Comments to EPA – NHTSA Technical Assessment Report by the Urban Air Initiative, Governors' Biofuels Coalition, Nebraska Ethanol Board, and Clean Fuels Development Coalition

The responders appreciate this opportunity to comment on the draft Technical Assessment Report (TAR) on the Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuels Economy Standards for Model Years 2022 – 2025,[1] prepared by the U.S. Environmental Protection Agency (EPA), the National Highway Traffic Safety Administration (NHTSA), and the California Air Resources Board (CARB). The draft TAR states that "the MTE will be a collaborative, data-driven, and transparent process and must entail a holistic assessment of all the factors considered in the initial standards setting".[2]

About the Urban Air Initiative (UAI).
The Urban Air Initiative is a non-profit entity dedicated to research and education in the area of fuel quality and its relationship to mobile source emissions, especially in urban areas. The climate and public health impacts of mobile source (traffic) pollution—in the U.S. and globally—are of great importance to policymakers, industries, and the billions of people that are regularly exposed to harmful pollutants in their homes, schools, and vehicles. Among the most vulnerable are infants and children. The responders believe that protecting our children's health and well-being is the most important investment society can make to build a better future.

About the Governors' Biofuels Coalition (GBC).
The Governors' Biofuels Coalition is a group of twenty-one (21)of the nation's governors who believe that increasing the use of clean-burning biofuels can decrease the nation's dependence on imported energy resources, improve public health and the environment, and stimulate the state economies.

The Nebraska Ethanol Board (NEB) is a state agency supporting ethanol production and use in Nebraska and the development of markets nationwide. NEB Board members and staff have been directly involved in major legislative and regulatory actions since 1970.

The Clean Fuels Development Coalition (CFDC) is a non-profit organization now in its 25th year of continuous operation and has a broad based membership from the ethanol, automotive, agriculture, technology, and engineering industries.

Both the NEB and CFDC have significant experience and expertise in issues relating to fuels, emissions, and related fields having served on the Clean Air Act advisory Committee, the EPA Blue Ribbon Panel on Oxygenates, the Renewable Fuel Standard Advisory Group, and dozens of similar boards and advisory groups.

Summary of Comments. The responders respectfully urge the agencies to adopt the recommendation of the National Research Council (NRC), and "*determine how to implement an increase in the minimum octane*

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[1] [1]EPA, Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025, Draft Technical Assessment Report (2016) (Draft TAR).The draft TAR, at more than 1,200 pages, can be found athttps://www3.epa.gov/otaq/climate/documents/mte/420d16900.pdf
[2] Ibid., p. ES-1.

level so that manufacturers would broadly offer engines with significantly increased compression ratios for further reductions in fuel consumption."[3] Encouraging the widespread availability of higher octane gasoline in advanced, high compression engines is justified for the following reasons:

1. Once all upstream and downstream emissions factors are properly considered, it would shrink the carbon footprint of the U.S. transportation sector to levels equivalent to, or smaller than, that which is achievable by electric vehicles (EVs).
2. It would substantially benefit the nation's economy, environment, and energy security, and would save consumers and auto manufacturers billions of dollars over the life of this rulemaking.
3. It would be the most cost effective option for complying with tightening fuel efficiency and carbon reduction standards.
4. An orderly transition to higher octane gasoline could be done over the near- to mid-term with minimal disruption, and would provide significant economic and environmental benefit while the gradual transition to EVs (including hybrid EVs) takes place over the longer term. In the longer term, advanced vehicle technologies—such as Nissan's Solid Oxide Fuel Cell—could utilize the biofuels as feedstock for hydrogen generation.[4]
5. It would substantially reduce harmful emissions of carbon-related co-pollutants that are predominant precursors of urban ground level ozone, particle-borne toxics, and black and brown carbon, and would save taxpayers and businesses billions of dollars in reduced health care costs.
6. It would help the agencies comply with cost-benefit analysis requirements imposed by the Office of Management and Budget.
7. It would be consistent with recommendations made by the U.S. Department of Energy and its national laboratories, whose recent studies have endorsed the widespread use of High Octane Fuels (HOFs).
8. It would be consistent with the 1990 Clean Air Act Amendments, which required EPA to replace "dirty octane" components with "clean octane" components to the greatest extent achievable as technologies present themselves.

Higher octane gasoline has been a top priority of auto manufacturers and fuel producers for the past 100 years. A recent paper by Oak Ridge National Laboratory (ORNL) fuel experts traced the 100 year evolution of gasoline octane number and spark-ignition engines.[5] They noted that "…historically fuel octane number has been an enabler for increases in fuel economy or performance through engine compression; however, since the mid-1970s fuel octane number has remained stagnant." [6] However, the authors state that ".with the looming emphasis on unprecedented increases to fuel economy in the current CO2 age, it is hard to argue that the current stagnant fuel octane number can be sustainable over the long term. Therefore, increasing fuel octane number offers significant motivation to achieve fuel economy and CO2 targets, which continue to be of primary concern".[7]

The ORNL study makes it clear that the agencies overlooked an important means of improving fuel efficiency when they failed to include higher octane gasoline in the draft TAR list of options.

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[3] National Academy of Sciences, National Research Council to the National Academies, "Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles", June 2015.
[4] "Nissan's Game Changer, the Bio-Electric Car", Canadian Report on Fuel Ethanol, Vol. 6 , Number 5, September 14, 2016.
[5] Splitter et al., "A Historical Analysis of the Co-evolution of Gasoline Octane Number and Spark-Ignition Engines", Frontiers in Mechanical Engineering, January 2016, Volume 1, Article 16.
[6] Ibid, p. 2.
[7] Ibid., p. 11.

"…increasing fuel octane number alone from intermediate ethanol blends provides a pathway for improved engine efficiency"[8]. Henry Ford and GM scientists proposed (and patented) E30 – E50 blends as early as 1923, and warned about the health dangers of tetraethyl lead (TEL) and benzene/aromatic hydrocarbon alternatives. In May 1925, the U.S. Surgeon General suspended the use of TEL in gasoline due to the mounting evidence of serious health problems. However, Rockefeller and Standard Oil prevailed, and Prohibition and the oil industry's anti-competitive practices took ethanol out of the octane picture.

Fifty years later, lead's devastating effects were impossible to ignore, and the newly-formed EPA began to phase out its use in gasoline. The transition from leaded to unleaded gasoline took nearly twenty years. In the 1990 Clean Air Act Amendments (1990 CAAA), Congress finished the job by banning TEL from gasoline. Not wanting to repeat the same mistake with benzene, Congress inserted mandatory provisions that required EPA to ensure that carcinogenic aromatic hydrocarbons were reduced to the greatest achievable extent "as technologies presented themselves."[9]

Inexplicably, for the past 25 years, EPA has not shown any interest in enforcing these mandatory provisions of the Clean Air Act. In fact, in a 2013 presentation, EPA's Director of Fuel Quality said that "*Octane historically has had little or no effect on criteria pollutants or air toxics, but could affect GHG emissions".*[10]

However, if one were to substitute "The petroleum-derived octane-enhancing components of gasoline" for "Octane," that statement would be insupportable. Clearly, benzene and its aromatic hydrocarbon counterparts have had, and continue to have, enormous effects on criteria pollutants, air toxics, and carbon emissions. The Health Effects Institute (HEI) reported that "aromatics represent one of the heaviest fractions in gasoline…The aromatic content of gasoline has a direct effect on tailpipe carbon dioxide emissions. The EPEFE study demonstrated a linear relationship between CO2 emissions and aromatic content. A reduction of aromatics from 50% to 20% was found to decrease CO2 emissions by 5%."[11] The report also noted that "about 50% of the benzene produced in the exhaust is the result of decomposition of aromatic hydrocarbons in the fuel…Reducing the aromatic content of gasoline also contributes to the reduction of NOx."[12]

In the 2012 GHG – CAFE rule, and again in the 2014 Tier 3 rule, EPA requested comment on whether it should approve the use of mid-level ethanol high octane blends like E30 in order to improve fuel

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[8] Ibid., p. 14.

[9] See the1990 CAA conference report debate on the Senate floor: "Aromatic compounds include benzene, toluene, and xylene. All three are air toxics listed in Title III of the bill…Aromatics have a higher carbon content than the rest of gasoline, so gasoline high in aromatics contributes more to global warming." "Aromatics… have been used to replace the octane that was lost as a result of the lead phase down. Oxygenated fuels could be used in lieu of the aromatics to provide the octane." *Congressional Record,* Vol. 136, No. 150, October 27,, 1990, p. 16922

[10] Paul Machiele, EPA Fuels Center Director, "Statutory and Regulatory Backdrop for Fuel Standards", January 28, 2013, slide 13.

[11] Health Effects Institute, Panel on the Health Effects of Traffic-Related Air Pollution, "Appendix B. Fuel Composition Changes Related to Emission Controls" in Special Report 17, Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects, p. 3, Chapter 2. Emissions from Motor Vehicles. 2010.

[12] Ibid., pp. 3-4.

efficiency and reduce tailpipe carbon emissions. Regrettably, in both cases, EPA did nothing in the final rules to encourage the use of such fuels.

The TAR (and Mid-Term Evaluation (MTE) which it will inform) will have an enormous impact upon the nation's economy, environment, and energy security. The TAR provides the technical underpinning for a final rulemaking that will have enormous impacts on the nation's economy, environment, and energy security. Improving fuel efficiency and reducing the carbon footprint of the U.S. light duty fleet—and the fuels that power it—will impact tens of billions, perhaps trillions, of dollars in capital investment, consumer purchases of vehicles and fuel, and related economic activity over the life of the MTE rule. Making the wrong decisions about the composition of hundreds of billions of gallons of gasoline that will power hundreds of millions of internal combustion engines (ICEs) will adversely affect job creation, substantially increase U.S. oil imports, and cost the nation billions of dollars each year in premature mortalities and lost productivity caused by avoidable carbon and gasoline-related tailpipe emissions. Consistent with recent Executive Orders and regulatory precedents, the Office of Management and Budget (OMB) should require EPA and NHTSA to undertake a comprehensive cost-benefit analysis before the MTE is finalized in June 2018.

The TAR's glaring omission: higher gasoline octane. One of the most striking things about the TAR is not what it contains, but what it excludes. Except for several fleeting references, the 1,000+ page document that is supposed to guide the agencies' Mid-Term Evaluation (MTE) of the 2012 GHG – CAFE rule made no mention of the importance of high octane, low carbon (HOLC) fuels for improving fuel efficiency and reducing carbon emissions from light-duty vehicles (LDVs).

In the Executive Summary, the agencies say that they "discuss infrastructure for ethanol (E-85) flex-fueled vehicles and natural gas vehicles. The agencies' assessment is that, as we concluded in the 2012 rule, high penetration levels of alternative fueled vehicles will not be needed to meet the MY 2025 standards…".[13] Of course, this entirely misses the point about the importance of HOLC mid-level ethanol blends that can benefit both today's legacy vehicles, as well as EXX-optimized LDVs that manufacturers can make available at little, if any, incremental cost and relatively short lead-times, compared to the electrification options.

In fact, a growing number of experts contend that higher octane fuels can be used by the existing, legacy fleet. Recently, BMW-owned MINI Cooper recommended that its owners use 93 AKI octane with E25. The BMW X-1 SUV has followed suit. A BMW spokesman said that the vehicles will be available in the U.S. and Canada, and that the move was made "due to the increasingly strengthened requirements for fuel economy". He added that "It is Mini's intention that all new models will be E25 compatible."[14]

Some automotive experts suggest that "if all current fleet vehicles were recertified and re-flashed for premium certification fuel, a 0.5-2.5% increase in fuel economy might be possible".[15] Similar fuel economy results were recently reported by the Glacial Lakes Energy (GLE) E30 Challenge. Even without re-flashing, 50 standard (non-flex fuel) vehicles were carefully monitored with performance data logging

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[13] See supra note 1, p. ES-5.

[14] "Mini Cooper Shares E25 Know-How with BMW", Canadian Report on Fuel Ethanol, Vol. 6, No. 5, September 14, 2016.

[15] See supra note 5, p. 13, citing Leone et al., "The effect of compression ratio, fuel octane rating, and ethanol content on spark-ignition engine efficiency", Environmental Science & techno9logy, August 3, 2015, Volume 49, 10778-10789.

devices supervised by certified professionals. Owners reported better power and performance, and no complaints were registered.

At p. 5-42 of the draft TAR, the agencies referenced the DOE's Co-Optima program, which is evaluating "fuel and engine R & D and deployment assessment. They correctly note the promise of improved fuels: "By using low-carbon fuels, such as biofuels, GHGs and petroleum consumption can be further reduced". However, EPA states that these options will not be explored until "2026 and beyond". The responders believe there is no reason for the agencies to delay taking advantage of the many benefits higher octane gasoline can bring to motorists, automakers, and the nation.

Automakers, U.S. Department of Energy and its national labs, and the National Research Council recommend higher octane gasoline. Automakers have pleaded with EPA for years to remove its barriers to higher octane gasoline (e.g., 93-94 AKI octane, vs. today's 87 AKI), to no avail.

According to the Alliance of Automotive Manufacturers and other experts, the agencies must treat fuels and vehicles as equally important components of a synergistic, tightly integrated system if they are "to achieve the lowest technologically and economically feasible emissions targets".[16]

Auto manufacturers were particularly emphatic about the need for higher octane gasoline in their Tier 3 comments, filed on July 1, 2013).[17] For more details on the manufacturers' comments, please see Appendix A.

Gasoline-powered internal combustion engines will dominate. One area in which most everyone seems to agree is that widespread electrification of the U.S. LDV fleet is a long way off. The draft TAR states that "Advanced gasoline vehicle technologies will continue to be the predominant technologies, with modest levels of strong hybridization and very low levels of full electrification (plug-in vehicles) needed to meet the standards".[18]

The National Research Council (NRC) predicts that in 2025, 98% of the U.S. fleet would still be internal combustion engines (ICEs) powered by gasoline, and that such vehicles will dominate the U.S. fleet for decades.[19] In the TAR, the agencies agreed that to comply with tighter standards, automakers will have to rely upon advanced engines and powertrain technologies—such as turbocharging, higher compression, and direct injection—and downsize their vehicles. In fact, DOE's Energy Information

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[16] See Letter from Mitch Bainwol, Alliance of Automobile Manufacturers, to EPA Administrator Lisa Jackson, Re: Changes to U.S. Retail Gasoline, October 6, 2011. "…[T]o help achieve future requirements for the reduction of greenhouse gas emissions, we also recommend increasing the minimum market gasoline octane rating, commensurate with increased use of ethanol. Adding ethanol to gasoline increases its octane rating. To attain necessary octane levels, it is important that refiners not be permitted to reduce base gasoline octane ratings in light of the additional octane contribution from higher ethanol." Ibid.

[17] See, e.g., Cynthia Williams, Ford Motor Company, Comments on Proposed Tier 3 Rule, EPA-HQ-OAR-2011-0135-4349 (July 1, 2013) ["strongly recommending that EPA pursue regulations…to facilitate the introduction of higher octane rating market fuels", noting that they "offer the potential for the introduction of more efficient vehicles".

[18] Supra note1, p. ES-2.

[19] See supra note2, Chapter 2.

Administration (EIA) recently projected that by 2025, 83.3% of all U.S. LDVs will be turbocharged.[20] Turbocharging increases cylinder pressure and compression, and the EIA says that future vehicles will require higher octane gasoline to prevent premature combustion of the fuel (knocking), which can damage the engine.

EPA prevented NHTSA from modeling higher octane gasoline. Interestingly, NHTSA's engine simulation modeling (Chapter 5 of the Draft TAR) relied upon 93 AKI fuel—"(R+M)/2"—for turbocharged engines.[21]

"All the turbocharged direct injection engines described below have been developed using 93 octane [AKI]. NHTSA understands that using such fuel might lead to overestimating the effectiveness of the technology, especially for high BMEP engines. While the engine maps will be updated to represent regular grade octane gasoline, NHTSA does not expect significant effectiveness change on the standard driving cycles as the engines operate at lower loads."[22]

[Since engine knock happens at high load (a regular occurrence in the real world), NHTSA's expectation about adequate performance at lower loads is not particularly reassuring.]

After EPA and NHTSA conducted their "largely independent" analysis, NHTSA had concluded that higher octane should be part of the solution. After consulting with EPA, they reversed course and only considered regular grade 87 AKI octane gasoline. "NHTSA will ensure that all future engine model development is performed with regular grade octane gasoline."[23].

This suggests that NHTSA knows that EPA's 87 AKI octane restriction misses a major opportunity for increased efficiency.

NRC study recommended higher octane gasoline. This belief is further reinforced by the NHTSA-commissioned NRC study, which the TAR described as "a significant study informing the agencies' analysis…which the agencies discuss throughout this document".[24] NHTSA commissioned the NRC study (NRC is an operating arm of the National Academy of Sciences) 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*,[25] reviewed whether the work done by NHTSA and EPA to evaluate the 2012 standards—and their underlying assumptions—is still appropriate based upon new data and changes that have occurred over the past five years.

As explained in more detail in Appendix B, one thing the agencies do not say about the NRC study is the serious concerns it expressed about EPA's opposition to higher octane gasoline. Throughout its comprehensive analysis, NRC experts pointed out why higher octane fuels are important if the goal is to improve fuel efficiency and reduce carbon emissions. In fact, in its conclusions, the NRC recommended

[20] U.S. Energy Information Administration, "Engine design trends lead to increased demand for higher-octane gasoline", April 6, 2016.
[21] Ibid., p. 5-504.
[22] Ibid., p. 5-509.
[23] Ibid., p. 5-512.
[24] Ibid., p. ES-3.
[25] Supra note 3.

that EPA and NHTSA determine how best to increase the minimum octane rating of U.S. gasoline. [Emphasis added]

"*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."*

Best Available Science confirms high octane ethanol qualifies as a low carbon fuel. The responders respectfully urge EPA and NHTSA to adopt NRC's recommendation, and perform an in-depth well-to-wheels analysis of the effects of using HOLC fuels to increase the minimum octane level of U.S. gasoline. 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. If all upstream and downstream emissions from electricity generation, battery manufacture, etc. are properly accounted for, and compared to corn ethanol's upstream and downstream emissions, mid-level ethanol blend HOLC fuels do as well, or better, than EVs from a carbon footprint standpoint.[26]

A recent study by Argonne National Laboratory (ANL) found that E40 blends using corn ethanol could reduce well-to-wheel GHG emissions by 18%, and that corn stover ethanol would provide a 32% GHG reduction.[27] These are impressive results, but they will only get better:

ANL has not yet incorporated the considerable carbon sequestration benefits provided by today's high-yield corn acres, especially that which occurs below ground. ANL's comprehensive evaluation of deep soil carbon sequestration studies concluded that modern high-yield corn acres sequester nearly two tons of CO_2 per acre.[28] Please see a more detailed discussion of this critically important issue in Appendix C.

For additional validation, the responders also ask that the agencies give careful consideration to the updated science that was recently submitted to the EPA by Urban Air Initiative, Energy Future Coalition, Governors' Biofuels Coalition, et al. The Lifecycle Request for Correction can be found on the EPA website: https://www.epa.gov/quality/epa-information-quality-guidelines-requests-correction-and-requests-reconsideration#16004

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[26] According to a 2012 CBO report, "[c]ompared with an average-fuel-economy conventional vehicle, an electric vehicle of similar size and performance will have about 35 percent lower life-cycle emissions, assuming that the power plants that produce the vehicle's electricity emit greenhouse gases at a rate equal to the national average for the electricity sector." CBO, Effects of Federal Tax Credits for the Purchase of Electric Vehicles, January 2012, p. 18.

[27] Han et al., "Well-to-Wheels Greenhouse Gas Emissions Analysis of High-Octane Fuels with Various Market Shares and Ethanol Blending Levels", ANL/ESD-15/10, July 14, 2015.

[28] Qin et al., Argonne National Laboratory, "Soil carbon sequestration and land use change associated with biofuel production: empirical evidence", GBC Bioenergy (2015), doio: 10.1111/gcbb.12237. p. 8. [Conversion factors: 1.18 tons of carbon per hectare = .53 U.S. tons per acre of carbon = 1.93 tons of CO2 per acre.]

TAR findings seem to defy the reality of U.S. gasoline consumption trends. The U.S. Energy Information Administration projects that in 2016 the U.S. will consume approximately 140 billion gallons of gasoline, which will emit the CO_2 equivalent of slightly more than 1 billion metric tons per year. EPA's target is for the average light-duty vehicle (LDV) to emit only 163 grams per mile of CO2 by 2025. Since conventional gasoline (non-HOLC fuels) emits approximately 8,890 grams of CO_2 per gallon equivalent, this means that the U.S. would have to reduce gasoline consumption by almost half in less than ten years.
The data shows this is unlikely. The EIA reports that motorists are demanding more gasoline, not less. EIA predicts 9.3 million bpd next year = 143 billion gallons per year (GPY) of gasoline.[29]

In 2011 – 2012, when EPA initially proposed its targets, it was believed that pure electric vehicles and hybrids would account for an increasingly larger share of the LDV fleet. The AAM's recent analysis of the agencies' assumptions concludes that "up to 47% of the U.S. LDV fleet would have to be as efficient as modern hybrids" by 2025.[30]

The Alliance of Automotive Manufacturers (AAM) fact sheet points out that the U.S. LDV fleet showed a 23% actual improvement in CAFE performance over the 2005-2014 model years, but that the agencies' required improvement over the 2012-2025 model years will require a 66.7% improvement.[31] Unless the agencies encourage the widespread availability of higher octane fuels, the responders believe such aggressive targets are unlikely to be achieved. In addition to falling short of important environmental and health goals, failure to include HOLC fuels in the final MTE package could inflict substantial economic harm on the U.S. economy and labor force.

The agencies should provide manufacturers a commercially realistic pathway to avail themselves of the most cost effective, timely, and commercially feasible compliance tool: higher octane gasoline. If manufacturers are to successfully comply with tightening fuel efficiency and carbon standards, the gasoline that powers their ICEs must be improved. The U.S. Department of Energy (DOE) and its national labs—Oak Ridge National Lab (ORNL), Argonne National Lab (ANL), and the National Renewable Energy Lab (NREL)—have all advocated the widespread use of High Octane Fuels (HOFs), specifically HOFs which contain 25 – 40% ethanol.[32] The Energy Information Administration (EIA)

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[29] http://www.eia.gov/forecasts/steo/report/us_oil.cfm

[30] Alliance of Automotive Manufacturers, "Light-Duty Vehicle CAFE and GHG Standards: Key Considerations for the Mid-Term Evaluation", August 20-16, p. 10. "EPA projected in 2012 that 2025 compliance would not require significant hybridization or electrification of the fleet. However, that projection seems to reflect a leap of faith, in further Internal Combustion Engine (ICE) improvements, that goes beyond current technological realities. Even if gasoline or diesel engines significantly improve between now and 2025, those powertrains must become as fuel efficient or more efficient than current hybrid electric vehicles in one to two design cycles (i.e., 5-10 years). Such a conclusion is not realistic…One scenario…modeled shows that up to 47 percent of all cars must be HEVs to meet the existing 2025 targets." Ibid. p. 8.

[31] Alliance of Automotive Manufacturers, "Light-Duty Vehicle CAFE and GHG Standards: Key Considerations for the Mid-Term Evaluation", August 2016, p.6.

[32] Oak Ridge National Laboratory, Summary of High-Octane Mid-Level Ethanol Blends Study, July 2016, at http://info.ornl.gov/sites/publications/Files/Pub61169.pdf

recently projected that by 2025, 83.3% of U.S. LDVs will be turbocharged, and will require higher octane gasoline for optimum performance.[33]

Both EPA and CARB have recently acknowledged the importance of higher octane fuels. EPA and CARB have admitted that increasing minimum octane ratings could facilitate OEM compliance with the GHG – CAFE rule, and that EPA has the authority to encourage the use of higher octane gasoline. "[Octane] will have to be part of the conversation," said Mike McCarthy, CARB's chief technology officer. "I think it has to be on the table," he said at Traverse City .However, EPA says that it does not plan to initiate such a proceeding until after 2025, and that it will be another ten years after that before final action could be taken.[34]

Unfortunately, while EPA unnecessarily waits another twenty or more years, literally trillions of miles will be driven by ICEs powered by gasoline, with all of the unnecessary carbon and related toxic emissions that could have otherwise been avoided if EPA were to improve gasoline quality in an orderly and timely manner.

The draft TAR cites "extensive state-of-the-art research projects by experts at the EPA National Vehicle and Fuel Emissions Laboratory (NVFEL)".[35] Paradoxically, NVFEL experts have been attempting to patent higher octane EXX blends since 2008, thus far without success.[36] Regrettably, the draft TAR makes no mention of this research. UAI respectfully urges the agencies to acknowledge the work NVFEL has done in this area in the final TAR. If nothing else, the effort to patent EXX blends indicates EPA's appreciation for the value of high octane, low carbon fuels containing ethanol.

EPA's patent application reinforces the importance of HOLC fuels: *"However, the preferred fuels in terms of an overall business case may be E30 and/or M30. This is because, an engine of the present invention adapted to combust E30 or M30 fuel shows a 10-12% increase in efficiency over a comparable gasoline engine…As a result, the fuel would meet or outperform gasoline on a per gallon performance basis and would be acceptable for consumers…while also, on a global policy level, significantly reducing the global demand for conventional gasoline."*[37]

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[33] Green Car Congress, EIA: Trends in Downsized Engine Design Leading to Increased Demand for Higher-Octane Gasoline, April 6, 2016, at http://www.greencarcongress.com/2016/04/20160406-eia.html
[34] Truett, Automotive News, "EPA signals it will start looking at mandating higher octane gasoline", August 23, 2016. http://www.autonews.com/article/20160823/BLOG06/160829969/epa-signals-it-will-start-looking-at-mandating-higher-octane-gasoline.

[35] Supranote1, p. ES-3.
[36] Higher Efficiency Alcohol Fuel Engine Patent Application Number 200080230041, at http://www.faqs.org/patents/app/20080230041
[37] Ibid. ¶ 53.

"In addition, in consideration of potential supply constraints in the use of ethanol from renewable feedstocks to displace part of the demand for petroleum in transportation, the use of E30 would allow a more readily achievable quantity of ethanol from such feedstocks for widespread use as a long-term sustainable option than E85."[38]

Supplementary material:

1. The US transportation sector has eclipsed electricity as the largest source of greenhouse gases.
    - http://www.vox.com/2016/6/13/11911798/emissions-electricity-versus-transportation. "We've certainly been trying to get transport emissions down: Over the past decade, the United States has been using more corn-based ethanol instead of gasoline in its cars. But ethanol is currently stuck at around 10 percent of the gasoline supply — a contentious issue known as the "blend wall"(http://www.vox.com/2014/11/21/7259885/the-fightover-ethanol-and-the-epa-explained)."
    - The U.S. light-duty vehicle fleet—approximately 250 million cars and light-duty trucks—is predominantly gasoline-powered (now 90% gasoline and 10% ethanol, E10).
2. Internal combustion, spark ignition engines (ICEs) powered by gasoline and other liquid fuels will dominate the marketplace for decades to come.
    - The EPA/NHTSA projected compliance demonstration path for the industry fleet as a whole, shown in Table 2.1, indicates that SI engines are projected to be used in 98 percent of the 2025 MY fleet, with 2 percent projected to be battery electric vehicles.
    - The International Energy Agency projects that in 2040, 95% of the world's vehicles will still be powered by gasoline and other liquid fuels.
    - Consumers turn over their vehicles slowly, and electric vehicle sales are projected to account for smaller percentages of total vehicle sales in the U.S. for many years.
3. To facilitate cost effective compliance, regulators must ensure that improved fuel quality complements advanced vehicle technology to maximize fuel economy and carbon reductions.
    - The National Research Council's 2015 study emphasized that the development of fuels and vehicle technology must be treated as a system.
    - "EPA has long recognized that vehicle technology and the fuel employed with that technology need to work in concert as an integrated 'system' so that vehicles can operate efficiently and achieve the lowest technologically and economically feasible emissions targets." [Alliance of Automobile Manufactures to EPA Administrator Jackson, October 6, 2011]
    - That same letter called upon EPA to increase minimum octane ratings for U.S. gasoline, and to encourage the use of higher volumes of high-octane ethanol.
4. Octane is the single most important fuel property in maximizing the efficiency and performance of an internal combustion engine.
    - "Octane is the single most important property of gasoline when determining engine design." - Mercedes Benz in comments to the Tier 3 rulemaking, July 1, 2013
    - Oak Ridge National Lab scientists have identified octane as a key pillar of engine efficiency, CAFE compliance, and carbon reduction technologies as ICEs will dominate the U.S. light-duty fleet for the foreseeable future (2016 Splitter et al.)
    - Oak Ridge found that if ethanol were used to boost gasoline octane instead of poisonous tetraethyl lead (as Henry Ford recommended in 1920), E25 (25% ethanol/75% gasoline) would have yielded a super-premium 95 AKI gasoline, eight octane numbers higher than

[38] Ibid., ¶ 54.

today's unleaded regular grade.

- DOE Assistant Secretary for Transportation Rueben Sarkar mentioned E25 – E40 blends as top priorities for the Department in its 2015 Quadrennial Technology Review, p. 285: *"Currently, the only renewable high-octane fuel available at large scale is ethanol, which makes up 10% of gasoline sold by volume. Increasing this percentage of ethanol can dramatically increase the octane rating of the finished gasoline/ethanol fuel blend, with most of the benefit being around 25 – 40% ethanol by volume."*

5. A 2015 NHTSA-commissioned National Research Council (National Academies of Science) study recommended higher gasoline octane levels.
    - 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.
    - "***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 warned that failure to provide auto manufacturers with significantly higher octane gasoline (e.g., 100 RON) would interfere with, and likely reverse, attainment of stricter fuel efficiency and carbon reduction standards in the out-years.
    - Nevertheless, EPA's "ground rules" required NRC to assume that auto manufacturers' advanced engines must use today's 87 AKI (91 RON) gasoline.
6. HOLC fuels would help automakers comply with fuel economy and carbon reductions in a cost effective and timely manner.
    - "Higher octane is necessary for better engine efficiency," said GM's Nicholson. "It is a proven low-cost enabler to lower CO2. 100 RON fuel is the right fuel for the 2020-25 timeframe." http://www.governorsbiofuelscoalition.org/?p=16924
    - "One pathway to improved vehicle efficiency and lower GHG emissions is to increase the engine compression ratio (CR)…Since ethanol has a higher octane number than gasoline, a mid-level gasoline-ethanol blend will allow the engine to be designed with a higher CR. Ethanol's higher heat of vaporization…and its high octane number…can increase engine efficiency." General Motors Tier 3 comments, July 1, 2013
    - In the Tier 3 rule, most auto manufacturers urged EPA to raise gasoline's minimum octane standard by encouraging higher level blends of high octane ethanol (see Appendix A).
    - A 2015 study by Ford and GM scientists (Leone et al.) found that E30 blends used in downsized and higher compression engines could improve fuel efficiency by 7% and reduce tailpipe carbon emissions by 7%.
    - A recent study by scientists at Oak Ridge National Laboratory (ORNL) confirmed mid-level ethanol blends' many advantages as a high-octane fuel for high performance spark ignition engines. The ORNL concluded that "midlevel ethanol blends—such as E30" are "the enabling technology" for "near-term increases in vehicle efficiency and reductions in CO_2," such that they "could enable simultaneous compliance with RFS II and CAFE"

and even "set the sustainable transportation trajectory to extend beyond the requirements set by RFS II and CAFE legislation."

- MIT and Argonne National Lab scientists have also reported major benefits and cost savings from the use of HOLC fuels.

7. EPA has acknowledged that EXX fuels can help to advance CAFE/GHG objectives, and that it has the authority to facilitate their use.
    - In its proposed Tier 3 rulemaking in 2013, EPA asked for comment on whether it should allow the certification of higher octane fuels such as E30 to "help manufacturers who wish to raise compression ratios to improve vehicle efficiency as a step toward complying with [EPA's greenhouse gas and fuel efficiency] standards".
    - EPA acknowledged that certifying E30 blends would "enhance the environmental performance of ethanol as a transportation fuel by using it to enable more fuel efficient engines." Tier 3 Rule, 79 Fed. Reg. at 23528–29.
    - Paul Machiele, director of fuel programs in EPA's Assessment and Standards Division in Ann Arbor, MI, has publicly stated on numerous occasions that the agency has "broad authority" under the air law to regulate fuels and fuel additives that can likely now extend to octane, a component of fuel used to reduce engine knock, "since mandating higher levels can improve efficiency and cut GHGs".
8. Widespread use of HOLC fuels would yield significant GHG and health-related co-benefits.
    - In the draft TAR, the agencies noted that "The state/local governments want to ensure not only the significant GHG reductions from these standards, but also the co-pollutant benefits that come from reduced fuel consumption."[39]
        - Scientists have expressed increasing concern about the global warming impacts of black carbon (BC), a so-called "short-lived climate forcing agent" which has a GWP (Global Warming Potential) second only to carbon dioxide.[40]
        - A primary precursor of urban BC emissions is gasoline aromatic hydrocarbons, which are also used to boost octane ratings.
        - The increased use of HOLC fuels for higher octane would have an environmental and health "co-benefit" by simultaneously reducing both the BC emissions, in addition to the associated air toxics. Studies by automakers and the California Air Resources Board (CARB) confirm that use of HOLC fuels such as E30 would reduce BC and particulate-borne toxics emissions by 45 – 85%, depending upon engine type.[41]
        - A recent University of California-Riverside study found that HOLC fuels could reduce BC by up to 350% in direct injection engines, which are expected to dominate the U.S. LDV fleet in coming years.
9. Comparisons of CBO and DOE national lab studies show that, from a lifecycle analysis perspective, EXX vehicles are as good, or better, than EVs in reducing carbon emissions.
    - A 2012 Congressional Budget Office study concluded that a typical EV would have a

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[39] Supra at note1, p. 2-8.

[40] California Air Resources Board, "Reducing Short-Lived Climate Pollutants in California, August 9, 2016. **http://www.arb.ca.gov/cc/shortlived/shortlived.htm**

[41] Please see Urban Air Initiative comments to the California Air Resources Board "Proposed Short-Lived Climate Pollutant Reduction Strategy", May 26, 2016.

carbon footprint 35% lower than a typical gasoline-powered vehicle, factoring in the upstream carbon emissions from the U.S. electricity sector.

- New science from Argonne National Labs (ANL), the USDA, and soil scientists show that high-yield corn acres have a heretofore unrecognized ability to sequester substantial amounts of carbon.
- Once this "carbon sink" data is combined with other advancements in agricultural practices (e.g., nitrogen fertilizer management), HOLC fuels used in an optimized, high compression ICE are predicted have the same, or lower, carbon footprint of an electric vehicle.
- As corn yields continue to increase, and technologies and practices continue to improve, the carbon sequestration benefits will get better and better, and corn ethanol's footprint will shrink even further. Some experts predict that corn ethanol will soon be considered a "zero carbon fuel".[42]
- An OMB cost-benefit analysis that used "best available science" would justify a major role for HOLC fuels in the final Midterm Evaluation package.
- For major rules like the Mid-Term Evaluation, Presidential Executive Orders require OMB to conduct a thorough cost-benefit analysis, and to ensure that the agencies have used "best available science" in their analyses.
- In its 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 since then been silent on this question, and they have failed to address 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 $30 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 bring multi-billions of dollars per year in 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 EVs to arrive), and result in substantial carbon and related health co-benefits.
- Experts from the DOE and its national labs, the National Research Council, the auto manufacturers, and dozens of prestigious universities are on record confirming the value of HOLC fuels. They should be an important part of the final TAR and the final MTE package, and they deserve to play a central role in reducing the U.S. transportation sector's carbon footprint.

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

Appendix A

Tier 3 Comments Synopsis
Automaker Stakeholder Group

Alliance of Automobile Manufacturers & Association of Global Automakers (Alliance & Global).

- ✓ For the OEMs (original equipment manufacturers) to support a final Tier 3 rule, EPA must ensure that test (certification) fuels reflect market fuels, and that uniformity must be established between Federal EPA and California CARB rules. The OEMs are requesting "permanent mutual reciprocity" between the two so they can design to a uniform 50 state set of specifications.
- ✓ Throughout their comments, the OEMs remind EPA that fuels and vehicles are part of a synergistic system. At footnote 34, the comments state: "As EPA further states, combined with the fuel economy and greenhouse gas program, this rule would bring auto investment in the vehicle emission reduction programs through 2025 to more than $216 billion—about 100 times the investment that the oil industry is being asked to make under the NPRM."
- ✓ The OEMs were quite pointed in expressing their disappointment with the EPA. They suggested that the Agency had assured them that they would address fuels issues (such as octane and RVP) in either the GHG – CAFE rulemaking, or most certainly in the Tier 3 rule. The comments urge EPA to do a "supplemental Tier 3 rule" to ensure that "proper fuels are widely available".
- ✓ AAM – AGA note that higher octane fuels enable higher compression engines, which in turn facilitate compliance with the new efficiency and carbon reduction requirements.
- ✓ The comments strongly urge EPA to change the alternative fuels (especially higher ethanol blends') test fuel certification rules. In particular, the OEMs object to the E30 gating items, and especially the requirement that the automakers should be responsible for ensuring widespread market availability of E30 blends before EPA would establish an E30 certification standard.
- ✓ The OEMs note that EPA promised to update the R-Factor many years ago, and provided data to show why it should be increased to no less than 1.0. Alliance – Global go so far as to say that EPA is "required to issue CAFE adjustments".

Daimler Benz (Mercedes).

- ✓ Mercedes states that "Octane is the single most important property of gasoline when determining engine design."
- ✓ A mid-blend cert fuel "such as E25 is a key enabler for GHG reduction".
- ✓ Failure to increase the R-Factor to 1.0 will greatly reduce automakers' acceptance of MLEBs.
- ✓ Mercedes' comments were distinguished by two proposals for incenting both flex fuel vehicles and increased production of ethanol. For the first, Mercedes proposes that EPA should provide a "CO2 Burden Reduction Multiplier" to OEMs who manufacture vehicles capable of using "Tier 3 fuels" (MLEBs). For the second, Mercedes proposes a Producer Credit (either some form of tax credit or RIN credit) to ethanol producers. Both of these should be phased out by MY2023, or when the Tier 3 fuel retail market penetration reaches 90%.

Ford Motor.

- ✓ Ford "strongly supports" the goal of higher octane MLEBs, but suggests that "further development" is needed to determine the optimum blend level.
- ✓ "Quandary of insufficient fuel infrastructure must also be addressed."

- ✓ Ford stresses throughout that splash-blending of ethanol (as opposed to match-blending) is imperative, and that the new test fuel should have a minimum of 91 AKI, whose octane then increases proportionally as more ethanol is splash-blended to it.
- ✓ Ford states that "Introduction of an [MLEB] would allow for a faster introduction of more efficient vehicle designs from Europe [which has higher octane fuels] with lower CO2 emissions and increased efficiency that are designed to operate on 91 AKI market fuel without the need for significant design changes." Like Mercedes, Ford seems to be suggesting that global harmonization of production platforms is possible with higher octane MLEBs.
- ✓ Ford calls upon EPA to increase the R-factor to 1.0 at the "earliest possible date".

General Motors (GM).

- ✓ "GM supports the future of higher octane and higher ethanol content in order to provide a pathway to improved vehicle efficiency and lower GHG emissions."
- ✓ With regard to EPA's proposed E30 cert fuel gating items, GM notes that current alternative fuel test rules are flawed, and cannot work in practice.
- ✓ GM urges EPA to "support the progress toward cleaner vehicles by ensuring that the proper fuels are widely available". EPA must address the promised fuel quality issues in a supplemental rulemaking if it does not do so in the final Tier 3 rule.
- ✓ GM urges EPA to immediately increase the R-factor to 1.0.
- ✓ GM notes that Sec. 211(v) requires the EPA to submit an anti-backsliding report to Congress, and that it is long overdue. GM urges EPA to complete its modeling work, and determine whether "mitigation" steps are needed to address emissions effects from increased ethanol use.

Appendix B

Excerpts from June 2015 National Research Council Study on EPA/NHTSA GHG – CAFE Rulemaking

- *"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 percent 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 percent 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 percent during launch conditions."*

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 percent reduction in fuel consumption for naturally aspirated engines if compression ratio is increased by 2 ratios from today's typical level, and possibly even greater reductions in fuel consumption for turbocharged engines by allowing operation at higher boost pressures for further downsizing."*
- *"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)**

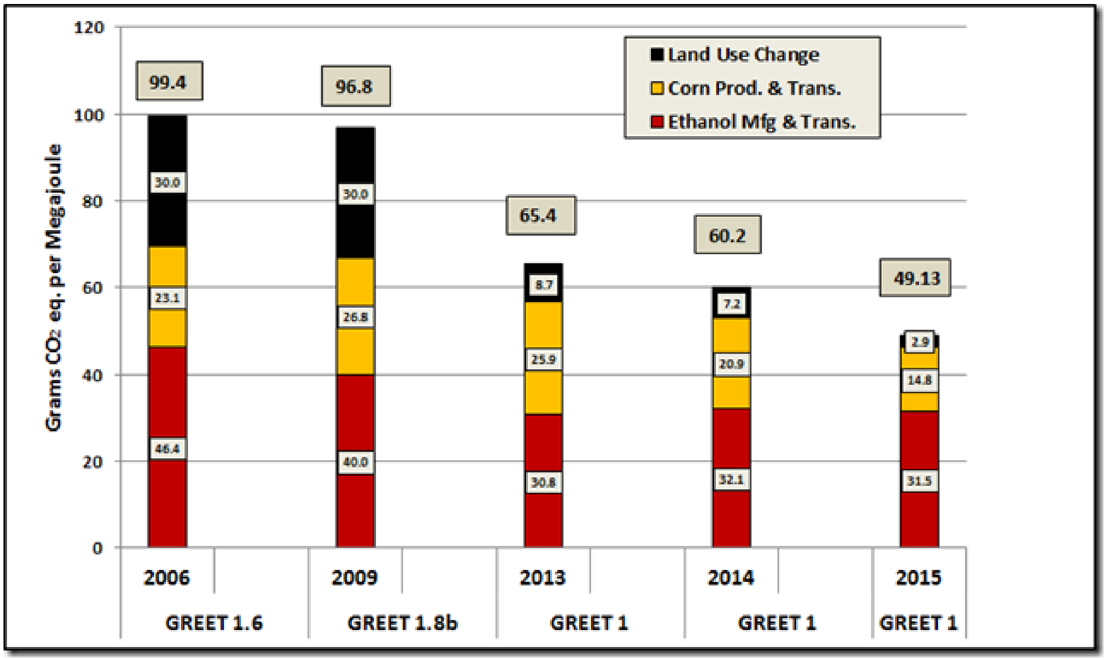
- *"EPA and NHTSA should investigate the overall well-to-wheels CAFE and GHG effectiveness of increasing the minimum octane level and, if it is effective, determine how to implement an increase in the minimum octane level so that manufacturers would broadly offer engines with significantly increased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

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

Appendix C

The Evolving 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 nearly two tons 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.[43]

[43] See Alverson, "Capturing the Value of Carbon Intensity Reduction in Corn Ethanol Plants and Farms", NEB Emerging Issues Forum, April 26, 2016, slide 27.



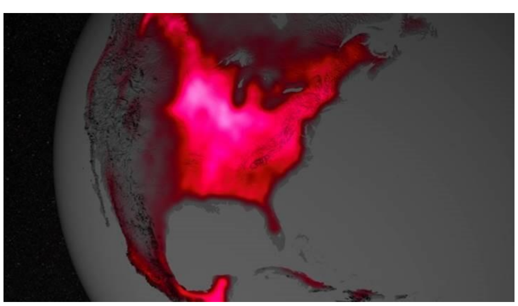
NASA Confirms Corn's Photosynthetic Efficiency from Outer Space

March 31, 2014

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. Results were published March 25 in Proceedings of the National Academy of Sciences.



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.

Data showed that fluorescence from the Corn Belt, which extends from Ohio to Nebraska and Kansas, peaks in July at levels 40 percent 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 percent.

"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."[44]

[44] Michael Pollan, "*The Omnivore's Dilemma*", Penguin Press, 2006, 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.

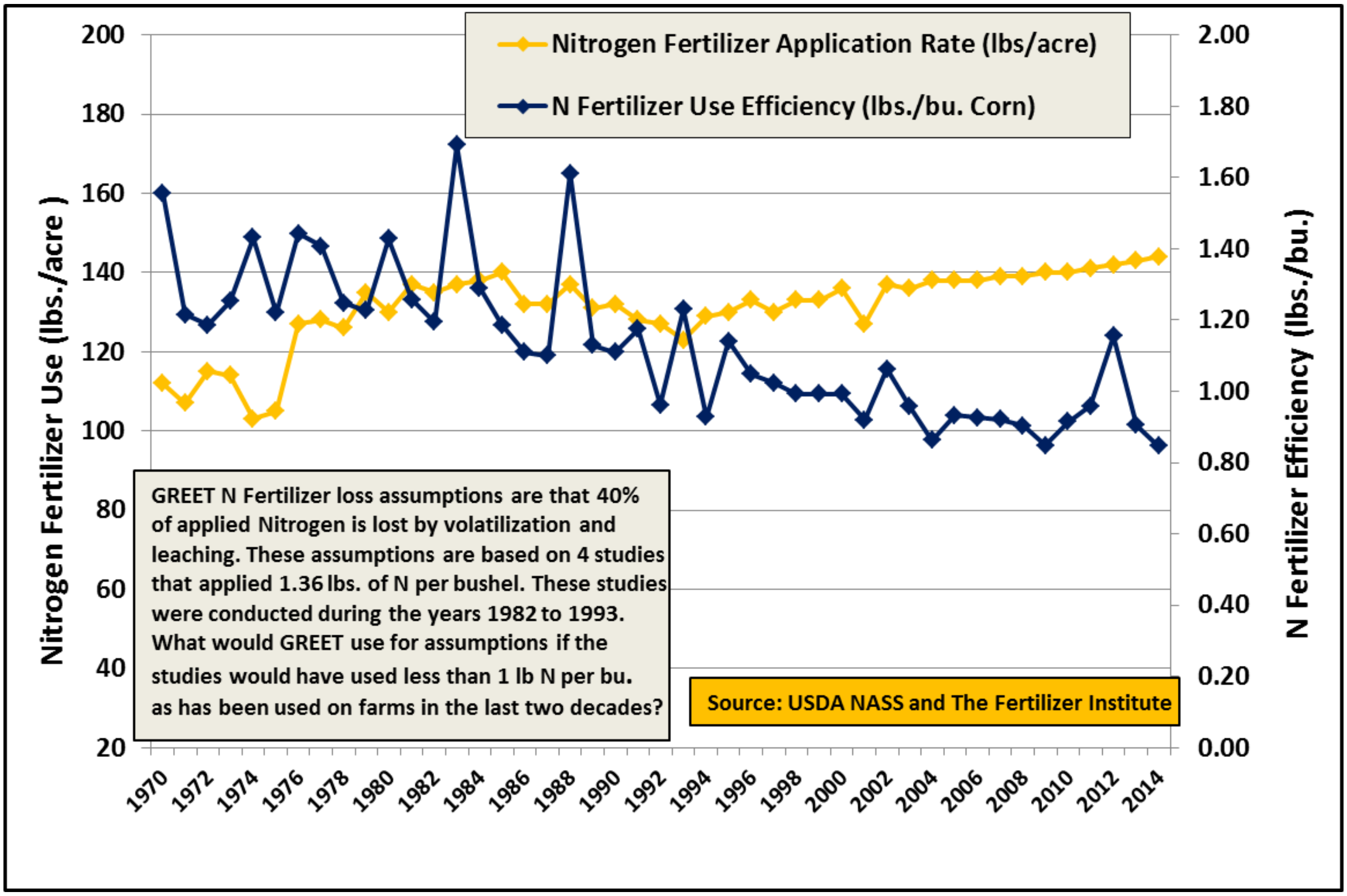
Crop Soil Carbon Budgets	Corn	Soybean	Sorghum	Corn Stover
Yield level (bu/acre)	170	50	100	170
Stover/Residue Carbon Additions to Soil (Mg/Ha/Year)	3.73	1.57	2.77	3.73
Stover/Residue Carbon Removal (Mg/Ha/Year)	0	0	0	1.5
Soil Carbon Maintenance Requirements (Mg/Ha/Year)	2.2	2.2	2.2	2.2

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 N2O emissions from nitrogen fertilizer applications to crops. The IPCC uses decades old research data to support their N2O 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 overapplication 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 balance 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 N2O model used by Argonne GREET modelers also assumes that the nitrogen in corn stover results in N2O 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 N2O as does nitrogen in fertilizer.

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