THE HIGH OCTANE-LOW CARBON FUEL ALLIANCE

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Overview

These comments are submitted on behalf of the High, Octane, Low Carbon (HOLC) Alliance in response to the U.S. Environmental Protection Agency and National Highway Transportation Safety Administration's request for comments for the Draft Technical Assessment Report of the Mid-Term Evaluation of the 2017-2025 CAFE and GHG standards for light-duty vehicles. The HOLC Alliance is a group of stakeholders representing a wide range of energy and agricultural interests with a specific focus on motor fuels. HOLC Alliance members have considerable experience and expertise in areas relating to fuel performance, emissions, carbon intensity and health effects and as such are qualified to provide these comments.

The Corporate Average Fuel Economy (CAFE) standards are the most important and readily available tool to lower GHG emissions, because more efficient cars mean less CO2 emitted from the tailpipe. Yet EPA's Technical Assessment Report (TAR), released on July 27, 2016 acknowledged that the U.S. auto fleet will not reach the 54.5mpg goal envisioned for 2025 and states that this is in part because Americans are not buying electric or hybrids vehicles at the rate expected.[1] The TAR stated that officials are estimating that the new mix of vehicles will mean that the 2025 fleet average will be at 50.0-52.6 mpg. In other words, the U.S. auto fleet will be producing 7.4% more GHG emissions than expected.

At the same time, the National Research Council (NRC) 2015 study, which was commissioned by the National Highway Transportation and Safety Administration (NHTSA), acknowledged that higher octane fuels could increase engine efficiency, yet the TAR failed to consider the fuel economy or GHG reductions that could be enabled by high-octane fuels, not to mention compare the overall costs and infrastructure requirements to alternatives such as electric or hydrogen fuel cell vehicles, and instead defaulted to the low octane status quo.[2]

By way of background, in 2007 the Supreme Court asserted the EPA Administrator's authority to regulate GHG emissions from "new motor vehicles or new motor vehicle engines" per Clean Air Act (CAA) section 202(a)(1) as a pollutant "which may reasonably be anticipated to

[1] Both NHTSA and EPA expect only 3% of 2025 vehicles to be EVs. The National Research Council (NRC) agrees

[2] The TAR references that EPA and NHTSA will closely follow **the Co-Optima program** as this program, according to the TAR, has the potential to provide meaningful data and ideas for GHG and fuel composition reduction in the light-duty vehicles fleet for 2026 and beyond.

endanger public health or welfare."[3] In 2015, the United States, along with more than a hundred other countries, agreed to aggressive reductions in greenhouse gas (GHG) emissions to reduce potential catastrophic warming of the planet.[4] The United States pledged to reduce emissions by 28% below 2005 levels by 2025. A comprehensive assessment of U.S. emissions, with a special focus on the U.S. transportation sector, which is now the largest source of U.S. emissions, is required to meet this benchmark.

All fuels are not created equal when it comes to protecting our climate. The lifecycle emissions resulting from fuel production, the acquisition of feedstock, the transportation, and ultimately the resulting combustion of fuels, are among the factors needed to be accounted for when assessing policy solutions to reducing greenhouse gases. As a result, any responsible solutions must address not only the efficiency of the cars and trucks we drive, but the fuels that power these vehicles.

It is essential for EPA to reconsider exercising its authority, as study after study from DOE and others show that dramatic efficiency gains can be had in gasoline vehicles by using higher-octane fuels (RON 98-100) than are currently available at the pump.[5,6,7] Encouraging the introduction of optimized high-octane vehicles sooner rather than later can help to ensure that footprint standards are met in 2025.

EPA's own assessment in the Tier 3 final rule highlights that a high-octane fuel such as a mid-level ethanol blend "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" and that such a strategy would "enhance the environmental performance of ethanol as a transportation fuel by using it to enable more fuel efficient engines."[8]

The HOLC Alliance believes we cannot afford to wait to take the action needed to reduce GHG emissions and that high-octane, low-carbon fuels are one of the most immediate, attainable, and market-based solutions to drastically reduce GHG emissions.

Research indicates that the transition from liquid fuels to electricity will evolve slowly over the next several decades. Meanwhile, trillions of miles will be driven on hundreds of billions of gallons of lower-octane gasoline, with all of the harmful carbon emissions they

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

[4] UN, Dec. 2015, *Paris Agreement*

[5] ORNL, July 2016, S*ummary of High-Octane, Mid-Level Ethanol Blends Study*

[6] ORNL, April 2014, *Intermediate Alcohol-Gasoline Blends, Fuels for Enabling Increased Engine Efficiency and Powertrain Possibilities*

[7] In fact, in May 2015, and reiterated as recently as July 12, 2016, EPA's Director of the Fuels Center confirmed that higher-octane gasoline would help automakers improve efficiency and reduce carbon emissions, and that EPA has the authority to encourage a transition to high-octane fuels. However, the Director said that EPA did not plan to begin the necessary steps until after 2025, and that the process would require an additional ten years to finalize.

[8] EPA, April 28, 2014 *Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards*, p. 29911

release. However, with relative ease, automakers can put vehicles on the road over the next several years that operate dramatically more efficiently, with far less carbon emissions, if more high octane, low carbon fuels are made available. In other words, we don't have to reduce our ambitions for better vehicle efficiency and reduced GHG emissions, we simply need to ensure that automakers have every available tool to make it happen.

We therefore ask, respectfully, that EPA and NHTSA investigate all viable options for the goals set out in the National Program, including the use of high-octane, low-carbon fuels to meet those goals. High-octane, low-carbon fuels, for example, can be readily produced today from a combination of gasoline and ethanol, and only need EPA approval for use to begin.

Automakers have made great technological strides in order to make cars better, safer, cleaner, and more efficient, but vehicle technology is only half of the equation. In order to build on and accelerate progress toward our climate goals, we must address the other half, which is fuels.

The highest available octane today isn't enough to provide maximum benefits to GHG and fuel economy. Beyond turbocharging and direct injection, the ability to raise engine compression ratio, enabled by the use of higher octane fuels, will vastly improve our ability to meet the goals of the National Program. For instance, studies have shown that increasing compression ratios alone can provide up to 6% added efficiency[9].

High-octane, low-carbon fuels are superior in many ways to the high carbon, low octane status quo. Current fuels will not allow for sufficient improvements in new engines to make significant CO2 reductions. Thus it is imperative that we provide a path for the development and wide availability of high-octane, low-carbon fuels.

The HOLC Alliance comments will focus on higher octane and lower carbon fuels and request that the requisite agencies review the potential of high-octane, low-carbon fuels and that OMB produce a cost benefit analysis related to high-octane, low-carbon fuels.

The Need to Consider Liquid Fuel Options

The 2012 Final Rulemaking states that the TAR should be "a holistic assessment" of factors "set forth in this final rule and other relevant factors."[10] This is of particular relevance amidst the changed realities of the intervening four years. The transportation sector recently surpassed power generation as the single largest source of U.S. GHG emissions, accounting for 41% of the overall total.[11] Light-duty vehicles are responsible for 60% of that total,[12] reflecting the importance and urgency required to reduce GHGs from cars and trucks. At the same time, oil

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[9] Leone, T., Anderson, J., Davis, R., Iqbal, A., Reese, R., Shelby, M., Studzinski, W., *The Effect of Compression Ratio, Fuel Octane Rating, and Ethanol Content on Spark-Ignition Engine Efficiency*, August 3, 2015

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

[11] EIA, July 26, 2016, *Monthly Energy Review July 2016,* p. 176

[12] EPA, NHTSA, August 2012, *Regulatory Announcement: EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks*, p. 1

prices have unexpectedly decreased, resulting in a shift of anticipated driving habits, as well as a change in the anticipated mix of cars and trucks on the road.

The primary mechanism for light-duty vehicles to contribute to meeting U.S. climate and fuel economy goals has long been the National Program of GHG and CAFE standards. While the National Program has achieved significant gains in fuel economy and emissions reductions in new vehicles, overall CO_2 emissions from the combustion of motor gasoline has continued to rise in recent years[13]. This underscores that the National Program must focus on more efficient vehicles, but also must ensure that it is actually directing light-duty transportation towards an overall decrease in GHG emissions. Raising the bar over time only exacerbates this challenge.

Despite the rapid advancements in alternative drivetrains such as electric vehicles (EVs), it has become clear that internal combustion engines (ICEs) powered by gasoline will dominate the U.S. on-road vehicle fleet, not only through 2025, but far beyond.[14,15] Consequently, the impact and success of the National Program will depend heavily on maximizing the effectiveness of ICEs toward meeting CAFE and GHG standards of the future. Further, the potential of ICEs to sufficiently increase fuel economy and reduce GHGs in light-duty transportation will ultimately depend on better fuels.

While the CAFE/GHG standards to date have primarily focused on vehicle engine technology, these vehicles perform best in concert with fuels of suitable properties and composition to optimally enable and power them. This is true for tailpipe emissions, as demonstrated by the fuel initiatives of the past,[16] and equally true for CAFE and GHG standards. A robust body of research clearly shows that, for GHG reductions and fuel economy, the combined performance of co-optimized fuels and vehicles exceed the total of their individual contributions.[17]

The increasingly urgent need to reduce GHG emissions from transportation and simultaneously increase fuel economy have inspired much recent research to analyze the potential for optimized ICE-fuel combinations to meet the challenge. Despite the well-documented benefits to GHG reduction and fuel efficiency of optimized ICE technology with ideal fuel properties, the Draft TAR limited the spark-ignition engine technologies under consideration to those powered by 87 AKI gasoline. This limitation excluded from the Draft TAR perhaps the most promising lower-cost technology recommended by the NRC report in 2015—higher compression ratio engines coupled with higher-octane fuel.[18]

The omission of promising foreseeable technology combinations, such as higher-octane fuels in conjunction with higher-compression ratio engines, from the Draft TAR, or from the Midterm

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[13] EIA, July 26, 2016, *Monthly Energy Review July 2016,* p. 176

[14] EPA, NHTSA, Oct. 15, 2012, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule*, p. 62696

[15] EPA, NHTSA, July 2016, *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. ES-2

[16] Burns V., Rapp L., Koehl W., Benson J., et al., Oct. 01, 1995, *Gasoline Reformulation and Vehicle Technology Effects on Emissions - Auto/Oil Air Quality Improvement Research Program*

[17] ORNL, July 2016, S*ummary of High-Octane, Mid-Level Ethanol Blends Study*, p. 5

[18] NAS, 2015, *Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,* p. 67-69

Evaluation (MTE) process extending into 2018, will have significant consequence for the ability to meet the CAFE and GHG standards by 2025; and is certainly of consequence for sustaining progress beyond to 2050. Steadily increasing fuel economy and decreasing GHG emissions will require an orderly evolution of vehicle technology, which means a timely introduction of appropriate fuels to enable and power these advancements. With an approval process that can take up to 7 years, EPA and CARB should initiate the necessary analysis within the MTE timeframe to ensure market readiness by 2025.

Technologies considered in the TAR and the MTE should include an assessment of the full range of technologies, fuels and incentives appropriate and necessary to encourage their introduction.

A. Treat Fuels and Vehicles as a System Again

A snapshot of criteria pollutant regulation highlights the history of considering vehicles and fuels as a combined system. The Auto-Oil Program of the 1990s lowered tailpipe emissions by reformulating gasoline to reduce sulfur and aromatics, and adding oxygenates to reduce smog-forming pollutants.[19] Models to predict the emission performance of vehicles were developed based on the fuel composition, and were used to reduce smog in non-attainment areas with reformulated gasoline. The models were subsequently updated for fuel property effects with modern Tier 2 vehicle technologies, to determine how fuel properties affected smog-forming and toxic emissions.[20]

In 1996 a major milestone in assessing fuels and vehicles as a system was Argonne National Lab's (ANL) development of the GREET model to assess well-to-wheels GHG emissions.[21] GREET showed the importance of holistically evaluating not only in-use vehicle GHG and tailpipe emissions, but also GHG emissions from fuel production and distribution. Quantifying this entire lifecycle of GHG emissions from the combined fuel-vehicle system is essential to adequately compare the various fuel and vehicle technologies that could be implemented together to reduce GHG emissions in transportation. However, the Draft TAR lacks an assessment of combined fuel and vehicle technologies for reducing GHG emissions.

The National Program has consistently focused primarily on vehicle technologies, and the Draft TAR reflects this trend. The TAR analyzes only the fuel economy and GHG emissions implications of vehicle technologies, without any discussion of the carbon intensity of the fuels. This means that EPA's approach to meeting the standards of 2025 relies almost exclusively on 87 AKI gasoline engine and vehicle efficiency improvements. Regrettably, there is no contemplation of specific fuel properties that would further improve the vehicle efficiency and lower CO_2 equivalent upstream and tailpipe emissions, nor any discussion of the infrastructure requirements of proposed alternative formulations. At a minimum, EPA's and CARB's analyses in the final TAR should discuss the implications of vehicle technologies and the fuels currently included as well as any additional fuels, in the context of GHG lifecycle emission reductions.

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[19] Leppard W., Koehl W., Benson J., Burns V., et al., Oct. 01, 1995, *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*

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

[21] ANL, June 01, 1996, *GREET 1.0 - Transportation Fuel Cycles Model: Methodology and Use*

B. Include Additional Fuels in the Final TAR

A major constraint of the Draft TAR is the sole consideration of a single liquid fuel for spark-ignition engines—87 AKI gasoline. While 87 AKI gasoline is the dominant fuel in the marketplace today, accepting the status quo as a given, limits improvements in the fuel economy and environmental performance of vehicles on the road;[22] the range of feasible engine technologies;[23] and the technical flexibility for auto manufacturers to continue to develop and introduce into the marketplace vehicles that satisfy a broad range of consumer preferences and budgets[24] in 2022-2025 and into the future. The Draft TAR outlines significant advances in ICE vehicle efficiency with 87 AKI gasoline, yet to continue to reduce GHG emissions and increase fuel efficiency will require fuels suited to meet these goals, by maximizing the performance of the vehicle-fuel system.

The TAR should therefore include an analysis of liquid fuel alternatives that can enable engine advancements in the spark-ignition vehicles that will dominate the U.S. fleet for decades to come.[25] At minimum, the TAR should compare the fuel economy and GHG emissions performance of relevant engine technologies using 87 AKI gasoline to the highest octane gasoline currently available in the market--91/93 AKI, as well as a higher-octane (~RON 98-100), lower-carbon option for potential approval and introduction in the future.

C. Evaluate Higher Octane Fuel in the TAR to Enable Advanced Spark-Ignition Engine Technologies

The 2012 Final Rulemaking criteria requires that the TAR include “a holistic assessment.”[26] We believe that this requirement should include an assessment of higher-octane fuels and their ability to comply with and advance the National Program. While many fuel properties determine how a fuel is combusted and what the associated emissions will be, chief among those for improving CO_2 emissions and fuel economy in spark-ignited internal combustion engines is the octane rating. This fact was noted by the NRC, in its recommendation to thoroughly assess the possibility of raising the minimum octane in the marketplace, as an enabler for ICE engine technologies.[27]

High-octane fuels enable an increase in the compression ratio in new vehicles, while still providing benefits in vehicles not optimized for higher octane. An increase in octane alone,

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[22] Leone T., February 17, 2016, *High Octane Discussion at #RFANEC [Interview]*, from http://energy.agwired.com/2016/02/17/high-octane-discussion-at-rfanec/
[23] Remmert S., Cracknell R., Head R., et al., April 2014, *Octane Response in a Downsized, Highly Boosted Direct Injection Spark Ignition Engine*
[24] ORNL, July 2016, S*ummary of High-Octane, Mid-Level Ethanol Blends Study*, p. 2
[25] EPA, NHTSA, Oct. 15, 2012, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule*, p. 62696
[26] EPA, NHTSA, Oct. 15, 2012, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule*, p. 62652
[27] NRC, 2015, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,* p. 84

without modifications to the engine, can increase efficiency by 1-2% in existing vehicles.[28] CRC's review of the benefits of increasing octane shows that an extra 1-2% vehicle efficiency improvement can be obtained in naturally-aspirated ICEs due to engine down-speeding, while more gains could be achieved in a direct-injection engine if the octane is derived from ethanol.[29] Additionally, high-octane mid-level ethanol blends have been shown to increase fuel efficiency in new vehicles by 5-10%.[30] These studies highlight that the source of octane is important. In the TAR and MTE, EPA should fully evaluate potential sources of octane along with fuel effects, because, in addition to in-vehicle benefits, octane can have different costs and emissions associated with their production and use.[31]

Fuel composition, specifically the source of octane, has strong bearing on both fuel economy and CO2 emissions. A large portion of vehicle benefits using higher octane fuels could be achieved with either a low or high-carbon feedstock. However, all octane is not created equal. For instance, additional efficiency benefits accrue to octane sources with a cooling effect, such as ethanol.[32] Octane sources also widely differ in carbon intensity. Higher-carbon sources can negate a portion of the GHG emissions savings achieved through increased efficiency.[33] Given this possibility, the urgency to decrease GHG emissions in particular justifies a holistic assessment.

The appeal of combining high-octane fuel properties and low carbon fuel components is not new; however, the increasingly urgent need to decrease GHG emissions from transportation and increase fuel economy have inspired much recent research. Lifecycle analyses have favorably compared the well-to-wheels GHG emissions impact of biofuels to petroleum, including ANL and others, focused specifically on high-octane options.[3435] And a robust body of recent literature indicates that higher octane and lower carbon are essential properties for sustaining progress in spark-ignition engines toward the three primary goals of the National Program of CAFE and GHG Standards: improve fuel economy, reduce petroleum consumption, and decrease the carbon intensity of the light-duty transportation system.[36,37,38,39] Given the extensive existing research to inform an analysis, EPA and CARB should, as previously suggested, assess lifecycle GHG

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[28] Leone T., February 17, 2016, *High Octane Discussion at #RFANEC [Interview]*, from http://energy.agwired.com/2016/02/17/high-octane-discussion-at-rfanec/

[29] CRC, Sept. 2012, *Review to Determine the Benefits of Increasing Octane Number on Gasoline Engine Efficiency: Analysis and Recommendation – Tasks 2-5*, p. 60-61

[30] ORNL, July 2016, S*ummary of High-Octane, Mid-Level Ethanol Blends Study*, p. 16

[31] Hirshfeld D., Kolb J., Aug. 21, 2016, *Refining Economics of U.S. Gasoline: Octane Ratings and Ethanol Content*

[32] ORNL, April 12, 2010, *Investigation of Knock Limited Compression Ratio of Ethanol Gasoline Blends*

[33] ANL, July 14, 2015, *Well-to-Wheels Greenhouse Gas Emissions Analysis of High-Octane Fuels With Various Market Shares and Ethanol Blending Levels*, p. 1

[34] ANL, July 14, 2015, *Well-to-Wheels Greenhouse Gas Emissions Analysis of High-Octane Fuels With Various Market Shares and Ethanol Blending Levels*, p. 1

[35] CARB, June 30, 2016, *LCFS Pathway Certified Carbon Intensities*, from http://www.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm

[36] Leone T., Anderson J., Davis R., et al., Aug. 2015 *The Effect of Compression Ratio, Fuel Octane Rating, and Ethanol Content on Spark-Ignition Engine Efficiency*

[37] Chow E., Heywood J, Speth R., April 2014, *Benefits of a Higher Octane Standard Gasoline for the U.S. Light-Duty Vehicle Fleet*

[38] Winkler S., Wallington T, Maas H., May 05, 2014, *Light-Duty Vehicle CO2 Targets Consistent with 450 ppm CO2 Stabilization*

[39] UCS, Feb. 2016, *Fueling a Clean Transportation Future*

emissions implications in the final TAR to compare the vehicle-fuel systems such as high compression-AKI 87 gasoline, EVs-grid mix(es) and hydrogen fuel cell vehicles-fuels in the Draft TAR, to combinations of higher compression ratio engines with, at minimum, the highest market octane gasoline and with a lower carbon option.

D. The Time is Now to Fully Consider Higher-Octane, Low-Carbon Fuel Alternatives

The documented potential and possibility of higher-octane,[40] lower-carbon[41] fuels have not escaped notice of the agencies. EPA and NHTSA have acknowledged the potential of higher-octane fuels to enable spark-ignition engine advancements, most recently in EPA's Tier 3 Proposed Rulemaking.[42] EPA has acknowledged its authority and identified specific Clean Air Act bases to regulate fuel octane levels.[43,44] Both in reference to the U.S. Department of Energy's Co-Optima program in the Draft TAR and in more recent remarks, EPA has recently signaled a willingness to consider raising octane levels, yet has explicitly placed the possibility beyond 2025.[45] Given the rigorous approval process (possibly requiring up to 7 years or more for a higher-octane, lower-carbon alternative such as a mid-level ethanol blend)[46] the MTE is the vital timeframe for EPA and CARB to initiate the detailed supporting technical, environmental, cost-benefit, feasibility, and economic analyses required for approval of higher-octane, lower-carbon fuels that can enter the marketplace by 2025.

The introduction of a mid-level ethanol gasoline blend will require engines to be designed and certified, while high-octane gasoline will also require certification over EPA test cycles. Time will be required to get new fuel formulations approved for use and to develop and implement the needed infrastructure. Waiting until after 2025 to start this progress would result in an unnecessary delay of a cost-effective GHG control that could be implemented starting now. A future-centric approach to looking at not only vehicles, but the fuels to power them, is being employed for electric and hydrogen platforms in the Draft TAR, despite much higher technology costs, and in the case of hydrogen fuel cell vehicles, no expectation of meaningful introduction before 2025. With much lower costs, and fewer technical hurdles and barriers to market entry, higher-compression engines coupled with higher-octane fuel pathways have even stronger merit for inclusion in the TAR, and in the MTE.

At the same time, like the electricity and hydrogen infrastructure discussion in the Draft TAR, and to reiterate NRC's recommendation to investigate higher octane[47], the final TAR should

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[40] EPA, March 2008, *Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions*

[41] EPA, February 2010, *Renewable Fuel Standard Program: Regulatory Impact Analysis,* section 2.6

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

[43] Machiele P., May 5, 2015, *Mobile Sources Technical Review Subcommittee [Presentation]*, from https://www.epa.gov/sites/production/files/2016-01/documents/mstrs_050515summary.pdf, p. 9-10

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

[45] EPA, NHTSA, July 2016, *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. 5-42

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

[47] NRC, 2015, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,* p. 84

include an assessment of the infrastructure requirements and transition strategy of migrating to higher octane in the marketplace.

Summary

The HOLC Alliance believes that the following specific actions will ensure that the ambitious CAFE and GHG standards are met for 2022-2025, and the correct preparations are made today to ensure greater incremental improvements to 2050:

- As shown in the past with Auto-Oil, and as evidenced by the prominence of GREET and other lifecycle analyses, vehicles and fuels should be evaluated as a system in the TAR in order to understand and compare the holistic implications of transportation policies, and to ultimately maximize environmental performance and overall costs and benefits.

- Rather than limit the analysis to 87 AKI gasoline, the TAR should compare the CAFE and GHG performance of 87 AKI to premium gasoline currently in the market, as well as an even higher-octane, lower-carbon option such as a 98-100 RON midlevel ethanol blend as proposed by EPA in the Tier 3 NPRM.

- EPA, NHTSA and CARB should evaluate the costs of higher-compression ratio engines coupled with higher octane fuels, in order to compare them to the costs of vehicle-fuel pairings already included in the TAR, and ultimately inform a more thorough cost-benefit analysis by OMB as proposed below.

- Under its acknowledged authority under the Clean Air Act, EPA should initiate a process within the MTE to ultimately raise the minimum octane in the marketplace.

A Thorough OMB Cost-Benefit Analysis of the TAR/MTE is Warranted

The HOLC Alliance respectfully urges the Office of Management and Budget (OMB), and the agencies—EPA and NHTSA—to include in their final determination of whether the current CAFE and GHG standards are "appropriate" a thorough cost-benefit analysis, as is customarily required for "regulations" and "significant regulatory actions." The HOLC Alliance believes that such an analysis requires an informed evaluation of the synergy that exists between fuels and vehicles, as set forth earlier in these comments.

The HOLC Alliance further submits that the "final determination" on whether the current CAFE standards are "appropriate" (scheduled for April 2018) should be construed as a "regulation" for purposes of EO 13563 and a "significant regulatory action" for purposes of EO 12866. EPA may not be required to do a cost-benefit analysis *in the TAR itself*, but cost-benefit considerations are certainly relevant to the feasibility and "appropriateness" of the existing CAFE and GHG standards.

A. Thorough Cost-Benefit Analysis is Imperative

The TAR provides the technical underpinning for a final rulemaking that will have enormous ramifications on the nation's economy, environment, and energy security. Improving fuel efficiency and reducing the carbon footprint of the U.S. light duty vehicle (LDV) fleet—and the fuels that power it—will influence tens of billions, perhaps trillions, of dollars in capital investment, consumer expenditures,[48] and economic activity over the life of this rule. The LDV fleet's carbon and other criteria pollutant emissions will also be responsible for tens of billions of dollars in social costs from adverse health effects and premature mortalities.[49] While a transition to all-electric vehicles fueled by renewable electricity can dramatically lower transportation's carbon footprint,[50] the transition will require decades, perhaps even generations, and is yet uncertain. Making the right decisions on improving the quality of fuels used in advanced internal combustion engines (ICEs) could save the nation tens of billions of dollars every year, and improve the quality of life for hundreds of millions of Americans, especially our children and those who live in urban areas and near congested roadways.

The stakes are enormous. The shape of the final MTE package will impact consumers, the environment, public health, auto manufacturers and workers, agricultural producers, the rural economy, and the nation's energy security.

B. Executive Order 13563

On September 2, 2011, Cass R. Sunstein, then-Administrator of OMB's Office of Information and Regulatory Affairs, wrote then-EPA Administrator Lisa Jackson instructing the Agency to reconsider its proposed ozone NAAQS rulemaking. Sunstein based the President's instruction for reconsideration on several criteria: the rule 1) "must be based on best available science;" 2) "must promote predictability and reduce uncertainty;" and, 3) must "protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation." The HOLC Alliance agrees, and believes that the same standard should be applied to the MTE process.

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[48] EPA, NHTSA, July 2016, *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. ES-11,12

[49] Interagency Working Group on the Social Cost of Carbon, US Government, Feb. 2010, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis - Under Executive Order 12866*, from: //www3.epa.gov/otaq/climate/regulations/scc-tsd.pdf

[50] ANL, Oct. 2, 2015, *GREET Model*

C. Technology Cost Matters

Consumer vehicle purchases are heavily influenced by vehicle costs,[51] which has significant implications for the mix of cars and trucks on the road. Therefore, the fleet-wide success of the National Program depends to a large extent on relative vehicle affordability. The NRC study, and the Draft TAR, rightfully evaluate vehicle technology costs. However, costs should be more fully considered, in order to thoroughly assess estimated costs versus expected benefits. For example, the Draft TAR excluded promising low-cost technologies identified by the NRC such as high-compression ratio engines coupled with high-octane fuels.[52] At the same time, the Draft TAR included a detailed discussion of longer-term technologies such as hydrogen fuel cells without regard to their cost, and without any expectation that they would contribute to meeting the CAFE or GHG standards for 2022-2025. The final TAR should more fully consider the question of technology cost to balance against benefits, and in particular take into account the robust body of research that demonstrates the potential for higher-octane fuels to affordably enable not only more efficient engines of the future that could enter the marketplace before 2025, but provide fuel economy gains and GHG emissions reductions from most vehicles already on the road.

D. DOE Labs, the National Research Council, and Auto Industry Scientists Agree: Octane is Key.

In recent years, numerous experts from a variety of diverse organizations and disciplines have singled out the need for higher octane fuels to complement higher compression engines. These ICE technologies could enable a cost-effective, and quicker to implement complement to the evolution of electric and hydrogen fuel cell vehicle technologies. A mounting body of research confirms that high-octane, low-carbon fuels would be better for consumers, for their cars, for the environment, for public health, and for the economy.

One such study, by MIT, found that compression ratio increases and engine downsizing enabled by an increase of 4 RON in the fuel would lead to a 4.45% reduction in fuel consumption in naturally aspirated vehicles and a 7.34% reduction in turbo charged vehicles.[53] That study then extended those findings to a fleet projection tool to find that high octane fuels with high compression ratios could contribute to an fleet-wide reduction in fuel consumption of 26.8% compared to 2012 levels. The study also noted the limited contribution of electric and hydrogen fuel cell vehicles to fuel consumption levels due in part to the "substantial, higher upfront costs associated with them."

A Ford study found that a higher compression ratio engine fueled with an E20 96 RON fuel enabled a 4.8 to 5.1% improvement in tailpipe CO_2 emissions, depending on the drive cycle, and a 1% improvement in fuel economy relative to an E10 91 RON fuel.[54] They also observed a 9.1%

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[51] NAS, 2015, *Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,* p. 325-327

[52] NRC, 2015, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,* Finding 2.3

[53] Chow E., Heywood J., and Speth R., April 1, 2014, *Benefits of a Higher Octane Standard Gasoline for the U.S. Light-Duty Vehicle Fleet*

[54] Leone T., Olin E., Anderson J., Jung H., and Shelby M., Jan. 2014, *Effects of Fuel Octane Rating and Ethanol Content on Knock, Fuel Economy, and CO2 for a Turbocharged DI Engine*

improvement in CO_2 emissions 1.2% improvement in MPG on the US06 drive-cycle for an E30 101RON fuel, with slightly lower results for the EPA M/H drive cycle. When testing these higher octane fuels in a standard 10:1 compression ratio engine they still observed a 1.1 to 1.5 percent improvement in CO_2 emissions compared to an E10 91 RON fuel, hinting at the possibility of achieving benefits even in vehicles not designed for higher octane.

An August 2016 U.S. Department of Energy analysis confirmed the benefit of higher octane fuel in improving combustion efficiency and reducing engine-out CO_2. Gasoline mixed with 25% to 40% ethanol could provide the higher-octane fuel automakers will need for high efficiency, high compression spark ignition engines they are developing to reduce carbon emissions and boost fuel economy.[55] The study, issued by DOE's Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), and the National Renewable Energy Laboratory (NREL), stated that "ethanol has an inherently high octane number and would be an ideal octane booster for lower-octane petroleum blendstocks." The labs concluded that experimental and analytical results of the study show that high-octane fuels, "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."

NHTSA commissioned a study by the National Research Council to assess the 2012 GHG – CAFE rule's assumptions. The 600-page report, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles* reviewed the work done by the National Highway Traffic Safety Administration and the US Environmental Protection Agency (EPA) leading to the 2012 adoption of standards raising fuel economy to a nominal 54.5 miles per gallon on average in 2025. In its section of the TAR, NHTSA reported that naturally aspirated engines were calibrated with conventional regular unleaded (87 AKI octane) gasoline, while the turbocharged engines used 93 AKI octane fuel. However, pages later, NHTSA reversed course, and said that in the future, all engine model development will be performed with regular grade octane gasoline.[56] The NRC expressed concerns about this limitation, noting that "EPA 'ground rules' stated that the engine should operate on 87 AKI (91 RON) fuel (see Fuel Octane Issues section for a definition of AKI). Although the engine may operate on 87 AKI fuel the knock control system likely would retard the spark timing from the best efficiency timing under more conditions than was the case with the original EBDI engine. Even though the tendency to knock occurs at high loads, controlling knock at these conditions is essential for engine integrity…Effective control of knock generally requires a reduction in compression ratio, which would also have a detrimental effect on fuel consumption under the CAFE driving cycle conditions." These stipulations automatically preclude the evaluation of a readily available high-octane fuel, 93 AKI, in the context of the National Program, despite its ability to enable higher efficiency by avoiding knock-limited operation.

NRC's experts repeatedly pointed out the need for higher octane fuels if the goal is to improve fuel efficiency and reduce carbon emissions. In fact, the NRC recommended that EPA and NHTSA determine how best to increase the minimum octane rating of U.S. gasoline"

[55] ORNL, July 2016, S*ummary of High-Octane, Mid-Level Ethanol Blends Study*, p. 1

[56] EPA, NHTSA, July 2016, *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. 5-512

"***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."*

The NRC cautioned that failure to ensure widespread availability of higher octane gasoline could significantly interfere with, even reverse, manufacturers' compliance with fuel efficiency and carbon reduction standards. EPA's decision to require turbocharged, higher compression engines to use 87 AKI gasoline would increase fuel consumption and carbon emissions. It would deprive vehicle owners of the performance improvement that would occur with higher octane gasoline, and in some cases, could even damage their engines due to engine knock, especially under high load conditions. For a more detailed discussion of the NRC study, please see Appendix A.

As such, we believe that policy to reduce GHG emissions and increase fuel economy must commit to a liquid fuel pathway no less so than an electric or hydrogen fuel cell vehicle pathway.

E. EPA Notes that a Thorough Cost-Benefit Analysis Is Vital for Decision Making.

Excluded from the TAR or the current MTE discussion are toxic or criteria pollutants. However, these are a lynchpin in an overall assessment of costs and benefits. As stated by EPA in its Draft Regulatory Impact Analysis for the 2017-2025 CAFE and GHG standards, it "is important to quantify the health and environmental impacts associated with the proposed standard, because a failure to adequately consider these ancillary co-pollutant impacts could lead to an incorrect assessment of their net costs and benefits."[57]

The NRC report and EPA's Tier 3 Rulemaking both noted that high-octane can enable low-cost engine technology pathways to National Program compliance. Additionally, a just-released study using EPA's OMEGA model found dramatically reduced compliance costs by replacing conventional ICEs with high-compression engines powered by high-octane fuels, provided these fuels were generally available nationwide.[58] We respectfully urge EPA and NHTSA to work with OMB/OIRA as they consider the "appropriateness" of the CAFE standards for the future to fully consider these compliance costs and benefits. This is especially important in light of the additional mounting evidence from DOE and other experts which confirms the cost- and environmental-effectiveness of transitioning to high octane, low carbon fuels.

F. Agency Decisions Must Be Based on Best Available Science

[57] EPA, Nov. 2011, Draft Regulatory Impact Analysis: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards p. 6-32

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

The HOLC Alliance urges EPA and NHTSA to adopt the NRC's Recommendation 2.3 referenced above, and perform an in-depth analysis of the cradle to grave effects of using high-octane, low-carbon fuels to increase the minimum octane level. A vast amount of new science is available to update EPA's outdated lifecycle carbon emissions models for corn ethanol compared to the baseline gasoline carbon intensity. A more detailed discussion of this critically important issue is in Appendix B.

Numerous studies have linked negative health implications to GHG emissions. The Union of Concerned Scientists, for example, found that increased ozone levels caused by warmer temperatures could lead to millions more cases of respiratory illnesses with a negative economic impact reaching into the billions of dollars.[59] Other research by the U.S. Global Change Research Program has found that "already in the United States, we have observed climate-related increases in our exposure to elevated temperatures; more frequent, severe, or longer-lasting extreme events; degraded air quality; diseases transmitted through food, water, and disease vectors (such as ticks and mosquitoes); and stresses to our mental health and well-being".[60] Black carbon, another GHG emitted by light-duty vehicles in the form of particulate matter, has been cited by the U.S. Department of Energy as causing a range of adverse health outcomes, including cardiovascular disease, cancers, adverse birth outcomes, and central nervous system effects.[61] While diesel has been the primary culprit for black carbon emissions, gasoline is also a contributor. The HOLC Alliance urges OMB and the agencies to reassess the direct or indirect health impacts of motor gasoline carbon emissions, including an assessment of the black and brown carbon impacts compared to the impact of lower-carbon substitutes such as high-octane mid-level ethanol blends.

Summary

The HOLC Alliance submits that a thorough OMB cost-benefit analysis would justify singling out high-octane, low-carbon fuels for a major role in the final MTE package.

- For major rules like the MTE, Presidential Executive Orders require OMB to conduct a thorough cost-benefit analysis, and to ensure that the agencies have used the "best available science" in their analyses. They also require that final rules "protect public health, welfare, safety, and our environment while promoting economic growth, innovation, competitiveness, and job creation."

- In its 2012 GHG – CAFE rulemaking, EPA itself acknowledged that "it is important to quantify environmental and health impacts associated with the proposed standard, because a failure to adequately consider these ancillary co-pollutant impacts could lead to an incorrect assessment of the net costs and benefits."

- Unfortunately, EPA has been silent on these questions, and they have failed to address

[59] UCS, June 2011, *Rising Temperatures, Worsening Ozone Pollution*
[60] USGCRP, April 2016, *The Impacts of Climate Change on Human Health in the United States*
[61] Grahame et. al., Journal of the Air & Waste Management Association, April 2014 *Public Health and Components of Particulate Matter*

the discrepancy in the Draft TAR.

- A 2014 Harvard study found that avoided social costs (from premature mortalities only, with no consideration of morbidity, e.g., health costs) if HOLC fuels were used could exceed $40 billion, which puts it on par with, or greater than, EPA's proposed Clean Power Plan. The additional petroleum reduction, and energy security benefits would generate multi-billions of dollars per year in additional benefits to the nation.

- The encouragement of HOLC fuels 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.

- Experts from the DOE and its national labs, the National Research Council, auto manufacturers, and dozens of prestigious universities are on record confirming the societal value of high-octane, low-carbon fuels. These fuels should be an important part of the final MTE package, and should play a central role in reducing the U.S. transportation sector's carbon footprint effective 2020 and beyond.

Appendix A

Excerpts from June 2015 National Research Council Study on EPA/NHTSA GHG – CAFE Rulemaking (Direct Quotes from Document)[62]

- *"The EPA 'ground rules' stated that the engine should operate on 87 AKI (91 RON) fuel (see Fuel Octane Issues section for a definition of AKI). Although the engine may operate on 87 AKI fuel the knock control system likely would retard the spark timing from the best efficiency timing under more conditions than was the case with the original EBDI engine. Even though the tendency to knock occurs at high loads, controlling knock at these conditions is essential for engine integrity... Effective control of knock generally requires a reduction in compression ratio, which would also have a detrimental effect on fuel consumption under the CAFE driving cycle conditions. Based on the foregoing considerations, the committee determined that reductions in compression ratio of turbocharged, downsized engines could be needed to provide satisfactory operation on 87 AKI fuel. "*

Reduced Compression Ratio for 87 AKI (91 RON) Gasoline

- *" If U.S. regular gasoline instead of European "regular" gasoline were used in the 24 bar BMEP turbocharged, downsized engine, then approximately a 1 ratio reduction in compression ratio may be required to avoid knocking at high load conditions, as described in Appendix J. This reduction in compression ratio would result in up to a 1.5% loss in fuel consumption reduction effectiveness."*

- *"With the likely onset of knock within the CAFE drive cycles for turbocharged, downsized engines, spark retard would be required to prevent knocking conditions. Spark retard to avoid knock was estimated to result in an increase in fuel consumption of approximately a 6% at the high load conditions susceptible to knock, as described in Appendix J."*

- *"These changes would result in higher engine speeds, which could increase fuel consumption by up to 6% during launch conditions."*

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[62] The 600-page report, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles* reviewed the work done by the National Highway Traffic Safety Administration and the US Environmental Protection Agency (EPA) leading to the 2012 adoption of standards raising fuel economy to a nominal 54.5 miles per gallon on average in 2025.

Limits of Downsizing - Octane Requirement

- *"Fuel octane requirements for high BMEP engines remain a concern… "*
- *"One manufacturer plans to specify premium fuel for its turbocharged, downsized engines, since it found that the use of cooled EGR is not adequate to facilitate operation on 91 RON fuel. "*
- *"Some European manufacturers also specify premium fuel for turbocharged engines. Specifying premium fuel for turbocharged downsized engines will raise the cost of operation for the consumer…"*
- *"However, a few manufacturers indicated that higher BMEP levels would require 100 RON gasoline, which is not currently available in the United States. "*

Importance of Treating Vehicle Technology and Fuels as a System

- *"It has long been recognized that vehicle technology and fuels are a system. The Alliance of Automotive Manufacturers (AAM) reiterated that the EPA Tier 3 emission standards must continue to treat vehicles and fuels as a system (AAM 2013).*
- *The 2017-2025 CAFE standards will lead to further efforts to ensure compatibility of engines and fuels. Some examples where engines and fuels will need to continue to be treated as systems include the following:*
- *The possibility of E30 as a commercial fuel, as suggested by the option to use E30 as a certification fuel in the Tier 3 standards, or the availability of higher octane gasolines, may facilitate the development of higher compression ratio engines."*

Finding 2.9 (High Octane Gasoline)

- *"Increasing octane from 87 AKI (91 RON) of regular grade gasoline to 91 AKI (95 RON) has the potential to provide 3 to 5% 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."*
- *"If the octane of the current gasoline blend stock were to be retained at current levels by the refiners, the increased ethanol content might provide the increase in octane level needed to facilitate higher compression ratio engines. However, regular grade gasoline with a higher minimum octane level would need to be widely available before manufacturers could broadly offer engines with significantly increased compression ratios."*
- *"EPA's Tier 3 program, which changes the certification test fuel to E10 with octane representative of today's level of 91 RON (87 AKI), does not contemplate the above scenario. However, EPA's Tier 3 program does allow manufacturers to use high-octane gasoline for testing*

vehicles that require premium if they can demonstrate that such a fuel would be used by the operator."

***Recommendation 2.3* (High Octane Gasoline)**

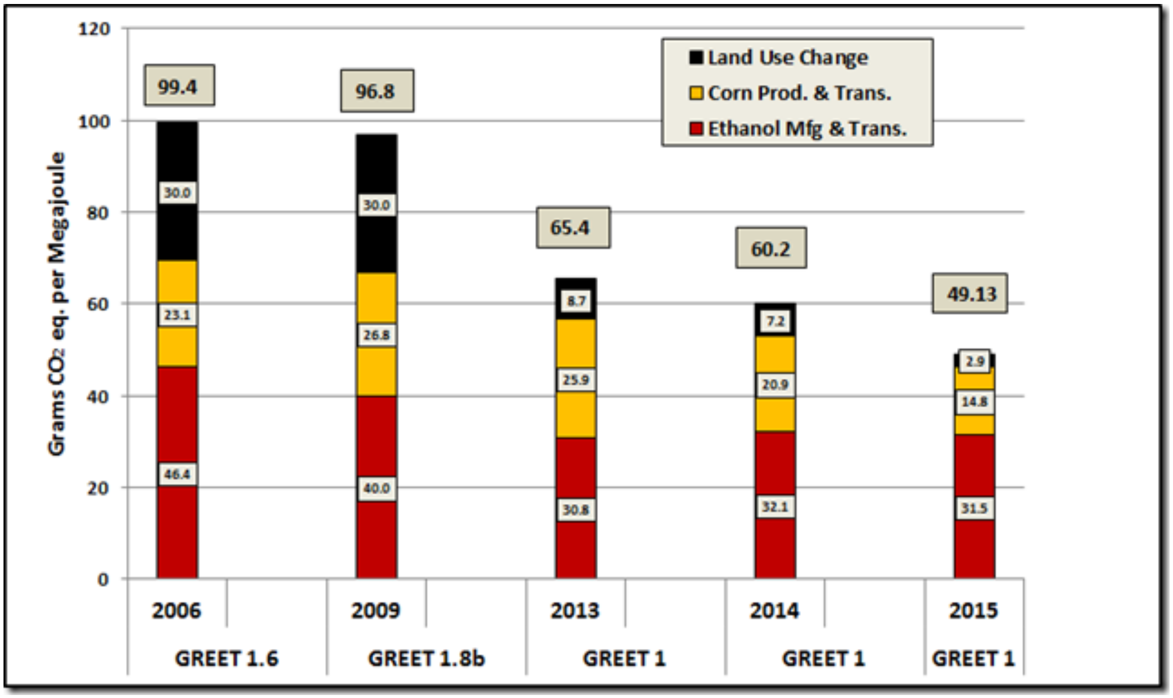
- *"EPA and NHTSA should investigate the overall well-to-wheels CAFE and GHG effectiveness of increasing the minimum octane level and, if it is effective, determine how to implement an increase in the minimum octane level so that manufacturers would broadly offer engines with significantly increased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

http://aceee.org/blog/2015/06/2025-cafe-standards-under-microscope

Appendix B

The Changing Assessment of Corn Ethanol's Carbon Footprint: Corn Acres Sequester Substantial Amounts of Carbon. New science confirms that high-yield corn acres are substantial carbon sinks, sequestering more than one ton of CO_2 per acre per year. Scientists at the Argonne National Laboratory evaluating upstream and downstream lifecycle carbon emissions of corn ethanol feed-stocks and production facilities confirm that U.S. corn ethanol has a carbon footprint approximately 50% smaller than that of CARB's baseline gasoline, see Argonne GREET chart below. Importantly, corn ethanol's carbon footprint is shrinking rapidly as agricultural practices and technologies continue to improve, while the fossil fuel carbon footprint is expanding rapidly as tar sands and tight oil supplies increase their market share. That same Argonne research gives no credit for corn's ability to fix carbon in soil permanently. However, recent research confirms that modern, high-yield continuous corn grown using conservation or no-till practices is in fact sequestering and rebuilding the carbon content of soil in the Midwest. Argonne is beginning a new study of soil carbon fixation, as well as nitrogen oxide (NOx) emissions related to fertilizer use (without which today's productivity advances would be impossible), to update corn ethanol's lifecycle carbon footprint. Some experts believe that proper recognition of corn's ability to sequester carbon and reduced nitrogen use due to improved management practices will show that corn ethanol's carbon footprint is only 15 grams of CO_2 per MJ, approximately 80% less than CARB's gasoline baseline.[63]

[63] Alverson R., April 26, 2016, *Presentation to NEB Emerging Issues Forum, Capturing the Value of Carbon Intensity Reduction in Corn Ethanol Plants and Farms*, slide 27



NASA Confirms Corn's Photosynthetic Efficiency from Outer Space

March 31, 2014
RELEASE 14-016
Satellite Shows High Productivity from U.S. Corn Belt

Data from satellite sensors show that during the Northern Hemisphere's growing season, the Midwest region of the United States boasts more photosynthetic activity than any other spot on Earth, according to NASA and university scientists.
Healthy plants convert light to energy via photosynthesis, but chlorophyll also emits a fraction of absorbed light as fluorescent glow that is invisible to the naked eye. The magnitude of the glow is an excellent indicator of the amount of photosynthesis, or gross productivity, of plants in a given region.

Research in 2013 led by Joanna Joiner, of NASA's Goddard Space Flight Center in Greenbelt, Md., demonstrated that fluorescence from plants could be teased out of data from existing satellites, which were designed and built for other purposes. The new research led by Luis Guanter of the Freie Universität Berlin, used the data for the first time to estimate photosynthesis from agriculture. Results were published March 25 in Proceedings of the National Academy of Sciences.

According to co-author Christian Frankenberg of NASA's Jet Propulsion Laboratory in Pasadena, Calif., "The paper shows that fluorescence is a much better proxy for agricultural productivity than anything we've had before. This can go a long way regarding monitoring – and maybe even predicting – regional crop yields."

The magnitude of fluorescence portrayed in this visualization prompted researchers to take a closer look at the productivity of the U.S. Corn Belt. The glow represents fluorescence measured from land plants in early July, over a period from 2007 to 2011.

Guanter, Joiner and Frankenberg launched their collaboration at a 2012 workshop, hosted by the Keck Institute for Space Studies at the California Institute of Technology in Pasadena, to explore measurements of photosynthesis from space. The team noticed that on an annual basis, the tropics are the most productive. But during the Northern Hemisphere's growing season, the U.S. Corn Belt "really stands out," Frankenberg said. "Areas all over the world are not as productive as this area."

The researchers set out to describe the phenomenon observed by carefully interpreting the data from the Global Ozone Monitoring Experiment 2 (GOME-2) on Metop-A, a European meteorological satellite. Data showed that fluorescence from the Corn Belt, which extends from Ohio to Nebraska and Kansas, peaks in July at levels 4% greater than those observed in the Amazon.

The research could also help scientists improve the computer models that simulate Earth's carbon cycle, as Guanter found a strong underestimation of crop photosynthesis in models. The analysis revealed that carbon cycle models – which scientists use to understand how carbon cycles through the ocean, land and atmosphere over time – underestimate the productivity of the Corn Belt by 40 to 60%.

Unlike most vegetation, food crops are managed to maximize productivity. They usually have access to abundant nutrients and are irrigated. The Corn Belt, for example, receives water from the Mississippi River. Accounting for irrigation is currently a challenge for models, which is one reason why they underestimate agricultural productivity.

"If we don't take into account irrigation and other human influences in the agricultural areas, we're not going to correctly estimate the amount of carbon taken up by vegetation, particularly corn," Joiner said. "Corn plants are very productive in terms of assimilating carbon dioxide from the atmosphere. This needs to be accounted for going forward in trying to predict how much of the atmospheric carbon dioxide will be taken up by crops in a changing climate."

Corn Ethanol: Food + Fuel + Soil Organic Matter Restoration = Low Carbon Fuel. After processing in an ethanol plant, an acre of corn yields as much protein as an acre of soybeans. (The ethanol process only takes the starch portion of the corn and leaves behind a valuable, concentrated high-protein by-product that is in great demand as a livestock feed.) A photo-synthetically superior C4 plant, corn has an extraordinary ability to sequester carbon, and move fertilizer nutrients back to the surface for plant growth rather than polluting ground water. Corn's extensive deep root system makes it one of the few plants with this important capability that makes crop production sustainable. **A multi-year USDA research project recently confirmed that no-till corn equaled switchgrass in SOC (soil organic carbon) formation, and that over half the increase in SOC was below one-foot depth. The researchers estimated that deep soil SOC sequestration benefits of corn have been understated by 60 – 100% in modeling done to date.**

So-called "Food vs. Fuel" attacks have been mounted against corn ethanol by big oil as well as processed food producers and animal feeders who want subsidized U.S. corn to boost their profits. However, 98% of U.S. corn is not directly consumed by people (less than one bushel per person per year, out of a ten plus billion bushel crop), but instead used as livestock feed and for other purposes. Importantly, when the starch portion of an acre of corn is converted to ethanol, what remains is as much protein and other equivalent high value feed products as found in an acre of soybeans. Since corn yields are nearly four times greater than soybean yields, the economically and environmentally smart thing to do is to first process the corn to ethanol. Doing so results in the same amount of protein and feed co-product equivalents offered by an acre of soybeans, but with the additional advantages of the corn ethanol industry's job creation, health cost savings, oil import reduction, and environmental benefits.

Even Michael Pollan, author of "*An Omnivore's Dilemma*" and a frequent critic of the current agricultural system, has effusive praise for corn's efficiency. "Few plants can manufacture quite as much organic matter (and calories) from the same quantities of sunlight and water and basic elements as corn." Pollan praises corn's ability to extract carbon from the air. "The C-4 trick represents an important economy for a plant, giving it an advantage…By recruiting extra atoms of carbon during each instance of photosynthesis, the corn plant is able to limit its loss of water and "fix"—that is take from the atmosphere and link in a useful molecule—significantly more carbon than other plants."[64]

[64] Pollan M., 2006, *The Omnivore's Dilemma*, p. 21

Corn Ethanol's High Octane, Low Carbon Value Proposition. Substituting High Octane Low Carbon ethanol—derived from one of nature's most efficient converters of sunlight and water, most efficient carbon fixing plants, and a highly efficient source of protein on par with soybeans—for carcinogenic, oil-derived, carbon intensive, and costly aromatic hydrocarbons offers society a rare win – win – win proposition.

Sen. Timothy Wirth/Ambassador C. Boyden Gray, Yale *Environment 360, "Is it Time for Greens to Reassess Their Opposition to Ethanol?"*, May 25, 2016. *"The criticism of ethanol by environmentalists is misguided and just plain wrong. In fact, thanks to improvements in farming techniques, increasing the amount of corn ethanol in U.S. gasoline would reduce air pollution, provide significant health benefits, and lower greenhouse gas emissions."*

http://e360.yale.edu/mobile/feature.msp?id=2997

GREET Model/Corn Ethanol Carbon Sink Addendum: Improved Nitrogen Management Practices Justify Reducing EPA's Nitrous Oxide Penalties in Corn Ethanol's Carbon Intensity Models.

The life cycle GHG scientists at Argonne National Lab (using the GREET model) have documented a rapid reduction in corn ethanol life cycle GHGs. EPA regrettably, has not updated its models.

Argonne GREET model LCA GHG reductions are mostly due to reductions in energy use (natural gas and electricity) at ethanol plants and reductions in land use change emissions.
GREET model corn production GHG emissions have only seen modest reductions.

Unfortunately, EPA/GREET modelers do not account for each biofuel feedstock's effect on soil carbon stocks. This is a crucial omission because the type of biofuel feedstock grown has a large impact on soil carbon stocks and changes in soil carbon stocks have a very large impact on life cycle GHG emissions. Soil scientists frequently refer to crop soil carbon budgets. Soil carbon budgets are an accounting of carbon inputs to soil from root and unharvested above ground stover/residue less the soil carbon losses from natural and tillage induced soil organic carbon decomposition.

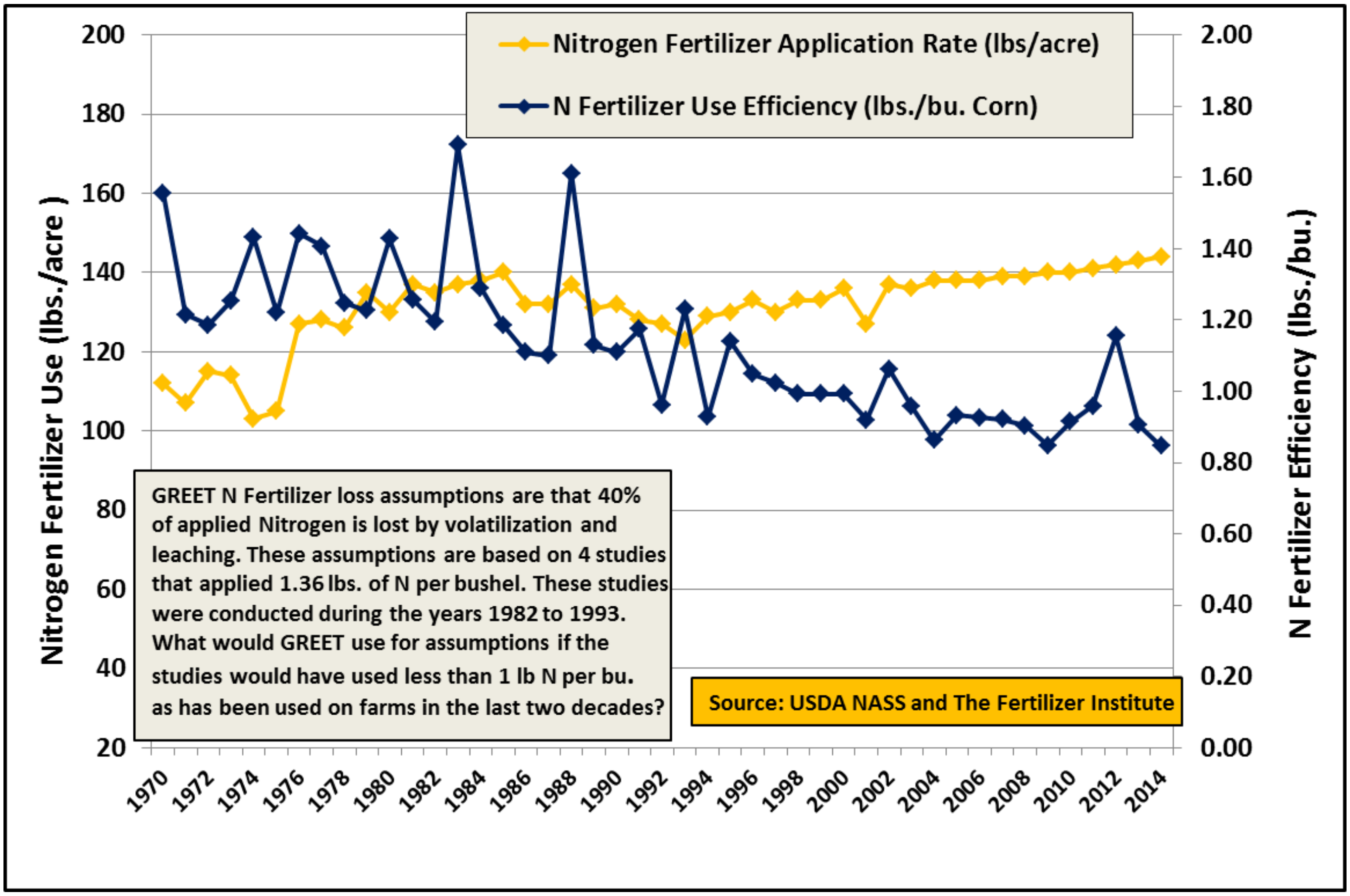
Below is an abbreviated version of soil carbon budgets of the four major biofuel crops currently grown in the U.S. Mid-west: Corn, soybeans, sorghum, and corn stover ethanol.

Crop Soil Carbon Budgets	Corn	Soybean	Sorghum	Corn Stover
Yield level (bu/acre)	170	50	100	170
Stover/Residue Carbon Additions to Soil (Mg/Ha/Year)	3.73	1.57	2.77	3.73
Stover/Residue Carbon Removal (Mg/Ha/Year)	0	0	0	1.5
Soil Carbon Maintenance Requirements (Mg/Ha/Year)	2.2	2.2	2.2	2.2
Soil Carbon Balance (Mg/Ha/Year)	1.53	-0.63	0.57	0.03

Source: Johnson et al. 2006

Many corn producers across the Midwest use management practices that result in a large positive soil carbon budget and produce net zero carbon corn. It must be noted that because corn yields continue to increase significantly, the soil carbon budgets are getting more positive as each year goes by. This has a dramatic effect on full life cycle GHGs of corn ethanol, reducing the carbon intensity to very low levels, and needs to be accounted for in models.

Improved Nitrogen Management Practices Should Be Incorporated. EPA and GREET GHG modeling scientists rely on Intergovernmental Panel on Climate Change (IPCC) guidance to determine N_2O emissions from nitrogen fertilizer applications to crops. The IPCC uses decades old research data to support their N_2O modeling estimations. For example, the IPCC research indicates that 40% of the total Nitrogen fertilizer applied to fields is lost by volatilization, runoff and leaching. This was undoubtedly true in the 1970s, 1980s and 1990s when this research was conducted. During those earlier decades, nitrogen fertilizer was routinely applied at higher rates than crops could utilize. This lead to significant quantities of unused nitrogen left in soil and that unused nitrogen often was leached from soil during the fall, winter and spring. Factors that lead to this over application of N were very cheap fertilizer prices, lack of technology to precisely manage fertilizer applications, and a general lack of awareness of the negative environmental impact of nitrogen losses. . However, crop producers have dramatically changed nitrogen fertilizer management in the past couple decades and this has led to large reductions in fertilizer use per unit of production. Below is a graphical illustration of USDA fertilizer use per bushel of corn production.



Corn grain removes .9 lbs of Nitrogen from soil for each bushel of production. Since over the past decade, nitrogen application rates to corn have been closely balanced with removal at .9 lbs per bushel, this means little N is left in soil and losses from volatilization, runoff and leaching have been greatly reduced. This reduction in N losses from leaching has been confirmed by recent research (Daigh et al. 2015) that found only about 10% of applied N was leached/lost on average over several years in a pattern tiled field (worst case scenario) in central Iowa.

The IPCC N_2O model used by Argonne GREET modelers also assumes that the nitrogen in corn stover results in N_2O GHG emissions equivalent (per lb N.) to fertilizer nitrogen. Recent research (Lesschen et al. 2011) indicate that the nitrogen in corn stover, because corn stover has a very high Carbon to Nitrogen ratio, produces only 20% as much N_2O as does nitrogen in fertilizer.

It is crucial that modelers/accountants of crop production GHGs use the latest science and data in their models.

Appendix C

Gasoline Exhaust Black and Brown Carbon Emissions Predominate in Urban Areas. To make the case that gasoline BC emissions are an important, if not dominant, factor in the climate change debate, HOLC respectfully submits the following: 1) new science now points to higher GWP for BC; 2) there is mounting evidence of higher black and brown carbon emissions from gasoline (relative to diesel); and 3) gasoline black and brown carbon emissions will get worse as GDI engines proliferate unless fuel quality is improved.

1. **GWP of BC = 3200**. [65]This is a recent Bond study (2013) with a higher range of GWP values for BC (average 3200 instead of 680)."
2. **Gasoline BC Emissions Exceed Diesel BC Emissions**. A recent European study found that gasoline BC emissions were significantly higher than diesel emissions: "Particulate and black carbon emissions from the gasoline engines were significantly higher than those from the Diesel engines equipped with DPF."

http://www.sciencedirect.com/science/article/pii/S1352231016304885

The Manufacturers of Emissions Control Association (MECA) reports that 70% of mobile source BC emissions are from diesel, based on the assumption that "40% of gasoline PM is black carbon". However, CARB reports that gasoline PM is 70% black carbon.[66] Correcting for this new science would significantly change the gasoline/diesel ratio for black and brown carbon emissions.

"Because of the combination of high absorption, a regional distribution roughly aligned with solar irradiance, and the capacity to form widespread atmospheric brown clouds in a mixture with other aerosols, emissions of black carbon are thought to be the second strongest contribution to current climate change, after CO2 emissions. For example, in the Himalayan region, solar heating from black carbon may be just as important as CO2 in the melting of snowpacks and glaciers. Estimates of the global warming potential of black carbon are in the range of 60% of the warming potential of CO2. It is estimated that 70% of the black carbon emissions from mobile sources are from diesel-fueled vehicles, with the assumption that 40% of gasoline PM is black carbon and 60% of diesel PM is black carbon."
http://www.meca.org/technology/technology-details?id=30

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[65] Bond T., Doherty, S., Fahey D., Forster P., Berntsen T, DeAngelo B, Flanner M., Ghan S., Kaȑcher B., Koch, D., et al., June 16, 2013, *Bounding the role of black carbon in the climate system: A scientific assessment*., p. 5380−5552
[66] CARB, Dec. 7, 2011, *Development of particulate matter mass standards for future light-duty vehicles,* p. 123

3. **GDI Will Make Gasoline BC Emissions Worse Unless Fuel Quality is Improved.** This is excerpted from the attached study by Zimmerman et al.:

"The effect of ethanol on GDI BC engine emissions may also be convoluted by the impacts of other fuel properties, such as aromatic content and blending technique (i.e., splash vs match blending). In Karavalakis et al.,30 fuel aromatic content was systematically increased from 15% to 35% and the impact on particle number, PM, and BC emissions was measured. <u>They found that that increasing fuel aromatics from 15% to 35% resulted in a 395% increase in PM, a 266% increase in particle number, and a 154% increase in BC, suggesting that aromatic compounds are precursors for soot formation.</u> Ramos16 also observed that doping commercially available E0 gasoline with 10% toluene, a common fuel aromatic, resulted in approximately 70% higher particle number emissions, and when doping E10 with 10% toluene, particle number emissions further increased by 64%, potentially suggesting a synergistic effect that is not currently understood. Differences in blending techniques between studies may also influence results, as "splash" blended fuels may have different hydrocarbon profiles and vapor pressures than fuels produced using match blending.59 <u>In California, regulations on reformulated gasoline mandate a maximum aromatics content of 25% by volume; no such regulation exists federally in the United States or in Canada. Of the studies used to compile the BC emission scenarios, over half were conducted in California, thus our scenarios would be disproportionately influenced by data reported from this state, where fuel aromatics are lower.</u> <u>In contrast, a commercially available summer-blend premium 91 octane fuel sample in Toronto, Canada contained 43% aromatics by volume (fuel analysis in SI). The BC emissions data from two separate Canadian studies were roughly an order of magnitude higher than those from California studies,</u> suggesting that understanding the impact of fuel properties on BC emissions, which may vary significantly by region, is critical to developing a more precise climate trade-off analysis of GDI engine emissions."

Gasoline Aromatic Hydrocarbons Are a Predominant Source of Aerosol "Brown Carbon" Emissions in Urban Areas. A 2014 study underlines the importance of aerosol particles—and particularly secondary organic aerosols (SOAs) in understanding radiative forcing that has been found to be a major contributor to global warming. An excerpt:

"Globally, organic compounds compose 50% of the aerosol mass, and in certain polluted areas, this amount can be as high as 90%. Secondary organic aerosols (SOAs) compose up to 80% of all organic aerosols and contribute to the attenuation of regional visibility, climate change and potential health hazards8–10. Considering the ubiquity and predominance of SOAs, understanding the optical properties of SOAs is of great concern. <u>Aromatic hydrocarbons compose 20–50% of the non-methane hydrocarbons in urban air and are considered to be some of the primary precursors to urban SOAs</u>11. Anthropogenic aromatic compounds yield 76% of the calculated secondary organic particles in Beijing City and are thought to be the major source of

SOAs, while among the aromatic hydrocarbons, benzene, toluene and theC8 aromatics(e.g.,xylene and ethylbenzene) are the most abundant species12."
http://www.nature.com/articles/srep04922

Harvard Center for Risk Analysis SOA Study Highlights
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- SOA is a form of PM2.5, which is widely viewed as the most lethal air pollutant in the US.

- The Harvard study found that EPA's models err in their prediction of SOA formation from motor vehicle fuel ***by a factor of two*** nationwide. In other words, although EPA has already admitted that SOA formation from gasoline is a problem, the reality is actually ***twice as bad*** as EPA has assumed.

- SOA formation from gasoline is solely the result of fuel's aromatic (BTX) content. (See text accompanying footnote 18.)

- The formation of SOA by aromatics in gasoline is responsible for approximately ***3800 deaths every year*** **(1800 – over 4700 range)**.

- If one correctly assumes that the contribution of SOA from motor vehicle exhaust is higher in urban areas, this estimate climbs to up to **6300 deaths every year** or a total social cost of up to $**46.8 billion.**

- The ranges above reflect uncertainty about how many people will die when exposed to a certain amount of SOA—*not* uncertainty about how much SOA will be in the ambient air because of aromatics in gasoline.

- These numbers account only for actual deaths that result from aromatics in gasoline, and do not account for the myriad other health problems that are the result of SOA and UFP inhalation, including asthma, upper respiratory problems, and endocrine issues.

- The costs associated with gasoline SOA are in the same realm as the benefits EPA claims will result from its recent major rule limiting pollution from power plants, known as the "Utility MACT." However, the MACT Rule will cost billions to implement, and will bring reductions mainly in sparsely populated areas. Reducing aromatics in gasoline, on the other hand, would bring reductions in densely populated urban areas, reducing exposure for greater numbers of people. In addition, reductions in aromatics could actually be implemented in a way that *reduces* costs.

Harvard Study Links Gasoline Aromatics to Urban SOA Pollution

It is important to keep in mind that Harvard's findings of up to $50 billion per year in social costs quantify just a small slice of the full spectrum of health damage caused by gasoline aromatics. The Harvard study looked only at PREMATURE MORTALITIES (as opposed to MORBIDITY short of death) caused by PM2.5 SECONDARY ORGANIC AEROSOLS (SOAs) only. In other words, Harvard did not attempt to quantify the hundreds of billions per year of health costs associated with PAH-borne UFPs, including the increasing evidence of the damage they do [as EDCs] to infants and developing children in particular.

Highlights:

1. *"Modeled aromatic SOA concentrations from CMAQ fall short of ambient measurements by approximately a factor of two nationwide...Assuming that the contribution of SOA precursors originating from aromatic hydrocarbons in gasoline is higher in urban areas increases these estimates to 5100 predicted premature mortalities nationwide...associated with total social costs of $37.9B". p. 3*

2. *"...particulates from vehicular emissions of aromatic hydrocarbons demonstrate a sizeable public health burden. The results provide a baseline from which to evaluate potential public health impacts of changes in gasoline composition." P. 3*

3. *"Evidence is growing that aromatics in gasoline exhaust are among the most efficient secondary organic matter precursors. In general, air quality models do not adequately capture these increased yields or potential interactions, although improvements have been made." P. 4*

4. *"In the United States, gasoline-powered vehicles are the largest source of aromatic hydrocarbons to the atmosphere...Therefore, it has been suggested that removal of aromatics could reduce SOA concentrations and yield a substantial public health benefit...a number of studies have noted that gas-phase vehicle emissions lead to a substantial fraction of observed SOA. For example, a source apportionment study of SOA formation during a severe photochemical smog event in Los Angeles found that gasoline engines represented the single-largest anthropogenic source of SOA." P. 4*

5. *"Although CMAQv5.0 contains updated...processes for predicting SOA formation, evidence suggests that the model may still underestimate secondary PM2.5 concentrations." P. 5*

6. *"Source-specific speciation reveals that the U.S. emissions of aromatic hydrocarbons are 3.6 million tons per year, of which 69% are from gasoline-powered vehicles as shown in Table 3." P. 8*

7. *"In addition to premature mortality, which dominates monetized estimates of total social cost, exposures to SOA from aromatics in gasoline are associated with other health outcomes, including exacerbation of asthma, upper respiratory symptoms, lost work days, and hospital emergency room visits." P. 9*

8. *"A recent study in Los Angeles found that gasoline emissions dominated SOA formation, accounting for nearly 90% of total aerosol formation, and the ratio of SOA to primary organic aerosol was approximately a factor of three...Anthropogenic SOA have been shown to enhance biogenic SOA formation." P. 9*

http://www.ehjournal.net/content/12/1/19/abstract