

ESSENTIAL ENERGY

2021
POCKET
GUIDE TO
ETHANOL



THE POCKET GUIDE TO ETHANOL

is a quick reference of significant statistics for the U.S. ethanol industry. It is a companion to the Renewable Fuels Association's more comprehensive *Ethanol Industry Outlook*, found at EthanolRFA.org/publications/outlook.

THE RFA has been the leading trade association for the U.S. ethanol industry for 40 years! We are focused on driving expanded demand for American-made renewable fuels and bioproducts worldwide. Membership includes grain-based and advanced ethanol producers, the ethanol value chain, academia, and other industry advocates.



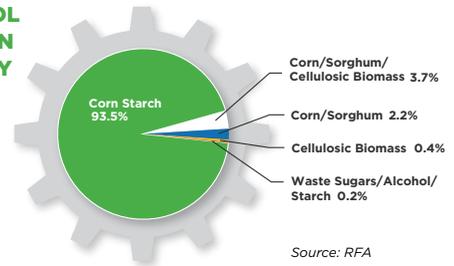
Geoff Cooper
President & CEO

RFA—Helping the world breathe easier with the power of renewable fuels.

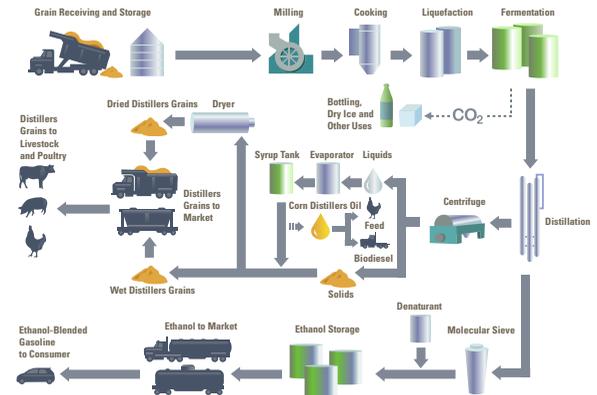
ETHANOL EXPLAINED

Ethanol is a renewable, biodegradable, high-octane and low-carbon motor fuel primarily derived from the sugars, starches, and cellulosic matter found in plants. Most U.S. ethanol is made from corn and processed through dry milling.

U.S. ETHANOL PRODUCTION CAPACITY BY FEEDSTOCK TYPE



DRY MILL ETHANOL PROCESS



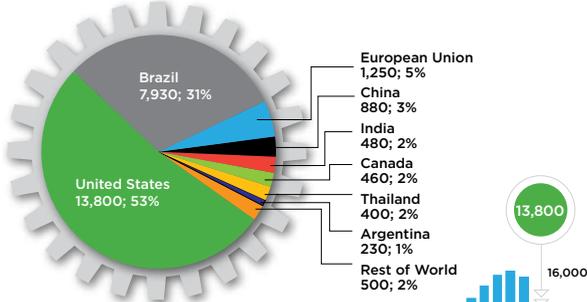
Source: RFA

WHERE IS ETHANOL MADE?

Global ethanol production fell to 26 billion gallons in 2020 as a result of the coronavirus pandemic. The United States remained the largest producer, accounting for over half of global output.

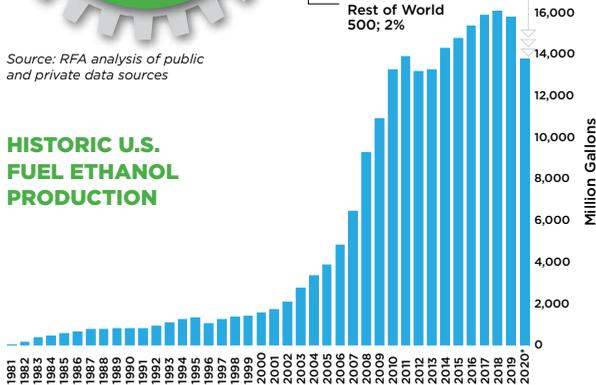
2020 GLOBAL ETHANOL PRODUCTION BY COUNTRY

(Country, million gallons, share of global production)



Source: RFA analysis of public and private data sources

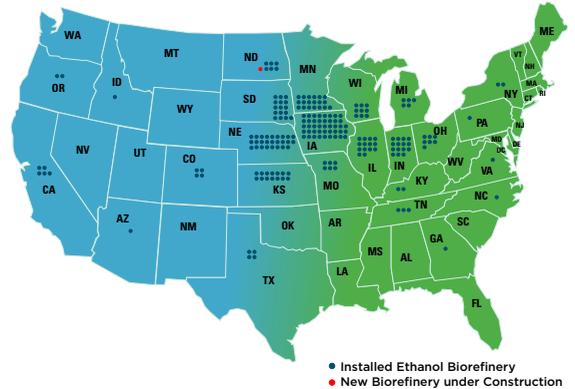
HISTORIC U.S. FUEL ETHANOL PRODUCTION



Source: RFA and U.S. Energy Information Administration * Estimated

Twenty-five states are home to 209 biorefineries. Half of total nameplate capacity is based in Iowa, Nebraska, and Illinois—the leading producers of corn.

U.S. ETHANOL BIOREFINERIES BY STATE



State	Installed Ethanol Biorefineries	Existing Production Capacity (mgy)	Biorefineries Under Constr./Expansion	Capacity Under Constr./Expansion (mgy)
Iowa	43	4,593	-	-
Nebraska	26	2,296	-	-
Illinois	14	1,867	-	-
Minnesota	19	1,384	-	-
Indiana	15	1,337	-	-
South Dakota	16	1,223	-	-
Ohio	7	676	-	-
Kansas	14	615	-	-
Wisconsin	9	603	-	-
North Dakota	6	542	1	16
Other 15 states	39	2,300	-	-
TOTAL U.S.	209	17,436	1	16

Source: RFA

ESSENTIAL FOR THE ECONOMY

The economic disruptions following both the spread of COVID-19 and the associated economic shutdowns were especially hard on rural economies, exacerbating the challenges facing U.S. farmers following several years of trying production and market conditions. Fortunately, the ethanol industry remains a major driver fueling the rural economy.



Ethanol's Value-Added Proposition

Based on average prices and product yields in 2020, a typical dry mill ethanol plant was adding approximately \$1.27 of additional value—or 37%—to every bushel of corn processed.

CORN COST PER BUSHEL



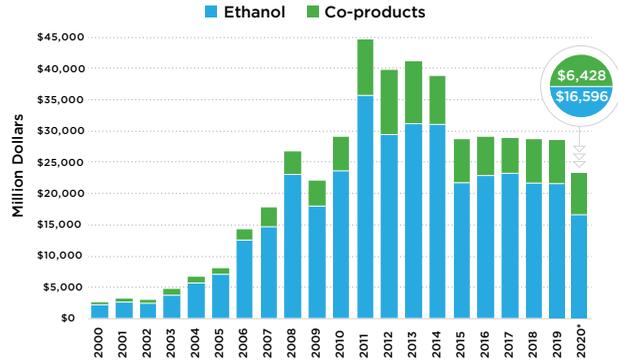
VALUE OF OUTPUTS PER BUSHEL

Ethanol.....	\$3.48
Distillers Grains.....	\$1.03
Corn Distillers Oil.....	\$0.18

TOTAL **\$4.69**

The impact of this value-added proposition ripples throughout rural America in terms of higher tax revenues and GDP as job creation and higher household incomes.

GROSS VALUE OF U.S. ETHANOL INDUSTRY OUTPUT



Source: RFA based on U.S. Dept. of Agriculture data *Estimated

In 2020, the production of ethanol and coproducts—a \$23 billion market—had substantial economic impacts, including:

62,180 direct jobs

242,600 indirect and induced jobs

\$34.7 billion contribution to GDP

\$18.6 billion in household income

Ethanol biorefineries offer skilled jobs and good wages in rural communities where attractive employment opportunities are often hard to find.

Notably, 1 in 5 employees is a military veteran—more than triple the national average.

EFFICIENT PRODUCERS

American farmers are becoming more efficient at growing corn, harvesting a robust 172 bushels per acre in 2020 for a total production of 14.2 billion bushels.

U.S. CORN ACREAGE AND AVERAGE YIELD



Source: U.S. Dept. of Agriculture

Corn producers have been implementing conservation practices and innovative technologies to reduce their footprint. These favorable farming practices combined with minor land use change have significantly lowered the carbon intensity of today's corn ethanol.



THE PANDEMIC PIVOT

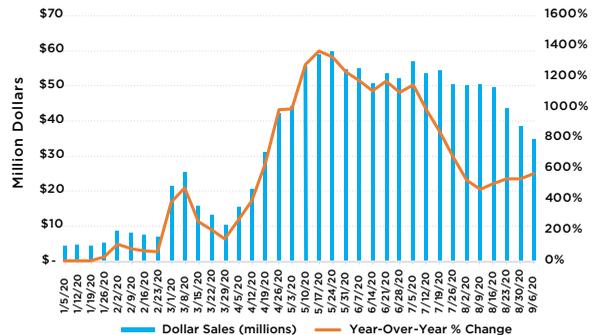
The spread of COVID-19 early in 2020 upended the ethanol industry. At the peak of the crisis in late April, **more than half of ethanol capacity was idled** and less than a quarter of the nation's biorefineries were running at full capacity.

From just March through November, more than **2 billion gallons** of ethanol demand had been forgone. This represents more than **700 million bushels** of lost corn demand and revenue losses to the U.S. ethanol industry of more than **\$3.8 billion**.



But the U.S. ethanol industry is nothing if not resilient. Many plants pivoted to add technology allowing them to produce the high-purity ethanol used in hand sanitizers and expanded CO2 capture to meet the rising demand for dry ice for the transport and storage of the COVID-19 vaccine.

RETAIL HAND SANITIZER SALES, REPORTED WEEKLY



Source: Information Resources, Inc.

COPRODUCTS ON THE RISE

If there was a silver lining to COVID-19 for U.S. ethanol producers, it was that the pandemic brought focus to the fact that the industry makes more than renewable fuel—a lot more.

On average, 1 bushel of corn (56 pounds) processed by a dry mill ethanol biorefinery produces:

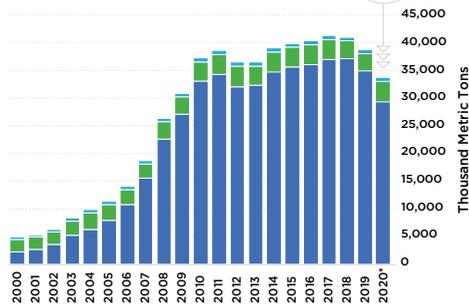
- 2.9 gallons of denatured fuel ethanol
- 15.2 pounds of distillers grains animal feed (10 percent moisture)
- 0.8 pounds of corn distillers oil
- 1.1 pounds of captured biogenic carbon dioxide



In 2020, ethanol biorefineries captured roughly 2.3 million tons of CO₂, which was used for dry ice production, bottling, food processing, and other uses.

Source: RFA based on U.S. Dept. of Agriculture data

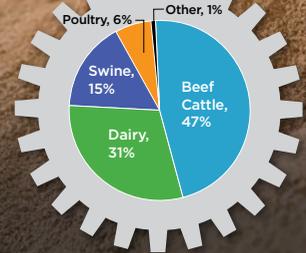
U.S. ETHANOL INDUSTRY COPRODUCT ANIMAL FEED OUTPUT



Source: RFA and U.S. Dept. of Agriculture. Note: All co-products converted to 10% moisture basis *Estimated

The U.S. ethanol industry generated **33.1 million metric tons** of distillers grains and gluten feed/meal. These bioproducts are valuable corn and soybean meal substitutes in animal rations around the world.

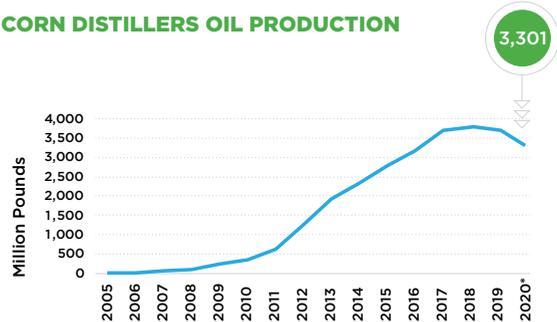
DISTILLERS GRAINS CONSUMPTION BY SPECIES



Source: Distillers grains marketing companies

Ethanol plants also extracted **3.3 billion pounds** of corn distillers oil—a **\$940 million** market underpinning the production of biodiesel and animal feed.

CORN DISTILLERS OIL PRODUCTION



Sources: U.S. Dept. of Agriculture and RFA *Estimated

EXPANDING GLOBAL DEMAND

In 2020, the United States remained the world leader in producing and exporting ethanol despite pandemic impacts on fuel consumption and prices and a further ratcheting up of trade restrictions. Exports fell 9 percent from 2019 to an estimated **1.3 billion gallons** worth **\$2.3 billion**.

U.S. biorefineries satisfied growing domestic animal food needs while also exporting one of every three tons of distillers grains produced, or 11.0 million metric tons. In 2020, four countries purchased roughly half of all U.S. DDGS exports, while remaining volumes shipped to another 50 around the globe.



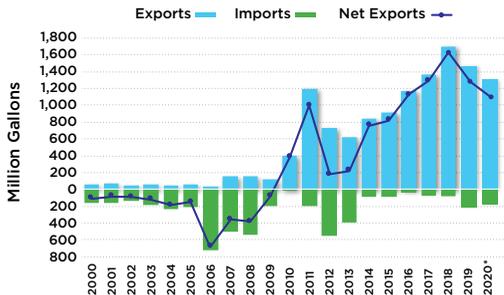
TOP DESTINATIONS FOR U.S. ETHANOL:

1. Canada
2. Brazil
3. India
4. European Union
5. South Korea

TOP DESTINATIONS FOR U.S. DISTILLERS GRAINS:

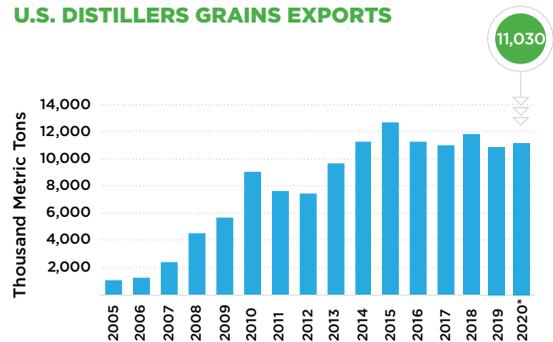
1. Mexico
2. Vietnam
3. South Korea
4. Indonesia
5. Thailand

U.S. ETHANOL EXPORTS AND IMPORTS



Sources: U.S. Dept. of Commerce, U.S. Census Bureau, Foreign Trade Statistics *Estimated based on Jan.-Nov. 2020 data

U.S. DISTILLERS GRAINS EXPORTS



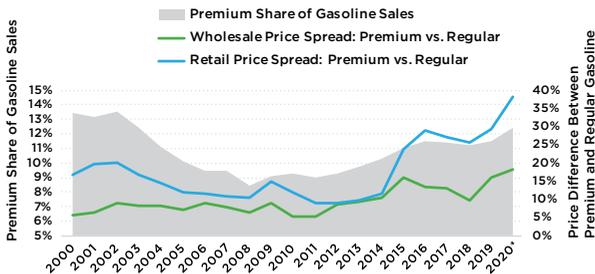
Sources: U.S. Dept. of Commerce, U.S. Census Bureau, Foreign Trade Statistics *2020 estimated based on Jan.-Nov. 2020

THE POWER OF OCTANE

Automakers are increasingly using turbocharged, higher-compression engines requiring the use of high-octane gasoline. And as the pandemic hit U.S. and global fuel markets, the need for ethanol as a clean, affordable source of octane became even more apparent. While the price of regular unleaded gasoline fell, the price of premium gasoline remained elevated. As a result, the price spread between premium and regular gasoline spiked to the highest level in at least 25 years.

A fuel's **OCTANE RATING** is the measure of its ability to resist “knocking” in the engine, which is caused when the air/fuel mixture detonates prematurely during combustion. Using a lower octane fuel than required can cause the engine to run poorly and can damage the engine and emissions control system over time. It may also void your warranty.

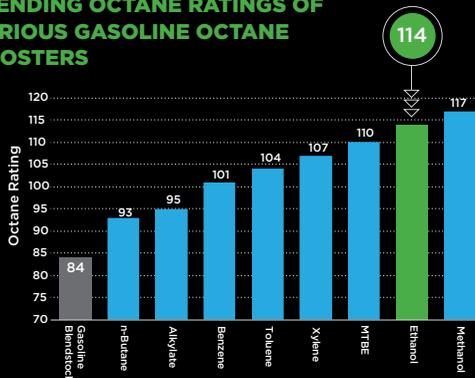
PREMIUM GASOLINE: SHARE OF SALES AND PRICE DIFFERENCE VS. REGULAR



Source: Argus Media; *Based on Jan.-Aug. 2020 data

Ethanol has a blending octane rating of **114 AKI—the highest value** of any competing octane source. Additionally, aromatic hydrocarbons like benzene are toxic and worsen air pollution.

BLENDING OCTANE RATINGS OF VARIOUS GASOLINE OCTANE BOOSTERS



Source: U.S. Department of Energy

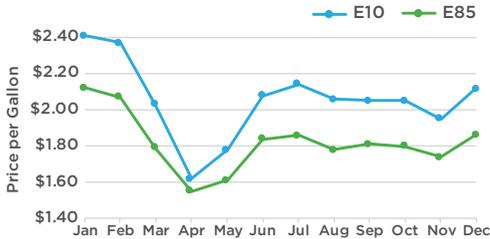
Refiners have largely optimized their processes to reduce hydrocarbon-based octane production to take advantage of ethanol’s properties. Today, most regular gasoline in the U.S. is produced using lower cost blendstock with an octane rating of 84, which is then upgraded to a rating of 87 by adding 10 percent ethanol. Higher blends like E15 and E30 offer an even greater octane boost when blended on top of today’s regular gasoline.



ABOVE AND BEYOND E10

E15 typically has an octane rating of 88 but costs less than regular unleaded.

2020 NATIONAL AVERAGE RETAIL PRICES FOR E10 & E85



Source: RFA based on data from E85prices.com

EPA issued a rule in 2019 allowing E15 to be sold year-round nationwide. Sales have since grown significantly, fueled by an uptick in stations offering E15 and widespread automaker approval. Remarkable increases in infrastructure have largely been driven by USDA's Higher Blends Infrastructure Incentive Program, through which RFA helped many retailers secure grant funding.

EXPANSION OF U.S. RETAIL STATIONS OFFERING E15 AND E85



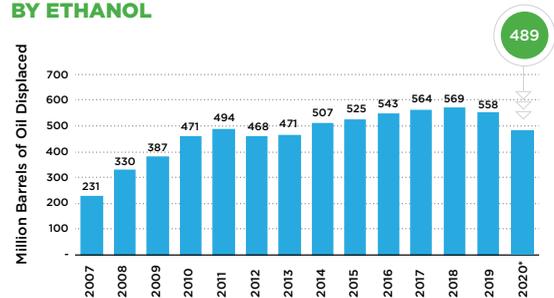
Source: RFA

ESSENTIAL FOR ENERGY SECURITY

In 2020, several events threatened the security and stability of U.S. energy markets. First came a “race-to-the-bottom” crude oil price war between Saudi Arabia and Russia. Then in April, government restrictions and other precautions related to the pandemic caused U.S. ethanol and gasoline consumption to be cut nearly in half. Yet, the U.S. remained a significant net importer of crude oil, sending some \$13 billion—or \$100 per American household—to OPEC nations to pay for crude oil imports.

Fortunately, the addition of 13.8 billion gallons of ethanol to the U.S. fuel supply displaced nearly 500 million barrels of foreign oil.

HISTORIC OIL IMPORT DISPLACEMENT BY ETHANOL

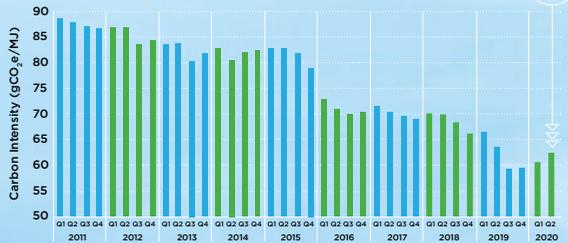


Source: RFA based on U.S. Dept. of Energy data *Estimated

ESSENTIAL FOR CUTTING CARBON

The Renewable Fuel Standard has been an essential policy for our climate, reducing CO₂-equivalent GHGs from the transportation sector by 47.3 million metric tons. The Low Carbon Fuel Standard policy model already has a decade of success in California, where ethanol has provided more than 40 percent of the carbon reductions achieved under the program—more than any other low carbon fuel.

CARBON INTENSITY OF STARCH-BASED ETHANOL IN CALIFORNIA GASOLINE



Source: RFA using California Air Resources Board data

Corn ethanol from a typical dry mill has **roughly half** the GHG emissions of gasoline.

We don't have to wait and hope for major technological or economic breakthroughs to drive decarbonization of our liquid fuels—**ethanol is available now at a low cost.**

Ethanol is also the best tool available to reduce tailpipe emissions of harmful pollutants such as carbon monoxide, exhaust hydrocarbons, air toxics like benzene, and fine particulate matter.

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