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Can Octane Play a Cost-Effective Role in Lifting Automobile Fuel Efficiency Standards?

Automobile manufacturers have been facing increasing regulatory requirements to meet to fuel efficiency standards under U.S. and state laws since the 1970s. Fuel efficiency improvements for automobiles can be achieved through improvements in technological advances in automobile engine performance and car design, and these advances often require modifications to fuels used to power the engines. As the fuel efficiency standards have become more stringent, manufacturers are exploring a range of alternatives to meet the new standards, including new fuels. One such proposal is to substantially raise octane in US transportation fuels to permit the deployment of higher compression and thereby more fuel-efficient vehicles.

In response to these proposals, EPRINC has initiated a research effort to evaluate both the cost and feasibility of deploying alternative fuels for the American auto fleet. The initial project is focused on evaluating the costs and benefits of raising octane levels for motor fuels and this note outlines the research effort. A detailed assessment of lifting octane levels will be issued later this year.

Corporate Average Fuel Economy (CAFE) Standards were first adopted in 1975 through the passage of EPCA 1975 (The Energy Protection and Conservation Act of 1975). The purpose of the Standards has been to increase fuel efficiency in newly manufactured vehicles, thereby limiting fuel consumption. Because of public opinion, Congress was unwilling to reduce gasoline consumption through taxes. Instead, Congress passed a mandate under EPCA requiring manufacturers and marketers to assemble and sell vehicles with minimum fuel efficiency performance, increasing incrementally with each model year (MY). The enforcement and recalibration of the CAFE standards has been uneven; but by most analyses the program has caused fuel economy to approximately double between the 1970s and the mid-1980s. The program has continued to go through more extensive revisions and the most recent standards set in 2012 are now under review. EPRINC has written on some of the challenges facing the program and links to those papers are at the end of this note.

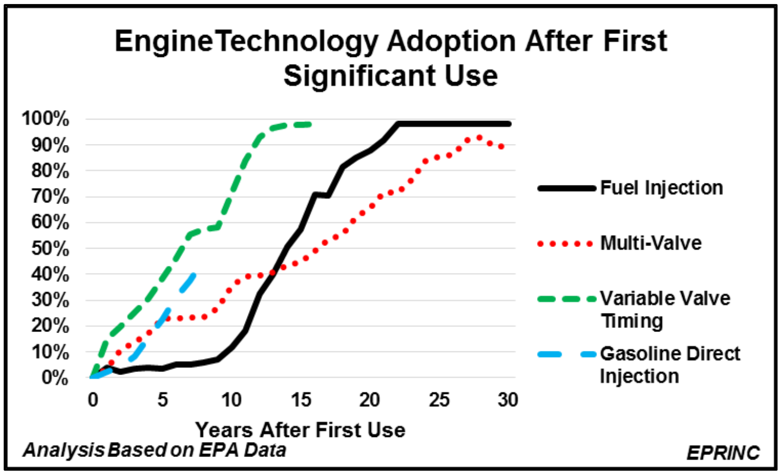
In order to meet the CAFE MY 2022-2025 goals, there are several compliance paths under consideration; the choices are not mutually exclusive. These would include the increased production and marketing of electric-powered vehicles (EVs). If EVs were the sole option, this would involve a considerable re-allocation of capital as well as a shift in design and manufacture, requiring new infrastructure and realignments of fueling/re-charging. Another compliance path is the increase of gasoline octane levels in order to design and produce vehicles with higher engine compression ratios, lower engine displacement, more efficient fuel delivery systems, higher gearing, and extensive engine valve and cylinder modifications.

Octane is a term that originally denoted a hydrocarbon molecule that is composed of eight carbon atoms. Some of the first anti-knock blending components that were used were octanes. Since then other components have been introduced and continue to be used to deal with a spark-ignited engine's propensity to knock. While they might not be "octanes" in the literal sense, their anti-knocking effectiveness is determined by their "octane-rating" or "octane number."

An octane number or rating is a representation of how much gasoline can be compressed before it spontaneously ignites, unassisted by a timed spark. Computation of the octane-ratings of gasoline components are obtained from standardized testing procedures by various standards-setting organizations calibrate octane. In the U.S., ASTM International (originally American Society for Testing and Materials), a voluntary, consensus organization established in 1898, is the authoritative organization for validating octane-rating procedures.

There are two principle octane-rating methodologies that are used: 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.

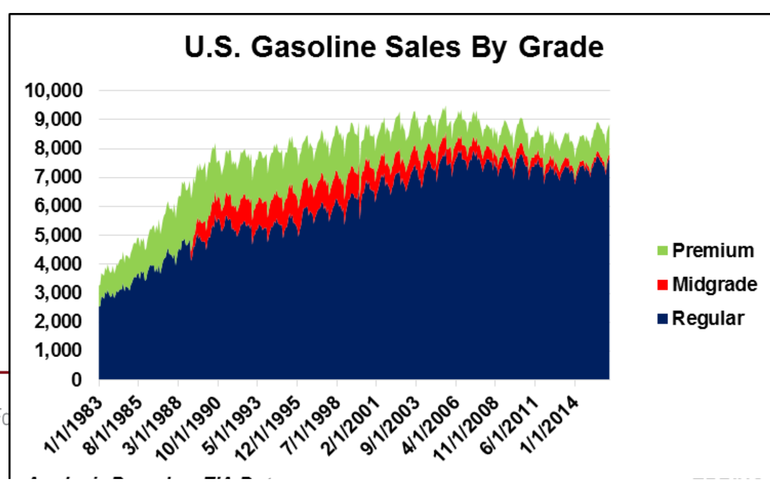
For a any gasoline formulation, the difference between RON and MON indicates the sensitivity of the gasoline to changes in operating conditions. In the U.S., the octane-rating that is posted on gasoline pumps is the average of RON and MON; this average is also referenced as the AKI (anti-knock index).



While substantial progress has been made through incremental improvements and innovations to existing engine, transmission, and exhaust technologies, manufacturers are signaling that new higher-octane gasoline will be necessary in order to successfully implement the final stage of the CAFE standards. In order to produce marketable vehicles with higher fuel economy at existing and increasing demand for horsepower, engines will require higher compression-ratios; in order for these new engines to be functional, higher-octane fuels will be required.

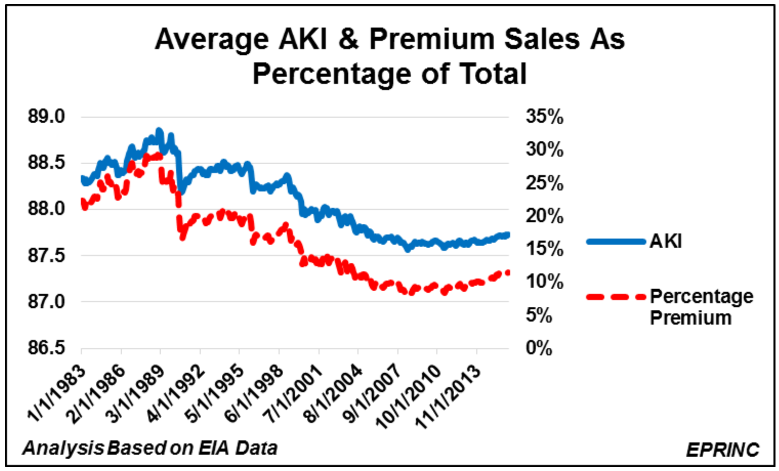
One of the proposed high-octane fuels would be a gasoline with a 100 RON and a 95 AKI. This would allow for the assembly of engines with a 14-to-1 compression ratio, up from the current average of 10.5-to-1, a considerable step-change. Even though, gasoline is sold at the pump in three formulations based on octane-level (87 AKI, 89 AKI, and 93 AKI), the weighted average AKI of all gasoline sold has incrementally declined from a peak of 88.75 in 1989 to current levels of 87.5. This indicates that there is considerable distance to achieving the production and marketing of a 95 AKI gasoline. Proponents have proposed various names for this high-octane gasoline formulation, including "National Clean Gasoline" and "Super Premium."

Furthermore, current high-octane gasoline is marketed as a premium fuel, geared towards performance-oriented vehicles and consumers, not fuel-efficiency buyers. Overall, premium sales have been declining as a percentage of total U.S. gasoline sales from 22.3% in 1983 to a low of 7.8% in



2008. However since then, they have partially recovered to current levels of 11.4%. This is generally attributed to the increasing sales of vehicles equipped with "turbocharged-and-downsized" engines, requiring higher octane.

Last, implementation of a new gasoline formulation would raise compatibility issues. There is a significant base of agricultural machinery, marine transportation, power tools such as chainsaws, and lawn and garden maintenance equipment that relies on gasoline for fuel. Some sort of resolution would have to be made.



Some of our existing analysis suggests that enhancements to existing gasoline-powered engine technology are small to manufacturers; possibly less than 5% of the total price of currently produced vehicles. However, compliance costs of moving to alternative powertrains such as hybrids, electrics, and diesels represent would add 20% to 30% abo e current production costs.

If oxygenates would be the sole source for octane, then ethanol blends for conventional motor vehicles (not flex fuel vehicles - FFVs) would have to be increased from 10% to 20%. This would mean that at the point of full 95 AKI saturation and no change in gasoline consumption levels, the requirement for fuel ethanol would have to rise from 13 BGY (billion gallons per year), or 874 TBD (thousand barrels per day) (10% blend levels - E10) currently to approximately double this. Given the lack of development of cellulosic and advanced ethanol, the overarching majority of ethanol would be sourced from corn. This would mean that dedicated acreage for corn ethanol would have to almost double (the non-linearity assumes that corn crop yields continue increasing) from 36% of current harvested acreage to possibly 70%, putting considerable pressure on food prices, greater production from grasslands, and the associated environmental consequences from a rapid increase in corn production.

Our initial work indicates that moving to higher octane fuels will not be a low-cost initiative, but our research will provide a more detailed assessment of this conclusion. As policymakers move forward to evaluate the costs and benefits of higher fuel efficiency standards, it will not be enough to evaluate only the cost of building the new automobile, but also the cost of producing the fuels to power those automobiles.

Further Reading

Links to previous EPRINC downstream reports

EPRINC's Updated Primer on Gasoline Blending
http://eprinc.org/2015/06/eprincs-updated-primer-on-gasoline-blending/

Condensate: An EPRINC Primer
http://eprinc.org/2015/02/condensate-eprinc-primer/

The Biofuel Mandate: Technical Constraints And Cost Risks
https://www.dropbox.com/s/j9lw1i7urw2fwc6/Biofuel%20Mandate%20Nov%202015.pdf?dl=0

CAFE, Gasoline Prices and the Law of Diminishing Returns: A New Agenda for the Midterm Evaluation. http://eprinc.org/2016/03/cafe-gasoline-prices-and-the-law-of-diminishing-returns-a-new-agenda-for-the-midterm-evaluation/

Lucian Pugliaresi testified before the U.S. Senate Committee on Environment & Public Works on February 24, 2016. The topic was the Renewable Fuel Standard. There were a series of follow-up questions from Senator Deb Fischer of Nebraska. Lucian Pugliaresi and Max Pyziur prepared answers for the record. Both the testimony and the responses to Senator Fischer are part of the official record of the Senate. A copy of the testimony can be found here: http://eprinc.org/wp-content/uploads/2016/03/Testimony-before-EPW-on-RFS-Feb-24-2016.pdf

A copy of the follow-up questions and responses can be found here: http://eprinc.org/wp-content/uploads/2016/04/ResponseToQuestionsFromSenatorDebFischerApril2-2016.pdf