GASOLINE BLENDING: AN EPRINC PRIMER

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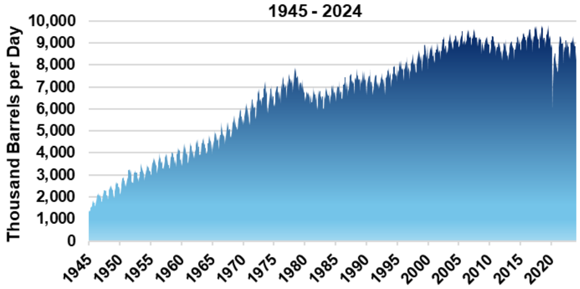
Introduction / Executive Summary

In its current form, gasoline is a blend of several components, most of which are derived from crude oil; the remaining balance is from agricultural sources. Its mixture is calibrated to adhere to specific operational, climatic, and regulatory standards.

Gasoline is the primary fuel for light-duty motor vehicles that are used for mobility that includes commuting, shopping and other personal errands, and leisure. To a lesser degree, it is the fuel for farm tractors as well as other agricultural machinery, and commercial vehicles such as light and medium-duty trucks. It achieved this dominance over time in tandem with the development of automobiles and paved roads (*Figure 1*).

Figure 1 **U.S. Monthly Gasoline Consumption**
1945 - 2024



Analysis Based on EIA Data — *EPRINC*

Gasoline's origins begin with the discovery and refining of crude oil during the mid-/late-nineteenth century. In the U.S., this was in 1859 with Drake's Well in Western Pennsylvania. Until this time primary liquid energy requirements were met by products such as whale oil that were used for both heating and lighting.

Using basic distillation processes, crude oil is separated into four distinct molecular ranges. Viewed by weight from the lightest to heaviest, there is a small group in refining jargon they are known as "light ends" (together comprised of ethane, propane, and butane). The next three ranges ordered by weight are naphthas, middle distillates, and heavy distillates.

In order to have a basic understanding of gasoline blending, it is first important to grasp the basics of crude oil, refining, operational attributes of gasoline, biofuels, distribution, environmental regulations, and blending mandates.

Each impacts the evolution of the formulation of gasoline and where across the supply chain the blending takes place.

Kerosene and diesel are the two primary fuels derived from middle distillates. Kerosene was the first crude oil-derived dominant fuel that quickly came to replace the use of whale oil for heat and light. Heavy distillates are primarily used in ocean-going vessels.

Precursors of contemporary internal combustion engines began appearing in the 1860s and technologically advanced rapidly. Of these that are still prevalent today: compression-ignition and spark-ignition. Diesel (taken from the middle distillates pool) is the fuel used in compression-ignition types while the general formulation for spark-ignition engines is what came to be known as gasoline and uses naphthas as its foundation.

Compression-ignition engines require heavier, more durable materials, and are therefore more costly. This led to spark-ignited gasoline engines becoming the dominant propulsion system for motor vehicles. Of the current total 18 million barrels of crude that is processed daily in U.S. refineries, half of it is refined into gasoline.

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Crude oil production, quality, and sources

Crude oil is a viscous substance comprised of hydrocarbon molecules of varying dimensions along with other minerals and impurities. Summary descriptions of crude oil quality are generally determined by two metrics: weight (or density), and sulfur content. Sulfur content is described as being in a range from sweet (low-sulfur) to sour (high-sulfur). Heavier and more sour crudes require more complex processing capacity; lighter and sweeter crudes produce more premium products and have little residue.

A more descriptive set of metrics is a crude oil assay. It details in percentage terms how much of a unit of crude oil is expected to be distilled into particular molecular ranges.

Crude oil is found globally both onshore and offshore in underground geological formations of differing porosity and permeability. The greater the porosity and permeability, the easier it is to extract. New technologies such as lateral drilling and hydrofracking have improved access and retrieval of hydrocarbons from formations with low permeability and porosity. Among other things, this has led to a rebound in crude oil and natural gas production in North America.

Refining

Crude oil in its original form is rarely usable as a fuel. It needs to be refined in order to produce products such as gasoline. There are four sets of refining processes listed in order of use: distillation, conversion, treating, blending.

Distillation boils and separates crude oil into distinct ranges based on their molecular weight. Initially, distillation produced products directly for consumption. However, product demand varied and grew, and distillation could only produce product volumes in proportions determined by a crude oil's assay. Since crude oil assays vary, this has required the development of conversion processes in order to boost or shift yields to accommodate particular product demand.

Conversion processes change the size or structure of various streams produced by distillation. There are three subcategories:

- decomposition, where larger molecules are broken down into smaller molecules;
- unification, where smaller molecules are combined into larger ones, and;
- reforming, where molecule components are altered or rearranged.

Treatment processes involve the removal of impurities such as salt, sulfur, and wax. *Blending* is the process of combining components into intermediate and finished products according to established operating and regulatory specifications.

Operational Requirements and Primary Quality Determinants of Gasoline: Octane and Reid Vapor Pressure (RVP)

The quality of gasoline is judged and priced primarily by two attributes: octane and RVP. Octane is a measure of a gasoline's combustibility. Gasoline-powered engines require minimal levels of octane so that the fuel's combustion causes no damage to the engine during normal operations.

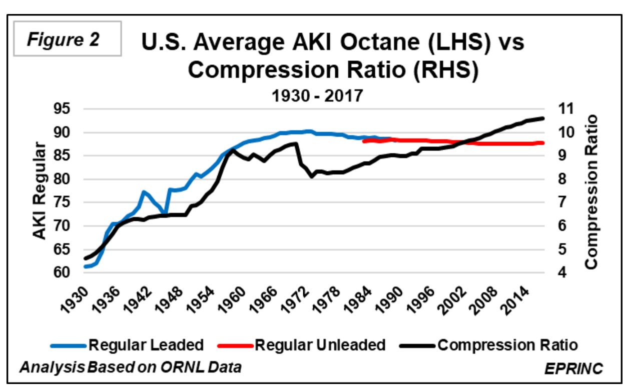
Reid Vapor Pressure is the vapor pressure of the gasoline blend when the temperature is 100 degrees F. Gasoline RVPs generally range from 8 to 14 psi. The higher the number, the greater the fuel's propensity to vaporize. Gasoline’s volatility is directly tied to the proportion of combustible vapors, and thus choosing a gasoline with appropriate RVP for the specific engine and atmospheric conditions is essential for a gasoline product that combusts efficiently but does not explode. RVP standards vary by climatic region and season.

Operational Requirements - Octane

Naphtha was used as the primary gasoline fuel for the early forms of spark-ignition engines. Initially, these gasoline-powered engines had a compression ratio that averaged 4-to-1 (compared to current compression ratios that average close to 10.5-to-1). However, automobile manufacturers quickly sought ways to accommodate increasing demand for vehicle power and speed. There were several possible ways to attain this, none to the exclusion of the other:

- increase the number of cylinders in an engine;
- adjust and expand the gearing of the transmission.
- increase the compression-ratio of the engines.

With increased compression, naphtha would prematurely combust from compression alone (commonly referred to as "pinging" or "knocking"), causing engines to overheat, deliver less power, and potentially damaged and unusable. To mitigate and eliminate knocking, naphtha required something to suppress compression-ignition and to combust from the electric spark alone. The solution was to blend in octane (*Figure 2*).



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Originally, octane components had a molecule of eight carbon atoms (hence "oct"). However, with time, different additives were used that behave like the original octane components but were not octanes in the literal sense (having eight carbon atom molecules). Nevertheless, the term "octane" has been retained to describe them.

An octane number or rating is a representation of how much gasoline can be compressed before it spontaneously ignites, unassisted by a timed spark; this is proportional to the amount of octane blended into the gasoline formulation. Octane-rating computations of gasoline are obtained through testing procedures. In the U.S., ASTM International (originally American Society for Testing and Materials), established in 1898, is the authoritative organization for validating octane-rating measuring procedures.

There are two principal octane-rating methodologies in use: RON (Research Octane Number) and MON (Motor Octane Number). RON measures a gasoline's capability to resist knocking while accelerating; MON calibrates its rating based on the simulation of high-speed driving.

In the U.S., the octane-rating that is posted on gasoline pumps is the average of the RON and MON numbers; this average is also referenced as the AKI (anti-knock index). The earliest posted AKI measures are from 1930 when regular gasoline had an AKI of 61 and premium gasoline had an AKI of 71. This compares with 87 and 93 AKI, respectively, for current formulations of gasoline. A midgrade formulation is also marketed with an AKI of 89. In Europe and most other parts of the world, the posted octane-rating on gasoline pumps is the RON number only.

Manufacturers specify the octane-level required by a particular vehicle. Gasoline purchased with higher octane-levels than specified produces no additional impact on an engine's power.

The octane-rating of gasoline can be adjusted using different ratios of blends of octane components. Octane components can either be sourced from petroleum refining processes or from non-petroleum-based additives. Of the latter, they can either be oxygenates or metallic additives.

- Octane: *Metals*

Since the first octane-enhancing refinery processes did not become commercially operational until the 1930s, and then only to a limited degree, other non-refining octane-enhancers had to be sourced. There were three gasoline-soluble chemicals that were first used, all of metallic origin:

- lead, most often in the form of tetraethyl lead (TEL), and sometimes tetramethyl lead (TML);
- manganese in the form of methylcyclopentadienyl manganese tricarbonyl (MMT), and;
- iron, referenced as ferrocene.

All of these were powerful octane-enhancers, requiring small amounts to be added to naphtha to raise the octane number at very low cost.

TEL was first used in 1923. It was controversial from the outset, since it was a known toxin; in 1925, it was banned for a full year, but subsequently reinstated. Average concentrations of lead in gasoline increased until it reached a maximum of about 2.5 grams per gallon in the late 1960s.

MMT has been banned in the U.S. since 1977, but it is still used in Canada, Australia, and China. Iron/ferrocene is in limited use in Europe.

- Octane: *Oxygenates*

The dominant non-metallic, non-refining octane-enhancing blending agents are oxygenates. The best-known ones are ethanol and MTBE (methyl tertiary butyl ether). MTBE was introduced in 1979; but it only became widespread with the introduction of reformulated gasoline in the mid-1990s and the final complete ban on lead. Ethanol use also began to increase at this time, but only in and close to the corn-producing states and biorefineries. Two other oxygenates that were introduced with the program were ETBE (ethyl tert-butyl ether) and TAME (tert-Amyl methyl ether). ETBE is prevalent in Europe; TAME, while functioning well as an oxygenate and octane-enhancer, is highly toxic.

Despite providing octane, the primary intent of oxygenates was to produce gasoline that generates less smog and toxic pollutants by raising the oxygen content of gasoline.

- Octane: *Refinery produced components*

Modern refining has several processes that produce octane blending components. These include, reforming, fluid catalytic cracking, alkylation, and isomerization (*Table 1*). Of these, reformate, sometimes known as aromatics or the BTX complex (incorporating the first initial of its components - benzene, toluene, and xylene) is the prevalent refinery-produced octane component.

Table 1: Refinery Produced Octane

Year	Process Name	Octane Blendstock
1930	Thermal reforming	Reformate
1935	Catalytic Polymerization	Isomerate
1937	Catalytic Cracking	Higher Octane Naphtha
1940	Alkylation	Alkylate
1940	Isomerization	Isomerate
1942	Fluid Catalytic Cracking	Higher Octane & Yield
1952	Catalytic Reforming	Reformate
1957	Catalytic Isomerisation	Isomerate
Source: OSHA, U of CO Data		*EPRINC*

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Operational Requirements - Reid Vapor Pressure (RVP) and Seasonal and Regional Blending

While the octane of a particular gasoline grade is constant, the RVP specification is adjusted during the onset of two key periods during the year: summer and winter. For proper engine operation a distinct amount of vaporization is needed. RVP is a specialized parameter that offers a comparative assessment of the volatility of hydrocarbons such as gasoline. It is essentially a metric of the seasonal utility of fuels as well as their potential to contribute to pollution.

As atmospheric conditions change, gasoline of a fixed RVP will combust at different temperatures and pressures in accordance with the ideal gas law. During winter months higher vaporization is required so that fuel flows easily to an engine; during summer months, excessive vaporization can clog fuel lines making a vehicle inoperable as well as contribute to ground-level pollution.

Consequently, the blending of gasoline is adjusted based upon the season to achieve the target RVP, with higher values required in the winter and lower values in the summer. Summer gasoline blending components are more costly causing gasoline prices to shift 10 to 50 cents during the switch from winter to summer blends.

Biofuels

Ethanol (grain alcohol) is an alcohol produced through the fermentation of sugar using yeasts. There are a variety of feedstocks; but the one used most frequently in the U.S. for motor fuel production is corn.

Ethanol has a long and varied history of being both an alternative and additive to petroleum-based gasoline. Henry Ford's first motor vehicle in 1896 was designed to run exclusively on ethanol, not naphtha. Beginning in the 1990s with the increased need for oxygenates, ethanol was one of the additives along with MTBE (methyl tert-butyl ether). Currently, because of mandates, ethanol is blended into almost all gasoline sold in the U.S.

Distribution

In the U.S., the primary distribution mode for refinery-produced gasoline and gasoline blending components are product pipelines. Since the 1930s, the U.S. has commissioned an extensive system of product pipelines that stretch from places such as the refining centers along the Gulf Coast towards the Southeast, Northeast, Upper Midwest, and Eastern Rockies. Other pipelines such as the Buckeye system move products between the Northeast and Midwest.

In addition to pipelines, other modes for moving gasoline and its components from refineries include product tankers and river barges. Biofuel components, which are mostly produced in Midwestern agricultural regions, are generally moved by rail.

The penultimate stop before filling stations are terminals. Comprised of tanks, pumps, and truck racks, terminals are at the receiving end of pipelines, rail transport. and waterborne vessels. From there, tanker trucks move gasoline and other petroleum products to filling stations and other points of consumption.

Regulations - Pollution Mitigation, Biofuel Blending Mandates, California, and Labeling

- Pollution mitigation

Beginning in the 1950s, published studies began to document tight correlations between motor vehicle pollution and smog-filled skies. Momentum increased for regulation and oversight of these and other related phenomena. This culminated in three key things:

- the 1969 passage of the National Environmental Policy Act (NEPA) that led to, among other things, the establishment of the Council on Environmental Quality in the Office of the President;
- the 1970 passage of the Clean Air Act (CAA);
- President Nixon's 1970 establishment of the Environmental Protection Agency by executive order (soon after approved by the U.S. Congress).

Together, NEPA, CAA, and EPA formed the foundation for national environmental regulations that were to follow (these and other key legislation is listed in *Table 2).* They have given EPA broad authority to regulate the handling and combustion of fuel that contribute to air or water pollution that may endanger public health.

Table 2: Key Legislation and Executive Orders

Year	Legislation
1969	National Environmental Policy Act (NEPA)
1970	Clean Air Act (CAA)
1970	Environmental Protection Agency
1975	Energy Policy and Conservation Act
1978	Energy Tax Act
1980	Energy Security Act
1990	Clean Air Act amendments
2005	Energy Policy Act (RFS first established)
2007	Energy Independence and Security Act of 2007

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These regulations have become increasingly stringent with time. In order to comply, motor vehicle manufacturers have re-engineered engines as well as fuel and exhaust systems; fuel producers and blenders have adjusted gasoline formulations and blending procedures.

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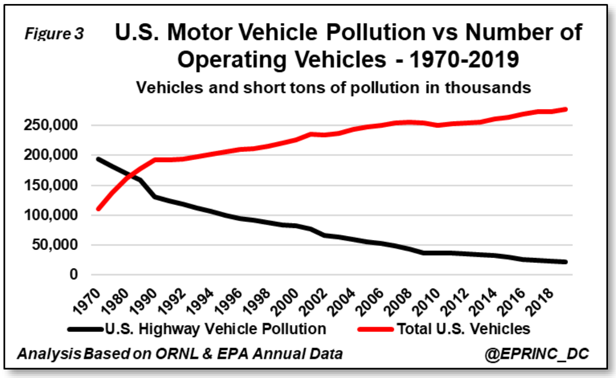
The impact they have made on can be seen by the considerable decline in the motor vehicle pollution emitted (*Figure 3*).



- Biofuel Blending Mandates

During the Great Depression with the oversupply of agricultural products, Midwest farmers in Illinois and Iowa lobbied for national mandates for the use of alcohol produced from U.S. crops to be blended into gasoline. However, their efforts were unsuccessful.

But it is during periods of supply constraints and shortages, policymakers sought ways to produce motor fuel from agricultural sources. In the late 1970s and during the time surrounding the 1979 Iranian Revolution, President Jimmy Carter signed both the Energy Tax Act of 1978 and the 1980 Energy Security Act. The former instituted an exemption to the 4 cent per gallon U.S. gasoline excise tax in gasoline blends; the latter earmarked funds for research into and additional subsidies for ethanol production and blending into gasoline. In December 1980, President Carter signed an executive order requiring all federal agency vehicles, where possible, to use 10% ethanol/gasoline blends. The order created the neologism "gasohol" to describe the blend.

Facing another period of tight supply/demand balances and high prices during the mid-to-late-2000s, legislators saw domestically produced ethanol as an antidote to high-cost foreign petroleum imports. Ethanol blending received a boost first from the 2005 Energy Policy Act and then fortified by the 2007 Energy Independence and Security Act. Combined, this legislation is known as the Renewable Fuel Standard (RFS); it mandates increasing volumetric (in the case of gasoline, designating the explicit minimal amount of ethanol required in the gasoline blend) blending of ethanol into gasoline, ending in 2022 with a total requirement of 36 billion gallons of which 15 would be from corn. From that point on, EPA would have full discretion over volumetric mandates.

Compliance is validated using RIN (renewable identification number) credits: with each ethanol gallon blended into gasoline, blenders submit one RIN to EPA to show compliance. If blenders fail to acquire sufficient RINs through blending to show compliance, they may purchase them from others who hold a surplus.

- California: EPA Waiver Authority and California's Low-Carbon Fuel Standard (LCFS)

Given the mid-20th-century severity of California's motor vehicle pollution problems, the state undertook aggressive regulatory action. But once national environmental regulatory activity accelerated during the 1960s and 1970s, it explicitly pre-empted states from adopting and enforcing their own standards.

However, provisions were made in the 1970 CAA (known as "Section 209(b)") for the EPA Administrator to grant waivers if a state's standards will be, "in the aggregate, at least as protective of public health and welfare as applicable federal standards," In addition, these waivers were granted only if they were not "arbitrary and capricious;" sought to meet "compelling and extraordinary conditions;" and technically feasible and providing adequate lead time to manufacturers.

Under the CAA waiver authority, California has been successful at least 50 times in requesting and receiving waivers. California's waivers have affected the design of vehicles' fuel and exhaust systems as well as gasoline blending. Following the authority that was successfully granted to California, other states adopted California's initiatives.

California's most contentious waiver request has been to adopt greenhouse gas (GHG) regulations applicable to motor vehicles and fuel. This was predicated on the U.S. Supreme Court April 2007 ruling in Massachusetts vs EPA granting EPA authority to regulate GHG emissions. It has gone through four iterations of rejection and acceptance, As of March 2022, it was reinstated through authorization by the Biden Administration's EPA Administrator Michael Regan.

Separately, California passed LCFS legislation, the goals of which are to lower the carbon intensity (CI) of transportation fuels along with reducing petroleum use. The LCFS was first enacted in 2009 targeting a CI decrease of at least 10% by 2020 from a basis in 2010; 2018 amendments extended the program through 2030 requiring another 10% CI reduction.

The LCFS program uses a credit-trading mechanism to achieve its targets. Any regulated party that is not able to do so needs to purchase credits; the cost of the credits are passed through to the final price of gasoline.

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- Labelling

On retail gas pumps, octane labelling is under the jurisdiction at the national level of the Federal Trade Commission (FTC). The FTC has precise specifications as to the size, color, and font of octane information on pump labels. With respect to other additives such as ethanol, the FTC also requires labelling for ethanol blends above 15%. Other labelling requirements are controlled by state and municipal authorities.

Blending

Initially, gasoline blending was determined by operational requirements. As mentioned, higher engine compression required increasing amounts of octane. The least cost octane solution was lead. Consequently, gasoline formulations were primarily a mixture of naphtha and TEL (tetraethyl lead) with TEL amounts peaking at 1.5 grams per gallon from 1950 to 1980. Beginning in the early 1970s, gasoline formulations have become increasingly determined by environmental and blending mandate regulations.

- Transition away from lead

Possibly the most extensive shift in U.S. transportation was the transition from lead to unleaded gasoline. In order to improve air quality, especially the removal of harmful ozone-precursors, vehicles needed to be assembled with pollution control equipment such as exhaust catalytic converters; for the catalytic converters to work correctly, unleaded gasoline needed to be used. More reformate and other gasoline blendstocks needed to be produced to replace lead; this required increased capital investment in refiners' conversion capability. Additional capital investment needed to be made at filling stations with the addition of new tanks and pumps. Finally, consumers needed to purchase new vehicles. Beginning with model year 1975, lead was progressively eliminated from gasoline with the last sales of leaded gasoline taking place in 1996.

- Development of reformulated gasoline (RFG)

With the 1991 CAA Amendments, more stringent pollution control regulations were promulgated that further tightened targeting ground-level ozone precursors. Regulations also increasingly required fuller combustion of aromatics.

Certain areas of the U.S. are designated by EPA as having "nonattainment" status; this indicates that the region is not able to comply with NAAQS standards and is prone to smog. This has led to expanded use of oxygenates such as MTBE and ethanol. These designated areas use a formulation of gasoline known as "reformulated" (RFG) having lower RVP and lower amounts of aromatics, especially benzene. The first phase of the RFG program began in 1995 and the second (current) phase began in 2000. RFG is currently used in parts of 16 states, the District of Columbia, and all of California. About 25% of gasoline sold in the U.S. is reformulated.

California instituted several in-state RFG programs that have been more stringent than those at the national level. The first program was implemented in 1991 eliminating lead before the rest of the U.S. and setting limits on RVP. The second further lowered limits on sulfur, aromatics, and RVP that began being sold in June 1996.

- Tier 2 and Tier 3: maximum sulfur requirements

In 2000, EPA finalized the Tier 2 sulfur rule. Sulfur in gasoline impairs the implementation of more stringent emission control systems in motor vehicles, as well as contributes to air pollution. The Tier 2 rule specified that beginning in 2004, gasoline as shipped from a refinery would contain no more than 30 parts per million (ppm) of sulfur. Tier 2 rules were strengthened with the promulgation of Tier 3 sulfur rules effective in 2017 lowering maximum gasoline sulfur levels to 10 ppm.

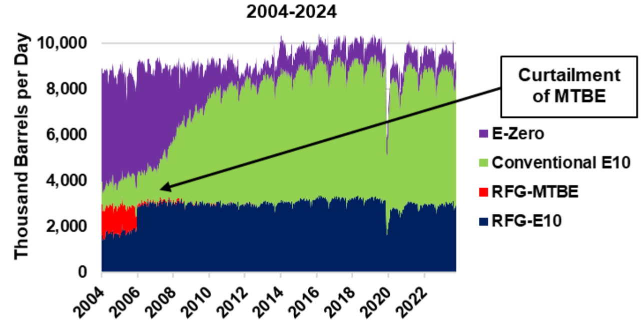
- MTBE bans and use of ethanol

MTBE at very small concentrations contaminates water supplies giving it a turpentine odor (15-45 parts per billion). Higher concentrations bring on health reactions such as nose and throat irritation. While the EPA did not explicitly ban the use of MTBE, individual states did. California's third RFG program began banning MTBE in January 2003 and completed in 2004; twenty-six states joined California and subsequently banned MTBE within a two-year period. By default, ethanol has become the dominant oxygenate used almost exclusively. The 2005 and 2007 Energy Acts elevated ethanol's use mandating increasing volumes to be blended into gasoline through 2022.

Figure 4 shows the evolution of formulations in response to regulations (E-Zero is a non-ethanol blend used in vehicles such as motorboats and snowmobiles whose tanks are prone to collect considerable moisture).

Figure 4 **U.S. Gasoline Production by Formulation**

2004-2024



Analysis Based on Weekly EIA Data *EPRINC*

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Ethanol has its own operational challenges. In particular, it can absorb water up to 100% of its mass. When the ethanol in an ethanol-gasoline blend has absorbed enough water, it will separate from the gasoline (a process known as phase separation) making the gasoline unusable. For this reason, gasoline-ethanol blends are not transported in pipelines where water often collects. Rather, ethanol is blended into tanker trucks at terminals just before delivery to filling stations. Ethanol-blended gasoline also requires more stringent standards when handled at filling stations where water contamination can also take place.

Table 3 shows a simplified example of contemporary gasoline blending using 10% ethanol with an AKI representing regular gasoline and an RVP suitable for summer use.

***Table3*: Gasoline Blended With Two Refinery FeedStocks & Ethanol = E10**

Blendstock	Blend vol%	RON	MON	AKI	RVP	Aromatics vol%	BTU/gal
Naptha	45%	63.7	61.2	62.4	10.8	2.2	101,550
Reformate	45%	109.3	100.4	104.9	1.0	94.2	104,145
Ethanol	10%	132.0	106.0	119.0	11.0	0.0	76,330
Volume Average Blending	100%	91.1	83.3	87.2	6.4	43.4	100,195

* Octane numbers - RON & MON do not necessarily behave linearly when blended. These values are provided for illustration.

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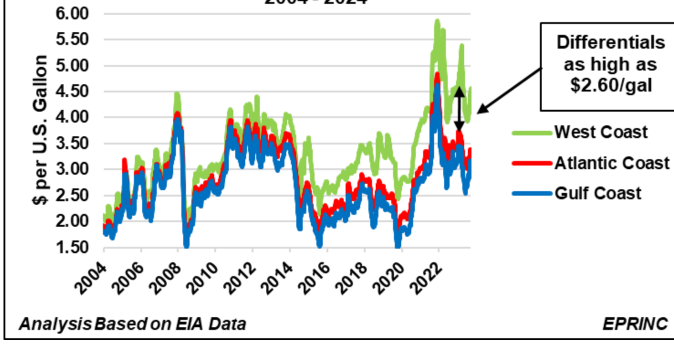
Policy Considerations and Issues

Gasoline blending first focused on operational issues and standardization. Refiners produced gasoline formulations that sought to meet performance requirements of motor vehicles and to be standardized across a wide geographic space.

In response to environmental pollution from motor vehicles, gasoline blending has been increasingly determined by regulations since the 1960s. New and different blending components have been introduced to meet both environmental needs while maintaining octane and RVP standards. This has led to the reduction of pollution, an important and necessary achievement.

Biofuel mandates and the LCFS in California, coupled with their respective credit trading programs, introduce another layer of regulations determining gasoline formulations. All combined, compliance has become more complicated and costly with these costs passed through to consumers. Note the recent differential between West Coast (i.e. mostly California) gasoline and other regional prices in *Figure 5*.

Figure 5 **Weekly U.S. Regular Gasoline Prices**
2004 - 2024



In 2018 and 2019, the U.S. House Energy & Commerce Committee deliberated the 21st Century Transportation Fuels Act. While the legislation never left the Committee, legislators tried to address the complexity of the myriad of regulations governing gasoline production along with other motor vehicle environmental standards, Committee legislators sought to streamline compliance by producing one set of regulations while maintaining and improving environmental and fuel efficiency goals.

More broadly, challenging large-scale aggressive policy initiatives to lower petroleum use to achieve more stringent GHG emission targets pose significant risks. Limiting legacy petroleum production usage especially of products such as gasoline before any reliable alternatives (both energy sources and vehicles) of equivalent commercial and operational utility are available could impair the national economy and the strategic position of the U.S.

- Direct and Near-Term Issues

As mentioned, ethanol blending has been politically contentious since the 1930s with interests vying to control mandates. In particular, ethanol is corrosive and damaging to those untreated metal, plastic, and rubber components that it comes into contact in motor vehicles and filling station underground storage tanks (USTs).

Currently, 10% ethanol-gasoline blends (E10) can be used in motor vehicles and handled by all USTs. However, higher ethanol gasoline blends pose challenges: most motor vehicles assembled since model year 2001 can use ethanol gasoline blends up to 15% (E15). However, a large portion of filling USTs have not been certified for E15 or higher. Adding new USTs, capable of E15 or higher blends, is costly, especially for low-margin businesses such as filling stations.

In addition, ethanol gasoline blends of 15% or higher increase a gasoline's RVP; higher RVP increases a gasoline blend's evaporative emissions. Those evaporative emissions increase ground-level pollution. E10 already is exempt by 1 psi so that it can be sold during summer

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months. E15 and higher sales are generally not allowed during summer months. Nevertheless, beginning with the 112th Congress (in session from 2011 to 2013), legislators have sought RVP exemptions so that E15 and higher blends could be sold year-round. The justification used by E15 proponents is that E15's RVP is indistinguishable from that of E10.

But on April 19, 2024, EPA announced that it would allow "the continued sale of E15 during the summer driving season" to address "extreme and unusual fuel supply circumstances caused by a confluence of events, including the ongoing war in Ukraine and conflict in the Middle East, that are affecting all regions of the Nation."

In addition, in April 2022 eight states petitioned EPA for a permanent waiver on year-round E15 sales. EPA granted the waiver in February 2024, effective April 28, 2025. EPA's brought criticism from trade associations saying that the eight-state ruling created multiple specifications for gasoline indicating that there would be higher costs producing for different markets and jurisdictions.

Further Reading

- *Octane: Pathway to a Compromise?* – joint author – (February 14, 2019) – assessment of proposed H.R.4690 – 21st Century Transportation Fuels Act.
- *Understanding California's High Transportation Fuel Prices* – sole author – (November 2016)
- *CAFE, Gasoline Prices, and the Law of Diminishing Returns: A New Agenda for the Midterm Evaluation* (also published in O&G) – joint author – (March 2016)
- *Biofuel Mandate: Technical constraints and Cost Risks* – lead author (November 14, 2015)

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