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Octane's Value Proposition

American Coalition for Ethanol Annual Conference

August 10, 2016

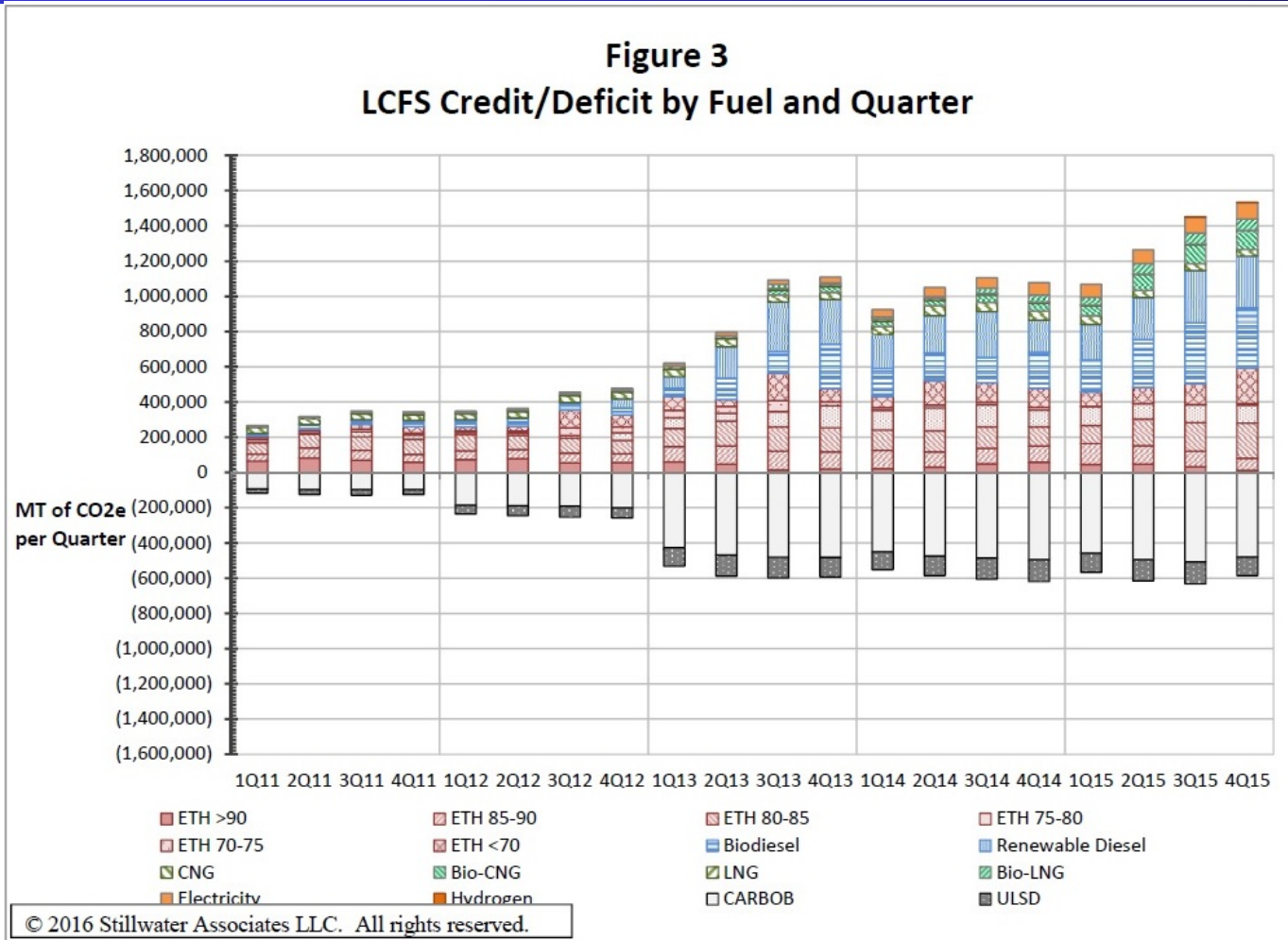
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Stillwater publishes an LCFS report



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We show the breakdown of credits by fuel in this graph

This morning's agenda



1. Refining 101
2. What is octane?
3. The octane market
4. Octane blending issues
5. Going forward

First, a little organic chemistry



Hydrocarbon	Carbon Count	Use
Methane	1	Natural Gas
Ethane	2	Natural Gas/Chemicals
Propane	3	Heating
Butane	4	Heating/Gasoline
Pentane	5	Gasoline
Hexane	6	Gasoline
Octane	8	Gasoline



Fuels are defined by the size of their molecules



Fuel	Typical Range of Carbon Molecules
Natural Gas	C1 & C2
Liquefied Petroleum Gas	C3 & C4
Gasoline	C4 – C10
Jet Fuel & Kerosene	C11 – C15
Diesel & Heating Oil	C16 – C22
Fuel Oil/Asphalt	Greater than C23



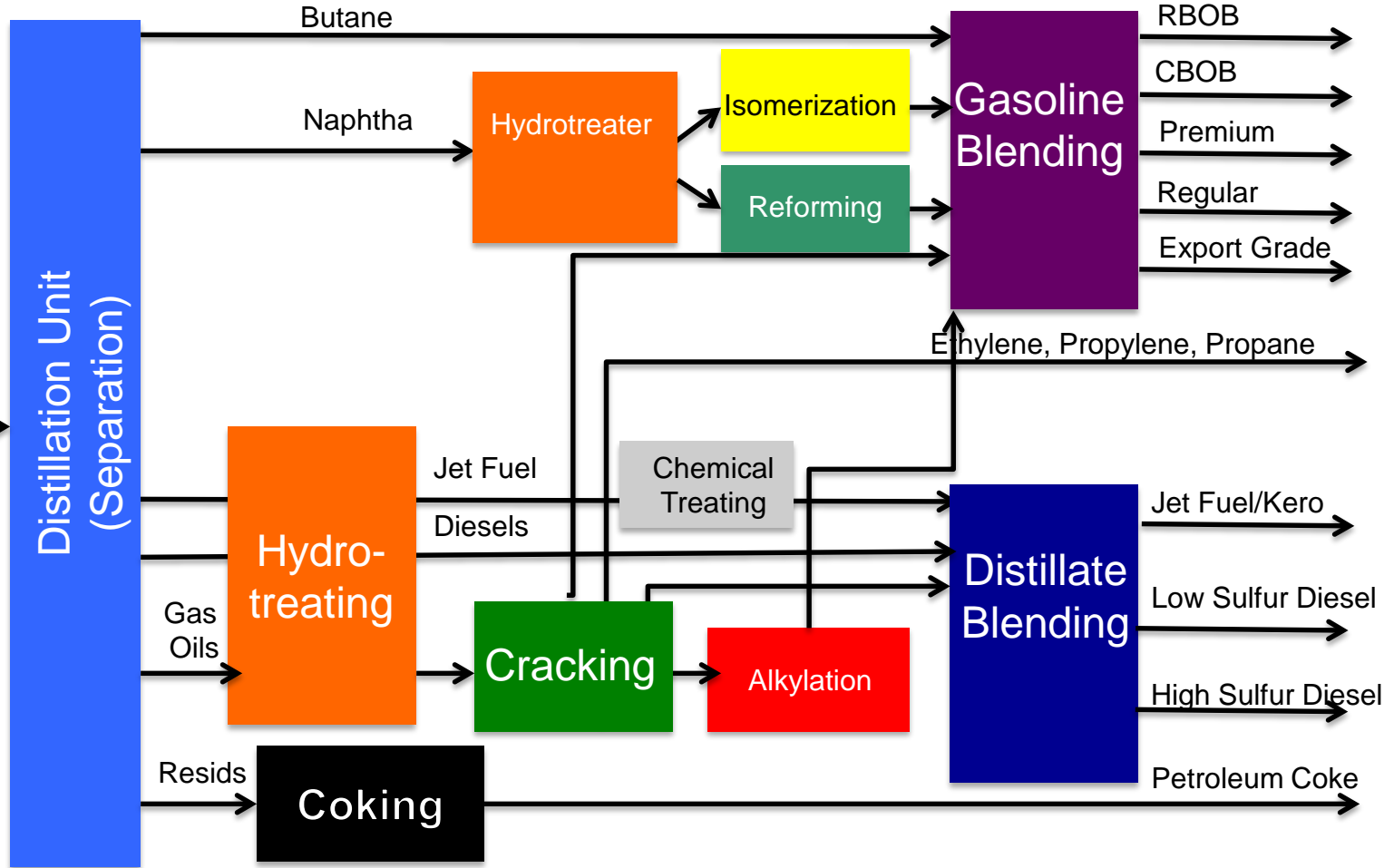
...and other qualities like sulfur, distillation, octane, cetane too.

A refinery's first job is to separate hydrocarbon molecules by size

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Crude Oil



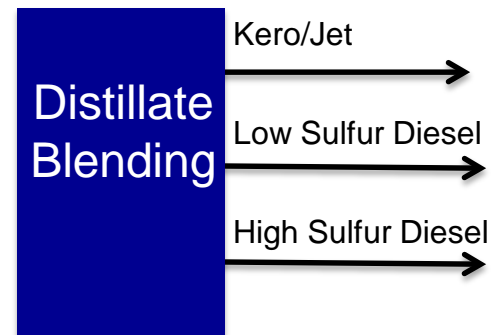
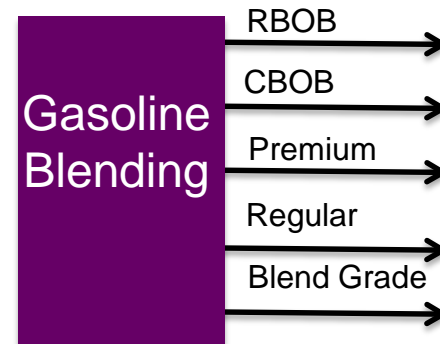
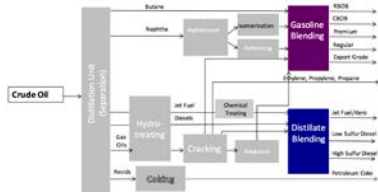
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Then the refinery upgrades, cracks, and recombines the molecules

Once refining is completed, products are blended to delivery specifications

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1. Product blending brings the different petroleum fractions together to make the final blend that meets product specifications
2. Product blending has been significantly impacted by tightened product specifications to meet new environmental regulations and performance requirements
3. Gasoline, diesel, and sometimes even jet fuel utilize product blend recipes to meet specs
4. The recipes for gasoline requires the right ratio of naphtha, reformate, catalytic gasoline, alkylate and butane to meet the required specifications

This morning's agenda



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2. **What is octane?**
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What is octane?



1. The octane rating is an indicator of spontaneous combustion when fuel is compressed in an engine, i.e. knock
2. Two measures of octane – Research & Motor
3. Pump ratings are the average – $(R+M)/2$ aka Road octane
4. Anti Knock Index (AKI) is the terminology used by the autos
5. Set on a regional basis
 - a. Regular is 87 AKI, except in the Rockies
 - b. Premium is 91-93 AKI, except in the Rockies for the West
3. Raw naphtha is low in octane: around 50 $(R+M)/2$
 - a. Refiners have investments and operating costs to create high octane gasoline
 - b. Reforming is the process that refiners normally swing on to meet octane requirements

Octane is measured in a lab using a special engine



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Octane is an important specification to the refiner because of its cost

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Refiners can make incremental octane by changing their refining processes

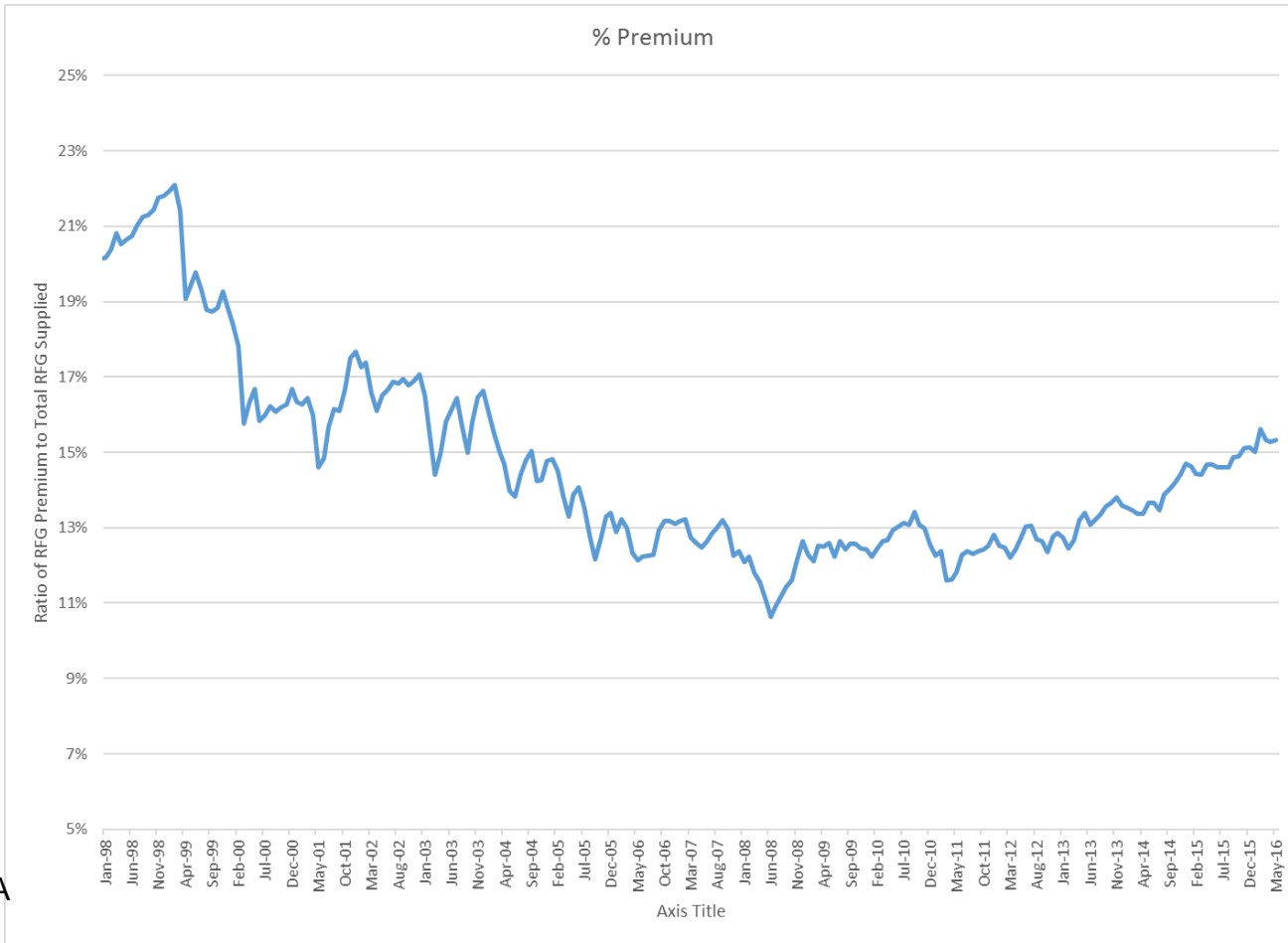


1. Generally refiners will change their octane production by changing the operating parameters of the reformer
2. Many reformers have run at low levels because refiners are using ethanol's octane to meet retail octane levels
3. Some refiners can extract aromatics like benzene, xylene, and toluene from their gasoline blending pools
 - a. Most leave these in their gasolines
 - b. Abandon specialty chemical market for commodity octane markets?
 - a. Not very likely.
4. Refiners can build additional alkylation capacity to make octane without aromatics, but the costs are high

The demand for octane is creeping up



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Source: EIA

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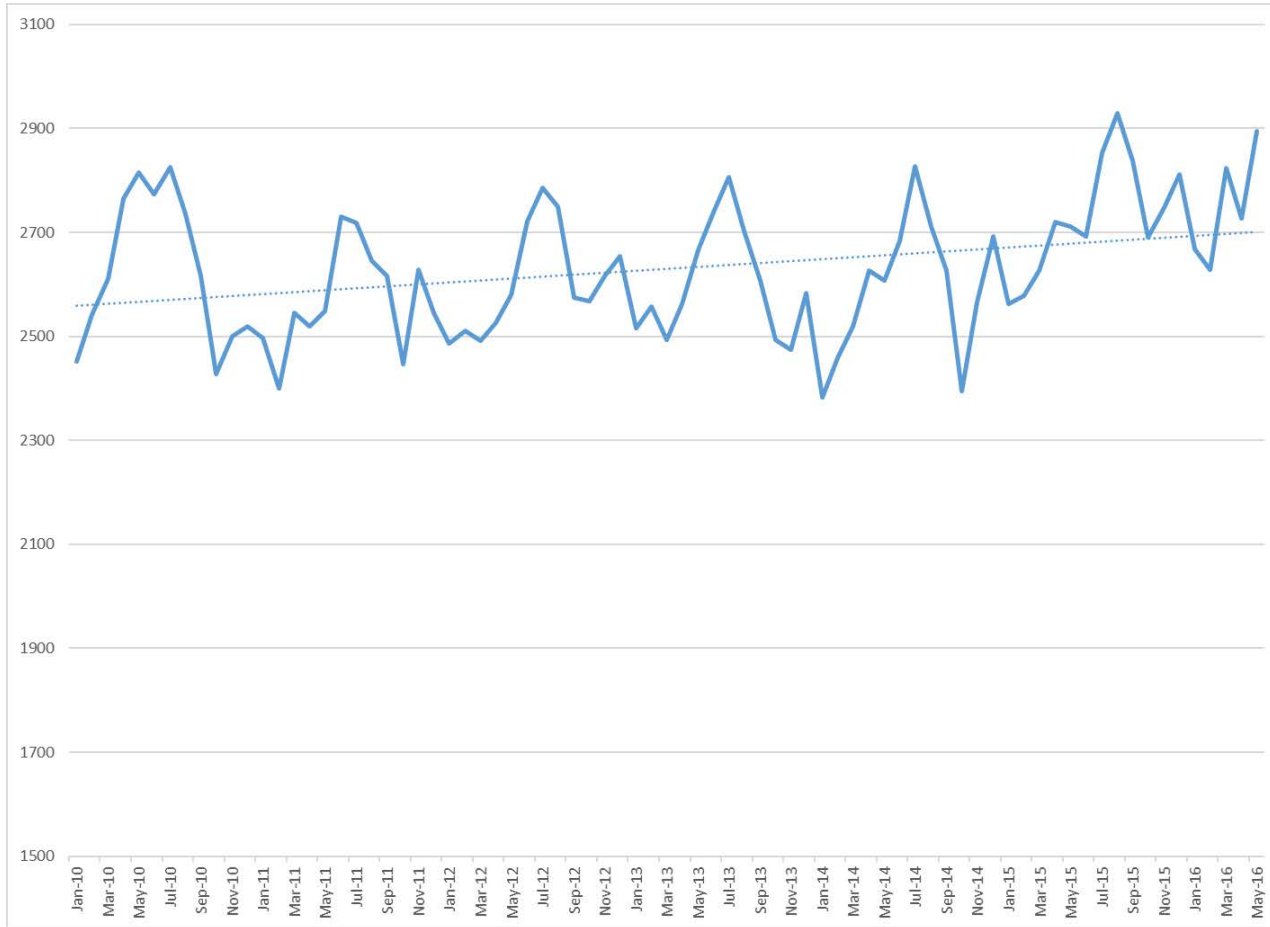


Cheap gasoline and increasing demand from small turbos

Reformer rates are trending up slightly



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Source: EIA

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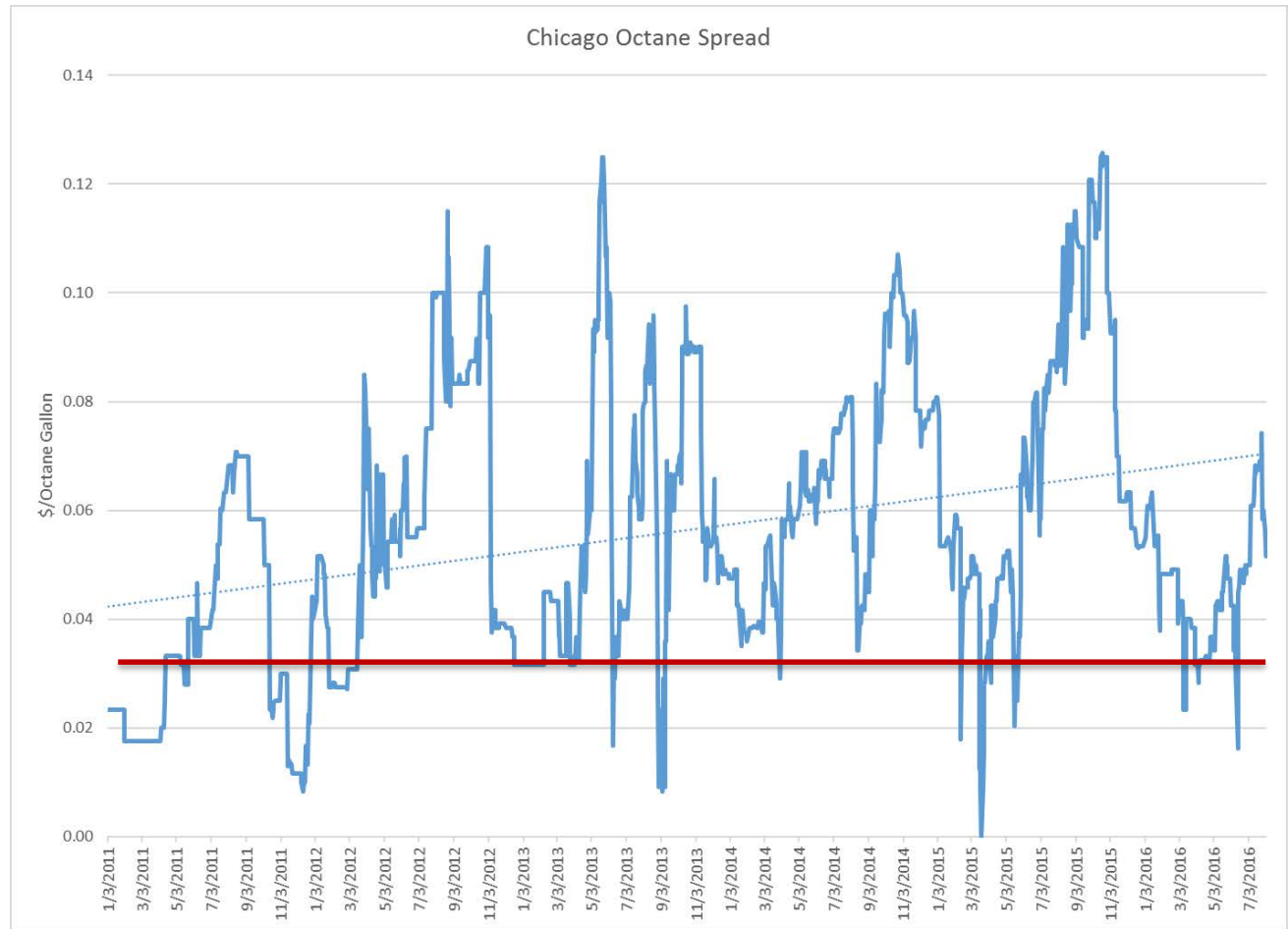
Presumably due to increasing demand for premium

The spot market for octane is volatile



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Spot Chicago
PBOB minus
Spot Chicago
RBOB, \$/octane
gallon



Source: DTN

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Cost for the high cost producer looks to be around 3 cents per octane gallon

The price of octane at the pump has increased dramatically



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Source: EIA

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Octane blending is not straightforward



1. RON vs MON
 1. Smaller high speed engines may need MON more than RON
 2. Motor Octane Number (MON), is determined at 900 rpm engine speed under load instead of the 600 rpm for RON.
 3. Europe and other parts of the world uses RON-Europe's 95 RON roughly equals US 89 R+M/2
2. Non-linear Octane blending effects
 1. May result in octane giveaway to meet minimum specs
 2. Different blending curves for RON vs MON
3. Final Gasoline blends are certified at the refinery where there is a lab capable of testing all specs
 1. BOBs are hand blended with the appropriate amount of ethanol and certified to meet required specifications.
 2. Adding different amounts of ethanol violates EPA regulations and ASTM requirements
 3. It is possible to dual certify fuels

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The demand for octane is likely to increase



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1. As the autos move towards high compression and turbocharged engines, octane demand will go up
2. The autos are interested in even higher octane fuels
3. Much research remains to be done to optimize engine design and to optimize fuel octane
4. Higher level ethanol blends are being tested
5. Refining industry may want a piece of that higher octane requirement
6. Supply chain issues will have to be worked out





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