Influence and Importance of Fuel Octane in Future Engine Developments

Executive Summary prepared for Renewable Fuels Association by Ricardo
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Summary

Regulatory standards for reduced greenhouse gas emissions and pollutants will require significant changes to light duty vehicles and their powertrains. Vehicle electrification will be part of the solution, but OEMs still predict the vast majority of vehicles sold through 2025 in the United States will use gasoline-fuelled, spark-ignited internal combustion engines as the primary form of propulsion.

So if it is expected that battery-only electric vehicles will represent only a niche market by 2025, how will OEMs respond to converging emissions and fuel economy regulatory requirements over the next decade? Several technology options are sufficiently developed to enable vehicle performance under tightening regulatory requirements. These technologies include advanced boost systems, direct injection fuel systems, advanced valvetrains, changes to compression ratio, and advanced fuels. In fact, the turbo-boosted, downsized engine technology that is currently being adopted by OEMs could be further used if the minimum octane level of the motor fuel pool was increased from base levels used today.

	2010	2025
Gasoline based fuels	92%	74% (25–80%)
Diesel based fuels	6%	6% (5–20%)
HEV	2%	9% (4–15%)
PHEV/EREV	0%	9% (5–25%)
CNG	0%	2% (1–12%)
Fuel Cell	0%	0%

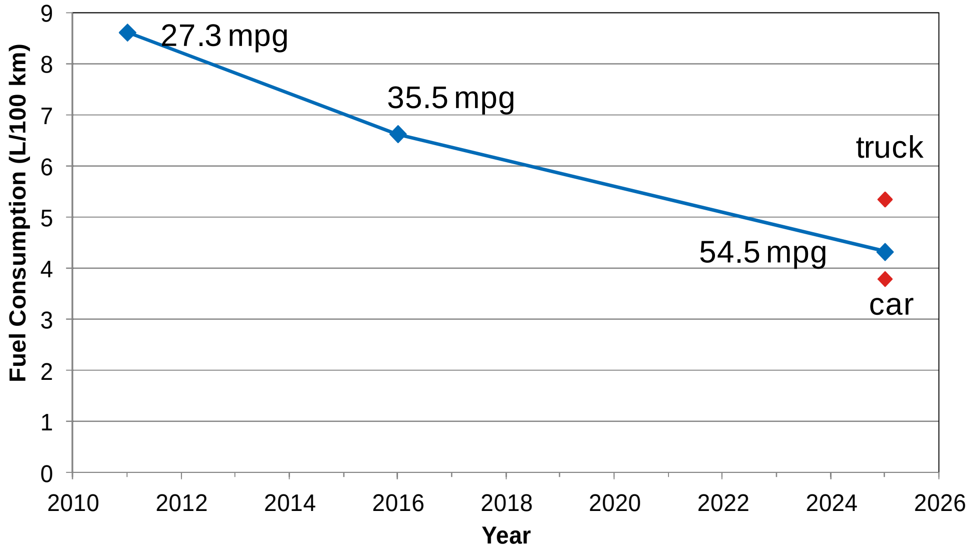
Potential Market Share of Light Duty Powertrains over 15 Years

What Is Octane?

Octane rating or octane number is a standard measure of the anti-knock properties (i.e., the performance) of a motor or aviation fuel. The higher the octane number, the more compression the fuel can withstand before detonating. The conventional Pump octane number, shown as (R+M)/2, averages the Research Octane Number (RON) and the Motoring Octane Number (MON), which are both measured by testing.

Regulatory Requirements Will Drive Development Of Light-Duty Vehicles

The effect of the recently proposed Federal regulations from the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) and the U.S. Environmental Protection Agency (EPA) on today’s spark ignition engine technology is still uncertain. The standards will raise fleet fuel economy standards while lowering greenhouse gas emissions, but do not mandate vehicle technologies. The proposed fleet fuel economy target will increase from 35.5 mpg in Model Year (MY) 2016 to 54.5 mpg in MY 2025, including 62.0 mpg for passenger cars and 44.0 mpg for light trucks. This represents a 50% cut in fuel consumption for new vehicles sold in MY 2025 from those sold in MY 2011.



Proposed Fuel Economy Legislation–Current Model through to MY 2025

For vehicle manufacturers, meeting these proposed regulations will require significant investments in all aspects of a vehicle affecting fuel economy or greenhouse gas emissions. Vehicle electrification will be part of the solution, but the vast majority of vehicles sold through 2025 are expected to have internal combustion engines in them, in both conventional and hybrid vehicles.

In parallel, the California Air Resource Board's proposed LEV III rules for pollutants starting with MY2022 vehicles will set a de facto national standard that will be increasingly expensive to meet with Diesel engines. The primary challenges are developing increasingly complex engines that emit less pollutants and increasingly complex and expensive aftertreatment systems to clean up the diesel exhaust, all at a competitive price.

Proposed LEV III NMOG+NO$_x$ Emission Standards				
Category	Existing NMOG standards [a] (g/mi)	Existing NO$_x$ standards [a] (g/mi)	Combined NMOG+NO$_x$ standards (g/mi)	Proposed NMOG+NO$_x$ emission standards [b] (g/mi)
LEV	0.090	0.070	0.160	0.160
ULEV	0.055	0.070	0.125	0.125
ULEV70	–	–	–	0.070
ULEV50	–	–	–	0.050
SULEV	0.020	0.010	0.030	0.030
SULEV20	–	–	–	0.020

[a] *120,000-mile durability basis*
[b] *150,000-mile durability basis.*

Proposed California Air Resource Board LEVIII Emission standards for light duty vehicles

What Options Are There?

Technology	Benefit	Cost	Vehicle Manufacturers Using
Advanced Fuels	+	0	n/a
Compression Ratio Increase	+	0	All
Cam Profile Switching	++	$$	Honda, Mitsubishi, Porsche, Audi
Active Valvetrain	+++	$$$	Fiat, BMW
Direct Injection Fuel Sys.	++	$$	Mitsubishi, Audi, GM, Ford, BMW, etc.
Turbocharging	++	$$	Ford, Volvo, GM, Audi, BMW, etc.
Advanced Boosting systems	+++	$$$	None
Exhaust Energy Recovery	+	$$$	Commercial vehicles

The costs and benefits of the leading fuel economy improvements show that a mix of options are available to manufacturers. The benefits indicated in the table above are not simply additive—some synergies are possible, but conflicts are also. Higher octane fuels will facilitate changes to engine compression ratio, direct injection fuel systems, and higher boost pressures.

Conclusions

During the next decade internal combustion engines will become significantly more efficient due to pressures from regulatory and consumer preference.

- Fleet fuel economy targets in the US will require significant changes in engine technology over the next 10–15 years
- Vehicle electrification will be part of the solution, but the vast majority of vehicles sold in 2025 will use internal combustion engines as the primary form of propulsion

  - Battery-only electric vehicles will only represent a niche market
- Engines will have higher specific power (power per displacement) from using technologies such as
  - Direct injection
  - Turbocharging, supercharging, and other advanced boost systems
  - Higher compression ratios

A higher fuel octane number moves the knock limit further from normal operation, which will support fully stoichiometric operation at high speed and high load. This benefit will lower fuel consumed to enrich the operation in this regime, which will also lower engine-out pollutant emissions.

Similarly, higher minimum fuel octane number will facilitate the engine technologies that will boost specific power and engine efficiency. Future powertrain solutions will have a natural thirst for higher octane fuels.