FUEL FREEDOM®

October 26, 2018

To: **Environmental Protection Agency (EPA)**
National Highway Traffic Safety Administration (NHTSA)

From: Robin Vercruse - Vice President of Policy and Environment, Fuel Freedom Foundation

Re: **EPA Docket ID: EPA-HQ-OAR-2018-0283**
NHTSA Docket: NHTSA-2018-0067 (Submitted via http://www.regulations.gov)

Introduction and Overview

These comments are submitted on behalf of the Fuel Freedom Foundation, in response to the *Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks.*

Fuel Freedom Foundation is a non-profit 501(c)(3) organization that conducts research and advocates for policies that will increase diversity and market competition when it comes to transportation fuels, in particular for cars and light-duty trucks. Fuel Freedom believes that a more diverse fuel pool will help to achieve a number of important U.S. public policy goals:

- Improve national security by reducing our dependence on petroleum
- Mitigate recurring macroeconomic effects of petroleum dependence
- Reduce emissions of greenhouse gases (GHG)
- Improve public health by reducing emissions of toxic and criteria air pollutants
- Increase economic opportunities from greater use of U.S. domestic sources of fuel

Consequently, Fuel Freedom supports the National Program and its primary goals: to improve fuel economy, reduce GHG emissions, and decrease petroleum use**. These goals are intimately entwined with our fundamental national interests. We cannot afford to stall or go backward. Joining Fuel Freedom in urging continued progress in fuel economy and in reducing both petroleum use and GHG emissions are more than 24,000 signers of the petition in Appendix A.**

The Corporate Average Fuel Economy program was established by Congress in the wake of the 1970s oil crisis. While the consequences of oil dependence were more obvious at that time, U.S. strategic interests remain no less bound to the economics and geopolitics of petroleum.

The strategic imperative to reduce petroleum dependence has not vanished by record-breaking domestic drilling. Oil prices have risen 24% in 2018 alone,[1] as the U.S. surpassed Saudi Arabia as the world's largest producer. We remain subject to such price fluctuations, driven by geopolitics and market dynamics that reflect a lack of fuel alternatives.

[1] As of Oct 5, 2018 per EIA https://www.eia.gov/dnav/pet/pet_pri_spt_s1_w.htm

Our national options remain inhibited by overwhelming petroleum dependence in transportation. We can only gain genuine energy and economic security by weakening oil's strategic consequence. The National Program provides essential tools to move us in the right direction.

Instead, the preferred option in the SAFE rule proposes to reverse course by increasing oil consumption by up to 500,000 barrels per day. It effectively brushes aside the Congressional mandate designated by NHTSA: to reduce petroleum use by setting the maximum feasible fuel economy that automakers can achieve in a given model year. It further proposes to minimize or eliminate incentives for production of vehicles that use non-petroleum-based fuels.

On the EPA side, transportation is the largest source of GHG emissions in the U.S. The rise in atmospheric CO_2 and rising temperatures reflect an increasingly urgent need to mitigate potential impacts on health and human welfare. Yet the SAFE proposal's preferred option goes backward. The EPA has simply deferred its legal obligation to reduce greenhouse gas (GHG) emissions in light-duty transportation. This deferral not only ignores the EPA's own endangerment finding for CO_2, but compromises global competitiveness of U.S. industry when light-duty standards in the rest of the world are moving in the opposite direction.

In partnership, the agencies can effectively achieve National Program goals. By its requirement to reduce petroleum use, NHTSA's CAFE program is implicitly about fuels. However, its designated toolkit is indirect, through vehicle technologies. NHTSA's legal purview can and should be exercised by increasing vehicle fuel economy and incentivizing the manufacture of vehicles that can use fuels other than gasoline or diesel. EPA, with its mandate to reduce GHG emissions, has various avenues of authority over both tailpipe CO_2 and fuel. In order to maximize effectiveness of the National Program, the EPA should incrementally increase stringency of CO_2 standards, include GHG program incentives that complement NHTSA technology credits, and exercise its authority to remove barriers to use of fuel alternatives, enabling greater adoption of fuels with a lower carbon footprint than gasoline or diesel.

Fuel Freedom Foundation's (Fuel Freedom) comments focus on the following topics:

- Strategic imperative to reduce petroleum use
- Consumers and fuel economy standards
- Fuel economy and CAFE and GHG incentives to meet National Program goals
- Potential of high-octane for fuel economy and CO_2 emissions reductions
- Increasing octane in the marketplace
- Effects on global competitiveness
- Long-term GHG reductions in light-duty transportation
- Need to continue One National Program

These comments focus on the specific purview of the EPA and NHTSA as regulating agencies. However, as outlined in Appendix B, the following comments and recommendations embody and advance four of the Administration's stated priorities: reducing regulatory costs, promoting energy independence and national security, promoting rural prosperity, and ensuring clean air.

Strategic Imperative to Reduce Petroleum Dependence
Fuel Freedom strongly disagrees with NHTSA's assessment in the SAFE Proposed Regulatory Impact Analysis (PRIA) that U.S. domestic oil drilling and production has eliminated, or will ever eliminate, the broad economic and national security consequences of petroleum dependence. While the U.S. became the world's largest oil producing nation, prices have risen 24% in 2018, and we once again had to urge OPEC to ease prices on behalf of American drivers.[2] The PRIA assertion that "current prices [are] at their lowest levels in nearly a decade" is already outdated, and the increase refutes the implicit conclusion that U.S. domestic shale production controls the world price.[3]

As accurately noted in the SAFE PRIA, incrementally decreasing petroleum consumption does not significantly decrease the military spending to protect and ensure its flow around the world.[4] In other words, small measures will not disrupt the persistent status quo. **Only a fundamental shift in the marketplace can address our central vulnerability: no matter how much petroleum we produce in the U.S., our national interest, our security, and ultimately our economic welfare, continue to be inexorably inbound to the fate—and the price—of the global petroleum market.**

The PRIA attribution of no domestic economic cost to higher expected fuel and petroleum product expenditures that would result from the SAFE proposal[5] depends on the PRIA's assumption that the U.S. will be a net exporter of petroleum.[6] But that assumption is false. The underlying EIA data contradicts the PRIA's assertion that the U.S. will "become self-sufficient in petroleum supply…within a decade."[7] While the bottom line EIA number shows a negative import balance as of 2028, the table includes non-crude oil products such natural gas plant liquids.[8] Non-petroleum, non-transportation fuel products should not be credited to petroleum's energy account in the PRIA's assessment.

The U.S. currently consumes 14.7 million barrels per day of petroleum for transportation alone,[9] while the agencies' preferred option adds up to 500,000 barrels per day,[10] a non-trivial addition of 3.4% for the sector. Yet total U.S. production is projected to remain below 12 million barrels per day through 2050,[11] against total current use of 19-20 million barrels per day. This reality, and its economic and national security costs, should be fully accounted for rather than dismissed as without cost in the SAFE regulatory analysis.

U.S. domestic oil production—while welcome from an investment and employment perspective—cannot be isolated from its context as a global strategic commodity. Petroleum is effectively a single resource pool, indistinguishable in the fuel marketplace from its country of origin. The fact of oil's 92%

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[2] https://www.wsj.com/articles/trump-asks-saudi-arabia-to-boost-oil-production-1530360926
https://www.bloomberg.com/news/articles/2018-06-05/u-s-said-to-ask-opec-for-1-million-barrel-a-day-oil-output-hike
https://www.washingtonpost.com/business/2018/09/20/trump-urges-opec-drive-down-oil-prices/

[3] Preliminary Regulatory Impact Analysis (PRIA) for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks, p.1075

[4] PRIA p.8

[5] PRIA p.1071

[6] PRIA p.1073

[7] PRIA p.1073

[8] EIA, Annual Energy Review 2018, Table 11 https://www.eia.gov/outlooks/aeo/data/browser/#/?id=11-AEO2018&cases=ref2018&sourcekey=0

[9] Fuel Freedom analysis of EIA data

[10] PRIA p.101

[11] Annual Energy Outlook, EIA Reference Case, Table 11, Petroleum and Other Liquids Supply and Disposition https://www.eia.gov/outlooks/aeo/tables_ref.php

market share in transportation, and its consequences, extend well beyond our borders, but the costs are largely drawn from U.S. accounts.

By ignoring the national oil deficit, the PRIA also ignores a major potential benefit of displacing petroleum: new economic opportunities for domestic energy and domestically produced light-duty motor fuels. The economic transfer from fuel consumers to producers referenced in the PRIA need not benefit the petroleum industry alone.

Corn ethanol is currently the only major alternative to gasoline. It adds $44.5 billion to U.S. annual GDP in addition to 72,000 direct and 285,000 indirect jobs to the U.S. economy,[12] yet remains locked at about 10% of the U.S. light-duty liquid fuel pool.[13] Due to rising agricultural yields[14] and ongoing process efficiency improvements,[15] the industry has ample room to grow. Ethanol can also be produced from other energy feedstocks that are abundant in the U.S. Cellulosic ethanol may finally achieve a major breakthrough for large-scale commercial production. And China is already deploying U.S.-developed technology that was designed to produce ethanol from natural gas.[16]

Whatever the source, displacing petroleum imports with domestically-produced fuels has the potential to not only reduce the annual U.S. trade deficit by roughly 10-20%,[17] but could add about 160,000 direct jobs[18] and multiples of that in indirect employment. And finished motor fuels produced in the U.S., from domestic energy sources, need not just power vehicles within our borders. Unlike energy exports like LNG, gasoline and ethanol are easily transported to rapidly growing vehicle markets to boost the U.S. trade balance.[19]

The U.S. has the world's largest petroleum refining capacity. Refineries produce a flexible mix of fuels and other finished products depending on profitability and market demand. Any decrease in domestic gasoline and diesel consumption allows U.S. refiners to shift outputs or export more finished products to growing markets. Recent growth in exports of refined petroleum products closely match the increased use of domestic ethanol and other alternative fuels, suggesting this is already happening.[20]

Consumers and Fuel Economy

Fuel economy standards directly and measurably benefits consumers. Consequently, American drivers

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[12] Renewable Fuels Association industry data at http://www.ethanolrfa.org/issues/economy/

[13] President Trump recently announced support for year-round sales of E15, which may increase ethanol's portion, provided that EPA successfully undertakes the necessary rulemakings and state regulations which forbid or seasonally limit E15 sales, are eliminated.

[14] U.S. Department of Agriculture, "Record yield outlook sinks corn prices" https://www.agriculture.com/markets/analysis/record-yield-outlook-sinks-corn-prices accessed Oct 12, 2018

[15] USDA study found improvement in corn ethanol's energy balance, despite using the prior assessment's 2008 survey of dry mill energy, rather than more efficient current data. Gallagher, Yee and Baumes, U.S. Department of Agriculture, *2015 Energy Balance for the Corn Ethanol Industry* (2016) https://www.usda.gov/oce/reports/energy/2015EnergyBalanceCornEthanol.pdf

[16] U.S. chemical company Celanese this year announced a joint venture to produce ethanol in China https://www.businesswire.com/news/home/20180718005814/en/Celanese-Sell-Ethanol-Production-Unit-Form-TCX%C2%AE Accessed Oct 15, 2018

[17] U.S. Census Bureau, "Petroleum as a percent of the total trade deficit" https://www.census.gov/foreign-trade/statistics/graphs/PetroleumImports.html accessed Oct 12, 2018

[18] Based on industry averages for fuel production

[19] China is the largest auto market as of 2017, 60% larger than the second-place U.S. In 2017, 28.3 million vehicles were sold in China, compared to 17.2 million in the U.S. China will continue to drive growth worldwide. India and Brazil are the fastest growing markets, but far behind China and the U.S. in absolute terms. https://focus2move.com/world-car-market/ accessed Oct 12, 2018

[20] Based on Fuel Freedom analysis of EIA data

widely and consistently support increasing fuel economy standards,[21,22,23] perhaps because they recognize that fuel economy standards have saved them money. A Consumer Federation of America analysis released just this week found average savings of $864 over 5 years.[24] In addition to lower driving costs, Americans also support genuine energy independence, including greater use of ethanol in transportation.[25]

Consumer impacts are central to determining maximum feasible fuel economy and CO2 standards. Many consumers have recently moved away from passenger cars to larger vehicles. To date, these vehicles have provided the largest fuel cost savings to consumers and per vehicle benefits to the National Program due to their lower fuel economy baseline. Drivers have noticed. The Consumer Federation analysis also found that sales of SUVs, crossovers, and trucks with greater fuel economy gains were 20% higher than those with lower improvement. Noting the fact of diminishing returns for each mile of fuel economy improvement as standards rise,[26] the light truck category also provides the greatest potential for future consumer and National Program benefits due to their lower standard relative to passenger cars.

Passenger cars are suitable for a wide range of vehicle technologies, as reflected in the diverse offerings in the market today. Both mainstream and luxury OEMs are producing an array of electric options in particular. However, light trucks are less suitable for electrification due to expected vehicle attributes such as towing capacity, power and range. The SAFE Final Rule should account for this fact by encouraging the entire range of promising technologies, including those most suitable for continued improvement in the spark-ignition engines that dominate U.S. roadways, as well as the fuels to best power and enable them.

Fuel Freedom's comments provide recommendations that prioritize consumer choice and cost-effectiveness in urging continued progress toward National Program goals.

Fuel Economy and Program Credits

The CAFE standards can reduce petroleum use in two ways: increasing efficiency and encouraging the use of alternatives to gasoline or diesel. Yet, despite the urgent strategic imperative, and NHTSA's legal obligation to decrease petroleum use, the preferred option of the SAFE proposal does neither.

While Fuel Freedom believes that the specific maximum feasible fuel economy and CO_2 emissions targets for MY 2021-2026 are best negotiated between the agencies and the OEMs, we strongly believe that our national interests require that the final proposal continues to incrementally reduce oil consumption and GHG emissions rather than stall or go backwards. At the same time, **Fuel Freedom**

[21] American Lung Association, "Voters Overwhelmingly Support Strong Fuel Efficiency Standards" (2018) https://www.lung.org/assets/documents/healthy-air/poll-results-voters.pdf Accessed Oct 19, 2018

[22] Consumers Union, "Nearly 9 in 10 Americans want automakers to raise fuel efficiency, according to latest Consumers Union survey," https://consumersunion.org/news/2017-fuel-economy-survey/ (2017) Accessed Oct 19, 2018

[23] Gallup, "Americans Green-Light Higher Efficiency Standards" (2009) https://news.gallup.com/poll/118543/Americans-Green-Light-Higher-Fuel-Efficiency-Standards.aspx Accessed Oct 19, 2018

[24] Consumer Federation of America, "Auto Fuel Efficiency Saves Consumers Almost Four Times Its Technology Cost" (2018) https://yubanet.com/life/auto-fuel-efficiency-saves-consumers-almost-four-times-its-technology-cost/ Accessed Oct 25, 2018

[25] Luntz, F., "Our divided nation is united on energy independence" (2018) https://www.realclearpolitics.com/articles/2018/09/06/our_divided_nation_is_united_on_energy_independence_137992.html Accessed 19 Oct, 2018

[26] NPRM p.16, PRIA p.96

believes that reducing or eliminating program incentives or credits for alternative vehicle technologies is contrary to U.S. national interests. Such incentives have little to no regulatory cost, but significant potential benefits. They also provide flexibility for OEMs to meet the needs of their customers while advancing National Program goals.

Fuel Freedom takes no position on off-cycle or similar credits. However, the agencies should continue to offer program incentives for vehicles technologies that accelerate reductions of petroleum use or GHG emissions. This should include incentives for electric, natural gas and hydrogen fuel cell vehicles. The credits should reflect the long-term value of the technologies. While they remain in the early adoption phase, growing markets like China are aggressively pursuing automotive development. Discouraging investments in research and development during this rapid growth and maturation period can threaten the long-term global competitiveness of U.S. companies.

Equally worthy of consideration for program incentives are the vehicles currently preferred by the majority of American drivers—internal combustion engines (ICEs) powered by gasoline. Analyses project the continuing dominance of ICE vehicles in the light-duty fleet, in the U.S. and around the world.[27] By deploying advancements such as high-compression engines burning high-octane fuel, ICEs are for the near-term lower in cost and less disruptive to the consumer behavior, making them more likely to achieve large-scale petroleum displacement and GHG emissions reductions in the MY2021-2026 timeframe under review. And, critically for nascent electric and other vehicle technologies, ICE evolution can complement rather than supplant the maturation and growth of other alternatives.[28]

As intended by Congress, flex-fuel vehicles (FFVs) were designed to interchangeably use either gasoline or ethanol blends of 51-83% (E85) to assist a transition from petroleum-based to renewable fuels.[29] FFVs provide a number of benefits to National Program goals. They can use any ethanol blend up to 85%. If midlevel blends of 20-40% ethanol are introduced—as supported by research, stakeholders, and the agencies as documented in Appendices C and D accompanying these comments—FFVs would provide a ready market for the fuels, in advance of new models of compatible or dedicated high-octane vehicles. Further, greater use of renewable ethanol reduces not only tailpipe CO_2, but full fuel cycle GHG emissions relative to gasoline. Consequently, Fuel Freedom believes that FFVs should receive credit for the petroleum reduction value from NHTSA, as well as their GHG reductions from EPA. The same is true for future vehicles dedicated for use with midlevel ethanol blends.

Given the value of incentives to National Program goals overall, and their ability to provide compliance flexibility and minimize regulatory costs, Fuel Freedom recommends:

- NHTSA and EPA should harmonize CAFE and CO2 program credits, including provisions for carry over, to reduce the regulatory burden and provide maximum OEM compliance flexibility
- The agencies should continue to offer a range of program incentives for emergent vehicle technologies such as electric and hydrogen fuel cell vehicles, for natural gas-powered vehicles,

[27] Comparison of worldwide vehicle fleet projections from Bloomberg, Goldman Sachs, and IEA at https://www.fuelfreedom.org/cars-in-2050/

[28] Air Improvement Resource, *Evaluation of Costs of EPA's 2022-2025 GHG Standards With High Octane Fuels and Optimized High Efficiency Engines* (2016)

[29] Congress provided a statutory goal of encouraging "the development of widespread use of…ethanol…as transportation fuel by consumers" and "the production of…ethanol…powered motor vehicles." Alternative Motor Fuels Act of 1988, Pub. L. 100-494 § 2, 102 Stat. 2441, 2442 (1988)

and for ICEs that enable or encourage the use of renewable fuel, including FFVs and dedicated high-octane vehicles designed for compatibility with midlevel ethanol blends

- For vehicles designed to use higher-ethanol blends, NHTSA and EPA should establish alternative fuel and petroleum equivalency factors that accurately credit the portions of ethanol versus gasoline, in keeping with their petroleum reduction and CO2 emissions performance

Potential of High-octane for Fuel Economy and CO_2 Emissions Reductions

Despite the EPA's long history of transportation policy and regulations proving that fuels and vehicles are best considered as an interconnected system, prior CAFE and GHG rulemakings have evaluated potential spark-ignition engine technology advancements in isolation by constraining their assessments to 87 AKI gasoline. But engine technology only goes so far. The next generation of ICE efficiency improvement will require more suitable fuels. Therefore, Fuel Freedom appreciates the SAFE Proposed Rule's specific request for comment on the potential of higher octane fuels.

The average age for light-duty vehicles has increased to 11.6 years.[30] With ICEs continuing to dominate the market,[31] spark-ignition engine technologies introduced before 2026 will have significant bearing on their ability to meet future CAFE and GHG standards.

The 2021-2026 model years are a pivotal juncture in the evolution of vehicle technologies and shifting market realities that will determine the long-term trajectory of light-duty transportation. The agencies should therefore not just consider the time period under review, but its context as the gateway to the future. Maximum feasibility assessments should include the full range of promising engine and fuel possibilities currently on the horizon, which:

- are more favorable to National Program goals than the fuels and vehicles in use today
- are cost-effective in reaching National Program goals
- are technically feasible or foreseeable
- provide maximum flexibility to meet CAFE and GHG standards of the future

Due to the length of the automotive technology development cycles, considering the range of technologies that satisfy these criteria is appropriate to prepare for a seamless evolution beyond the model years covered by the SAFE proposal.

Given these broad considerations, **Fuel Freedom strongly supports incorporating higher octane into the models for this rulemaking, as supported by the agencies' own assessments.** Higher-octane fuel was proffered by the EPA in Tier 3 to help automakers meet light-duty GHG standards,[32] and recommended as a low-cost means to improve fuel economy in Phase II of the NHTSA-commissioned National Research Council study (NAS 2015).[33] High-octane fuel is also the focus of the Department of Energy's (DOE) Co-Optima program, designed to demonstrate the efficiency and GHG reduction potential of optimizing ICE vehicles and fuels in tandem. Recent peer-reviewed research from universities, automakers, petroleum companies, national labs and others provide adequate inputs for

[30] DOT, *National Transportation Statistics* (2016)
[31] EIA, *Annual Energy Outlook 2016: Light Duty Vehicle Stock by Technology Type* (2016) from https://www.eia.gov/forecasts/aeo/data/browser/#/?id=49-AEO2016&cases=ref2016~ref_no_cpp&sourcekey=0
[32] EPA Tier 3 Notice of Proposed Rulemaking, *Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards: Proposed Rule*, p. 29825 (2013)
[33] National Research Council of the National Academies of Science, *Cost, Effectiveness and Deployment of Fuel economy Technologies for Light-Duty Vehicles* (2015)

incorporating high-octane fuels in the model. Appendix C provides a summary of research evaluating the impacts of high-octane fuel on fuel efficiency, petroleum usage, emissions, new and emerging ICE technologies, and costs. This body of literature documents substantial benefits that merit adding high-octane to the model in order to evaluate the potential of a new minimum octane level (95 RON) as well as higher-octane fuels (98-100 RON). With regard to NHTSA's prioritization of safety in transportation, Fuel Freedom is aware of no data or studies indicating that ICE vehicles designed for high-octane fuels would be any less safe than vehicles with the same physical attributes designed for a lower octane fuel.

High-octane fuels provide a variety of advantages for ICE vehicles, the primary being decreased propensity for pre-ignition (i.e. engine knock). This property enables greater efficiency and/or performance from ICEs, including aggressive spark timing, increased compression ratio, direct-injection, turbo-charging, downsizing and downspeeding. Some manufacturers are already employing these strategies, but to less benefit than if the minimum octane level were higher and therefore drivers were guaranteed to use high-octane fuel

Higher compression ratio engines coupled with high-octane fuel can improve efficiency by 5% to 11% compared to a high-compression ratio engine with low-octane fuel.[34,35] Turbocharged engines in stock configurations, without an increased compression ratio, have achieved efficiency gains of 4.6%[36] and noticeable miles per gallon equivalent (MPGe) improvements.[37] Without turbocharging, direct-injection and port fuel injection engines can benefit from high-octane in improved performance and increased thermal efficiency.

Despite being a premium offering today, high-octane fuels need not increase driving costs for consumers. A recent study found that high compression engines coupled with high-octane fuels could reduce costs compared to other vehicle technologies in the previously established MY2025 CAFE/GHG standards. The per vehicle cost savings of $436 relative to other vehicle technologies was especially high for large vehicles, with the Buick Enclave attaining 2025 standards at a cost savings of $873 with the use of high-octane fuels and high compression.[38] A study by NREL found high-octane fuels made with increasing levels of ethanol "are sufficiently competitive" with the current fuel to achieve "substantial market share."[39] A study by ORNL found "significant benefits for the United States" in that "automotive OEMs, consumers, fuel retailers, and ethanol producers all stand to benefit to varying degrees as HOF [high-octane fuels] increases its market share."[40]

Stakeholders, including OEMs, have publically recognized the potential for high-octane fuels and the engine technologies enabled by them, and advocated for their adoption by the agencies. A sample of such statements are in Appendix D. The petroleum industry has even recognized the benefits of high

[34] Jung, H., Leone, T., Shelby, M., Anderson, J. et al., "Fuel Economy and CO2 Emissions of Ethanol-Gasoline Blends in a Turbocharged DI Engine," SAE Int. J. Engines 6(1):422-434 (2013) https://doi.org/10.4271/2013-01-1321
[35] Sluder, C., Smith, D., West, B., "An Engine and Modeling Study on Potential Fuel Efficiency Benefits of a High-Octane E25 Gasoline Blend" (2017)
[36] Thomas, J.F., West, B., Huff, S.P. "Effects of High-Octane Ethanol Blends on Four Legacy FlexFuel Vehicles, and a Turbocharged GDI Vehicle" (2015)
[37] West, B., Huff, S., Moore, L., Debusk, M., Sluder, S. "Effects of High-Octane E25 on Two Vehicles Equipped with Turbocharged, Direct-Injection Engines" (2018)
[38] Darlington, T., Herwick, G., Kahlbaum, D., and Drake, D., "Modeling the Impact of Reducing Vehicle Greenhouse Gas Emissions with High Compression Engines and High Octane Low Carbon Fuels," SAE Technical Paper 2017-01-0906 (2017) doi:10.4271/2017-01-0906.
[39] Johnson, C., Newes, E., Brooker, A., et al "High-Octane Mid-Level Ethanol Blend Market Assessment" (2015)
[40] Theiss, T., Alleman, T., Brooker, A., "Summary of High-Octane, Mid-Level Ethanol Blends Study" (2016)

octane in general, and ethanol in particular. A recent study by Shell Global Solutions found that when using ethanol as an octane enhancer, ethanol's higher heat of vaporization and sensitivity contribute to efficiency gains beyond just an increase in octane, concluding that "the ethanol route provides additional tank-to-wheel CO_2 savings over fossil high octane fuels."[41] In addition, an industry insider recently stated that petroleum refiners are well suited to make high-octane fuels since refining capacity exceeds demand.[42]

The efficiency, cost, and emissions benefits show high-octane fuels and the vehicle technologies enabled by or benefitting from their use, to be well suited for compliance with CAFE and GHG standards. Studies differ on the ideal octane number, with the outcomes weighted by the purpose and priorities. Recent discussions have centered on 95 RON, which is already generally available in all 50 states and can therefore be an expedient new minimum octane rating. Above that, an E30 95-97 RON fuel could minimize refining costs[43] and provide consumers with a fuel cost savings of $0.08-$0.16 per gallon.[44] If ethanol is the primary source of octane, E25 may minimize infrastructure costs associated with fueling and distribution.[45] These two studies reflect that corn ethanol is generally cheaper than petroleum, and is most economical in a midlevel ethanol blend where its volumetric energy content penalty is compensated by engine efficiency. From an auto engineering perspective, there is consensus for 98-100 RON to maximize efficiency and/or performance gains[46] regardless of the fuel formulation, but with additional marginal benefit if ethanol is the octane source.

A new minimum octane number is necessary to enable and advance low-cost efficiency gains and GHG reductions; however, the new minimum must not preclude higher octane formulations. The agencies should simply exercise their respective authorities (NHTSA to reduce petroleum use through vehicle technology measures, and EPA to reduce GHG emissions in light-duty transportation) to facilitate and/or remove barriers to a national transition to a higher minimum octane, and ensure that no regulatory barriers bar the market from determining the blend levels and/or source of octane.

The recent E15 announcement offers a convenient and timely opportunity to raise octane levels. The E10 experience indicates that, in the absence of an octane requirement, the social benefit (consumer, economic, national security) will be lost by lowering the octane level of the base gasoline product. **Raising the national minimum octane will ensure the value of additional octane provided by E15 accrues to American consumers and U.S. national interest.**

Increasing Octane in the Marketplace

Transportation policy is stymied by a chicken-and-egg dilemma in trying to synchronize availability of fuels and vehicles. Yet continuing to improve vehicle efficiency and reduce CO_2 emissions will require fuels that are better suited to maximize fuel economy and environmental performance of the vehicle-fuel system. To fully realize expected National Program benefits as engine technology evolves, EPA

[41] Wilbrand, K., et al "The Role of High Octane Fuels in Future Mobility – A Technical Review" (2016)

[42] Comments made by Rick Weyen of Andeavor at SAE Government/Industry meeting during presentation of "Role of Petroleum Refineries in Supplying Low Carbon Fuels" (2018)

[43] Hirshfeld, D.S., Kolb, K.A., "Refining Economics of U.S. Gasoline: Octane Ratings and Ethanol Content' (2014)

[44] Johnson et al 2015

[45] Moriarty, K., Kass, M., Theiss, T., "Increasing Biofuel Deployment and Utilization through Development of Renewable Super Premium: Infrastructure Assessment" (2014)

[46] Thomas et al 2015, Sluder et al 2017, Splitter & Szybist 2014

must exercise its acknowledged authority[47] to approve appropriate higher-octane fuels,[48] and to decrease and ultimately eliminate low-octane fuels unsuitable for advanced engine technologies by raising the minimum octane in the marketplace.[49] In this, Fuel Freedom joins the Auto Alliance,[50] the Global Auto Alliance, the Renewable Fuels Association (RFA), the High Octane Low Carbon (HOLC) Alliance, [51] and others in urging EPA to consider fuels and vehicles as an interconnected system. The system is currently limited by 85-87 AKI gasoline.

Regardless of the octane source, high-octane fuels can enable significant reductions in fuel cycle CO_2 emissions. Argonne National Lab's comprehensive study[52] on the well-to-wheels GHG emissions of various high-octane fuels found a 6% reduction using high-octane RON 100 E10 compared to RON 92 E10. When using higher ethanol blends of E20 and E40 to achieve a RON 100, the emissions decreased by 17% and 27%, respectively.

Consumer demand has increased the share of premium fuel (91-93 AKI) sold in the marketplace. Yet the proportion remains less than 13%.[53] Even without optimization or new engine technology, premium fuel can provide a 1-2% efficiency benefit for existing vehicles.[54] However, consumer value requires either a larger efficiency gain or a lower price gap at the pump. To maximize cost effectiveness in achieving National Program goals, higher-octane fuels must be generally available, rather than a premium-priced niche offering. The most direct means of ensuring availability is for EPA to raise the minimum octane in the marketplace, which will take many years to fully realize.

Fuel Freedom recognizes that this recommendation is outside the scope of the CO_2 standards that will be established by the SAFE rulemaking. However, the full technical, environmental and economic analyses for regulatory approval of high-octane ethanol blends should be initiated concurrently, to maximize potential National Program benefits for MY2021-2026. The lead phase-out and more recent regulations for gasoline (Tier 2 and Tier 3 requirements) and low-sulfur diesel provide useful guides for a successful transition. Introduction of higher-octane ethanol blends will require development and approval of fuel formulation(s) and full adoption of ASTM engine testing specifications,[55] as well as engines to be designed and certified for its use. Adding fueling infrastructure and market transition time, a decade or more is expected for full implementation.

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[47] Machiele P., *Mobile Sources Technical Review Subcommittee [Presentation]*, from https://www.epa.gov/sites/production/files/2016-01/documents/mstrs_050515summary.pdf, p. 9-10 (2015)

[48] CAA Section 211 (f)(4)

[49] Legal experts assert that the EPA could rely on the CAA 211(c)(1) authority given the findings in CRC Final Report for CRC Project No. E-108 that "consistent with the loss of FE, the fleet CO2 results correspondingly increased for the 85 AKI test fuel"

[50] Nevers, Chris, Auto Alliance, presentation to Ag-Auto-Ethanol Annual Meeting (Oct 16, 2018)

[51] Global Alliance, RFA and HOLC comments at Public Hearing for the Reconsideration of the Final Determination of the Mid-term Evaluation of Greenhouse Gas Emissions Standards for Model Years 2022-2025 Light-duty Vehicles, Washington DC (2017)

[52] Han, J., Elgowainy, A., Wang, M., "Well-to-Wheels Greenhouse Gas Emissions Analysis of High-Octane Fuels With Various Market Shares and Ethanol Blending Levels" (2015)

[53] EIA, "Refiner Motor Gasoline Sales Volumes" https://www.eia.gov/dnav/pet/pet_cons_refmg_d_nus_VTR_mgalpd_m.htm Accessed Oct 11, 2018

[54] Leone, T., *High Octane Discussion at National Ethanol Conference* (2016) http://energy.agwired.com/2016/02/17/high-octane-discussion-at-rfanec/ Accessed Oct. 16, 2018.

[55] ASTM, Standard Specification for 100 Research Octane Number Test Fuel for Automotive Spark-Ignition Engines 1, work item 54471 (2016)

Fortunately, much of the current gasoline infrastructure could be modified to deliver either petroleum-derived high-octane fuels or higher ethanol blends such as a mid-level E25-E40.[56] As discussed above, market adoption of high-octane ethanol blends can also be facilitated by the 21 million FFVs[57] already on the road, as well as additional FFVs offered in the future.

Effects on Global Competitiveness

Automakers and auto suppliers have recently become the largest export sector in the U.S., contributing significantly to GDP and employment.[58] In order to continue to thrive, these manufacturers must remain competitive by producing the products demanded by consumers and industries worldwide.

To date, at least twenty-seven countries and cities have announced future bans on ICE vehicles. This includes some of the auto industry's largest export markets such as China, Germany, the United Kingdom and India. Beyond ICE bans are initiatives to expand the use of renewable fuels and increase engine efficiency. In particular China, by far the largest vehicle market, and India, the fastest-growing market—are aggressively pursuing a diverse approach.[59] With most of the growth in the automotive sector in the coming decades projected to come from the developing world, U.S. manufacturers must be able to compete in order to maintain industry growth and market share.

OEM automakers are already moving towards global standardization across vehicle platforms—a move that lowers research and development, manufacturing and production costs.[60] This standardization is enabled in part by the CAFE and GHG structure and program incentives to develop the expertise to establish global leadership. Ceding this advantage at this critical juncture will handicap U.S. industry moving forward, endangering $87.6 billion of annual exports of vehicles and automotive parts.[61] Fuel Freedom agrees with past comments from the Motor and Automotive Manufacturers Association, the United Auto Workers, and the Global Auto Alliance, among others,[62] that fuel economy and CO_2 standards should account for global fuel economy and market trends in order to assure market competitiveness and leadership of U.S. industry.

GHG Reductions in Light-duty Transportation

Fuel Freedom understands that full fuel-cycle analyses are beyond the National Program's current downstream purview. However, a more holistic perspective ultimately will be necessary for the EPA to significantly reduce GHG emissions in light-duty transportation. The necessity is highlighted by the fact that transportation is now the largest source of GHG emissions in the U.S.,[63] with light-duty vehicles accounting for the largest portion.

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[56] Market forces are already moving toward higher ethanol blends. All underground fuel storage tanks manufactured since 2005 are compatible with 100% ethanol. The ethanol industry continues its Prime and Pump initiative to install blending pumps at retail fueling stations. And major fuel pump manufacturers have incorporated higher ethanol compatibility into their standard offerings.

[57] EIA, Annual Energy Outlook, *Light-Duty Vehicle Stock by Technology Type*

[58] American Automotive Policy Council "State of the U.S. Automotive Industry" http://www.americanautocouncil.org/sites/aapc2016/files/2017%20Economic%20Contribution%20Report.pdf Accessed Oct 11, 2018

[59] Klein, T. Future Fuel Strategies, SAE Government/Industry Meeting "Panel Discussion: The Global State of Transportation & Air Quality" (2018)

[60] Thomas, J., Auto Alliance, SAE Government/Industry Meeting "Trade Negotiations and Regulatory Harmonization Recommendations for the new Administration" (2017)

[61] Dept. of Commerce, International Trade Administration, Office of Transportation And Machinery "Automotive Team: Industry Trade Data" https://www.trade.gov/td/otm/autostats.asp Accessed Oct 11, 2018

[62] Public hearing for the Reconsideration of the Final Determination of the Mid-term Evaluation, Washington DC (2017)

[63] EIA, *Monthly Energy Review September 2018,* p. 200 (2018)

EPA's authority, reaffirmed by the U.S. Supreme Court,[64] is not limited to vehicle emissions alone.[65] To maximize GHG reductions from light-duty transportation, the EPA must look upstream. The comments below recommend that the EPA plan to incorporate a full fuel cycle perspective in the future. The Department of Energy's Co-Optimization of Fuel and Engines program is a valuable guide to the synergistic GHG benefits of a holistic approach.

Since 2009, the EPA has significantly reduced GHG emissions from light-duty transportation by regulating tailpipe CO_2 standards. Yet transportation remains the biggest source of GHGs. In order to reduce the possibility of catastrophic consequences due to climate warming, EPA must account for upstream emissions.

The relationship between vehicle energy efficiency and fuel carbon intensity, and the necessity to consider fuels and vehicles as a holistic system, are described in detail in an NREL paper.[66] In evaluating ICE, hybrid electric vehicles (HEV), battery electric vehicles (BEV) and fuel-cell electric vehicles (FCEV), the study found that, without a decrease in the carbon intensity of the fuel, all fall short of reducing GHG emissions by 80% by 2050, as needed to limit global temperature rises to 2°C or less per the United Nations Framework Convention on Climate Change (Paris Agreement).

From a full fuel-cycle perspective, feedstocks and fuel production are significant contributors to GHG emissions. The carbon intensity of gasoline and diesel is increasing as production moves further afield, incorporates more carbon-intensive sources, and easier reservoirs are drawn down, yet renewable fuels are moving in the opposite direction.[67] Further, petroleum-derived octane enhancers such as reformates and alkylates not only increase petroleum use—contrary to national goals—but also increase carbon intensity relative to biomass-derived octane sources such as corn or cellulosic ethanol,[68] negating a portion of the downstream CO_2 savings and fuel reductions from increased efficiency.[69]

Fuel Freedom funded a forthcoming analysis to evaluate possible scenarios for achieving an 80% fuel cycle reduction in light-duty vehicle GHG emissions for the U.S. and for California by 2050. The analysis uses government estimates[70] of fuel carbon intensity, vehicle efficiency improvements (including those contained in the SAFE proposal), and incremental costs for each fuel-vehicle combination, to develop feasible market penetrations for various pathways. Pathways include gasoline technologies (including high-octane fuels with high-compression-ratio ICEs coupled with electrification), biofuels used in ICEs with and without hybridization, HEVs, plug-in hybrid electric vehicles (PHEVs), FCEVs, and BEVs in order to compare both feasibility and relative cost effectiveness for carbon reductions.[71] Long-term results to 2050 reflect that it is critical to provide market flexibility in the near term. Regulations should not

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[64] U.S. Supreme Court, *Massachusetts, et. al., Petitioners v. Environmental Protection Agency, et al,* 549 U.S. 497 (2007)

[65] Clean Air Act, Title I, Air Pollution Prevention and Control

[66] Gearhart, C., *Implications of Sustainability for the United States light-duty transportation sector*, (2016)

[67] Union of Concerned Scientists, "Fueling A Clean Transportation Future: Smart Fuel Choices for A Warming World" (2016)

[68] CARB, *LCFS Pathway Certified Carbon Intensities* (2016) from http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm

[69] Han, J., Elgowainy, A., Wang, M., *Well-to-Wheels Greenhouse Gas Emissions Analysis of High-Octane Fuels With Various Market Shares and Ethanol Blending Levels*, (2015)

[70] EIA *Annual Energy Outlook 2016*; Argonne National Laboratory (ANL), *Greenhouse Gasses, Regulated Emissions and Energy Use in Transportation (GREET) Model*, VISION2015, and Cradle-to-Grave Lifecycle Analysis of U.S. Light Duty Vehicle Fuel Pathways (2016);); National Academies of Science Transitions report (2013); EPA-NHTSA Draft Technical Assessment Report, EPA Fuel Economy Guide; CARB VISION2.1 and CA-GREET2 models

[71] Each pathway centered on a dominant vehicle technology, constrained by practical limitations and the attributes of cars versus trucks or SUVs. Vehicles not suitable for battery electric propulsion were assumed to be ICEs.

foreclose, and should instead encourage, feasible vehicle-fuel pathways that can maximize GHG reductions for the long term by a transition to renewable sources, including biofuels, hydrogen, and electricity.

Another key finding of this analysis is that policies that accelerating a decrease in the carbon intensity of fuels could reduce total GHGs sooner. As noted in the PRIA, "future [GHG] emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change."[72] Given the uncertainties in measuring the long-term impacts of GHG emissions,[73] and the accumulated impacts of carbon emissions,[74] EPA should not discount the benefits of pathways with significant promise to reduce emissions faster in the near-term.

On the vehicle side, encouraging earlier introduction of advanced and alternative vehicle technologies can be achieved through CAFE and GHG program credits as recommended above. For liquid fuels, octane is a lynchpin. As the average age of vehicles on the road increases, greater use of lower carbon intensity fuels would accelerate near-term GHG reductions. High-octane ethanol blends have a lower carbon intensity than current gasoline offerings and national grid average electricity. High-octane fuels with a maximum of 15% ethanol have been approved for all vehicles MY2001 or newer. The 21 million flex-fuel vehicles on the road can use up to 85% ethanol, including midlevel blends. The measures to increase octane recommended above can facilitate a market transition to high-octane, low-carbon fuels that are compatible with new vehicles and the majority of the legacy fleet in order to achieve greater near-term reductions in GHG emissions in the next decade.

Therefore, Fuel Freedom recommends that EPA investigate measures to ensure that all potential pathways to reduce GHG emissions in the light-duty transportation sector, including those that foster demand for low carbon intensity fuels, are placed on equal footing with other technologies evaluated in the SAFE Rule.

Need to Continue One National Program

The agencies have proposed to revoke California's waivers to regulate GHG emissions from mobile sources. Rather than instigating inevitable litigation that would drag on for years and create unwelcome regulatory uncertainty, Fuel Freedom strongly supports negotiations to ensure a continuation of One National Program. Fuel Freedom recognizes that a bifurcated system increases compliance costs and ultimately consumer price. However, there is ample room for compromise between the SAFE preferred option to freeze standards entirely and the aggressive approach and dominant commitment to EVs and FCEVs by the California Air Resources Board (CARB). Ambitious standards and appropriate program incentives encourage not only petroleum and GHG reductions, but U.S. industry leadership. The negotiations with CARB and in the agencies final proposal should recognize and fully consider these benefits.

Higher octane, lower carbon fuels and the technologies enabled by them can be an ideal basis for compromise to maintain One National Program. Thanks to its Low Carbon Fuel Standard (LCFS) program, California has the lowest-carbon ethanol in the U.S. and could therefore achieve greater per vehicle GHG reductions in its light-duty fleet by the same program incentives. Implementing high-

[72] PRIA, p. 1068
[73] PRIA, p. 1069
[74] National Academies of Sciences, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide,* (2017)

octane-related incentives as recommended above to encourage the production of ICE vehicles that use E85 or midlevel ethanol blends rather than standard gasoline, would result in lower carbon intensity of California light-duty ICE vehicles than the U.S. at large. Despite the state's commitment to EVs in particular, and little demonstrated interest in liquid fuels, the market is already nudging the outcome. Use of E85 grew more than 300% from 2012 to 2017, with committed fuel retailers leading the way.[75]

Summary and Recommendations

The SAFE Rule comes at a critical juncture for not only the future of light-duty transportation, but for both U.S. energy independence and the U.S. contribution to global efforts to reduce the possibility of catastrophic effects due to climate change. NHTSA and EPA have latitude and in fact legal obligations to, respectively, reduce petroleum use and GHG emissions, rather than stall or go backwards. Continued incremental progress will require an all-of-the-above strategy. Real world experience shows that consumer response cannot be either forced or taken for granted. Even the most optimistic estimates project that spark-ignition ICEs will dominate U.S. light-duty sales for decades, not to mention the total on-road fleet of legacy vehicles. Consequently, EPA and NHTSA (as well as CARB, within any negotiated terms to continue the One National Program) must incorporate provisions to coax maximum petroleum and CO_2 reductions from these ICE vehicles. This means looking not just to vehicle technologies as in the past, but to the liquid fuels that enable them. As a starting point, the model should assess performance of spark-ignition engines using high-octane fuel, including the full range of feasible technologies that could be enabled by it. EPA should, in parallel to the SAFE Rulemaking, initiate approval of higher-octane fuel(s) including midlevel ethanol blends and prepare for an expedient and minimally disruptive nationwide transition to raise the minimum octane in the marketplace.

With the above in mind, Fuel Freedom respectfully submits the following recommendations:

- ***EPA and NHTSA:*** Subject to negotiations with OEMs, establish CAFE and CO2 targets that continue to incrementally decrease petroleum use and GHG emissions through MY2026, in keeping with the agencies' legal obligations and National Program goals.

- ***NHTSA:*** Incorporate high-octane fuels in the Volpe model as an option for OEMs to meet the proposed fuel economy standards. This should include the potential for high-octane fuel to be a standard offering in a higher-minimum-octane scenario, rather than a premium cost fuel, and consider low-cost octane sources such as ethanol.

- ***NHTSA:*** More thoroughly evaluate the direct and indirect costs of petroleum dependence. The evidence of 2018 has proven that record domestic production has not resolved the national security or consumer fuel costs. NHTSA's analysis should fully account for the continuing costs of petroleum dependence, as well as potential economic benefits of supplementing new domestic petroleum with fuels produced domestically from other domestic energy sources, including higher volumes of corn ethanol and ethanol produced from cellulosic material or natural gas.

[75] California Air Resources Board data shows an increase of E85 use from 6.5 million gallons in 2012 to about 28 million in 2017

- ***EPA and NHTSA:*** Provide and harmonize to the greatest possible extent CAFE and GHG program incentives which adequately credit vehicle technologies for reducing petroleum use (NHTSA) or GHG emissions (EPA), while providing maximum compliance flexibility to OEMs. Such incentives should promote global competitiveness of U.S manufacturers and facilitate the use of alternatives to petroleum, including for liquid-fueled spark ignition ICEs which dominate U.S. roadways.

- ***EPA and NHTSA:*** Specifically, the agencies should offer CAFE and GHG program incentives for vehicles compatible with or designed for higher ethanol blends, including FFVs, in order to cost-effectively maximize petroleum and full fuel cycle GHG reductions in the U.S. light-duty fleet in the next decade.

- ***EPA:*** Eliminate regulatory barriers to greater use of ethanol as an octane source. Measures should include formulation and certification of midlevel ethanol blends as well as addressing the technical direct and indirect regulatory barriers to greater ethanol use collectively identified by the Ag-Auto Ethanol Alliance, which are listed in Appendix E.

- ***EPA:*** Initiate as soon as possible, a full technical, economic and environmental analysis in preparation to raise the national minimum octane level in the U.S. fuel supply.

- ***EPA:*** For the long term, incorporate a fuel-cycle perspective to thoroughly analyze and compare the GHG emissions and total costs and benefits of fuel-vehicle systems, and develop policies and regulations according to this holistic approach.

- ***EPA and NHTSA:*** Provide certainty to the automotive industry by negotiating with CARB to continue One National Program, in order to avoid extended and costly litigation related to revoking the California waiver.

Attachment to comments for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

EPA Docket ID: EPA-HQ-OAR-2018-0283
NHTSA Docket No.: NHTSA-2018-0067

Supplement to Fuel Freedom Foundation comments

Appendix A: Petition - Demand we stay the course on fuel economy

PETITION TEXT:

"The fuel economy standards are the best tool we have for reducing petroleum use. That's why Congress established them in the first place!

To end the oil monopoly, we're asking you to sign our petition demanding that the federal government not roll back the fuel economy standards, also known as CAFE.

The CAFE (Corporate Average Fuel Economy) program provides two pathways to reduce petroleum use: higher fuel efficiency and diversifying our fuels by encouraging use of alternatives to gasoline and diesel. The CAFE program should do both.

The current administration's proposal undercuts the gains achieved over the past decade by freezing progress after 2020.

Standing pat is falling behind. We will never be secure or energy independent as long as our transportation relies almost exclusively on petroleum. Our national security, our economy, and our environment depend on our efforts, right now, to break the oil monopoly once and for all."

https://www.thepetitionsite.com/takeaction/589/044/182/

The petition gathered more than 24,000 signatures. A list of signatories is available on request.

Attachment to comments for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

EPA Docket ID: EPA-HQ-OAR-2018-0283
NHTSA Docket No.: NHTSA-2018-0067

Supplement to Fuel Freedom Foundation comments

Appendix B: How High-Octane Fuels and CAFE and GHG Program Incentives Align with Administration Priorities, Actions and Executive Orders

Executive Order 13783 of March 28, 2017
Promoting Energy Independence and Economic Growth
"It is in the national interest to promote clean and safe development of our Nation's vast energy resources… It further is the policy of the United States that, to the extent permitted by law, all agencies should take appropriate actions to promote clean air and clean water for the American people… It is also the policy of the United States that necessary and appropriate environmental regulations comply with the law, are of greater benefit than cost, when permissible, achieve environmental improvements for the American people..."

- High-octane fuels (HOFs) are well suited to meet the requirements of this E.O., promoting both energy independence and U.S. energy-driven economic growth. High-octane fuels can "promote clean" development of our resources by enabling a market incentive for the increased domestic production of clean burning ethanol as an octane enhancer for increased ICE efficiency. Further, HOFs are well suited to provide efficiency benefits at lower vehicle and fuel costs than other pathways while providing environmental improvements through lower vehicle emissions and decreased GHG emissions.

- CAFE and GHG program incentives for production of alternative vehicle technologies can, **at no regulatory cost,** promote investments in the production and use of fuels produced from U.S. energy, for both domestic consumption and export to growing markets. Diversifying the transportation fuels in the U.S. marketplace will create genuine market competition and facilitate genuine energy independence.

Executive Order 13777 of February 24, 2017
Enforcing the Regulatory Reform Agenda
"It is the policy of the United States to alleviate unnecessary regulatory burdens placed on the American people."

- Current regulations pertaining to vehicle certification, fuels and their use in the marketplace place burdensome hurdles that prevent the introduction and proliferation of low-cost high-octane fuels. In light of new market realities that reflect growing availability of and demand for octane, the relevant regulations should be reexamined. Regulations that limit or bar the introduction and use of such fuels should be adapted to remove unnecessary barriers, in order to decrease costs to consumers, increase consumer choice, improve vehicle efficiency and/or performance, enable innovation in the industries and decrease GHG and harmful emissions.

Presidential Proclamation on National Energy Awareness Month, September 28, 2018
"American energy dominance means the end of our crippling dependence on foreign energy, and that our industries have access to reliable, affordable, and diverse energy supplies that enable them to compete in the global marketplace… Our Nation's increasingly innovative energy industry is proving that we can be responsible stewards of the environment while developing energy resources to grow the economy, lower costs, ignite job creation, and drive up incomes for American workers."

- Expanded use of higher ethanol blends up to 85% could further reduce dependence on foreign oil, of which we still import more than 10 million barrels per day,[1] by stimulating market demand for increased use of domestically produced fuels, the most cost-effective octane enhancer available. Ethanol is not only produced from corn, but can be produced from multiple other feedstocks including cellulosic material or natural gas. Using more fuel from domestically produced sources would grow the U.S. economy, create hundreds of thousands of high-paying jobs, lower driving costs, and spur exports of U.S.-produced fuels to fast-growing markets in China and elsewhere. Unlike other energy products such as LNG, finished fuels such as ethanol produced from U.S. energy of any source (e.g. corn, cellulosic material or natural gas) can be readily stored and transported to overseas markets to improve our trade balance. Ethanol's enhanced efficiency and lower CO_2 emissions would also ensure that we continue to reduce climate impacts from the transportation sector—the largest source of greenhouse gas emissions in the U.S.

[1] EIA, Petroleum & Other Liquids: U.S. Imports by Country of Origin – Total Crude Oil and Products, https://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbblpd_m.htm Accessed October 18, 2018

Executive Order 13790 of April 25, 2017
Promoting Agriculture and Rural Prosperity in America
"It is in the national interest to promote American agriculture and protect the rural communities where food, fiber, forestry, and many of our renewable fuels are cultivated."

- High-octane fuels are uniquely positioned to promote agriculture and enhance prospects for rural communities. Ethanol, which in America is produced almost entirely from Midwestern corn, is the lowest cost octane enhancer and its production creates associated high-value co-products like animal feed. Ethanol already contributes $44.5 billion to the rural economy and supports nearly 360,000 direct and indirect jobs.[2] Allowing for greater use of ethanol to produce affordable high-octane fuels could provide an additional boost to the rural economy through increased demand for corn and other agricultural feedstocks.

Fact Sheet: President Donald J. Trump Is Expanding Waivers for E15 and Increasing Transparency in the RIN Market, October 11, 2018
"We want to eliminate the intrusive rules that undermine your ability to earn a living, and we will protect the corn-based ethanol and biofuels that power our country."

- Updating regulations to allow for expanded use of lower cost high-octane fuels in blends of 15% ethanol or higher has the potential to not just protect the corn-based ethanol and biofuels industries, but spur rapid growth in rural communities by further increasing market demand.

[2] Urbanchik, J. "Contribution of the Ethanol Industry to the United States in 2017" February 2018 https://ethanolrfa.org/wp-content/uploads/2018/02/RFA-2017-Ethanol-Economic-Impact-01_28_17_Final.pdf

Attachment to comments for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

EPA Docket ID: EPA-HQ-OAR-2018-0283
NHTSA Docket No.: NHTSA-2018-0067

Supplement to Fuel Freedom Foundation comments

Appendix C: History of Comments in Support of High Octane from Federal Agencies, Auto Companies and Other Stakeholders

This appendix provides a sample of formal and other public comments made by government and industry stakeholders, in support of high-octane fuels. Rather than a comprehensive catalog of comments, it is intended as a representative guide to the history of the agencies' and industry interest in and support for high-octane fuels.

Section 1: Environmental Protection Agency, Tier 3 "Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards" Notice of Proposed Rule Making and Public Comments

Notice of Proposed Rulemaking –

"Furthermore, we are proposing to allow vehicle manufacturers to request approval for an alternative certification fuel such as a high-octane 30 percent ethanol by volume (E30) blend for vehicles they might design or optimize for use on such a fuel. This could help manufacturers that wish to raise compression ratios to improve vehicle efficiency, as a step toward complying with the 2017 and later light-duty greenhouse gas and CAFE standards (2017 LD GHG)."

"We are also seeking comment on whether there are other aspects of today's proposed standards that might need to be modified to provide an incentive for, or remove obstacles to, the development of highly efficient vehicles optimized for use on higher level ethanol blends."

Comments to the Rulemaking –

> ***Alliance of Automobile Manufacturers:*** Ethanol's "in-cylinder cooling effect" and high octane rating make a "mid-level gasoline-ethanol blend" particularly well suited for "improv[ing] vehicle efficiency and lower[ing] GHG emissions," through "increas[ing] the engine compression ratio" and "downsizing of the engine."
>
> ***Ford Motor Company:*** "Ford supports the development and introduction of an **intermediate level blend fuel** (E16-E50), with a minimum **octane rating** of 91 anti-knock index (AKI) that **increases proportionally as ethanol is splash-blended** on top of the base Tier 3 gasoline emission test fuel." Ford also submitted "Appendix A: Literature Review of Benefits of High Octane/High Ethanol Fuels". The appendix outlines the need to coordinate "market fuel availability and vehicle compatibility," how "higher minimum octane ratings

for regular-grade fuel would enable higher compression ratios," the role of FFVs in providing "maximum flexibility with respect to future ethanol content," and other issues related to the use of higher octane fuels.

General Motors: "**GM supports** the future of **higher octane** and **higher ethanol** content in order to provide a pathway to improved vehicle efficiency and lower GHG emissions."

Mercedes-Benz "Higher octane fuels permit higher **compression ratios** which directly improve **efficiency**. . . . [A] powertrain . . . optimized for a high-octane, mid-blend ethanol fuel . . . can simultaneously fulfill what the customer desires—**performance and economy**—while reducing the **environmental impact**."

Section 2: Draft Technical Assessment Report (TAR) for the Mid-Term Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025

NHTSA Commissioned Study: "Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles" NAS 2015

Finding 2.9 Increasing octane from 87 AKI (91 RON) of regular grade gasoline to 91 AKI (95 RON) has the potential to provide 3 to 5 percent reduction in fuel consumption for naturally aspirated engines if compression ratio is increased by 2 ratios from today's typical level, and possibly even greater reductions in fuel consumption for turbocharged engines by allowing operation at higher boost pressures for further downsizing.

Recommendation 2.3 (High Octane Gasoline) EPA and NHTSA should investigate the overall well-to wheels CAFE and GHG effectiveness of increasing the minimum octane level and, if it is effective, determine how to implement an increase in the minimum octane level so that manufacturers would broadly offer engines with significantly increased compression ratios for further reductions in fuel consumption."

Finding 2.4 Several technologies beyond those considered by EPA and NHTSA might provide additional fuel consumption reductions for spark ignition engines or provide alternative approaches at possibly lower costs for achieving reductions in fuel consumption by 2025. These technologies include… higher compression ratio with higher octane regular grade gasoline, if it were to become widely available, with estimated effectiveness of up to 5 percent and a direct manufacturing cost of $75 to $150."

Comments to the Rulemaking –

Alliance of Automobile Manufacturers: "It is unfortunate that the Agencies did not include octane as a technology analogous to powertrain technology options they did study…The co-design of fuels and engines is an important pathway to improve fuel economy in spark ignition gasoline engines. The widespread availability of **higher octane rated gasoline (having increased knock resistance) is a key enabler for the next phase of advanced engines** expected to occupy a large fraction of the vehicle fleet. In addition, **the implementation of higher octane rated gasoline in the marketplace could be a cost-effective means of immediately improving fuel economy** across a substantial portion of the existing light-duty vehicle fleet."

***American Coalition for Ethanol**: "*The goals of the CAFE GHG program will go unrealized until a compliance mechanism is set in motion for higher octane fuel. We call on EPA to provide for a certification and in-use high-octane fuel that contains between 25 and 40 percent ethanol to help meet the CAFE-GHG standards."

High Octane Low Cost Alliance: "EPA and NHTSA should investigate the overall well-to-wheels CAFE and GHG effectiveness of increasing the minimum octane level and, if it is effective, determine how to implement an increase in the minimum octane level so that manufacturers would broadly offer engines with significantly increased compression ratios for further reductions in fuel consumption….The encouragement of HOLC fuels [high-octane low-carbon] as part of a final MTE package would be cost effective, consumer friendly, timely (compared to waiting decades for the electric vehicles to arrive), and result in substantial carbon and related health co-benefits."

Section 3: Department of Energy Co-Optimization of Fuel and Engines Initiative (Co-Optima)

This DOE initiative has developed a "merit function" to identify optimum fuel properties for maximizing ICE efficiency. Based on the initiative's research it considered fuels that whose final blending properties would have a minimum RON of 98, and indeed all the candidate fuel now meet that criteria. Along with other fuel properties such as octane sensitivity and laminar flame speed, this initiative characterized the benefits of a minimum RON 98 as reducing "the need to retard combustion phasing under [high load] conditions, improving fuel efficiency." Further noting that "engine downsizing and down-speeding are well suited to take advantage of higher-octane fuels because these engines encounter the knock limit more frequently."(FY2016 Year in Review)

A key finding of this initiative:

- A unit increase in RON has the greatest impact on efficiency of the three main fuel properties (Fuel Blendstocks with the Potential to Optimize Future Gasoline Engine Performance, Jan 2018)

Section 4: General Comments by Government and Industry

Shell Oil Company During the session titled "Octane Requirements and Efficiency in a Fleet of Modern Vehicles" at the 2017 SAE World Congress, findings were presented that shows the efficiency disadvantage of low RON fuels (under 95) was higher than the advantages of higher RON fuels (above 95). This shows that the current low RON offering is hampering ICE efficiency. During the same event, at a different session of another Shell study titled "Impact of Fuel Sensitivity on Engine Efficiency" findings were presented that mirrored the findings of the DOE's Co-Optima initiative that RON has a greater impact on engine efficiency than other fuel properties.

General Motors, Dan Nicholson Vice President of Global Propulsion, before House Committee on Energy and Commerce Subcommittee on Environment April 2018: "We believe increasing the minimum octane level in U.S. gasoline for new vehicles will be a win for all industries and, most importantly, consumers… We have an opportunity to play a large role in offering consumers the most affordable option for fuel economy improvement and greenhouse gas reduction. We believe a higher efficiency gasoline solution with a higher Research Octane Number (RON) is very important to achieving this… Without this new fuel, we will continue to endure the impacts of fuel variation and forego related available fuel economy improvement opportunities."

American Fuel and Petrochemicals Manufacturers, Chet Thompson President and CEO, before House Committee on Energy and Commerce Subcommittee on Environment April 2018**:** *"*Higher octane fuels have the potential to benefit all stakeholders. Higher octane fuels, specifically 95-RON, would help auto companies improve the efficiency of the internal combustion engine and comply with fuel efficiency standards. It would provide the biofuel industry with the opportunity to expand its market share… And it could benefit consumers by creating a transparent and competitive market for all liquid fuels to compete."

Alliance of Automobile Manufacturers, Mitch Bainwol President and CEO, before House Committee on Energy and Commerce Subcommittee on Environment May 2018: "The Alliance has long supported a transition to higher-octane gasoline and the need for vehicles and fuels to be regulated as a system. Higher octane gasoline in the marketplace is a cost-effective means of incrementally improving fuel economy for the light-duty vehicle fleet (which currently translate into 4-5 percent year over year improvements). However, before any of those benefits could be realized, automakers must have adequate lead-time to design and develop vehicles optimized for a new fuel, and to cost-effectively certify them as compliant with regulatory emission limits."

Renewable Fuels Association, Bob Dinneen President and CEO, before House Committee on Energy and Commerce Subcommittee on Environment May 2018: "Pairing advanced internal combustion engine technologies with high octane low carbon (HOLC) fuels would result in low-cost fuel economy and emissions benefits in the near term."

American Petroleum Institute, Frank Macchiarola Group Director, before House Committee on Energy and Commerce Subcommittee on Environment May 2018: "We believe that the prospect of a higher-octane gasoline is an idea worthy of additional study to analyze the potential costs and benefits to all market participants throughout the value chain, including the consuming public, as well as to our nation's energy security and environment."

Attachment to comments for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

EPA Docket ID: EPA-HQ-OAR-2018-0283
NHTSA Docket No.: NHTSA-2018-0067

Supplement to Fuel Freedom Foundation comments

Appendix D: Summary of High-Octane Research

The Competitive Position of Ethanol as an Octane Enhancer
Authors: S. Irwin, D. Good
"The recent rise of ethanol prices above gasoline prices has raised the specter of ethanol losing its place as the cheapest source of octane. While this would not necessarily limit ethanol consumption due to the existence of the RFS conventional ethanol mandate, it would have implications for the cost of complying with the RFS mandates. To assess any changes in the competitive position of ethanol in gasoline blends, the price of the aromatic compounds benzene, toluene, and xylene were analyzed relative to the price of ethanol. These compounds have octane ratings generally similar to that of ethanol and have a long history as octane enhancers in gasoline blends. Despite the recent increase in ethanol prices relative to gasoline, ethanol prices still remain below that of the aromatics. As a result, ethanol continues to retain its position as the low cost octane enhancer in gasoline blends."
http://farmdocdaily.illinois.edu/2016/02/ethanol-position-as-octane-enhancer.html

The Effect of Compression Ratio, Fuel Octane Rating, and Ethanol Content on Spark-Ignition Engine Efficiency
Authors: T.G. Leone, J.E. Anderson, R.S. Davis, A. Iqbal, R.A. Reese, II, M.H. Shelby, and W.M. Studzinski
"New vehicle trends to improve efficiency include higher compression ratio, downsizing, turbocharging, downspeeding, and hybridization, each involving greater operation of spark-ignited (SI) engines under higher-load, knock-limited conditions. Higher octane ratings for regular-grade gasoline (with greater knock resistance) are an enabler for these technologies. This literature review discusses both fuel and engine factors affecting knock resistance and their contribution to higher engine efficiency and lower tailpipe CO_2 emissions. Increasing compression ratios for future SI engines would be the primary response to a significant increase in fuel octane ratings. Existing LDVs would see more advanced spark timing and more efficient combustion phasing. Higher ethanol content is one available option for increasing the octane ratings of gasoline and would provide additional engine efficiency benefits for part and full load operation."
http://pubs.acs.org/doi/abs/10.1021/acs.est.5b01420?journalCode=esthag

Effects of Fuel Octane Rating and Ethanol Content on Knock, Fuel Economy, and CO_2 for a Turbocharged DI Engine (2014)
Authors: T.G. Leone, E.D. Olin, J.E. Anderson, H.H. Jung, M.H. Shelby, R.A. Stein (Ford, AVL Powertrain Engineering study)
"The data were used in a vehicle simulation of a 3.5L EcoBoost F150, which showed that E20-96 RON at 11.9:1 CR offers 5% improvement in tailpipe CO_2 emissions and 1% improvement in miles per gallon (MPG) fuel economy relative to E10-91RON at 10:1 CR. E30-101 RON at 13:1 CR in this vehicle yielded 6–9% improvement in CO_2 emissions and 2% worse to 1% better MPG fuel economy, depending on the drive cycle."
http://papers.sae.org/2014-01-1228/

Effects of High-Octane E25 on Two Vehicles Equipped with Turbocharged, Direct-Injection Engines (2018)
Authors: B. West, S. Huff, L. Moore, M. DeBusk, S. Sluder
This report provides results for two distinct sets of vehicle experiments using turbocharged, direct-injection gasoline engines. The first is a 2015 Mini Cooper S and the second is a 2016 Ford F150. Both vehicles were evaluated with Tier 3 E10 (92 RON) and "Tier 3 E25" (98.7 RON). Use of E25 in both vehicles resulted in fuel economy in most drive conditions, but especially in high-load conditions such as with the use of downsizing, downspeeding and with the US06 drive cycle. The F150 saw an overall 6% fuel economy with E25 in a high-compression configuration of 13:1 versus E10 in the stock configuration of a 10:1 compression ratio. Across the board acceleration was improved in both vehicles with the use of E25 and NOx emissions were decreased in most conditions.
https://info.ornl.gov/sites/publications/files/pub109556.pdf

Effects of High-Octane Ethanol Blends on Four Legacy Flex-Fuel Vehicles, and a Turbocharged GDI Vehicle (2015)
Authors: J.F. Thomas, B. West, S.P. Huff
"Experiments were performed with four FFVs using a 10% ethanol fuel (E10) with 88 pump octane, and a market gasoline blended with ethanol to make a 30% by volume ethanol fuel (E30) with 94 pump octane. The research octane numbers were 92.4 for the E10 fuel and 100.7 for the E30 fuel. Two vehicles had gasoline direct injected (GDI) engines, and two featured port fuel injection (PFI). Significant wide open throttle (WOT) performance improvements were measured for three of the four FFVs, with one vehicle showing no change. Additionally, a conventional (non-FFV) vehicle with a small turbocharged direct injected engine was tested with a regular grade of gasoline with no ethanol (E0) and a splash blend of this same fuel with 15% ethanol by volume (E15). RON was increased from 90.7 for the E0 to 97.8 for the E15 blend. Significant wide open throttle and thermal efficiency performance improvement was measured for this vehicle, which achieved near volumetric fuel economy parity on the aggressive US06 drive cycle, demonstrating the potential for improved fuel economy in forthcoming downsized, downsped engines with high-octane fuels."
http://info.ornl.gov/sites/publications/files/Pub54888.pdf

Effects of Mid-Level Ethanol Blends on Conventional Vehicle Emissions (2009)
Authors: K. Knoll, B. West, S. Huff, J. Thomas, J. Orban, C. Cooper
"For the aggregate 16-vehicle fleet, increasing ethanol content resulted in reductions in average composite emissions of both NMHC and CO and increases in average emissions of ethanol and aldehydes. Changes in average composite emissions of NMOG and NOX were not statistically

significant. By segregating the vehicle fleet according to power-enrichment fueling strategy, a better understanding of ethanol fuel-effect on emissions was realized. Vehicles found to apply long-term fuel trim (LTFT) to power-enrichment fueling showed no statistically significant fuel effect on NMOG, NMHC, CO or NOX. For vehicles found to not apply LTFT to power-enrichment, statistically significant reductions in NMHC and CO were observed, as was a statistically significant increase in NOX emissions. Effects of ethanol on NMOG and NMHC emissions were found to also be influenced by power-to-weight ratio, while the effects on NOX emissions were found to be influenced by engine displacement."
http://papers.sae.org/2009-01-2723/

Effects of Octane Number, Sensitivity, Ethanol Content, and Engine Compression Ratio on GTDI Engine Efficiency, Fuel Economy, and CO2 Emissions (2017)
Authors: C.S. Sluder, D.E. Smith, M. Wissink, J. Anderson, T. Leone, M. Shelby
The purpose of this study was to "investigate efficiency advantages for increased octane number fuel quality that may be available from ethanol or other blend components in modern light-duty vehicles." Results indicate that higher octane fuels can achieve a 1-6% fuel efficiency improvement, depending on drive cycle, in a high compression configuration of 11.4:1 compared to the baseline E10 fuel with a 10.5:1 compression ratio. With the stock configuration of 10.5:1, high RON E30 fuel achieved a 0.6-8.4% fuel efficiency improvement, depending on drive cycle, meaning a fuel efficiency benefit can be achieved in current vehicles with the use of high-octane fuels.
https://crcao.org/reports/recentstudies2017/AVFL-20/AVFL20_Final%20Report_11032017.pdf

Economic and Environmental Benefits of Higher-Octane Gasoline (2014)
Authors: R.L. Speth, E.W. Chow, R. Malina, S.R.H. Barrett, J.B. Heywood, W.H. Green (MIT Study)
"We find that greater use of high-RON gasoline in appropriately tuned vehicles could reduce annual gasoline consumption in the U.S. by 3.0–4.4%. Accounting for the increase in refinery emissions from production of additional high-RON gasoline, net CO_2 emissions are reduced by 19–35 Mt/y in 2040 (2.5–4.7% of total direct LDV CO2 emissions). For the strategies studied, the annual direct economic benefit is estimated to be $0.4–6.4 billion in 2040, and the annual net societal benefit including the social cost of carbon is estimated to be $1.7–8.8 billion in 2040."
http://pubs.acs.org/doi/abs/10.1021/es405557p

An Engine and Modeling Study on Potential Fuel Efficiency Benefits of a High-Octane E25 Gasoline Blend (2017)
Authors: C.S. Sluder, D.E. Smith, B. West
A Ford F150 EcoBoost engine was tested with 92 RON E10 and 99 RON E25 with a stock configuration compression ratio of 10:1 and an increased compression ratio of 11.4:1. Use of E25 resulted in a decrease in tailpipe CO_2 emissions in all conditions and when used in the high compression ratio configuration fuel economy was improved by 2-5%, depending on drive cycle, with potentially better results in other untested drive cycles.
https://info.ornl.gov/sites/publications/Files/Pub100128.pdf

Experimental Investigation of Spark-Ignited Combustion with High-Octane Biofuels and EGR. 1. Engine Load Range and Downsize Downsized Opportunity (2014)
Author: D.A. Splitter, J.P. Szybist
"Data suggest that, with midlevel alcohol–gasoline blends, engine and vehicle optimization can offset the reduced fuel energy content of alcohol–gasoline blends and likely reduce vehicle fuel consumption and tailpipe CO_2 emissions."
http://pubs.acs.org/doi/abs/10.1021/ef401574p

Experimental Investigation of Spark-Ignited Combustion with High-Octane Biofuels and EGR. 2. Fuel and EGR Effects on Knock-Limited Load and Speed (2014)
Authors: D.A. Splitter, J.P. Szybist
"The results illustrate that intermediate alcohol–gasoline blends exhibit exceptional antiknock properties and performance beyond that indicated by the octane number tests, particularly E30."
http://pubs.acs.org/doi/abs/10.1021/ef401575e

Exploring the Relationship Between Octane Sensitivity and Heat-of-Vaporization (2016)
Authors: C.S. Sluder, J.P. Szybist, R.L. McCormick, M.A. Ratcliff, B.T. Zigler (ORNL, NREL study)
"New studies were performed at ORNL and NREL to further investigate the relationship between HoV and octane sensitivity. Three fuels were formulated for the ORNL study with matched RON and octane sensitivity, but with differing HoV. Experiments with these fuels in a 1.6-liter GTDI engine showed that the fuels exhibited very similar combustion phasing under knock-limited spark advance (KLSA) conditions. Fuels having a range of RON, octane sensitivity, and HoV were tested at NREL in a single-cylinder GDI engine under conditions where octane sensitivity has little effect on knock resistance. KLSA was found to be well correlated with RON. These results reinforce the concept that HoV anti-knock effects can be viewed as a contributor to octane sensitivity. From this viewpoint, HoV effects manifest themselves as increases in octane sensitivity."
http://papers.sae.org/2016-01-0836/

Fuel Economy and CO2 Emissions of Ethanol-Gasoline Blends in a Turbocharged DI Engine (2013)
Authors: H.H. Jung, T.G. Leone, M.H. Shelby, J.E. Anderson, T. Collings (Ford Study)
"The data was used in a vehicle simulation of a 3.5L EcoBoost pickup truck, which showed that the E20 (96 RON) fuel at 11.9:1 CR offers 5% improvement in U.S. EPA Metro-Highway (M/H) and US06 Highway cycle tank-to-wheels CO_2 emissions over the E10 fuel, with comparable volumetric fuel economy (miles per gallon) and range before refueling. The results also indicated that the E30 (101 RON) fuel at 11.9:1 CR provides improvements in CO_2 emissions of 5% on the EPA M/H cycle and 7.5% on the US06 Highway cycle, while volumetric fuel economy was 3% lower on the M/H cycle and approximately equal on the US06 Highway cycle, compared to the baseline E10 fuel at 10:1 CR."
http://papers.sae.org/2013-01-1321/

Heat of Vaporization Measurements for Ethanol Blends Up To 50 Volume Percent in Several Hydrocarbon Blendstocks and Implications for Knock in SI Engines (2015)
Authors: G.M. Chupka, E. Christensen, L. Fouts, T.L. Alleman, M.A. Ratcliff, R.L. McCormick
"Blends of ethanol at 10 to 50 volume percent were prepared with three gasoline blendstocks and a natural gasoline. Performance properties and composition of the blendstocks and blends were measured, including research octane number (RON), motor octane number (MON), net heating value, density, distillation curve, and vapor pressure. RON increases upon blending ethanol but with

diminishing returns above about 30 vol%. Above 30% to 40% ethanol the curves flatten and converge at a RON of about 103 to 105, even for the much lower RON NG blendstock. Octane sensitivity (S = RON - MON) also increases upon ethanol blending. Gasoline blendstocks with nearly identical S can show significantly different sensitivities when blended with ethanol."
http://papers.sae.org/2015-01-0763/

High-Octane Mid-Level Ethanol Blend Market Assessment (2015)
Authors: C. Johnson, E. Newes, A. Brooker, R. McCormick, S. Peterson, P. Leiby, R.U. Martinez, G. Oladosu, M.L. Brown
"The eight deployment scenarios were modeled by the Automotive Deployment Options Projection Tool (ADOPT) to estimate the adoption rate of HOFVs. As shown in Figure ES-1, all scenarios showed the potential for HOFVs to comprise a substantial percentage (43%−79%) of the light-duty vehicle (LDV) stock by 2035. In general, more HOFVs are adopted if HOF is E40 because they offer greater fuel cost savings and offer vehicle manufacturers a greater GHG emissions benefit than if HOF is E25. … The modeling analyses concur that feedstock availability and cost are not expected to be obstacles to the substantial development of a HOF market across all of the scenarios considered. In numerous scenarios, HOF costs are sufficiently competitive that substantial market share is attained—up to 75 billion gallons of E40 (30 billion gallons of fuel ethanol) by 2035. This would meet over 60% of LDV fuel demand in that year, given projections from the ADOPT model. However, all scenarios fell short of satisfying 100% of the fuel demanded by LDVs and were therefore limited."
http://www.afdc.energy.gov/uploads/publication/high-octane_mid-level_ethanol_mkt_assessment.pdf

High octane number ethanol–gasoline blends: Quantifying the potential benefits in the United States (2012)
Authors: J.E. Anderson, D.M. DiCicco, J.M. Ginder, U. Kramer, T.G. Leone, H.E. Raney-Pablo, T.J. Wallington
"Higher RON would enable greater thermal efficiency in future engines through higher compression ratio (CR) and/or more aggressive turbocharging and downsizing, and in current engines on the road today through more aggressive spark timing under some driving conditions. Such an approach would differ from the current practice of blending ethanol into a gasoline blendstock formulated with lower octane rating such that the net octane rating of the resulting final blend is unchanged from historical levels."
http://www.sciencedirect.com/science/article/pii/S0016236112002268

The Impact of Ethanol Fuel Blends on PM Emissions from a Light-Duty GDI Vehicle (2011)
Authors: M.M. Maricq, J.J. Szente, K. Jahr
As the ethanol level in gasoline increases from 0% to 20%, there is possibly a small (<20%) benefit in PM mass and particle number emissions, but this is within test variability. When the ethanol content increases to >30%, there is a statistically significant 30%–45% reduction in PM mass and number emissions observed for both engine calibrations. Particle size is unaffected by ethanol level. PM composition is primarily elemental carbon; the organic fraction increases from ∼5% for E0 to 15% for E45 fuel. Engine-out hydrocarbon and NOx emissions exhibit 10–20% decreases, consistent with oxygenated fuel additives. These results are discussed in the context of the changing commercial fuel and engine technology landscapes."
http://www.tandfonline.com/doi/abs/10.1080/02786826.2011.648780

The Impact of Low Octane Hydrocarbon Blending Streams on the Knock Limit of "E85" (2013)
Authors: J.P. Szybist, B. West
"Results show that nearly all ethanol-containing fuels are more resistant to engine knock than UTG-96 (the only exception being the ethanol blend with 49% n-heptane). This allows ethanol blends made with low octane number hydrocarbons to be operated at significantly more advanced combustion phasing for higher efficiency, as well as at higher engine loads. While experimental results show that the octane number of the hydrocarbon blend stock does impact engine performance, there remains a significant opportunity for engine optimization when considering even the lowest octane fuels that are in compliance with the current revision of ASTM D5798 compared to premium-grade gasoline."
http://papers.sae.org/2013-01-0888/

Impacts of mid-level biofuel content in gasoline on SIDI engine-out and tailpipe particulate matter emissions (2011)
Authors: X. He, J.C. Ireland, B.T. Zigler, M.A. Ratcliff, K.E. Knoll, T.L. Alleman, J.T. Tester
"Bi-modal particle size distributions were observed for all operating conditions with peak values at particle sizes of 10 nm and 70 nm. Idle and low-speed / low-load conditions emitted higher total particle numbers than other operating conditions. At idle, the engine-out particulate matter (PM) emissions were dominated by nucleation mode particles, and the production TWC reduced these nucleation mode particles by more than 50%, while leaving the accumulation mode particle distribution unchanged. At an engine load higher than 6 bar net mean effective pressure (NMEP), accumulation mode particles dominated the engine-out particle emissions, and the TWC had little effect. Compared to the baseline gasoline (E0), E10 does not significantly change PM emissions, while E20 and BU12 both reduce PM emissions under the conditions studied. Iso-butanol was observed to impact PM emissions more than ethanol, with up to 50% reductions at some conditions."
http://digitalscholarship.unlv.edu/renew_pubs/40/

Increasing Biofuel Deployment and Utilization through Development of Renewable Super Premium: Infrastructure Assessment (2014)
Authors: K. Moriarty, M. Kass, T. Theiss
"Retail fueling station equipment is commercially available to accommodate both an E25 and an E25+ fuel. Infrastructure costs to introduce E25 are not expected to be significant, but are much higher for any ethanol blend above E25. Both industry stakeholders and manufacturers are more supportive of an RSP at the E25 level with an octane number around 100. The challenges and barriers faced with RSP are not technical but economic, and are similar to those experienced in the deployment of E15 and E85. The higher level of ethanol in RSP does not make the fueling infrastructure issues any worse—the primary issue is demonstrating compliance with applicable legislation, codes, and standards. Retail station owners will need equipment records to demonstrate compatibility with tanks, pipes, and other associated underground equipment."
http://www.afdc.energy.gov/uploads/publication/increasing_biofuel_deployment.pdf

Intermediate Alcohol-Gasoline Blends, Fuels for Enabling Increased Engine Efficiency and Powertrain Possibilities (2014)
Authors: D.A. Splitter, J.P. Szybist (ORNL study)
"The results demonstrate that E30 may further the downsizing and downspeeding of engines by achieving increased low speed torque, even with high compression ratios. The results suggest that at

mid-level alcohol-gasoline blends, engine and vehicle optimization can offset the reduced fuel energy content of alcohol-gasoline blends, and likely reduce vehicle fuel consumption and tailpipe CO_2 emissions."
http://papers.sae.org/2014-01-1231/

Investigation of Knock Limited Compression Ratio of Ethanol Gasoline Blends (2010)
Authors: J.P. Szybist, M. Foster, W.R. Moore, K. Confer, A. Youngquist, R. Wagner
"It was found that at substantially similar engine conditions, increasing the ethanol content of the fuel results in higher engine efficiency and higher engine power. These results can be partially attributed to a charge cooling effect and a higher heating value of a stoichiometric mixture for ethanol blends (per unit mass of air). Additional thermodynamic effects on the ratio of specific heats (\yy) and a mole multiplier are also explored. It was also found that high CR can increase the efficiency of ethanol fuel blends, and as a result, the fuel economy penalty associated with the lower energy content of E85 can be reduced by about twenty percent. Such operation necessitates that the engine be operated in a de-rated manner for gasoline, which is knock-prone at these high CR, in order to maintain compatibility. By using early and late intake valve closing strategies, good efficiency is maintained with gasoline, but peak power is about 33% lower than with E85."
http://papers.sae.org/2010-01-0619/

Light-Duty Vehicle CO2 Targets Consistent with 450 ppm CO2 Stabilization (2014)
Authors: S.L. Winkler, T.J. Wellington, H. Maas, H. Hass (Ford study)
"New light-duty vehicle fuel economy and CO_2 regulations in the U.S. through 2025 and in the EU through 2020 are broadly consistent with the CO_2 glide paths. The glide path is at the upper end of the discussed 2025 EU range of 68–78 g CO_2/km. The proposed China regulation for 2020 is more stringent than the glide path, while the 2017 Brazil regulation is less stringent. Existing regulations through 2025 are broadly consistent with the light-duty vehicle sector contributing to stabilizing CO_2 at approximately 450 ppm. The glide paths provide long-term guidance for LDV powertrain/fuel development."
http://pubs.acs.org/doi/abs/10.1021/es405651p

Novel Characterization of GDI Engine Exhaust for Gasoline and Mid-Level Gasoline-Alcohol Blends (2014)
Authors: J.M Storey, S. Lewis, J.P. Szybist, J. Thomas, T. Barone, M. Eibl, E. Nafziger, B. Kaul (ORNL study)
"E30 was chosen to maximize octane enhancement while minimizing ethanol-blend level and iBu48 was chosen to match the same fuel oxygen level as E30. Particle size and number, organic carbon and elemental carbon (OC/EC), soot HC speciation, and aldehydes and ketones were all analyzed during the experiment. A new method for soot HC speciation is introduced using a direct, thermal desorption/pyrolysis inlet for the gas chromatograph (GC). Results showed high levels of aromatic compounds were present in the PM, including downstream of the catalyst, and the aldehydes were dominated by the alcohol blending."
http://papers.sae.org/2014-01-1606/

Octane Benefits (Mobile Source Technical Review Subcommittee) (2015)
Authors: C. Jones (GM)
A presentation by automakers highlighting the benefits of a high octane fuel combined with suitable engines.
https://www.epa.gov/sites/production/files/2015-05/documents/050515mstrs_jones.pdf

Octane Response in a Downsized, Highly Boosted Direct Injection Spark Ignition Engine (2014)
Authors: S.M. Remmert, R.F. Cracknell, R. Head, A. Schuetze, A.G.J. Lewis, S. Akehurst, J.W.G. Turner, A. Popplewell (Shell, Univ. of Bath, Jaguar Land Rover study)
"This study demonstrates that fuel octane quality continues to be important for the performance of emerging downsized engine technologies. Furthermore, the trend for continued engine downsizing will increase the potential performance benefit associated with knock resistant fuels."
http://papers.sae.org/2014-01-1397/

Refining Economics of U.S. Gasoline: Octane Ratings and Ethanol Content (2014)
Authors: D.S. Hirshfeld, J.A. Kolb
"Increasing the octane rating of the U.S. gasoline pool (currently ~93 Research Octane Number (RON)) would enable higher engine efficiency for light-duty vehicles (e.g., through higher compression ratio), facilitating compliance with federal fuel economy and greenhouse gas (GHG) emissions standards. The federal Renewable Fuels Standard calls for increased renewable fuel use in U.S. gasoline, primarily ethanol, a high-octane gasoline component. Linear programming modeling of the U.S. refining sector was used to assess the effects on refining economics, CO_2 emissions, and crude oil use of increasing average octane rating by increasing (i) the octane rating of refinery-produced hydrocarbon blendstocks for oxygenate blending (BOBs) and (ii) the volume fraction (Exx) of ethanol in finished gasoline. The analysis indicated the refining sector could produce BOBs yielding finished E20 and E30 gasolines with higher octane ratings at modest additional refining cost, for example, ~1¢/gal for 95-RON E20 or 97-RON E30, and 3–5¢/gal for 95-RON E10, 98-RON E20, or 100-RON E30. Reduced BOB volume (from displacement by ethanol) and lower BOB octane could (i) lower refinery CO_2 emissions (e.g., ~ 3% for 98-RON E20, ~ 10% for 100-RON E30) and (ii) reduce crude oil use (e.g., ~ 3% for 98-RON E20, ~ 8% for 100-RON E30)."
http://pubs.acs.org/doi/abs/10.1021/es5021668

Renewable Oxygenate Blending Effects on Gasoline Properties (2011)
Authors: E. Christensen, J. Yanowitz, M. Ratcliff, R.L. McCormick
"Chemical and physical properties of the blends were compared to the requirements of ASTM specification D4814 for spark-ignited engine fuels to determine their utility as gasoline extenders. Vapor pressure, vapor lock protection, distillation, density, octane rating, viscosity, and potential for extraction into water were measured. Blending of ethanol at 3.7% oxygen increased vapor pressure by 5–7 kPa as expected. 2-Propanol slightly increased vapor pressure in the lowest-volatility BOB, while all other oxygenates caused a reduction in vapor pressure of up to 10 kPa. Coefficients for the Wilson equation were fitted to the measured vapor pressure data and were shown to adequately predict the vapor pressure of oxygenate–gasoline blends for five individual alcohols and MTHF in different gasolines. Higher alcohols and other oxygenates generally improved vapor lock protection. Butyl levulinate blended at 2.7% oxygen caused the distillation end point to exceed 225 °C, thus failing the specification. Distillation parameters were within specification limits for the other oxygenates tested. Other than ethanol, MF, and DMF, the oxygenates examined will not produce blends with satisfactory

octane ratings at these blend levels when blended into lower-octane blendstocks designed for ethanol blending. However, all oxygenates tested except 1-pentanol and MTHF produced an increase in octane rating."
http://pubs.acs.org/doi/abs/10.1021/ef2010089

Review to Determine the Benefits of Increasing Octane Number on Gasoline Engine Efficiency (2012) Coordinating Research Council
The objectives of this comprehensive project was to "establish the relationship between engine (and vehicle) energy efficiency for a spark ignition (SI) engine and the octane number and composition of the fuel." Some of the major relevant findings include: "increasing engine thermal efficiency by about 0.7% per octane point… The use of high ethanol concentration blends (E30 and higher) with gasoline may be particularly beneficial to turbocharged DI engines for two reasons – the high RON and the high cooling power." An efficiency increase of 0.8%-2% for naturally aspirated engines due to compression ratio increases, while downspeeding can provide a 1%-2% efficiency improvement. For turbocharges engines, the efficiency gains achievable can be 5%-7%, whereas if the octane is obtained by an E30 91 RON fuel, torque could improve by 50%.

Summary of High-Octane, Mid-Level Ethanol Blends Study (2016)
Authors: T. Theiss, T. Alleman, A. Brooker, A. Elgowainy, G. Fioroni, J. Han, S. Huff, C. Johnson, M. Kass, P. Leiby, R.U. Martinez, R. McCormick, K. Moriarty, E. Newes, G. Oladosu, J.P. Szybist, J. Thomas, M. Wang, B. West
"The experimental and analytical results of this study considered together show that HOF, specifically mid-level ethanol blends (E25-E40), could offer significant benefits for the United States. These benefits include an improvement in vehicle fuel efficiency in vehicles designed and dedicated to use the increased octane. The improved efficiency of 5-10% could offset the lower energy density of the increased ethanol content, resulting in volumetric fuel economy parity of E25-E40 blends with E10. Most of the flex-fuel vehicles on the road today would be expected to have faster acceleration using HOF, which offers a marketing opportunity in the near term. Furthermore, dedicated HOF vehicles would provide lower well-to-wheel GHG emissions from a combination of improved vehicle efficiency and increased use of ethanol. If ethanol were produced using cellulosic sources, GHG emissions would be expected to be up 17 to 30% lower than those from E10 using conventional ethanol and gasoline. Refinery modeling suggests that refiners could use higher levels of ethanol to meet potentially high market shares of HOF. Analysis of the HOF market and the primary stakeholders reveals that the automotive OEMs, consumers, fuel retailers, and ethanol producers all stand to benefit to varying degrees as HOF increases its market share. The results depend on the underlying assumptions; but HOF offers an opportunity for improved fuel economy, and these dedicated vehicles are likely to be appealing to consumers. The possible limiting constraints to significant HOF market penetration were identified. Regulatory uncertainty and insufficient retailing investment were considered the most likely constraints to limit the introduction of HOF. HOF could be limited by the rate of construction of additional integrated biorefinery capacity, and poor dedicated HOF vehicle penetration would also limit the overall HOF market. Feedstock availability was not found to limit the growth of HOF."
http://info.ornl.gov/sites/publications/Files/Pub61169.pdf

Understanding the Octane Appetite of Modern Vehicles (2016)
Authors: A. Prakash, R. Cracknell, V. Natarajan, D. Doyle, A. Jones, Y. Suk Jo, M. Hinojosa, P. Lobato
"Octane appetite of modern engines has changed as engine designs have evolved to meet performance, emissions, fuel economy and other demands. The octane appetite of seven modern vehicles was studied in accordance with the octane index equation OI=RON-KS, where K is an operating condition specific constant and S is the fuel sensitivity (RON-MON)." The study "consistently found that fuels with higher RON and higher sensitivity performed better showing that the octane response of modern vehicles is moving further away from MON." These results may indicate that current on-road vehicles can already benefit from the use of higher RON fuels.
https://www.sae.org/publications/technical-papers/content/2016-01-0834/

A Vehicle Manufacturer's Perspective on Higher-Octane Fuels (2014)
Authors: T.G. Leone (Ford)
A presentation by Tom Leone/Ford on how high octane is both a good idea and necessary to meet CO_2 goals.
http://energy.gov/sites/prod/files/2014/11/f19/leone_biomass_2014.pdf

Well-to-Wheels Greenhouse Gas Emissions Analysis of High-Octane Fuels With Various Market Shares and Ethanol Blending Levels
Authors: J. Han, A. Elgowainy, M. Wang
"The overall WTW GHG emission changes associated with HOF vehicles were dominated by the positive impact associated with vehicle efficiency gains and ethanol blending levels, while the refining of gasoline blendstock for oxygenate blending (BOB) for various HOF blend levels (E10, E25, and E40) had a much smaller impact on WTW GHG emissions. The 5% and 10% MPGGE gains by HOF reduced the WTW GHG emissions by 4% and 8%, respectively, relative to baseline E10 gasoline. The additional WTW GHG reductions when corn ethanol was used for blending were 5% and 10% for E25 and E40, respectively. As a result, when corn ethanol was used, total WTW GHG emission reductions from using E10, E25, and E40 relative to baseline E10 gasoline were 5%, 10%, and 15%, respectively, with a 5% MPGGE gain, while using E40 achieved an 18% total WTW GHG emission reduction with a 10% MPGGE gain. When corn stover ethanol was used for blending, the additional WTW GHG reductions were 12% and 24% for E25 and E40, respectively. As a result, with the corn stover ethanol, total WTW GHG emission reductions from using E10, E25, and E40 relative to baseline E10 gasoline were 8%, 18%, and 28%, with a 5% MPGGE gain, while using E40 achieved a 32% total WTW GHG emission reduction, with a 10% MPGGE gain."
https://greet.es.anl.gov/files/high-octane-various-shares

FUEL FREEDOM®

Attachment to comments for the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

EPA Docket ID: EPA-HQ-OAR-2018-0283
NHTSA Docket No.: NHTSA-2018-0067

Supplement to Fuel Freedom Foundation comments

Appendix E: Regulatory Barriers for Greater Use of Ethanol Blended High-Octane Fuels

The "Sub-Sim" Rule

Section 211(f) (1) (A) of the Clean Air Act prevents manufacturers of "any fuel or fuel additive to first introduce into commerce, or to increase the concentration in use of, any fuel or fuel additive… which is not substantially similar to any fuel or fuel additive utilized in the certification of any model year 1975, or subsequent model year, vehicle or engine."

As gasoline now contains ethanol "used in certification", an update of the interpretation of this rule, as was done in 1981[1], 1991[2] and 2008,[3] to include a broader range of fuels, including those with higher blends of ethanol, would be an appropriate to allow for high octane fuels.

RVP Waiver

Currently, Reid vapor pressure (RVP) limits for gasoline stand at 9.0 psi or 7.8 psi depending on the state and time of year. However, gasoline with 9%-10% ethanol by volume receives a 1.0 psi RVP waiver allowing that fuel to be sold in the market so long as the RVP is no more than 1.0 psi higher than otherwise allowed. The RVP waiver could be amended to include fuels that have *at least* 9%-10% ethanol by volume. Such a change would include not only E15 as recently announced, but all current and future legal ethanol blends. Technical experts indicate that RVP concerns decrease with ethanol blends above the approximate 'worst case scenario' at roughly 10%-15% ethanol.

The "R-Factor"

The "R-factor", used by EPA to compute fuel economy for certification test cycles, was an equation originally compiled based on testing 1980s model vehicles. More recent testing and evaluation by EPA and the Coordinating Research Council have found that value of the R-factor

[1] EPA [EN-FRL 1821-4] *Fuels and Fuel Additives; Revised Definition of "Substantially Similar"* https://www.epa.gov/sites/production/files/2015-10/documents/july81.pdf

[2] EPA [FRL-3856-9] *Regulation of Fuels and Fuel Additives; Definition of Substantially Similar* https://www.epa.gov/sites/production/files/2015-10/documents/jan91.pdf

[3] 40 CFR Part 79 [EPA–HQ–OAR–2007–0071; FRL–8557–8] Revised Definition of Substantially Similar Rule for Alaska https://www.epa.gov/sites/production/files/2015-10/documents/e8-8944_0.pdf

to be higher.[4] The outdated figure undervalues ethanol. Revising the figure to be more in line with recent research, vehicles, engines and fuels, could place all liquid fuels on equal footing with regards to fuel economy certification.

[4] West, B., Sluder, C. S., *Preliminary Examination of Ethanol Fuel Effects on EPA's R-Factor for Vehicle Fuel Economy*, June 2013