



POCKET GUIDE TO ETHANOL 2018

WHAT IS ETHANOL?

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.

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 more than 16 billion gallons (bg) of ethanol and 41 million metric tons of animal feed.

On average, one 56-pound bushel of corn makes 2.87 gal. of ethanol, 16.4 lbs. of livestock feed, and 0.75 lb. of corn distillers oil.

How is Ethanol Made?

Fuel ethanol is made through the DRY MILL or WET MILL process. Most ethanol today is made by DRY MILLS, using these steps:

1. Milling: The 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 sugar is converted to ethanol and CO₂. The "beer" resulting from fermentation 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" animal feed that is dried or sold in wet form. The soluble liquids ("syrup") are mixed into the distillers grains or sold separately. Most plants also produce corn distillers oil, a feed ingredient or biodiesel feedstock.

Key Ethanol Industry Stats

Common Ethanol Blends:

- Nearly every gallon of gasoline sold in the U.S. today is **E10 (10% Ethanol)**. E10 is approved for all vehicles and small engines.
- **Ethanol Flex Fuels contain 51-83% ethanol** and are sometimes called "E85." These fuels are approved for Flex Fuel Vehicles (FFVs), which make up about 10% of the U.S. auto fleet.
- **E15 (15% Ethanol)** is approved for all vehicles built after 2000, representing 90% of the U.S. auto fleet.
- **Mid-Level Ethanol Blends contain 20-50% ethanol** for use in FFVs. E25 and E30 are popular examples.

| Historic Ethanol Production (billion gallons) | |
|---|--------|
| 2017 | 15.80* |
| 2016 | 15.41 |
| 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

| U.S. Ethanol Production | |
|--|-------|
| Installed Ethanol Plants | 211 |
| Ethanol Plants in Operation | 201 |
| Total Production Capacity (billion gals. per year) | 16.24 |
| Capacity in Operation (billion gals. per year) | 15.76 |
| Plants Under Construction/Expansion | 7 |
| Capacity Under Construction/Expansion (million gals. per year) | 465 |
| States with Ethanol Plants | 28 |
| Commercial-scale Cellulosic Ethanol Plants | 4 |

| 2017 U.S. Ethanol Demand Stats | |
|---|-------|
| U.S. Ethanol Consumption (billion gals.) | 14.4 |
| U.S. Ethanol Exports (billion gals.) | 1.3 |
| Share of U.S. Gasoline Blended with Ethanol | 98% |
| Average Ethanol Content of U.S. Gasoline | 10.1% |
| U.S. Stations Selling E15 | 1,215 |
| U.S. Stations Selling Flex Fuels and Mid-Level Blends | 4,077 |

Ethanol's Economic Impact

Growth in ethanol production is powering America's Heartland.

The production of 15.8 bg of ethanol in 2017 supported:

- **71,906** direct jobs
- **285,587** indirect and induced jobs
- **\$45 billion** in gross domestic product (GDP)
- **\$24 billion** in household income
- **\$10 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
- 19% are U.S. military veterans
- 91% are satisfied with their jobs, with 66% being "very/extremely" satisfied



Global Ethanol Trade

The United States is a global leader in ethanol production and trade:

- The U.S. is the **#1 ethanol producer** in the world, generating nearly **60% of global output** in 2017.
- U.S. ethanol exports surged to a **new record** of more than **1.3 billion gallons** in 2017, meaning **8%** of U.S. production was exported.
- The U.S. **imported** just 80 million gallons of ethanol in 2017, most of which came from Brazil due to favorable treatment under the California LCFS and RFS.



TOP 2017 Ethanol Export Markets

| Country | Share of U.S. Exports |
|----------------------|-----------------------|
| Brazil | 33% |
| Canada | 26% |
| India | 13% |
| Philippines | 6% |
| Peru | 3% |
| United Arab Emirates | 3% |
| South Korea | 3% |
| Jamaica | 2% |
| Mexico | 2% |
| Netherlands | 2% |
| Rest of World | 7% |

Ethanol's Octane Advantage

One of ethanol's most important benefits is its exceptional octane properties.

- A fuel's octane rating is the measure of its ability to resist "knocking."
- Ethanol has an octane rating of 114. 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.
- Using ethanol-based high-octane fuels like E25 or 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 1980s, thanks to booming domestic production of both renewable fuels and crude oil.

- The U.S. relied on imports to meet 60% of its petroleum needs in 2005. Growth in ethanol helped reduce our reliance on imports to just 20% in 2017.
- Petroleum import dependence would have been 27% without 15.8 bg of ethanol in 2017.
- In 2017, ethanol displaced an amount of gasoline refined from 540 million barrels of crude oil—more than the volume imported annually from Saudi Arabia and Venezuela.
- Even with the recent boom in domestic oil production, the U.S. remains heavily reliant on imported oil. The economy sent \$63 billion—or nearly \$500 per American household—to OPEC nations like Iraq, Saudi Arabia, and Venezuela in 2017 to pay for oil.

Growing supplies of ethanol have helped reduce prices at the pump for U.S. consumers. According to the *American Journal of Agricultural Economics*:

- Ethanol use under the RFS reduced gas prices by **9.5%** in 2015, or **\$0.18** per gallon
- U.S. consumers saved **\$17.8 billion** on gasoline spending in 2015, equivalent to **\$142 per household**



The Renewable Fuel Standard (RFS)

First enacted in 2005 and expanded in 2007, the RFS has ushered in tremendous growth in the U.S. biofuels sector. Since 2007:

- The number of ethanol plants has almost **doubled from 110 to 211**.
- Ethanol production has grown **nearly 150%** from **6.5 billion gallons to 15.8 billion gallons**.
- Ethanol industry jobs are **up nearly 50%** from 238,541 to 339,176
- Corn production is **up 12%**, but land dedicated to growing corn is **down 3%** and total cropland is **down 7%**.
- U.S. grassland and forestland has **expanded**, while Amazon deforestation has **slowed**.
- Crude oil imports have **fallen more than 20%**, while gasoline imports have **fallen to almost zero**.
- GHG emissions from transportation **fell 7%**, even as Americans drove more miles.

Meanwhile, the doomsday outcomes threatened by RFS critics haven't materialized. Since 2007:

Cellulosic and Advanced Biofuels

Ethanol's evolution continued in 2017, 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.
- 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.
- Other plants are adopting refining technologies like hydrocracking and isomerization to convert corn distillers oil into renewable diesel and naphtha.



Unfortunately, EPA's final RFS blending requirements for cellulosic biofuels in 2018 was a step backward from the 2017 volumes, creating uncertainty in the marketplace.

E15 Progress

Consumers enjoyed expanding access to lower-cost, higher-octane E15 in 2017.

Key facts on E15:

- E15 is approved by U.S. EPA for use in more than **90%** of today's automotive fleet.
- Nearly **90% of new (2018) models** are also clearly approved for E15 by the manufacturers.
- E15 is offered at more than **1,200 stations** across **29 states**, more than **double** the previous year.
- Leading retailers, including Sheetz, Kum & Go, Murphy USA, Cenex, RaceTrac, Thornton's, and QuikTrip, offer E15 at stations across the country.
- E15 typically offers an octane rating of **88**, compared to 87 octane for regular grade E10.
- More than **2.2 billion** trouble-free miles have been driven on E15 since its introduction.



E85 and Flex Fuels

Flex fuel consumption hit new heights in 2017.

Key facts on Ethanol Flex Fuels:

- Nearly **one out of every 10 vehicles** on the road is a Flex Fuel Vehicle (FFV) approved to use E85 and other flex fuels.
- The number of retail gas stations selling flex fuels topped **4,000** in 2017.
- Flex fuels can be found in **45 states** in almost 2,400 cities and towns across the country.



- On average, E85 was priced at a **20% discount** to E10 in 2017.
- E85 and other flex fuels significantly reduce emissions of greenhouse gases, carbon monoxide, air toxics, and other harmful pollutants.



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 **41 million metric tons** (mmt) of animal feed in 2017.
- About **11.3 mmt** of distillers grains were exported to more than 50 countries in 2017.
- Dry mill ethanol plants also produced about **3.6 billion pounds** of 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

In 2017, record grain supplies and low food prices put to rest any notion that biofuels somehow create a “food vs. fuel” dilemma.

- U.S. farmers produced the second-largest corn crop ever in 2017. More corn and co-products were **available to livestock and poultry feeders** than ever before.
- On a net basis, the U.S. ethanol industry used **less than 3%** of global grain supplies.
- U.S. retail price inflation rates continued to trend lower, with food prices **just 1%** higher in 2017 than 2016.
- Annual average food price inflation has averaged just **2.3%** since 2005 when the RFS was enacted, compared to an average of 3.0% from 1984-2004.

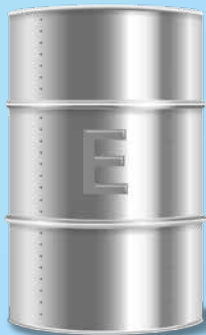


- The UN world food price index over the past three years has fallen to the lowest levels in thirteen years.
- Meanwhile, the prevalence of worldwide undernourishment hit its lowest point since the UN began keeping records more than 25 years ago.
- According to the World Bank, “most of the food price increases are accounted for by **crude oil prices.**”

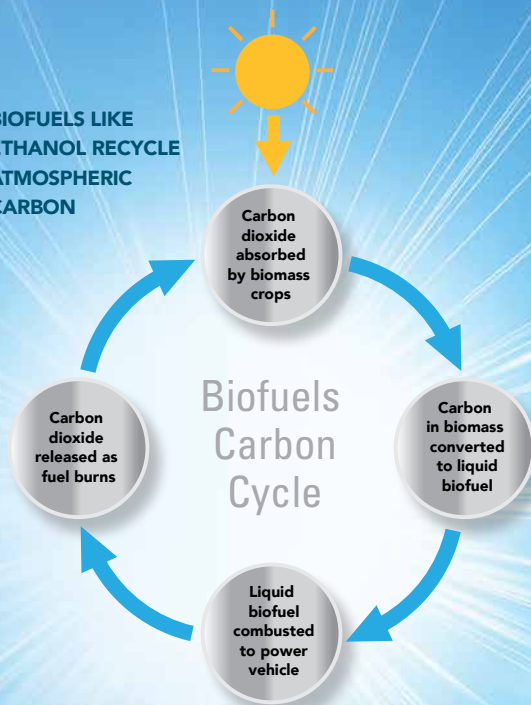
Ethanol and Greenhouse Gases

Ethanol is an effective, low-cost tool for fighting climate change.

- Corn ethanol from a typical dry mill reduces GHG emissions by **40-45% compared to gasoline**—even when hypothetical land use change emissions are included.
- The use of ethanol in gasoline in 2017 reduced GHG emissions from transportation by **53.5 million metric tons (mmt)**—equivalent to removing 11.4 million cars from the road for an entire year.
- The RFS2 has resulted in significant GHG reductions, with cumulative CO2 savings of **354 mmt** over the period of implementation.
- Agricultural land use has dropped from 402 million acres in 2007 to **376 million acres** in 2017, according to EPA, disproving the notion ethanol causes GHG emissions from “land use change.”



BIOFUELS LIKE ETHANOL RECYCLE ATMOSPHERIC CARBON



- Plants made into biofuels absorb carbon dioxide from the atmosphere as they grow, and that same CO2 is re-released when the biofuel is combusted in an engine.
- In this way, ethanol and other biofuels are simply recycling atmospheric carbon.

Ethanol: A Pollution Solution

The ethanol molecule is 35% oxygen, meaning it burns more cleanly and completely than petroleum-based hydrocarbons in gasoline.

The production of 15.8 bg of ethanol in 2017 supported:

- **Carbon monoxide**, which can cause harmful health effects by reducing oxygen delivery to the body's organs.
- **Exhaust hydrocarbons**, which contribute to ozone, irritate the eyes, damage the lungs, and aggravate respiratory problems.
- **Air toxics like benzene**, which can cause cancer and reproductive effects or birth defects.
- **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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