



RENEWABLE
FUELS
ASSOCIATION

POCKET GUIDE TO ETHANOL 2017



ETHANOL BASICS

Ethanol is a biodegradable, high-octane motor fuel derived from the sugars, starches, and cellulosic matter found in plants. It has been used as a fuel since the days of Henry Ford's Model T. Virtually every gallon of U.S. gasoline today contains at least 10% fuel ethanol.

Ethanol is part of our nation's solution to reducing our dependency on fossil fuels, lowering fuel prices, creating domestic jobs, boosting the farm economy, and cleaning our environment.

Today, more than 200 biorefineries in 28 states have the capacity to produce roughly 16 billion gallons (bg) of ethanol.

How is Ethanol Made?

Fuel ethanol can be made through the **DRY MILL** or **WET MILL** process. Most (90%) ethanol today is made by dry mills, using these steps:

1. Milling: The entire grain kernel is ground into “meal.”

2. Cooking & Liquefaction: The meal is slurried with water to form a “mash.” Enzymes are added to convert the starch to sugar. The mash is cooked, then cooled and transferred to fermenters.

3. Fermentation: Yeast is added and the conversion of sugar to ethanol and carbon dioxide begins. CO₂ is often captured here for commercial uses, like carbonating beverages. Resulting “beer” is separated from the remaining mash, or “stillage.”

4. Distillation & Dehydration: Alcohol is concentrated and water is removed from the hydrous alcohol to form “anhydrous ethanol.”

5. Denaturing: The anhydrous ethanol is blended with 2% “denaturant,” which renders it undrinkable and exempt from beverage alcohol tax. It is then ready for shipment and blending with gasoline.

6. Co-products: The leftover “stillage” is separated into solids and liquids. The solids become “distillers grains,” an animal feed that can be dried or sold in wet form. The soluble liquids, or “syrup,” can be mixed into the distillers grains or sold as a separate feed product. Most plants also extract corn distillers oil, a feed ingredient or biodiesel feedstock, from the stillage.

Key U.S. Ethanol Industry Stats

(as of Jan. 2017)

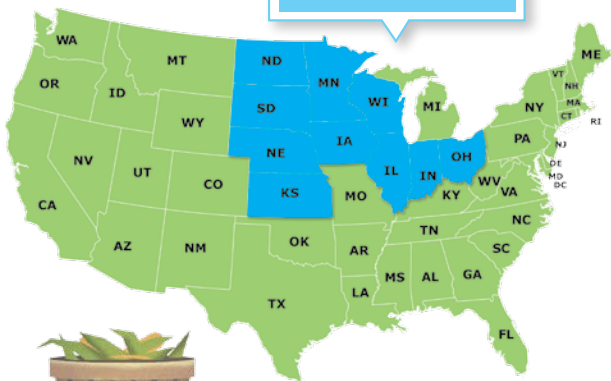
Installed Ethanol Plants	213
Ethanol Plants in Operation	200
Total Production Capacity (per year)	15.99 billion gal.
Capacity in Operation (per year)	15.56 billion gal.
Plants Under Construction/Expansion	3
Capacity Under Construction/Expansion (per year)	91 million gal.
States with Ethanol Plants	28
Share of Ethanol Produced from Corn	95%
Commercial-scale Cellulosic Ethanol Plants	4
Share of Gasoline Blended with Ethanol	98%
Ethanol's Share of U.S. Gasoline Supply	10.1%

HISTORIC ETHANOL PRODUCTION (BILLION GALLONS)

2016	15.25*
2015	14.81
2014	14.31
2013	13.29
2012	13.22
2011	13.93
2010	13.30
2009	10.94
2008	9.31
2007	6.52

**Estimated*

TOP 10 ETHANOL-PRODUCING STATES IN 2016



- 1 bushel of corn (56 lbs.) makes 2.85 gals. of ethanol, 16.5 lbs. of livestock feed, and 0.6 lb. of corn distillers oil
- 1 gal. of ethanol contains 76,300 BTUs, or 81.5 megajoules of energy
- Most ethanol is consumed in E10 gasoline blends (90% gasoline/10% ethanol)
- E15 gasoline blends (85% gasoline/15% ethanol) are growing in popularity
- “Flex fuels” like E20, E30, and E85 are available for use in flex fuel vehicles

Ethanol's Economic Impacts

Growth in ethanol production is driving wealth creation across industry sectors, states and households.

The production of 15.25 bg of ethanol in 2016 created:

- 74,420 direct jobs
- 264,756 indirect and induced jobs
- \$42 billion in gross domestic product (GDP)
- \$23 billion in household income
- \$9 billion in tax revenue

Ethanol employees are well compensated, highly educated and committed to their work.

- Over 60% of workers earn \$75,000 or more annually
- 62% are college graduates
- 91% are satisfied with their jobs, with 66% being “very” or “extremely” satisfied
- 58% have worked in the industry for at least 7 years
- Nearly 70% have worked at only one facility



Global Ethanol Trade



The U.S. ethanol industry has evolved into a global leader in both the production and trade of renewable fuel.

- The U.S. is the world's leading ethanol producer, generating 60% of the world's output in 2016.
- U.S. ethanol exports topped 1 billion gallons in 2016, the second-highest annual total on record.
- Canada and Brazil were the top markets for U.S. ethanol exports in 2016, together accounting for half of total shipments.
- China, India, the Philippines, Peru and South Korea were other leading markets.
- The U.S. imported less than 40 million gallons of ethanol in 2016, most of which came from Brazil.
- Net ethanol exports (exports minus imports) set a new record in 2016.

Ethanol's Octane Advantage

One of ethanol's most important benefits is also one of its best kept secrets: octane.

- A fuel's octane rating is the measure of its ability to resist "knocking."
- Ethanol has an octane rating of 113. It offers more engine knock resistance at a lower cost than any other gasoline additive on the planet.
- Most refiners add 10% ethanol to upgrade gasoline blendstock from 84 octane to 87 octane – the minimum allowable for "regular" grade gasoline.
- Ethanol is the cleanest and safest octane option available. Octane sources such as MTBE and aromatics (like benzene) are highly toxic and pose great risk to our air and water.
- A growing body of research finds that using ethanol-based high-octane fuels like E30 in advanced internal combustion engines can help meet stricter fuel economy and emissions standards in the future.



Ethanol and Energy Security

U.S. dependence on imported petroleum is falling to depths not seen since the early 1990s—and growth in ethanol is a primary reason.

- The U.S. relied on imports to meet 60% of its petroleum needs in 2005. Growth in ethanol helped drive our reliance on imports to just 25% in 2016.
- Petroleum import dependence would have been 33% without 15.25 bg of ethanol in 2016.
- Ethanol production in 2016 displaced an amount of gasoline refined from 540 million barrels of crude oil—more than the amount of oil imported annually from Saudi Arabia.
- Even with the recent boom in U.S. oil production, ethanol remains critically important. The United States has just 2% of the world's crude oil reserves, but consumes 21% of global supplies.
- Growing supplies of ethanol have helped reduce prices at the pump for U.S. consumers. Ethanol remains less costly than other octane enhancers and helps extend fuel supplies.
- Consumers pay \$0.50-\$1.50 per gallon less for gasoline today because of ethanol, according to university and government economists.

The Renewable Fuel Standard (RFS)

The Renewable Fuel Standard (RFS) is unquestionably one of the greatest success stories in the history of energy, environmental and agricultural policy. Since enactment of the RFS in 2005:

- U.S. ethanol production and consumption have grown by nearly 300%
- Net dependence on petroleum imports has fallen by more than half
- Greenhouse gas emissions from transportation have fallen
- Farm income and the value of agricultural products rose to record levels
- Communities across the country benefited from the job creation, tax revenue, and household income that stem from the construction and operation of a biorefinery.

EPA set the final 2017 RFS blending requirements at the statutory levels established by Congress when the RFS was expanded in 2007, marking a major win for the biofuel and agriculture sectors and restoring a healthy and certain growth trajectory for the ethanol industry. EPA's 2017 final rule included a 15-billion-gallon requirement for conventional renewable fuel and also increased blending obligations for advanced biofuels. Overall, the total renewable fuel volume required is set to grow by 1.2 billion gallons from 2016 to 2017, a 6% increase.

Cellulosic and Advanced Biofuels

Ethanol's evolution continued in 2016, as plants across the country adopted new technologies allowing them to process new feedstocks and produce new low-carbon biofuels and bio-products:

- “Bolt-on” technologies at existing corn ethanol plants allow production of both starch-based and cellulosic ethanol from the same corn kernel
- Other plants are adopting refining technologies like hydrocracking and isomerization to convert corn distillers oil into renewable diesel and naphtha
- Progress toward full capacity utilization also continued at commercial scale cellulosic ethanol plants that use agricultural residues as feedstock
- Some corn ethanol plants are integrating new process technologies to convert corn distillers oil into biodiesel, an advanced biofuel under the RFS

EPA's finalization of strong RFS blending requirements for cellulosic and advanced biofuels in 2017 injected badly needed certainty into the marketplace and finally restored a positive investment signal.



E15 and Ethanol Flex Fuels

Girded by the RFS and favorable economics, demand for ethanol blends above E10 is growing.

Key facts on E15:

- E15 is offered at nearly 400 stations across 28 states.
- Nearly 400 million trouble-free miles have been driven on E15 since its introduction.
- There have been no reported cases of “engine damage,” inferior performance or misfueling.
- E15 is approved by EPA for use in more than 90% of today’s automotive fleet.
- More than 80% of new (2017) models are explicitly approved for the use of E15 by the manufacturers.
- E15 offers a higher octane fuel blend typically at a lower price than E10.





Key facts on Ethanol Flex Fuels:

- Ethanol flex fuels, including E85, contain 51-83% ethanol.
- EPA has proposed to also define fuels containing 16-50% ethanol as "flex fuels."
- Flex fuels are currently approved for use only in flex-fueled vehicles (FFVs).
- More than 3,600 stations across the country sell E85 today in over 2,100 cities and towns across the country.
- On average, E85 was priced 19.9% below E10 at retail stations across the country in 2016.
- There are about 21 million FFVs on the road today, representing over 8% of the overall fleet.



Ethanol Co-products

Ethanol plants produce more than fuel—they also make a huge contribution to the global animal feed market.

- Roughly one-third of every 56-pound corn bushel processed by an ethanol plant returns to the feed market as distillers grains, corn distillers oil, corn gluten feed, or gluten meal.
- Ethanol production utilizes only the starch in the grain; the remaining protein, fat and fiber return to animal feed.
- Feed co-products are consumed by beef and dairy cattle, swine, poultry, and even fish.
- The ethanol industry produced roughly 42 million metric tons (mmt) of animal feed in 2016.



- About 11.5 mmt of distillers grains were exported to more than 50 countries—the second highest export volume on record.
- About 90% of dry mill ethanol plants are now producing corn distillers oil as well—a product used as an animal feed ingredient or biodiesel feedstock.
- Many ethanol plants also capture and sell CO₂ for commercial uses.

Ethanol and Food/Feed Markets

Ethanol opponents suggest using grain to make biofuel creates a “food vs. fuel” dilemma and increases food prices. The truth is, the industry produces both fuel AND food, and there is no evidence that ethanol adversely affects food prices.

- Grain consumption by the ethanol industry hit a record level in 2016, yet U.S. retail grocery prices experienced deflation for the first time since 1967.
- The UN world food price index hit a seven-year low as global grain and meat supplies hit all-time highs. The prevalence of worldwide undernourishment fell to its lowest level since the UN began keeping records more than 25 years ago.
- American farmers harvested a record corn crop of 15.1 billion bushels and achieved a new record average yield of 174.6 bushels per acre—erasing any notion that growers can't supply enough grain to meet both ethanol demand and growing global demand for food and feed.
- On a net basis, the U.S. ethanol industry will use just 2.94% of global grain supplies.
- According to the World Bank, “most of the food price increases are accounted for by crude oil prices.”

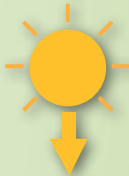


Ethanol and Greenhouse Gases

According to new analyses conducted for the U.S. Department of Agriculture, corn ethanol from a typical dry mill reduces greenhouse gas (GHG) emissions by 43% compared to gasoline—even when hypothetical land use change emissions are included. Data from USDA and EPA show that agricultural land use is actually shrinking, undermining the indirect land use change theory.

- The use of ethanol in gasoline in 2016 reduced CO₂-equivalent GHG emissions from transportation by 43.5 million metric tons—equivalent to removing 9.3 million cars from the road for an entire year.
- According to Life Cycle Associates, “The RFS2 has resulted in significant GHG reductions, with cumulative CO₂ savings of 354 million metric tonnes over the period of implementation.”
- U.S. EPA data shows that agricultural land use has dropped from 402 million acres in 2007 to 380 million acres in 2016, disproving the notion that the RFS2 would induce cropland expansion and emissions from “land use change.”

BIOFUELS LIKE
ETHANOL RECYCLE
ATMOSPHERIC CARBON



Carbon dioxide absorbed by biomass crops

Biofuels Carbon Cycle

Carbon dioxide released as fuel burns

Carbon in biomass converted to liquid biofuel

Liquid biofuel combusted to power vehicle

Ethanol: A Pollution Solution

Ethanol continues to serve as one of the most inexpensive and effective tools available for reducing harmful emissions from the transportation sector. The ethanol molecule is 35% oxygen, meaning it burns more cleanly and completely than petroleum-based hydrocarbons in gasoline. Adding ethanol to gasoline reduces tailpipe emissions of the following pollutants, among others:

- **Carbon monoxide**, which can cause harmful health effects by reducing oxygen delivery to the body's organs.
- **Air toxics like benzene**, which can cause cancer and reproductive effects or birth defects.
- **Exhaust hydrocarbons**, which contribute to ozone, irritate the eyes, damage the lungs, and aggravate respiratory problems.
- **Fine particulate matter**, which can pass through the nose and throat and enter the lungs, causing asthma and other serious health effects.



ABOUT THE RFA

As the leading trade association for America's ethanol industry, we work to advance the development, production & use of fuel ethanol and its co-products and to raise awareness of the benefits of renewable fuels. Our expertise, advocacy and member services focus on these areas:

- **Public Policy & Regulation**
- **Fuel Ethanol Technical Issues**
- **Trade Policy & Export Promotion**
- **Safety Training & Emergency Response**
- **U.S. Market Development**
- **Research & Analysis**
- **Communications, Media & Public Relations**
- **Consumer Advertising & Education**
- **Stakeholder Engagement**



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