



Ethanol is the Octane of the Future

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Just a bit about me....



- 1994- 2000: Started at largest ethanol distillery in the world.
- 2000: Worked on the California MTBE Phase Out team.
- 2007: Worked for largest ethanol trade association, lead on E15 application.
- 2015: KMoore Consulting formed to work on ethanol market development.
- Today: I work in all 50 of the United States and in about 20 countries.

Today's Discussion

What is ethanol and why ethanol use is increasing.

Ethanol and other oxygenates.

Global Fuel Standards and Specifications.

The U.S. Current State

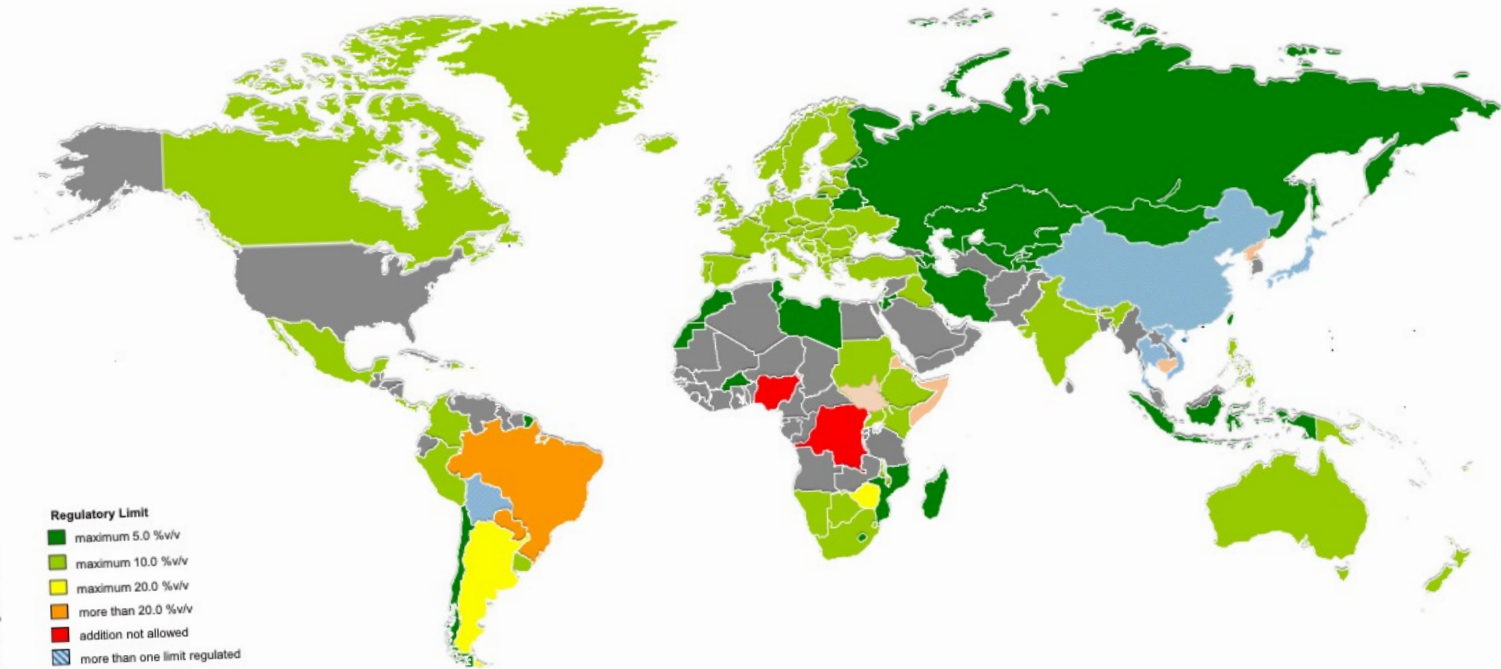
Ethanol is used successfully in 71 countries around the world.



INSPIRE

REGULATORY LIMITS FOR ETHANOL IN GASOLINE

DATE: JANUARY 1, 2021 (FORECAST)



Regulatory Limit

- maximum 5.0 %v/v
- maximum 10.0 %v/v
- maximum 20.0 %v/v
- more than 20.0 %v/v
- addition not allowed
- more than one limit regulated
- not regulated
- no information

These limits are for regular grade(s). Local legislation may allow for other grades with different ethanol limits. We introduced the limits for the sake of simplification of the global map, but the countries have limits that does not correspond directly with our upper limits.

Disclaimer for market study.

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Ethanol Use Globally

- 1970s: Brazil started a robust ethanol program to reduce fuel imports, create energy security.
- 1978: U.S. EPA approval for 10% ethanol blends with gasoline. 2010, 2011: U.S. EPA approval for 15% ethanol blends with gasoline. 2017: ~97% of all U.S. gasoline contains 10% ethanol.
- 2017: China allows use of E10 in 8 provinces. 2020: Nationwide use E10.
- 2018: Latin, South America moving to E10.

Rank	Country	Gasoline Consumption	Ethanol Use?
1	United States	388KMMT	E10, moving to E15.
2	China	90KMMT	Introducing E10.
3	Japan	39KMMT	Ethanol-based ether used (ETBE).
4	Russia	36KMMT	None.
5	Mexico	33KMMT	Introducing E5.8
6	Brazil	33KMMT	E27 and E95.
7	Indonesia	24KMMT	E7 and E3.
8	Saudi Arabia	22KMMT	None.

Most Common Ethanol Blends

- 10% Ethanol is the most common fuel in the world.
 - Largest gasoline markets in the world use this blend: U.S., China, Mexico, Germany, UK, Australia.
 - *Used in all spark ignition engines.*
- 5% Ethanol is second most common.
 - EU moving from 5% to 10% ethanol.
- $\geq 20\%$ and Higher blends are growing in popularity.
 - Brazil, Argentina, Philippines, Bolivia, Paraguay, Zimbabwe.



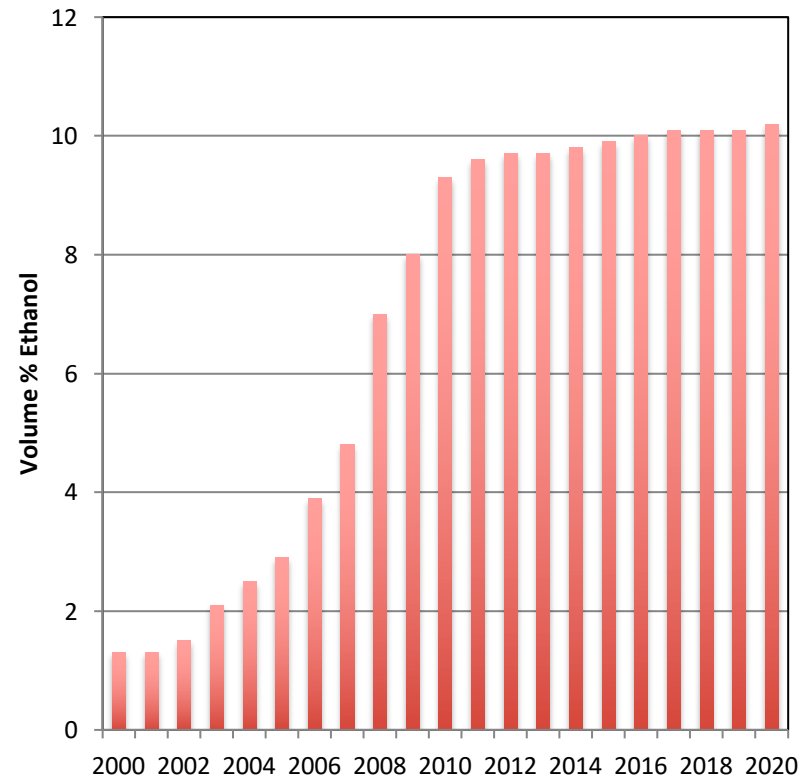
Brazil: 27% ethanol = Gasolina, Petrol
95% ethanol = Alcool

- Clean Air Act of 1970
 - Creation of EPA
- Ban of tetra-ethyl lead 1974
 - Creates need for new octane source
- Clean Air Act of 1990
 - Create evaporative and exhaust emissions controls and RFG
- Winter Oxygenate Fuel Program (1992)
 - Program includes Colorado (elevation)
- Gasoline Detergents (1995)
 - Deposit control additive requirement
- Phase 1 Reformulated Gasoline (1995)
 - Required 17% reduction in VOCs.
- Mobile Source Air Toxics of 2002, 2011
 - Reduction in benzene, etc.
- Tier 2, 3 Sulfur Standards (2004, 2017)
 - Gasoline to 30ppm first, then 10ppm.
- Energy Policy Act of 2005
 - Initiated funds from Department of Agriculture and Energy for alternative fuel sources
- Energy Independence and Security Act of 2007 (Renewable Fuels Standard 1& 2)
 - Required blending volume of renewable fuels into fossil fuels.

Why Ethanol?

Nearly every policy since the creation of the U.S. EPA requires a clean oxygenate like ethanol.

Ethanol as a Percent of U.S. Motor Gasoline Pool



United States Gasoline- Ethanol Logistics

Logistics

- Largest in the World:
Consumes ~134BGY of gasoline.
 - 15BGY ethanol blending.
- 1,331 terminals in the U.S.
 - Government tracked, published.
 - ~90% handle ethanol.
 - Example: terminals w/out ethanol are airport, jet fuel only.
- Gasoline travels in pipelines, railcars, trucks, barges, ships.
 - Ethanol travels in the same.

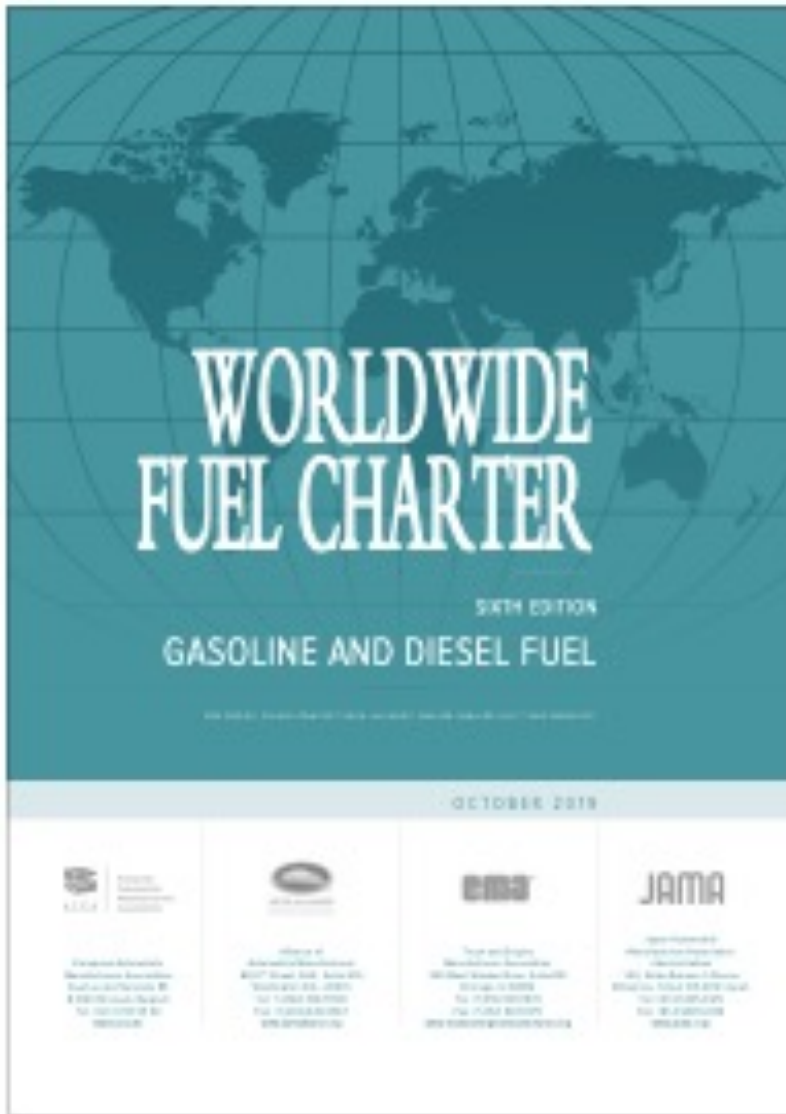
Retail Stations

- ~145,000 retail stations.
 - 60% are single store owners. <5% of the stations are oil company owned.
- 36% sell branded fuel; half are independent brands.
- 10% ethanol now 98% of all gasoline across all octane grades, (87/89/91AKI.)
- 15% ethanol being introduced stations.

Worldwide Fuels Charter

Established in 1998, the global auto manufacturers desired fuel properties for gasoline, diesel and blends with biofuels.

- Category 1: retired from service.
- Category 2 to 5: 10% ethanol is acceptable. (3.7% oxygen).
- Category 6: Future fuel at a 98- 102 RON octane, 10ppm Sulfur, 20-22% ethanol by volume.



The E15 Application

- March 6, 2009 waiver submitted to US EPA to increase the allowable ethanol content in gasoline to 15% volume.
- EPA process requires an application, Millions of dollars in health effects testing, EPA scientific panel review, Notice of Proposed Rulemaking process.
- In 2009. US EPA received >78,000 comments from the public on the E15 application.
 - 70% opposed
 - 30% in favor
 - 150 substantive comments
- EPA responded to Petitioner on Nov. 30, 2009
 - Indicated positive data for Vehicle MY2001 and newer
 - Indicated that a dual fueling system may be needed
 - Sufficient data may be available by August 2010 for EPA to rule

U.S. EPA Approval is only Step 1

- There are many steps to introducing a new fuel.
 - EPA Fuel Regulations
 - EPA Fuel Registrations
 - State Fuel Regulations
 - Marketplace Requirements
- Federal Level = EPA
 - Focused on Fuel Volatility, Sulfur
 - Detergent Additive Requirements
 - Renewable Fuel Standard
- State Level = Various State Agencies
 - State Implementation Plan
 - Legislative adoption of fuel quality expectations
 - Typically recognize ASTM specifications
- Existing Gasoline pool
 - Limited to 15% volume ethanol
 - Market conditions/ regulatory requirements
 - Gasoline saturation
 - Infrastructure/ throughput saturation
- Future fuel pool
 - Data is complete on E20.
 - Fuels like E85 (85% ethanol, 15% gasoline) for flexible fuel vehicles do not need an “application.”
- Several petitions, legislative actions have been filed for higher blends of ethanol.
 - Next Generation Fuels Act would require low carbon, high octane.
 - Still in state of proposal in the U.S. Congress

Future Considerations: High Octane, Low Carbon Fuels

Table 1. Properties of Gasoline and Ethanol

	Gasoline ^a	Ethanol
RON	91-93	109 ^b
MON	81-84	90 ^b
AKI	87-88	99
NHV (MJ/kg fuel) at 25°C (MJ/L fuel)	44 ^c 33	26.9 ^c 21.1
HoV (MJ/kg fuel) at 25°C (MJ/L fuel) (MJ/MJ LHV)	0.35 ^c 0.26 0.0080	0.92 ^d 0.72 0.034
Stoich. air-fuel ratio (kg/kg)	14.6 ^e	9.0 ^e
Density (kg/L) at 25°C	0.72-0.78 ^e	0.785 ^e
Molecular weight (g/mol)	95-115 ^{ee}	46

^a Typical U.S. regular-grade gasoline without ethanol (E0)

^b Hunwartz [6]

^c Heywood [7]

^d NIST Chemistry Webbook [8]

^e American Petroleum Institute [9], SAE International 1101

- India can gain from environmental and economic benefits that ethanol blending can provide.
 - Ethanol is a renewable energy source that can serve policy, performance, and supply goals.
 - Ethanol is priced competitively against other octane additives.
 - Ethanol brings dilution benefits that are also economic.
- Effective specifications must support both policy and the market needs.
 - Ethanol capital investment can have a short Return on Investment (ROI) due to the price and dilution economic benefits.
- Expanded global trade is a benefit of introducing new renewable energy sources like ethanol.

Thank you very much!

ANY QUESTIONS?



Thank you!

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