September 26, 2016

To: **Environmental Protection Agency (EPA)**
National Highway Traffic Safety Administration (NHTSA)
California Air Resources Board (CARB)

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Re: **EPA Docket ID: EPA-HQ-OAR-2015-0827**
NHTSA Docket No.: NHTSA-2016-0068
Submitted via http://www.regulations.gov and
http://www.arb.ca.gov/lispub/comm2/bcsubform.php?listname=drafttar2016-ws

Introduction and Overview

These comments are submitted on behalf of Fuel Freedom Foundation, in response to the Midterm Evaluation Draft Technical Assessment Report for Model Year 2022-2025 Light-Duty Vehicle GHG Emissions and CAFE Standards.

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:

- Improved national security by reducing our dependence on foreign oil
- Improved public health by reducing emissions of toxic and criteria air pollutants
- Reduced environmental impacts related to oil production and use
- Reduced emissions of greenhouse gases (GHG)
- Increased economic opportunities generated by greater deployment of U.S. domestic sources of fuel

Consequently, Fuel Freedom fully supports the National Program and its primary goals: to improve fuel economy, reduce GHG emissions, and decrease petroleum use.

Because these are so vital to our national interests, Fuel Freedom believes that the agencies should widen the net in their examination of technologies in the Technical Assessment Report (TAR), in order to most thoroughly assess National Program compliance scenarios for 2025 within the Midterm Evaluation (MTE). The Draft TAR focuses on selected technologies that will allow automakers to meet the 2022-2025 Corporate Average Fuel Economy (CAFE) and GHG standards, but these standards are only a first step and not an endpoint. Continuing progress will require a steady and incremental approach to meet both National Program and U.S. national climate goals.

Despite the Draft TAR's stated emphasis on technologies that are expected to contribute to National Program compliance to 2025, it goes beyond this timeframe – but only selectively. In discussing technology that might be important after 2025, the TAR only considers electric vehicles (EVs) and hydrogen fuel cell electric vehicles (FCEVs). A longer-term perspective is appropriate to ensure continued progress, but the scope should not be selectively limited.

Internal combustion engines (ICEs) are expected to dominate the roadways for decades[1]—not only in the U.S., but around the world[2]—and should similarly be considered for the longer term. The average age for light-duty vehicles has increased to 11.4 years.[3] Therefore, MY2022-MY2025 vehicles may significantly impact the on-road fleet for more than a decade after they are first sold. Moreover, spark-ignition engine technologies introduced before 2025 will have significant bearing on the ability of ICEs to meet future CAFE and GHG standards. ICE technologies should be assessed not only for their performance for 2022-2025, but also in the context of their ability to enable additional engine advancements in the future. Critically, these vehicles can complement rather than supplant the maturation and growth of alternative vehicle technologies. A recent study found that greater use of high compression engines to meet the MY2025 standards will not only lower compliance costs, but will do so without hindering consumer adoption of battery EVs.[4]

Yet considering vehicle technology in a vacuum is inadequate, as recognized by the discussion of electric and hydrogen fueling infrastructure in the Draft TAR. For maximum benefit, the National Program must also consider and address fuels.

The long history of transportation policy and regulations demonstrates that fuels and vehicles are best considered as an interconnected system. However, the National Program has to date focused on vehicle technology for ICEs, and accepted regular-grade gasoline as given. Unfortunately, the Draft TAR continues this trend, by limiting the analysis to spark-ignition vehicle technologies' performance using 87 anti-knock index (AKI) gasoline. **This approach is shortsighted, and ignores the potential for higher-octane-fueled ICE technologies to help meet National Program goals even before 2025, and certainly beyond.**

The rising urgency to retard the global increase in GHG emissions from transportation and at the same time raise fuel economy have inspired new investigations of high-octane (~100 RON) fuels to maximize the contribution of ICEs. Higher-octane fuel was proffered by Environmental Protection Agency (EPA) in Tier 3 to help automakers meet light-duty GHG standards,[5] and recommended for consideration to improve fuel economy in Phase II of the National Highway Traffic Safety

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[1] 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

[2] Navigant Research, *Transportation Forecast: Light Duty Vehicles*, March 1, 2016

[3] DOT, *National Transportation Statistics*, April 2016

[4] Air Improvement Resource, *Evaluation of Costs of EPA's 2022-2025 GHG Standards With High Octane Fuels and Optimized High Efficiency Engines*, September 16, 2016

[5] EPA Tier 3 Notice of Proposed Rulemaking proposed a high-octane mid-level ethanol blend that "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" EPA, *Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards: Proposed Rule*, p. 29825, May 21, 2013

Administration (NHTSA)-commissioned National Academy of Sciences study (NAS 2015).[6] High-octane fuel has also been the subject of a robust body of research, including Department of Energy's (DOE) Co-Optima program, to demonstrate the efficiency and GHG reduction benefits of optimizing vehicles and fuels in tandem. The wealth of credible, peer-reviewed information available justifies including higher-octane-fuel and engine technologies enabled by it in the Final TAR, in order to compare their relative potential benefits and costs to the technologies already considered in the draft, and to assess within the MTE the most efficient and effective incentives to continue the success of the National Program.

Expanding the TAR analysis to include higher-octane fuels is both appropriate and necessary. The 2022-2025 period under consideration in the MTE is a small slice of time in the evolution of technologies and shifting market realities that will determine the ability of the light-duty vehicle fleet to steadily reduce GHG emissions and increase fuel economy. The TAR should therefore not just look to the time period under review, but to its context as the gateway to the future. Technologies considered in the TAR and the larger MTE should include an assessment of the full range of promising engine and fuel possibilities currently on the horizon, which:

- are technically feasible or foreseeable
- enable further technology advancements, rather than result in a dead end
- are environmentally and climatically favorable to the fuels and vehicles in use today
- are cost-effective in reaching program goals
- can provide maximum technical flexibility to meet the GHG and CAFE standards of the future

Due to the length of the automotive technology development and implementation cycles, considering the entire range of technologies that satisfy these five criteria is appropriate within the TAR, in order to prepare for a seamless evolution beyond 2025. However, a seamless evolution will require not only consideration, but also supportive government policies.

Market forces have recently increased the share of premium fuel (91-93 AKI) sold in the marketplace. Nonetheless, the proportion remains less than 12%. ICEs can offer increased efficiency and GHG emission reduction benefits to help achieve National Program goals, but higher-octane fuels must be generally available, rather than a premium-priced niche offering. This requires EPA and California Air Resources Board (CARB) to raise the minimum octane in the marketplace, which will take many years to fully realize. Considering and initiating the necessary steps to make the promise of high-octane fuels a reality is essential within the MTE timeframe.

For the time horizon beyond the scope of the TAR and MTE, our ambitious long-term national goals for reducing GHG emissions will ultimately require a holistic fuel-vehicle perspective. Thus, EPA and CARB's separate efforts should include weighing the GHG implications for the post-2025 period, by evaluating the range of vehicle, engine, and fuel technologies according to their ability to set the trajectory toward 2050 climate targets. The necessary analyses are clearly beyond the downstream

[6] NAS, *Cost, Effectiveness and Deployment of Fuel economy Technologies for Light-Duty Vehicles*, 2015

purview of the CAFE standards and the scope set out for the TAR, but should include a side-by-side comparison of the full fuel-cycle GHG emissions, as well as the costs and benefits of fuel-vehicle system pathways that could facilitate or enable an 80% reduction of GHG emissions in light-duty transportation by 2050. This holistic view should guide National Program standards beyond 2025, to continue its success to date in progressively reducing the environmental impact of light-duty transportation, while minimizing disruption and maximizing benefits for American drivers.

Fuel Freedom's comments below focus on four specific topics:

1. Expanding the TAR to include high-octane fuels combined with vehicle technologies to better inform the MTE of National Program standards to 2025
2. Revisiting CAFE and GHG program incentives for 2017-2025 in light of the current vehicle-fuel technology and market realities
3. Considering an orderly national transition to higher-octane fuel
4. Synchronizing GHG standards for beyond 2025 with national climate goals by incorporating a full fuel-cycle perspective and a comprehensive assessment of relative benefits and costs of plausible long-term pathways

Expand the fuels and technologies considered in the TAR

The comments in this section, which are supported by more than 10,500 signatures to Fuel Freedom Foundation's online petition supporting high-octane fuels (see Appendix A), are in response to the TAR request for

> *"public comments on vehicle technologies, including data on costs and effectiveness of technologies discussed here or additional information on technologies which could be in production in the 2022-2025 timeframe or are already in production today that may have been omitted from this Draft TAR."*[7]

The Draft TAR on one hand explicitly limited engine technologies to those expected to contribute to National Program compliance through 2025, yet nonetheless took a longer-term view by including an analysis of EVs and FCEVs. And while it explicitly limited spark-ignition technologies to their performance using regular-grade gasoline, it considered in depth the infrastructure requirements for electric and hydrogen fueling systems. Given the robust discussion of fueling infrastructure needed for EVs and FCEVs, it is puzzling that the Draft TAR did not similarly consider high-octane fuels, in light of the body of research documenting the benefits. We believe that longer-term considerations are appropriate to ensure an orderly evolution of light-duty transportation, but that they should not be selectively restricted in the TAR. Given the expected ubiquity of ICEs for decades, feasible spark-ignition engine technologies and fueling requirements should be considered as fully as alternative fuel vehicles, with the longer-term in mind.

[7] EPA, NHTSA, *Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025*, p. 5-2, July 2016

Include a systems approach in the TAR analysis of ICEs

EPA has long recognized that fuel and vehicle technologies need to be considered as a system, on the basis that fuel composition affects emissions control equipment as well as tailpipe emissions. EPA has accordingly regulated both fuels and vehicles since the 1970s. Lead was phased out of gasoline to enable the use of catalytic converters. Gasoline vapor pressure was limited to reduce hydrocarbon emissions from vehicle and fueling systems and prevent subsequent smog formation. The Auto-Oil program of the 1980s and 90s took a system perspective to evaluate vehicles and fuels for toxic and criteria pollutant emissions performance, and ultimately provided the basis for updated EPA regulations to improve air quality. Auto-Oil's findings[8] and more recent research[9] have resulted in: reformulated gasoline that reduced the impact of vehicle exhaust on smog formation, gasoline specifications to limit sulfur and benzene, and the addition of up to 15% ethanol by volume. Similarly, EPA regulated sulfur content in diesel fuels to enable NOx and PM2.5 control technologies in heavy-duty diesel engines.

These programs and standards addressed toxic and criteria pollutant emissions by looking at vehicles and fuels together. More recently, EPA and CARB have begun regulating GHG emissions in transportation, and in 2012 established GHG emission standards through 2025, which is the agencies' focus in the TAR. However, like the National Program standards, the Draft TAR assessment is effectively limited to vehicle technology. Rather than evaluating the downstream potential of vehicles and fuels synchronized for maximum National Program benefit, the TAR focuses on ICE technology performance using AKI 87 gasoline, leaving off the table contemplation of additional spark-ignition engine technologies that can further improve fuel economy and reduce GHG emissions.

Analyze performance of TAR spark-ignition engine technologies using high-octane fuels

The Draft TAR provides a robust assessment of many technologies that can be employed to meet the MY2025 standards of the National Program; however, by limiting evaluation of spark-ignition engine technologies to their performance on 87 AKI gasoline, it falls short of "a holistic assessment of all the factors… including those set forth in this final rule and other relevant factors," as stipulated in the 2012 Final Rulemaking for the CAFE and GHG standards.[10] It also excludes "technologies where reliable evidence was available" in the existing literature.[11] Ample research shows that fuel economy and CO_2 emissions performance of the technologies evaluated in the Draft TAR, as well as other available technologies not discussed at length, can be improved when used in conjunction with premium gasoline in the marketplace (91-93 AKI, or ~97 RON), or with even higher-octane fuels (~100 RON), including mid-level ethanol blends.

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[8] Leppard, W., Koehl, W., Benson, J., et al., *Effects of Gasoline Properties (T50, T90, and Sulfur) on Exhaust Hydrocarbon Emissions of Current and Future Vehicles: Speciation Analysis - The Auto/Oil Air Quality Improvement Research Program,* Oct. 01, 1995

[9] EPA, *EPAct/V2/E-89 Tier 2 Gasoline Fuel Effects Study*, April 2013

[10] EPA, NHTSA, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule,* pg. 62652, Oct. 15, 2012

[11] Despite the introduction to Chapter 5, the Draft TAR excludes some "technologies where reliable information is available"

In its analysis to support the TAR development and MTE process, the NAS 2015 report considered a wide range of technologies to reduce fuel consumption in light-duty spark-ignition engines. These included key emerging and feasible technologies beyond those that had been originally set out for consideration. Prominent among the Chapter 2 findings and recommendations were the low-cost potential for higher-octane fuels, in their own right and when coupled with higher compression ratio engines. Given EPA's own reference to the possibility in Tier 3, and ample research documenting the potential fuel economy and CO_2 benefits as outlined below, higher-octane fuels merit consideration in the TAR, on the basis that "reliable evidence" is readily available in the robust body of existing literature, and that they could be introduced to market prior to 2025.

Comparing the fuel economy and GHG performance of higher-octane fuels paired with appropriate engine technologies would reflect a more "holistic assessment" of "relevant factors."[12] **The TAR should include an evaluation of available or potentially available fuels that can enable the use of, or greater use of, technologies that would increase fuel efficiency and decrease CO_2 emissions in line with National Program goals. Obvious candidates for comparison with 87 AKI gasoline would be 91 AKI premium gasoline, and a higher-octane (~100 RON) mid-level ethanol blend as proposed in EPA's Tier 3 Proposed Rulemaking.**[13]

Include high-octane-enabled spark-ignition engine technologies in the TAR

Several fuel properties that affect GHG emissions in ICEs include octane, heat of vaporization, and carbon intensity (CI). DOE, in its Co-Optima program, is investigating the effects of liquid fuel properties on GHG emissions, as well as combinations of advanced ICE combustion cycles and advanced fuels to improve vehicle efficiency. In addition, a wealth of research shows the benefits of higher octane and higher heat of vaporization on ICE efficiency (see Appendix B). Higher-octane fuels enable existing vehicles equipped with a knock sensor to advance spark timing and improve efficiency, and allows the design of new vehicles with higher compression to further increase engine efficiency and enable additional improvements with additive technologies such as downsizing and hybridization. Further, the combined CO_2 emissions benefits of high-compression ratio with high octane can exceed the sum of their individual CO_2 reductions.[14] **The cost of higher compression engines coupled with higher octane is competitive with many of the advanced ICE technologies suggested in the Draft TAR, and can provide greater certainty for meeting the 2025 standards without hindering the adoption of other advanced technologies such as battery EVs**.[15] As recommended in the NAS 2015:[16]

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[12] Per 40 CFR section 86.1818(h)(1), EPA must also consider in the MTE "availability and effectiveness of the technology" and "appropriate lead time for introduction of technology," both of which support including high-octane-fueled technologies that can be introduced prior to MY2025, to facilitate compliance for 2022-2025, and to assist an orderly transition to future CAFE and GHG standards

[13] EPA, *Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards: Proposed Rule*, p. 29825, May 21, 2013

[14] Jung, H., Leone, T., Shelby, M., Anderson, J. et al., *Fuel Economy and CO_2 Emissions of Ethanol-Gasoline Blends in a Turbocharged DI Engine*, April 8, 2013

[15] Air Improvement Resource, *Evaluation of Costs of EPA's 2022-2025 GHG Standards With High Octane Fuels and Optimized High Efficiency Engines*, September 16, 2016

[16] NAS, *Cost, Effectiveness and Deployment of Fuel economy Technologies for Light-Duty Vehicles:* pg. 84, 2015

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.

In support of this recommendation, a large body of research attests to the potential of high compression ratio engines coupled with high-octane fuels, combined with other improvements, to achieve greater fuel efficiency. All of these inherently undertake a systems approach to vehicles and fuels, to gauge maximum total benefits. As evidenced by the following sample of research and the list in Appendix B, these technologies are well known, nearly market-ready in automotive terms, and have shown great promise for increased efficiency and CO_2 reductions, all of which justify their addition to the technologies considered in the Final TAR.

NAS 2015 found that the spark retard needed to avoid knock in turbocharged, downsized engines using 87 AKI fuel would lead to "an increase in fuel consumption of approximately 6% at the high load conditions susceptible to knock." Thus use of 87 AKI fuel limits, and in some conditions can negate, the fuel economy improvements possible with turbocharging and downsizing. Conversely, a 2013 report by Oak Ridge National Lab (ORNL) found that a high-octane fuel (100 RON) displayed better knock performance in a high compression ratio engine (11.85:1) compared to regular 87 AKI gasoline, suggesting that a downsized, downspeed engine in a midsize sedan could increase fuel economy by 14% — from 38.6 MPG to 43.9 MPG.[17]

In the near term, high-octane fuels can be produced from petroleum or a combination of petroleum and ethanol. Ethanol blends reduce CI and increase engine efficiency due to higher octane and other favorable properties such as higher heat of vaporization. ORNL found that if mid-level ethanol blends provide the necessary octane, "engine and vehicle optimization can offset the reduced fuel energy content… and likely reduce vehicle fuel consumption and tailpipe CO_2 emissions."[18] A study using a Ford direct-injection 3.5L EcoBoost engine found a 1% increase in MPG in a high compression ratio (CR) engine (11.9:1) for an E20 96 RON fuel compared to an E10 91 RON fuel,[19] despite the lower energy density of the E20 fuel, showing "that the improved efficiency from higher CR more than offsets the fuel energy content difference." A more recent report tested high-octane mid-level ethanol (101 RON E30) on EPA drive cycles in unmodified vehicles and in vehicles modified to simulate a downsized, downspeed drivetrain.[20] The vehicles yielded a mile per gallon equivalent improvement of 5 to 5.7% in the stock configuration, and 10 to 10.7% in the modified configuration compared to 91 RON E10 fuel. The same report examined the

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[18] Splitter, D., Szybist, J., *Experimental Investigation of Spark-Ignited Combustion with High-Octane Biofuels and EGR. 1. Engine Load Range and Downsize Downspeed Opportunity*, December 28, 2013

[18] Splitter, D., Szybist, J., *Intermediate Alcohol-Gasoline Blends, Fuels for Enabling Increased Engine Efficiency and Powertrain Possibilities*, April 1, 2014

[20] Jung, H., Leone, T., Shelby, M., Anderson, J. et al., *Fuel Economy and CO_2 Emissions of Ethanol-Gasoline Blends in a Turbocharged DI Engine*, April 8, 2013

[20] West, B., Szybist, J., Theiss, T., et. al., *Summary of High-Octane Mid-Level Ethanol Blends Study*, p. 10, July 2016

effects of high-octane mid-level ethanol blends on legacy vehicles and found and a 5% efficiency improvement in vehicles equipped with turbocharged, direct-injection engines.

Looking beyond individual vehicles, a Massachusetts Institute of Technology (MIT) study identified a potential fleet-wide 4.5% decrease in fuel consumption by 2040 from wide-scale use of high-octane fuels (98 RON).[21] Other studies have found ethanol to be well-suited to compete as an octane enhancer,[22] have examined the feasibility of producing octane at the refinery,[23] and evaluated the full fuel cycle GHG emissions of high-octane fuels.[24,25] **Together, the literature documents the possibility of high-octane fuels to reduce CO_2 emissions and increase fuel economy, and details their feasibility and relative effectiveness towards meeting those goals.**

The body of recent research that documents the downstream fuel-vehicle system benefits of ICEs justifies the inclusion of additional high-octane-enabled ICE technologies in the TAR. The NAS 2015 report finding that higher octane combined with high-compression spark-ignition engines could provide a low-cost pathway for CAFE compliance supports this view.[26] Yet the current mix of technologies discussed in the Draft TAR seems selective when promising immediate- to near-term ICE technologies are excluded while EV and FCEV technologies, which appear to be much further from widespread adoption, are discussed in detail. **To provide a more thorough assessment and better inform the MTE—especially in light of the recent increase in market penetration of less efficient ICE vehicles and commensurate decrease in alternative fuel vehicle purchases—the final TAR must include an assessment of the costs and potential National Program benefits of promising high-octane ICE technologies, such as high compression engines, that are either already in the market, or on the foreseeable horizon**.

Revisit proposed CAFE and GHG program credits

CAFE and GHG incentives influence the effectiveness of the National Program, by encouraging or accelerating the development and market introduction of favorable technologies. Notwithstanding EPA's understanding that "individual manufacturers have been able to adopt new technologies at a faster rate than previous industry-wide analyses have shown," the earlier EPA signals its willingness to consider new technologies, the sooner they will be implemented by the automotive industry, and the sooner fuel economy and CO_2 reductions will be realized.[27] From a climate perspective, earlier GHG reductions are better than later.

The 2012 Rulemaking proposed alternative fuel vehicle credits for 2017-2025, centered on technologies that require the most regulatory support to gain a foothold in the market, including

[21] Chow, E., Heywood, J., Speth, R., *Benefits of a Higher Octane Standard Gasoline for the U.S. Light-Duty Vehicle Fleet*, April 1, 2014
[22] Irwin, S., Good, D., *The Competitive Position of Ethanol as an Octane Enhancer*, February 3, 2016
[23] Hirshfeld, D., Kolb, J., *Refining Economics of U.S. Gasoline: Octane Ratings and Ethanol Content*, August 21, 2014
[24] 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*, July 14, 2015
[25] West, B., Szybist, J., Theiss, T., et. al., *Summary of High-Octane Mid-Level Ethanol Blends Study*, p. 10, July 2016
[26] NAS, *Cost, Effectiveness and Deployment of Fuel economy Technologies for Light-Duty Vehicles: Finding 2.4*, pg. 83, 2015
[27] Hula, A., Alson, J., Bunker, A., et. al., *Analysis of Technology Adoption Rates in New Vehicles,* April 1, 2014

EVs, FCEVs, and compressed natural gas (CNG).[28] But even under the most optimistic projections for alternative fuel vehicles supported by attractive market and regulatory incentives, spark-ignition vehicles will dominate U.S. roadways far beyond 2025. Consequently, ICEs will exert significant sway over future compliance with National Program standards. Yet neither EPA nor NHTSA proposed any liquid-fueled vehicle incentives in the Draft TAR. Fuel Freedom supports the entire range of alternative fuel vehicles, but believes that liquid-fueled ICE technologies merit consideration for incentives to complement the proposed credits for EV, FCEV and CNG technologies. Recent evidence shows that circumstances can intercede to undermine projections of fleet average CO_2 reductions. Lower gasoline prices have reduced sales of hybrids and alternative fuel vehicles, in conjunction with an uptick in sales of light trucks. Appropriate incentives could provide a 'hedge' or insurance policy for progress.

We do not propose specific CAFE or GHG credit schemes. Appropriate incentives should be negotiated between the agencies and automakers as the regulated parties. However, one ICE incentive to consider would be material compatibility with higher alcohol blends. High-octane alcohol fuels can be used in future ICEs and provide additional National Program benefits when optimized across nearly all of the spark-ignition engine technologies considered in the Draft TAR. It could make sense to provide original equipment manufacturers with incentives to produce vehicles with materials compatible for higher alcohol content. In addition to the 20 million existing flex-fuel vehicles (FFVs), hardware changes to accommodate higher alcohol concentrations would facilitate a future introduction of high-octane, mid-level ethanol blends.

Raise minimum octane in the marketplace

Transportation policy development and implementation is dogged by a chicken-and-egg dilemma in trying to synchronize availability and use of fuels and vehicles. Yet continuing the trajectories of CO_2 reductions and higher vehicle efficiency will require fuels that are more suited, and perhaps even specifically designed, to meet these goals by maximizing the fuel economy and environmental performance of the vehicle-fuel system. Therefore, to ensure the realization of expected National Program benefits as engine technology evolves, EPA and CARB must exercise their acknowledged authorities[29,30,31] to approve appropriate higher-octane fuels, and to decrease and ultimately eliminate the availability of low-octane fuels unsuitable for advanced engine technologies.

Although it is outside the scope of the agenda set out for the MTE, the full technical, environmental and economic analyses for regulatory approval should be initiated by 2018 in parallel to the MTE process, in order to prepare for future rulemakings to establish the next generations of CAFE and GHG standards. The lead phase-out and more recent fuel regulations for gasoline (Tier 2 and Tier 3

[28] EPA, NHTSA, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule*, October 12, 2012

[29] 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, May 5, 2015

[30] Machiele P., D*OE Sustainable Transportation Summit [Interview],* July 12, 2016

[31] CARB, *Presentation to Clean Air Act Advisory Committee, Mobile Sources Technical Review Subcommittee [Presentation],* Slide 10, May 5, 2015

requirements) and fuel regulations for low-sulfur diesel fuels, provide useful guides for a successful transition. At the same time, they demonstrate that the process takes many years. Introduction of higher-octane fuels will require development and approval of fuel formulation(s) and full adoption of ASTM engine testing specifications,[32] as well as engines to be designed and certified for its use. Adding fueling infrastructure and market transition time, a decade or more can be expected. Fortunately, the current gasoline infrastructure could be modified to handle either petroleum-derived high-octane fuels or higher ethanol blends such as a mid-level E25-E40. The transition to high-octane ethanol blends may be facilitated by the 20 million FFVs on the road, which are compatible with any blend up to E85. These FFVs would provide a foothold for matching fuels and vehicles in a high octane transition.[33] **Nevertheless, given the long lead time, the Draft TAR does a disservice to an appropriately steady and incremental approach to CAFE and GHG standards by pushing consideration of higher-octane fuels to beyond 2025. We cannot afford to wait that long.**

Set the trajectory to meet national climate goals for 2050

Fuel Freedom understands that full fuel-cycle analyses are beyond the scope of the TAR, and the National Program's current downstream purview. However, a more holistic prospective ultimately will be necessary for light-duty transportation, in the context of our ambitious national climate goals. In the comments below, we recommend that EPA and CARB plan for such a holistic approach in the future. We do not propose specific policy recommendations.

While GHG emissions in power generation have decreased relatively quickly in the transition from coal to natural gas and aggressive additions of renewable capacity, progress in transportation has been more measured. The necessity to synchronize upstream and downstream GHG emissions regulations is highlighted by the fact that transportation has surpassed electricity as the largest source of GHG emissions in the U.S.,[34] with light-duty vehicles accounting for the largest portion.

Consider the full fuel cycle

Argonne National Lab's GREET model was developed to comparatively assess well-to-wheels emissions using a systems approach. However, such a full fuel-cycle perspective has not been integrated into light-duty transportation policy. To date, EVs and FCEVs have been the primary focus of analyses of long-term GHG reductions in light-duty transportation. However, considering these vehicles in isolation within the current context of the National Program, and thus ignoring well-to-wheels fuel-cycle implications, is insufficient to put the U.S. on a path to meeting its climate goals for the light-duty transportation sector. For instance, EPA's GHG standards currently consider only downstream use and therefore assign zero emissions to EVs and FCEVs, which ignores the fuel-cycle implications. From a CAFE program perspective, this makes sense, but EPA's authority,

[32] ASTM, Standard Specification for 100 Research Octane Number Test Fuel for Automotive Spark-Ignition Engines 1, work item 54471, 2016
[33] It is important to note that production of flex-fuel vehicles is rapidly declining due to the sunset of both CAFE and GHG program credits
[34] EIA, *Monthly Energy Review July 2016,* p. 176, July 26, 2016

reaffirmed by the U.S. Supreme Court,[35] is not limited to vehicle emissions alone. To ensure that GHG emissions reductions from light-duty transportation contribute a fair share toward national goals after 2025, EPA and CARB must look upstream. **Reducing GHG emissions by 80% by 2050 will depend heavily on the contribution of ICEs which are expected to dominate U.S. roadways for decades.** Therefore, EPA and CARB should consider the full current and potential future GHG emissions of the fuel cycle for electricity and hydrogen, and compare the results to the holistic fuel-cycle GHG profile of advanced ICEs powered by liquid fuels--both with and without electric hybridization--in order to provide a context for evaluating lower-carbon pathways for all three options.

The global context

As our domestic climate goals are in conjunction with the Conference of Parties agreements, U.S. transportation policies can also be a lynchpin in the global context. Countries struggling to mitigate GHG emissions from light-duty transportation may not only look to the U.S. for guidance, but may also benefit from the vehicle technologies that emerge. Vehicle technologies developed and adopted in the U.S. can "trickle-down" to other countries, especially small or developing nations that have less aggressive policies or less influence on the transportation sector. Even more so than in the U.S., relative cost will be a predominant factor. Therefore, a cost-effective approach to increase efficiency could amplify the GHG reduction benefits of the National Program, by ensuring that similar advancements are realized beyond our borders.

Feedstocks matter for achieving U.S. climate goals

High-octane fuels can enable advances in engine timing and compression ratio, and depending on the source of octane, further gains can be achieved by charge air cooling. These advances can collectively reduce petroleum consumption and CO_2 emissions--even more so when accounting for the CI of the fuel.

As previously outlined, fuel properties—most notably octane—influence downstream CO_2 emissions performance, but from a fuel-cycle perspective, feedstocks and fuel production are significant contributors to GHG emissions. Feedstocks used to produce fuels affect fuel economy, petroleum reduction—which is a major goal both nationally and in California[36]—and CO_2 emissions from vehicles. Petroleum-derived octane enhancers, specifically reformates and alkylates, not only increase petroleum use, but also increase gasoline CI relative to biomass-derived sources such as corn or cellulosic ethanol.[37] This negates a portion of the downstream carbon savings and fuel reductions achieved through increased efficiency.[38] The urgency to decrease GHG reductions in particular justifies a holistic assessment. Within the MTE timeframe, EPA and CARB should study

[35] U.S. Supreme Court, *Massachusetts, et. al., Petitioners v. Environmental Protection Agency, et al,* 549 U.S. 497, 2007
[36] Brown, E., *Inaugural Address,* Jan. 5, 2015
[37] CARB, *LCFS Pathway Certified Carbon Intensities*, August 11, 2016, from http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm
[38] 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*, July 14, 2015

the fuel-cycle GHG implications of fuels and vehicle systems to eventually establish the post-2025 trajectory to 80% reductions by 2050.

Optimizing the fuel-vehicle system to maximize GHG emissions reductions

A recent study by National Renewable Energy Laboratory (NREL) illustrates the relationship between vehicle energy efficiency and fuel CI.[39] This study estimates the efficiency improvements and CI necessary to reduce GHG emissions from the light-duty vehicle fleet by 80%.The analysis provides an overview of possible vehicle efficiency improvements, including mass reduction, better aerodynamics, and lower rolling resistance, coupled with more efficient powertrains. Figure 1 shows the relationship between these efficiency measures and fuel CI for efficiencies thought achievable for ICEs, hybrid-electric vehicles (HEVs), FCEVs and battery electric vehicles (BEVs). BEVs are the most efficient powertrain followed by FCEVs, HEVs and ICEs. The fuel CI for each of the powertrains to meet 80% GHG reduction by 2015 is shown in the vertical arrows that cross the CI axis.

For comparison, the CI values for current conventional and renewable fuels are indicated on the graph. Comparing these estimates to the fuel CI necessary to reduce GHG emissions by 80% shows that none of the current fuels—gasoline for ICEs and HEVs, hydrogen for FCEVs, or electricity for BEVs—meet that goal. All fuels require lower CI, which means increased use of renewable sources.

The study highlights that it is not sufficient to focus only on vehicle efficiency. To reach our national climate goals, transportation-related energy policies will need to improve both vehicle efficiency and fuel CI in combination. **Although the analysis does not provide an assessment of how to combine the various technologies, it does document the importance of considering vehicle and fuel technologies, including emissions related to their production, as a holistic system in order to dramatically reduce GHG emissions from light-duty transportation.**

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

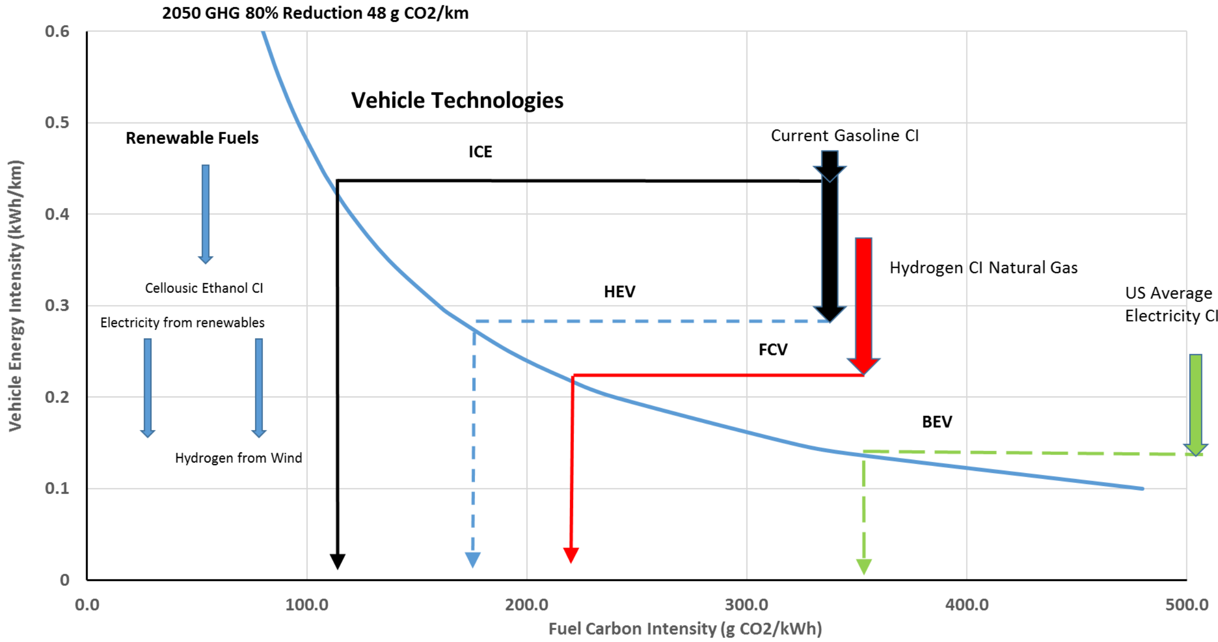

Figure 1. Estimates of Vehicle Efficiency and Carbon Intensity to Achieve 80% Reduction in GHG Emissions by 2050 (adapted from Gerhart, NREL)

GHG reductions sooner rather than later

This study reinforces that EPA and CARB need to assess both CI of fuels and vehicle efficiency in tandem, in order to move to pathways that will meet GHG reductions in 2050. The spark-ignition engine Thrust 1 of DOE's Co-Optima program should provide timely guidance for understanding the GHG reduction capabilities of advanced spark-ignition engines coupled with fuels optimized to power them. Various other efforts are ongoing for EVs and FCEVs. However, with the climate stakes so high, EPA and CARB should initiate efforts to reduce GHGs in light-duty transportation sooner rather than later.

Reducing a ton of carbon today is much more valuable than reducing that same ton in later years. As stated by the UN Environment Programme, "The benefits of strong and early action to curb greenhouse gas emissions and mitigate the effects of climate change far outweigh the economic cost of not acting."[40] Moreover, EPA itself recognizes in its discussion of the Social Cost of Carbon that the benefits of early carbon reduction are significant "because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater levels of climate change."[41]

One strategy for reducing CO_2 emissions sooner would be to facilitate reductions in a greater number of vehicles. While EVs and FCEVs receive generous credits in the 2012 Final GHG and CAFE

[40] UN, *United Nations Environmental Programme*, 2012 from http://www.unep.org/climatechange/mitigation/Introduction/tabid/29397/Default.aspx
[41] EPA*, Social Cost of Carbon*, pg. 1, Dec. 2015

Rulemaking and the Draft TAR, these are hampered by relatively high costs and implementation complexities. **ICEs, with higher-compression engines burning high-octane fuel, are by comparison lower in cost and less disruptive to the current marketplace, making them a more feasible option for near-term larger-scale GHG emissions reductions.** As described above, numerous analyses including the Draft TAR are projecting the continuing dominance of ICE vehicles in the light-duty fleet. Consideration should be given to accelerating CO_2 emission reductions strategies for the lower-cost and potentially higher-volume advanced spark-ignition engine technologies enabled by high-octane, low-carbon fuels.

Forthcoming light-duty transportation wedge analysis

Fuel Freedom has undertaken a wedge analysis to evaluate possible scenarios for achieving an 80% reduction in light-duty vehicle GHG emissions for the U.S. and for California by 2050. The analysis uses the most current estimates of fuel CI and vehicle efficiency improvements (including those contained in the Draft TAR), and the estimates of incremental costs for each fuel-vehicle combination to determine feasible market penetrations. Wedges are included for gasoline technologies (including high-octane fuels with high-compression-ratio ICEs coupled with electrification), biofuels used in ICEs with and without hybridization, HEVs, PHEVs, FCEVs, and BEVs. The results of these analyses will be available soon, but preliminary results indicate the importance of keeping vehicle technology options open for multiple renewable fuel pathways, including biofuels, hydrogen, and electricity. Focusing only on hydrogen and electricity in the light-duty vehicle sector can preclude the possibility of a complementary, and more cost effective, liquid biofuel option.

In Summary

The TAR and the MTE are instrumental for guiding a vital period of U.S. light-duty transportation. MY2022-2025 is a critical milestone for the National Program, when full compliance will have doubled fuel economy in new vehicles compared to 2005. At the same time, this period will set the stage for not only future CAFE and GHG standards, but for our ability to accelerate progress toward reducing GHG emissions by 80% by 2050. Success will require an all-of-the-above strategy. Despite continuing aggressive efforts to promote alternative vehicle technologies such as BEVs and, in California, FCEVs, the market has not responded as hoped. While circumstances may change, experience to date clearly shows that consumer response cannot be taken for granted. Even the most ambitious estimates of BEV and FCEV penetration project that ICEs will dominate new vehicle sales for a long time, not to mention the total on-road fleet of legacy vehicles. EPA, NHTSA and CARB must, therefore, develop policies to coax maximum benefits from these ICE vehicles. This means looking not just to vehicle technologies, but to the liquid fuels that enable them. As a starting point, the TAR should be expanded to assess the performance of spark-ignition engine technologies using high octane, to include the full range of well-known, feasible technologies that could be enabled by it, and to analyze fueling infrastructure requirements. EPA and CARB should, in parallel to the MTE, expeditiously initiate a process to approve a higher-octane fuel(s) and prepare for a nationwide transition to raise the market minimum octane. For the long term, EPA and CARB should also 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 accordingly.

Summary of Specific Recommendations:

- ***Analyze higher-octane fuels in the TAR.*** *The final TAR should compare the relative performance of Draft TAR ICE vehicle technologies using 87 AKI fuel to their performance using high-octane fuels that ample existing evidence demonstrates would increase fuel efficiency or decrease GHG emissions in line with National Program goals, including 91 or 93 AKI premium gasoline, and a higher-octane (~100 RON) mid-level ethanol blend as proposed in EPA's Tier 3 Rulemaking.*

- ***Analyze the infrastructure requirements for higher-octane fuels in the TAR.*** *Like it did for electricity and hydrogen, the final TAR should discuss the fueling infrastructure requirements for high-octane fuels, including mid-level ethanol blends.*

- ***Include additional low-cost high-octane spark-ignition engine technologies in the TAR.*** *The final TAR should, at minimum, quantify the marginal potential of higher compression ratio engines and high octane (~100 RON) together to increase fuel economy and decrease* CO_2 *emissions, as well as the additional potential combined with complementary technologies. The final TAR should also compare the relative total costs (vehicle and fuel) versus other vehicle technologies.*

- ***Consider CAFE or GHG program incentives for ICE vehicles within the MTE.*** *The agencies should use an expanded TAR to consider and negotiate with automakers high-octane-related ICE vehicle incentives for 2022-2025, in order to complement the previously proposed credits for EVs and FCEVs.*

- ***Initiate a timely process to raise the minimum octane in the marketplace.*** *EPA and CARB should undertake the multimedia analyses necessary to exercise their respective authorities to approve higher-octane fuel formulations and develop a plan within the MTE timeframe, as the first steps to ultimately raise the minimum octane (~100 RON) in the marketplace.*

- ***Evaluate vehicles and fuels as a system to maximize carbon reductions in future GHG standards.*** *EPA and CARB should consider the current and potential future GHG emissions fuel-cycle of electricity and hydrogen, and compare the holistic vehicle-fuel systems to the fuel-cycle GHG profile of advanced ICEs powered by liquid fuels, in order to establish lower-carbon pathways for all three options.*