

Ethanol and the Economics of Octane

The Superior Solution

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What is Octane?

- Spark-ignition gasoline engines work by **compressing** an **air-fuel mixture** and then **igniting the mixture** (with a spark plug) at a **specific instant** during the cylinder's compression stroke.
- A fuel's **octane number** is the **standard measure** of its **ability to resist pre-ignition** (or “**knocking**”) in the cylinder of a gasoline engine.



Chevrolet LT4

Measuring Octane

RON

- Research Octane Number
- Knock resistance at low-load operations (e.g., highway driving)
- Posted on pump in most of the world (e.g., Europe and Asia)

MON

- Motor Octane Number
- Knock resistance at high-load (e.g., acceleration, hauling)
- MON is always less than RON

AKI

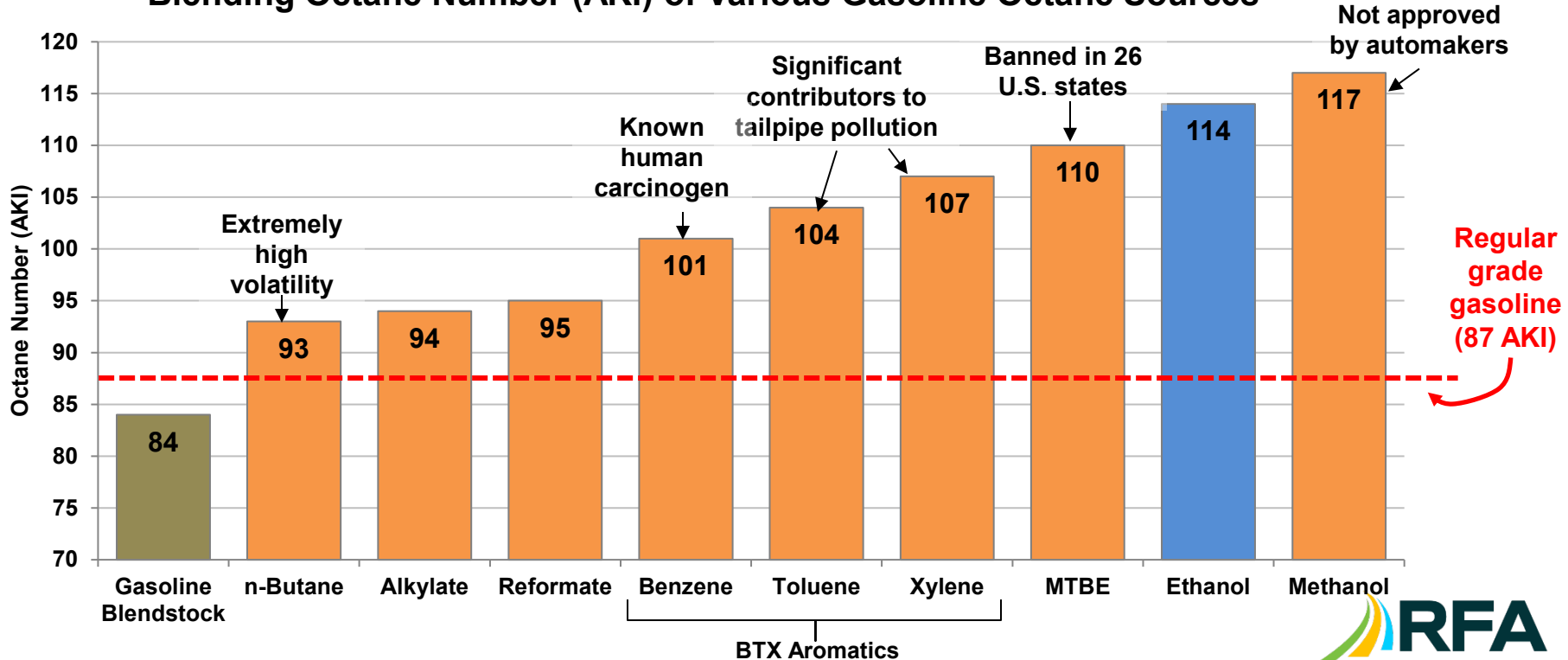
- Anti Knock Index...also called $(R+M)/2$
- Equal to $(RON + MON)/2$
- Posted on the pump in North America

Octane and Gasoline Blending

- The “naturally occurring” octane in the crude oil fractions that become gasoline is far less than what engines need.
- Refiners and blenders “create” the additional required octane by:
 - Carrying out chemical processes that “upgrade” low-octane hydrocarbon molecules into high-octane molecules; and/or
 - Purchasing and blending high-octane blendstocks.
- Making octane in the refinery is costly and energy intensive.
- Refiners must balance octane needs with other specs and properties.
 - e.g., volatility, sulfur content, benzene content

Ethanol's Octane Advantage

Blending Octane Number (AKI) of Various Gasoline Octane Sources

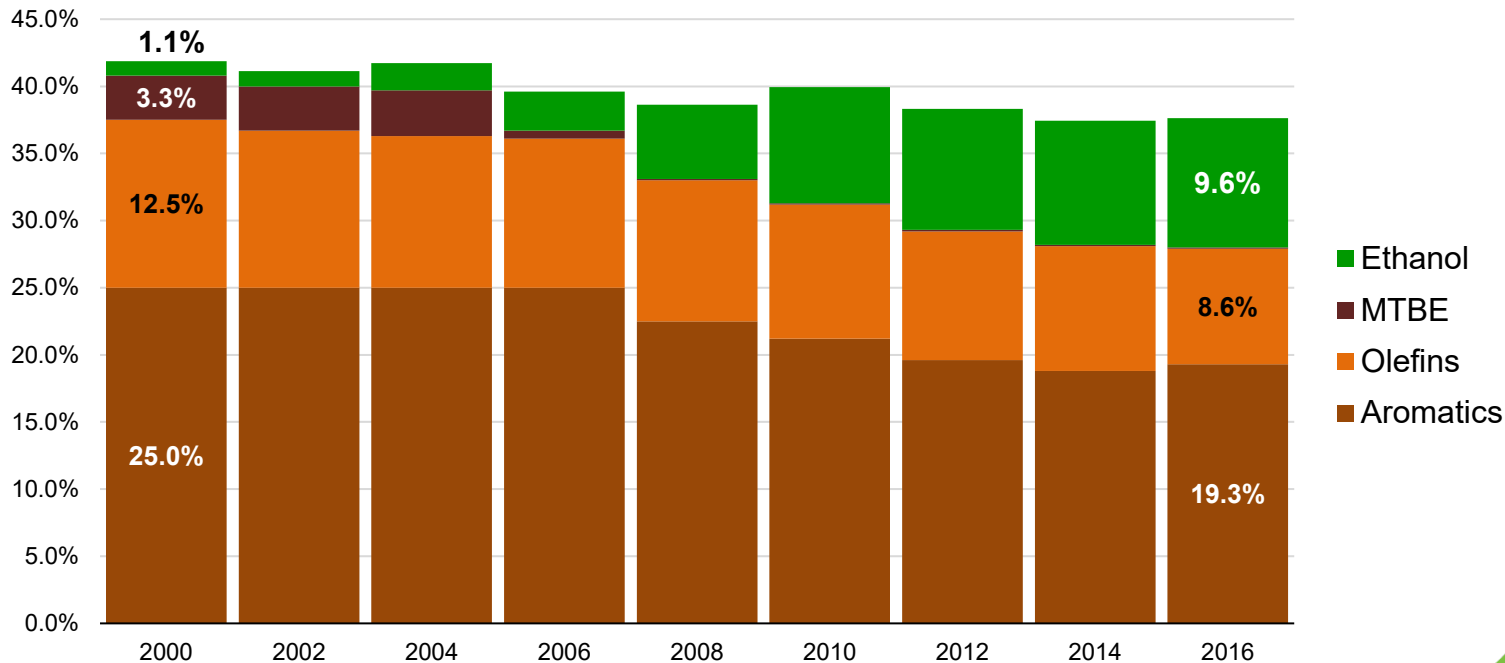


U.S. Ethanol Blending: Past and Present

- Prior to ~2002, ethanol used mainly as a **volume extender**, not an **octane booster**.
 - Refiners did not assume gasoline would be blended with ethanol downstream. Produced 87 AKI E0.
 - Ethanol was “splash-blended” far downstream of refinery in some locations (mostly Midwest)
 - Result was more octane than required to meet specifications for “regular grade”
- Regulations and policies significantly expanded the use of ethanol in 2002-2010 timeframe.
 - Winter oxygenated gasoline; Reformulated gasoline; State MTBE bans; **RFS**
- By ~2010, most gasoline in the U.S. blended with 10% ethanol.
- Refiners reconfigured to capture ethanol’s octane benefit and avoid octane “give-away.”
 - Widespread production of sub-octane gasoline “Blendstocks for Oxygenate Blending” (BOBs) designed for blending with 10% ethanol
 - **90% 84 AKI BOB + 10% 117 AKI Ethanol = 87 AKI E10**
 - **85% 84 AKI BOB + 15% 117 AKI Ethanol = 88 AKI E15**

Ethanol has rapidly emerged as a significant source of octane in U.S. gasoline

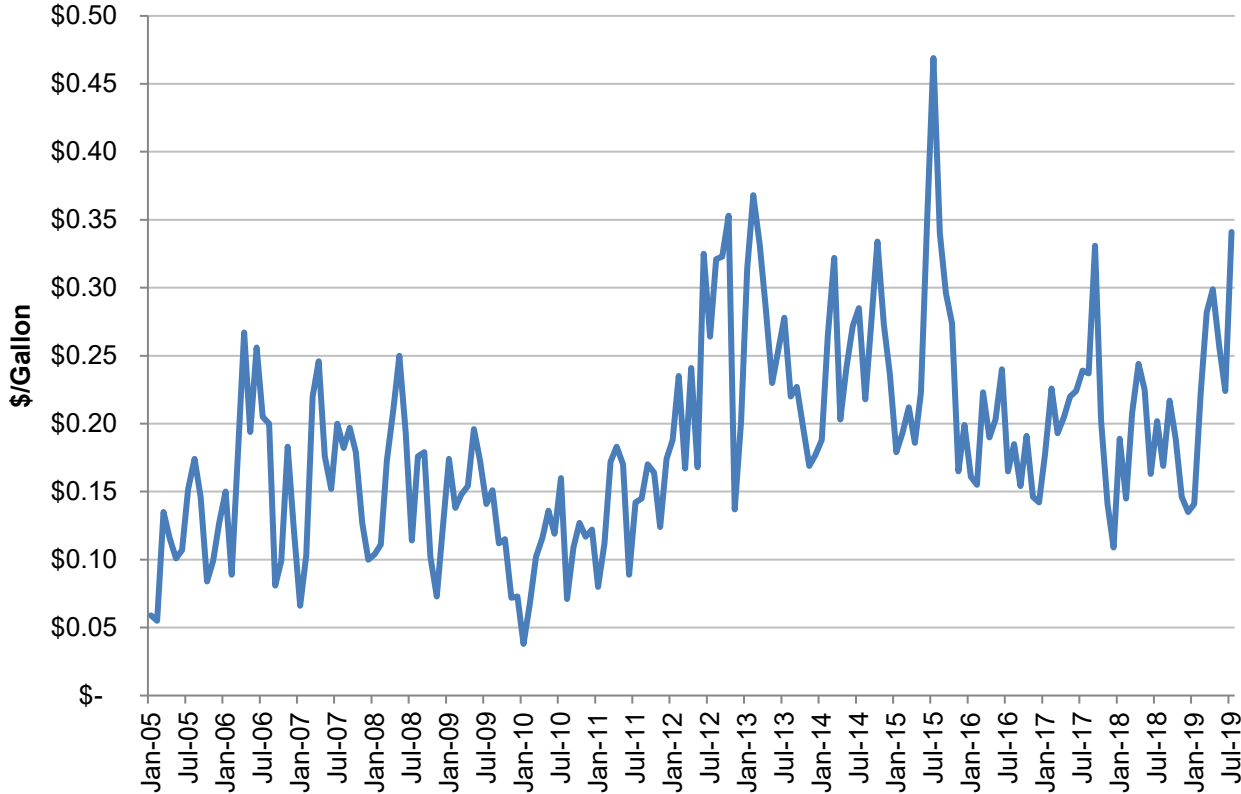
Average U.S. Gasoline Content of Ethanol, Aromatics, Olefins, and MTBE



The Economics of Octane

- **What is the economic value of octane?**
 - A common measure used in the U.S. is the “Premium-Regular Bulk Spread”
 - Difference between bulk spot prices for premium (90 AKI) and regular grade (84 AKI) gasoline BOBs
 - $(PRM - REG)/6$ pts AKI = value per AKI point of octane
 - Considered by refiners to represent the market value of octane
 - Good indicator of refining cost to produce incremental octane

Premium-Regular Bulk Price Spread



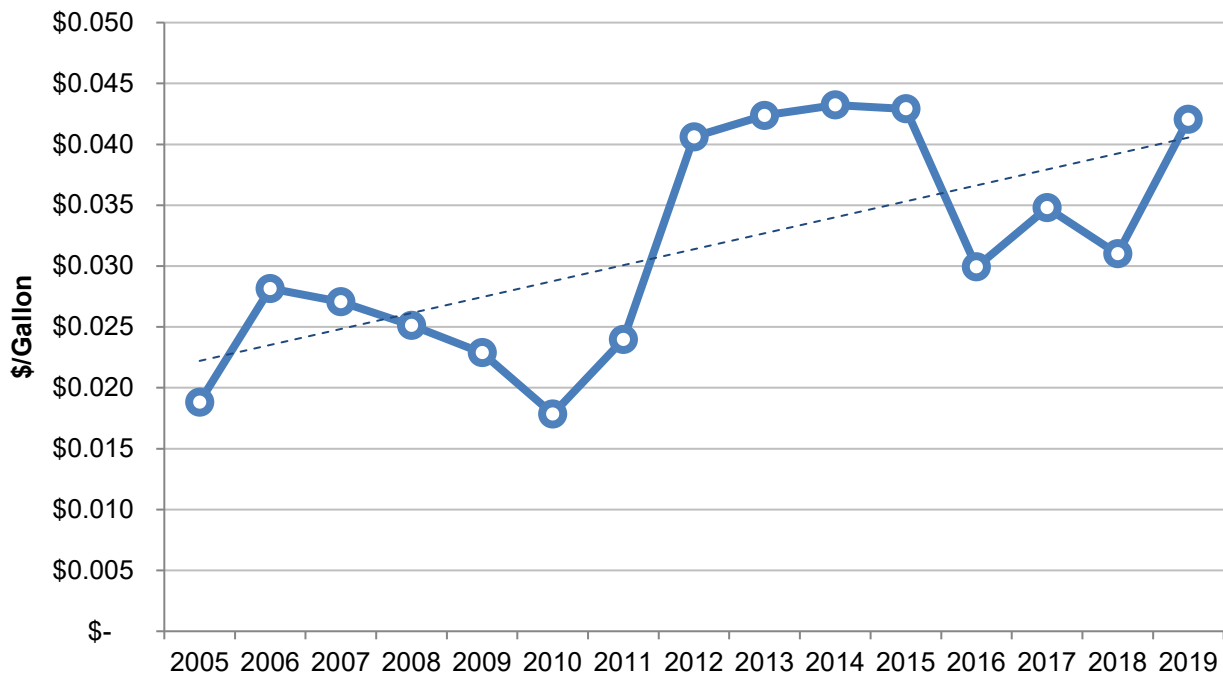
Annual Averages (Bulk)

	Spread (\$/Gal.)	PRM % Increase over REG
2008	0.15	6%
2009	0.14	9%
2010	0.11	5%
2011	0.14	5%
2012	0.24	9%
2013	0.25	9%
2014	0.26	10%
2015	0.26	16%
2016	0.18	13%
2017	0.21	13%
2018	0.19	10%
2019*	0.25	14%

* YTD through July

Value of Incremental Octane

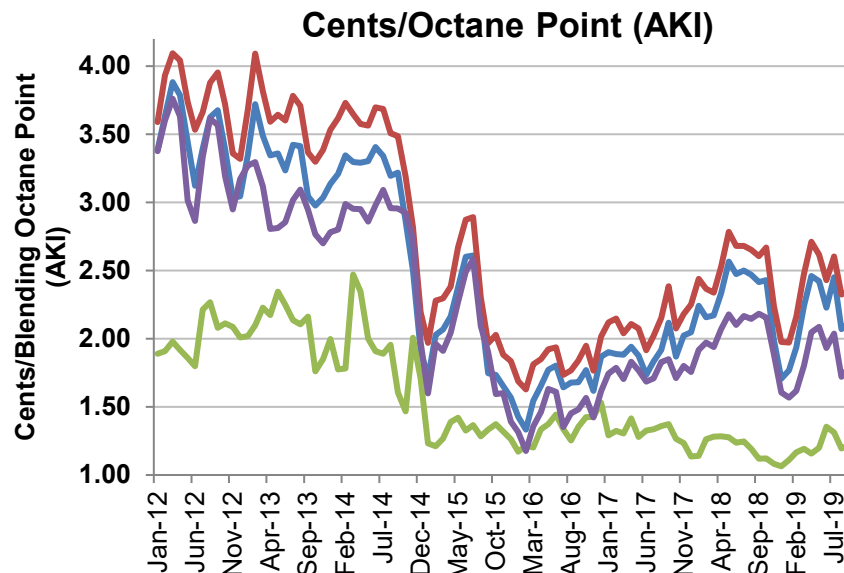
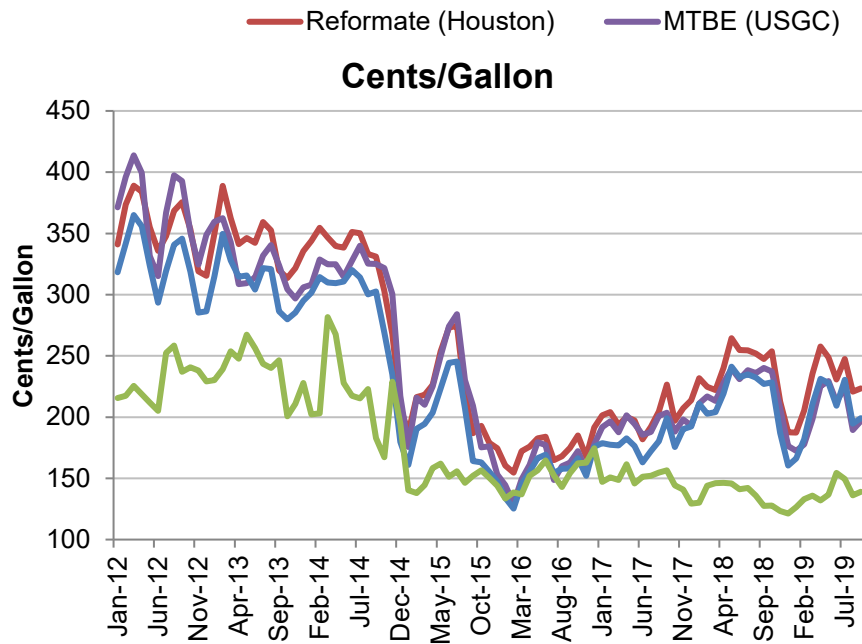
Value per Point of Octane (AKI) based on Bulk Prices



- Based on current Premium–Regular BOB bulk spread, each point of incremental octane (AKI) is worth **4 cents per gallon** to the refiner
- Ethanol’s current *theoretical* octane value is **\$1.20/gallon** over 84 AKI BOB price!
 - $(114 - 84) \times 4 \text{ cpg}$

Ethanol Priced Far Below Other Octane Sources

Ethanol, Reformate, Alkylate, MTBE Spot Prices (Cents/Gallon)



Source: Argus Media

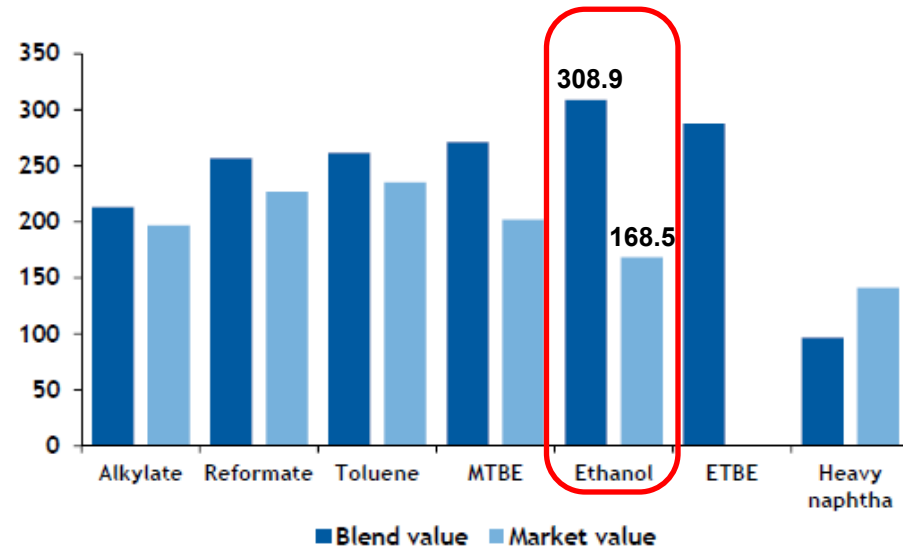
Ethanol's Value to Refiners and Blenders

Argus Fuels and Octane
Issue 19-41 Friday 11 October 2019

- Argus Media reports weekly market prices and a calculated “**octane blending value**” for various octane sources.
- In addition to octane number, the “octane blending value” formula takes into account energy density, sulfur dilution, RVP, and other important blending factors.
- **Last week, ethanol's blend value was nearly double its market price!**

Octane blending value vs market price

¢/USG

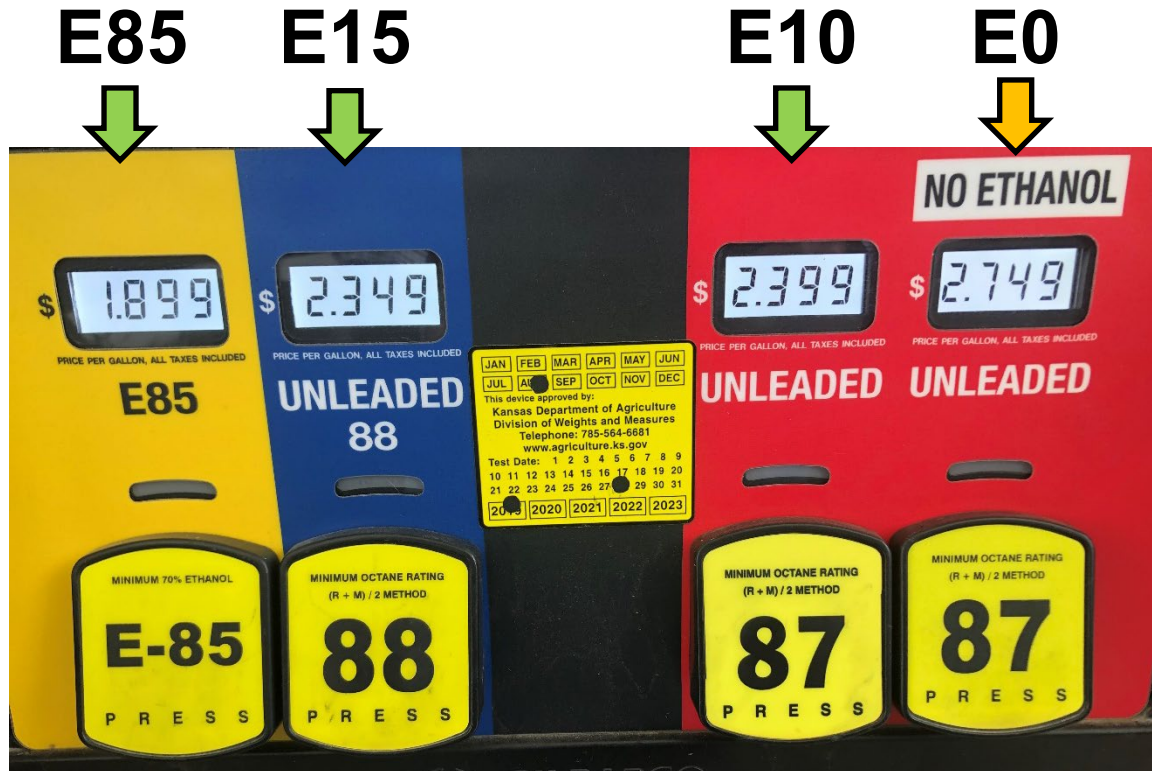


Proof of the Ethanol Advantage



- Buc-ee's station in Texas
- 87 AKI ethanol-free gasoline priced **53% above** 87 AKI E10 and **22% above** 93 AKI premium E10!

Proof of the Ethanol Advantage



- Casey's station in Kansas
- 88 AKI E15 is 5 cents per gallon lower than 87 AKI E10...and 40 cents per gallon below 87 AKI E0!

E10 is just the first step toward High-Octane Low Carbon Fuels!

E10
(91 RON)

E15
(92 RON)

(95 RON)

E25-E30

(98-100 RON)

Optimized Engines

- High compression ratio
- Turbo-charged
- Downsized

Optimized Infrastructure

- Supply chain E30+ compatibility
- E10-E85 blender pumps

Compared to E10:

- 5-9% gain in fuel efficiency
- 12-15% reduction in CO₂e emissions per mile (including lifecycle benefits)
- Lower cost at the pump
- Reduced tailpipe pollution (PM, CO, NO_x)
- **Same miles per volumetric gallon!**

Continued E85 FFV production throughout transition