will ensure that the city stays aware of funding and networking opportunities.

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DOE/GO-102015-3000 • January 2015

Prepared by the National Renewable Energy Laboratory (NREL), a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy; NREL is operated by the Alliance for Sustainable Energy, LLC.