

The background features a blurred image of a road with a car driving away, overlaid with a grid of chemical structures. The structures include a chain of three hydrogen atoms (H-H-H) and a chain of three carbon atoms (C-C-C), with various bonds and atoms visible.

Pocket Guide to **ETHANOL** 2016

The logo for the Renewable Fuels Association (RFA) consists of three stylized, overlapping curved shapes in shades of blue and green, resembling a flame or a leaf.

RFA RENEWABLE
FUELS
ASSOCIATION

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 or additive since the days of Henry Ford's Model T. Virtually every gallon of gasoline consumed in the United States today contains 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 29 states have the capacity to produce more than 15 billion gallons (bg) of ethanol. And we've just gotten started, as new plants are coming online that utilize the next generation of feedstocks and technologies to make cellulosic ethanol.

How is Ethanol Made?

There are two primary ethanol production processes: wet milling and dry milling. Roughly 90% of the ethanol produced today comes from the dry mill process, with the remaining 10% coming from wet mills.

In **dry milling**, the entire corn kernel is first ground into “meal.” The meal is slurried with water to form a “mash.” Enzymes are added to the mash to convert the starch to sugar. The mash is cooked, then cooled and transferred to fermenters. Yeast is added and the conversion of sugar to ethanol begins. After fermentation, the resulting “beer” is separated from the remaining “stillage.” The ethanol is then distilled and dehydrated. Next, ethanol is blended with 2% denaturant (such as gasoline) to render it undrinkable and exempt from beverage alcohol tax. It is then ready for shipment. The leftover stillage is sent through a centrifuge that separates the solids from the

solubles. These co-products eventually become distillers grains (a nutritious livestock feed) as well as corn distillers oil (a feed ingredient and feedstock for biodiesel production).

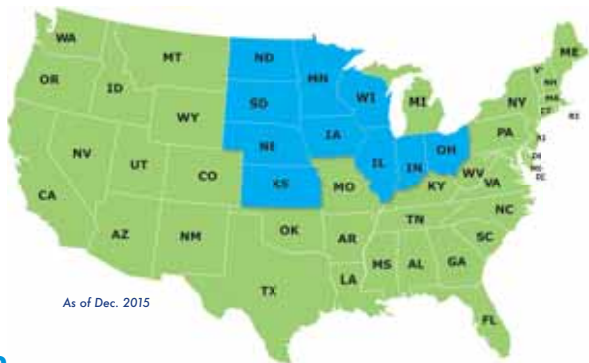
In **wet milling**, the grain is first separated into its component parts through soaking. After steeping, the slurry is processed through grinders to separate the corn germ. The remaining fiber, gluten and starch components are further segregated. The gluten (protein) is filtered and dried to produce animal feed. The remaining starch is then fermented into ethanol, using a process similar to the dry mill process.

Key U.S. Ethanol Industry Stats

(as of Jan. 2016)

Installed Ethanol Plants	214
Ethanol Plants in Operation	199
Total Production Capacity (per year)	15.59 billion gals.
Capacity in Operation (per year)	15.11 billion gals.
Plants Under Construction/Expansion	3
Capacity Under Construction/Expansion (per year)	162 million gal.
States with Ethanol Plants	29
Volume of Ethanol Produced from Corn	98%
Commercial-scale Cellulosic Ethanol Plants	4
Volume of Gasoline Blended with Ethanol	97%
Ethanol's Share of Gasoline Supply	10%

Top 10 Ethanol-Producing States in 2015



As of Dec. 2015



U.S. Ethanol Production Facts

- 1 bushel of corn (56 lbs.) makes 2.8 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
- Ethanol is blended in more than 97% of gasoline in the U.S. today
- In 2015, ethanol accounted for 10% of the U.S. gasoline supply
- More than 98% of the ethanol produced in 2015 was made from corn
- The first three commercial-scale cellulosic ethanol facilities began production in 2015

Historic Ethanol Production (billion gallons)	
2015	14.70*
2014	14.31
2013	13.29
2012	13.22
2011	13.93
2010	13.30
2009	10.94
2008	9.31
2007	6.52
2006	4.88

*Estimated

Ethanol's Economic Impacts

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

The production of 14.7 bg of ethanol in 2015 created:

- 85,967 direct jobs
- 271,440 indirect and induced jobs
- \$44 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
- 80% received a raise and 90% received a bonus within the past 12 months
- 62% are college graduates
- 28% have some college experience or vocational/technical training
- 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 nearly twice as much ethanol as Brazil—the No. 2 producer.
- The U.S. industry was responsible for about 55% of global ethanol output in 2015.
- The U.S. exported approximately 850 million gallons of ethanol in 2015, similar to 2014 volumes.
- Canada was the leading market for U.S. exports, accounting for 30% of total shipments.
- Brazil was the No. 2 market, receiving 15% of U.S. exports.
- The Philippines, China and South Korea were other leading markets.
- Despite the European Union's tariff against U.S. ethanol, about 28 million gallons were shipped to European countries in 2015.
- The U.S. imported approximately 90 million gallons of ethanol in 2015, most of which came from Brazil.

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" or "pinging." 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.
- Ethanol is the lowest-cost octane source. 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. Hydrocarbon 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 high octane fuels like ethanol 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.

- Petroleum (crude and products) import dependence peaked at 60% in 2005, but was less than 25% in 2015.
- Petroleum import dependence would have been 32% without 14.7 bg of ethanol in 2015.
- Ethanol production in 2015 displaced an amount of gasoline refined from 527 million barrels of crude oil—more than the amount of oil imported annually from Saudi Arabia and Kuwait combined.
- U.S. gasoline imports peaked at nearly 10 bg in 2005, but have since fallen to almost zero today as ethanol use has increased.
- 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 because of ethanol, according to Philip K. Verleger, former economic advisor to Presidents Ford and Carter.



The Renewable Fuel Standard (RFS)

The Renewable Fuel Standard (RFS) celebrated its 10th anniversary in 2015, and the occasion provided an excellent opportunity to reflect on the program's many successes.

Since enactment of the RFS, biofuel production and consumption have grown dramatically. Dependence on petroleum imports is down significantly. Greenhouse gas emissions from transportation have fallen. The value of agricultural products rose to record levels. And, communities across the country have benefited from the job creation, tax revenue, and household income that stem from the construction and operation of a biorefinery.

Given the success of the RFS over the past decade, EPA's decision in 2015 to backtrack on the program left ethanol supporters feeling disappointed and frustrated. EPA's 2014-2016 RFS volume requirements are far below the levels specified by Congress and the Agency relied on an unlawful methodology for setting the annual blending obligations.



	Total RFS	Total Advanced Biofuel	Cellulosic Biofuel	Biomass Based Diesel*	Other Advanced Biofuel	Conventional Renewable Fuel
2008	9.00	0.00	0.00	0.00	0.00	9.00
2009	11.10	0.60	0.00	0.50	0.10	10.50
2010	12.95	0.95	0.10	0.65	0.20	12.00
2011	13.95	1.35	0.25	0.80	0.30	12.60
		2.00	0.50	1.00	0.50	13.20
				1.00	0.75	13.80
						14.40

Cellulosic Ethanol

The year 2015 marked a seminal moment for cellulosic ethanol, as commissioning or production began at the nation's three largest commercial-scale cellulosic ethanol facilities.

- Abengoa's facility in Hugoton, Kansas, has the capacity to generate up to 25 mg of cellulosic ethanol annually from locally sourced agricultural residues.
- The DuPont biorefinery in Nevada, Iowa, will also use agricultural residues like corn stalks to produce up to 30 mg of cellulosic ethanol per year.
- POET-DSM's plant in Emmetsburg, Iowa, will produce 20 mg of cellulosic ethanol per year from corn residue.

Although 2015 was a breakthrough year for the cellulosic biofuels sector, many challenges remain. Market instability and policy uncertainty have continued to hamper growth.

Cellulosic ethanol projects that are under development will use a variety of feedstocks, including:

- Agricultural residues like corn cobs and stover, wheat straw, or soybean stubble
- Purpose-grown energy crops like algae, miscanthus, switchgrass, energy cane, and poplar
- Forestry residues and wood processing waste
- Organic matter in municipal solid waste
- Municipal yard and vegetative waste
- Food and citrus processing waste



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 roughly 180 stations in more than 20 states.
- Nearly 200 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 85% of today’s automotive fleet.
- More than 70% of new (2016) 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.
- E85 is approved for use only in flex-fueled vehicles (FFVs).
- More than 3,300 stations across the country sell E85 today, and more than 1,500 new stations are scheduled to open in 2016.
- There are about 20 million FFVs on the road today, representing over 8% of the overall fleet.
- Roughly 20-25% of new vehicles sold in 2016 will be FFV capable.



Ethanol Co-Products

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

- One-third of every 56-pound corn bushel processed by an ethanol plant returns to the feed market as distillers grains, 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 40 million metric tons (mmt) of animal feed in 2015.
- A record 12.6 mmt—more than 30% of the distillers grains produced in 2015—were exported to more than 50 countries.
- About 85% of dry mill ethanol plants are now producing corn distillers oil as well—a product an animal feed ingredient or biodiesel feedstock.



The Food vs. Fuel Debate

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.



- More grain is available for food and feed use worldwide today than at any time in history.
- On a net basis, the U.S. ethanol industry will use just 2.95% of global grain supplies.
- Corn prices in 2015 were lower than they were when the RFS2 was signed into law in 2007.
- Corn is a minor ingredient in retail food items. When corn prices are \$4 per bushel, there is just 5 cents worth of corn in a box of corn flakes.
- Food prices have increased more slowly since passage of the first RFS in 2005. From 1980 to 2004, food price inflation averaged 3.5% per year. Since 2005, food inflation has averaged 2.6% annually. Further, the world food price index in 2015 fell to its lowest point since the global financial crisis of 2009.
- Only 17 cents of every dollar spent on food pays for the value of the farm products in the groceries. The remaining 83 cents pays for labor, packaging, energy, and other costs.
- According to the World Bank, “most of the food price increases are accounted for by crude oil prices.”

Ethanol's Impact on the Environment

Innovation and new technology have revolutionized the agriculture industry and reduced the environmental impacts associated with producing corn. American farmers have grown the three largest corn crops in U.S. history in the

last three years—harvesting 13.6 billion bushels in 2015. National average yields in 2015 were the second highest in history at 168.4 bushels per acre, while acres used to grow corn continued to shrink.

Corn Ethanol Efficiency Indicators

Ethanol Yield – Dry Mill	<i>gals. ethanol/bushel corn</i>
Ethanol Yield – Wet Mill	<i>gals. ethanol/bushel corn</i>
Ethanol Yield – Industry Average	<i>gals. ethanol/bushel corn</i>
Dry Mill Natural Gas Use	<i>BTU/gal. ethanol</i>
Dry Mill Electricity Use	<i>kWh/gal. ethanol</i>
Dry Mill Water Use	<i>gal. water/gal. ethanol</i>
Average Corn Yield	<i>bushels/acre</i>
Corn Production	<i>million bushels</i>
Nitrogen Fertilizer Application	<i>pounds/bushel</i>
Ethanol per Corn Acre	<i>gals./acre</i>

Source: U.S. Dept. of Agriculture and U.S. Dept. of Energy

But efficiency improvements aren't just occurring on the farm—they are also happening at the ethanol plant. Natural gas and electricity use at dry mill ethanol plants has fallen nearly 40% since 1995, while consumptive water use has

been cut in half. Ethanol producers are getting more out of each bushel of corn processed as well. Dry mills produce 2.8-2.9 gallons of ethanol per bushel, up more than 15% over the past 20 years.

1995	2015	% Change
2.55	2.83	11%
2.50	2.61	4%
2.52	2.81	12%
37,000	23,862	-36%
1.20	0.75	-38%
5.5	2.7	-51%
113.5	168.4	48%
7,400	13,601	84%
1.15	0.83	-28%
286	473	65%



Ethanol and Greenhouse Gases

The result of efficiency improvements on the farm and at the ethanol plant is a smaller overall carbon footprint. According to the U.S. Department of Energy's GREET model, corn ethanol from an average dry mill reduces greenhouse gas (GHG) emissions by 34% compared to gasoline—even when hypothetical land use change emissions are included. Comparing direct emissions only, average corn ethanol reduces GHG emissions by 44% relative to gasoline.

- The use of ethanol in gasoline in 2015 reduced CO₂-equivalent GHG emissions from transportation by 41.2 million metric tons—equivalent to removing 8.7 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 show that agricultural land use has dropped from 402 million acres in 2007 to 379 million acres in 2015, disproving the notion that the RFS2 would include cropland expansion and emissions from "land use change."



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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