Response to questions for the record by

Jason Hill, Ph.D.
Associate Professor
Bioproducts and Biosystems Engineering
University of Minnesota

for the

Subcommittee on Energy
Subcommittee on Oversight
Committee on Science, Space, and Technology
United States House of Representatives

on

The EPA Renewable Fuel Standard Mandate

July 23, 2015

Chairman Smith, I offer my response to your question for the record:

> "**Questions for Dr. Jason Hill:** During the hearing, you were presented with several critiques of your research by minority members, including articles written by the Minnesota Biofuels Association, Growth Energy, and the Renewable Fuels Association. Please review the attached documents produced by the organizations listed above regarding your research. Can you respond to the specific critiques leveled by each organization?"

To facilitate the reading of my responses, I have copied below the entire text, unedited, of each of the three critiques of my research. My response to each point of each critique is in bold, indented text.

Response to RENEWABLE FUELS ASSOCIATION (RFA)

A recent paper by researchers at the University of Minnesota suggests that using corn ethanol in lieu of gasoline would increase emissions of fine particulate matter (PM2.5) and ground-level ozone. The results are based on numerous assumptions (many of which are unclear or concealed from the reader) and a series of complex hypothetical modeling scenarios.

> **All of our results and assumptions are publicly available and are not concealed from the reader.[1] In fact, we paid an extra fee for an "open access" option so that our article would be made free to download by anyone, including those not subscribed to the *Proceedings of the National Academy of Sciences*. The modeling approach we took was described in detail; others can replicate our results if they wish to do so.**

Ultimately, the authors' conclusions stand at odds with real-world data showing decreases in ozone and PM2.5 concentrations during the period in which ethanol blending substantially increased in the United States.

The RFA text confuses correlation with causation. Air pollution improved during 2000–2013, which were the years during which ethanol use increased most rapidly, but during that time there were also many other changes in our economy, including major environmental regulations impacting power generation, industry, and motor vehicles.[2] Indeed, it is quite possible that air pollution during 2000–2013 improved *despite* the increase in ethanol use, not *because* of it.

The findings also run counter to an existing body of research that shows ethanol reduces PM2.5 and emissions that contribute to the formation of urban ozone, including exhaust hydrocarbons and carbon monoxide (CO).

We are unaware of research showing that the production and use of corn ethanol reduces overall concentrations of $PM_{2.5}$ and ozone. We note that it is important to evaluate fuels in terms of their life cycle impacts to air pollution, not just their effects on tailpipe emissions.

Further, the paper is contradicted by the results of the Department of Energy's latest GREET model.

Our approach uses GREET; it does not contradict GREET.

Finally, the study omits important emissions sources from the petroleum and electric vehicle lifecycle, resulting in a "stacked deck" against ethanol.

We in no way stacked the deck against ethanol. We applied consistent assumptions across fuel production and use pathways, deviating from default GREET assumptions only where explicitly noted in our report, with the goal of rigorously evaluating all fuel options.

THE STUDY'S CONCLUSIONS ARE UNDERMINED BY REAL-WORLD OZONE AND PM2.5 TRENDS

The paper's assertion that increased ethanol use would cause higher emissions of ozone and PM2.5 is contradicted by EPA data from actual air sensors. Data from 222 EPA sensing sites show that ozone and PM2.5 concentrations have trended downward during the period in which the use of ethanol-blended gasoline has dramatically increased. Ozone concentrations have fallen 33% since 1980, while PM2.5 is down 34% just since 2000. In recent years, both ground-level ozone and PM2.5 emissions have dropped below their respective national standards, according to EPA. Specific "non-attainment" areas where reformulated gasoline (RFG) is required have shown similar reductions since ethanol was introduced as an oxygenate.

The RFA text confuses correlation with causation. Air pollution improved during 2000–2013, which were the years during which ethanol use increased most rapidly, but during that time there were also many other changes in our economy, including major environmental regulations impacting power generation, industry, and motor vehicles. Indeed, it is quite possible that air pollution during 2000–2013 improved *despite* the increase in ethanol use, not *because* of it. With regard to the status of

ethanol as an oxygenate, evaluation of the total impacts of ethanol requires consideration of the life cycle impacts to atmospheric pollutant concentrations, not just changes in tailpipe emissions.

THE STUDY'S FINDINGS ARE AT ODDS WITH EMISSIONS ESTIMATES FROM THE LATEST GREET MODEL

On a full lifecycle basis (i.e., including the contributions of upstream agriculture emissions), the study's results are contradictory to the results from the Department of Energy's latest GREET model. This is particularly confusing because the authors claim to have used an earlier version of the GREET model for their analysis. It is unclear whether the authors adjusted key inputs in the GREET model, and on what scientific basis such adjustments might have been made.

RFA asserts that there are contradictions but fails to give examples. There is nothing specific in RFA's comment that we can address other than restating that we also used GREET; there are no contradictions between our work and GREET. We applied consistent assumptions across fuel production and use pathways, deviating from default GREET assumptions only where explicitly noted in our report, with the goal of rigorously evaluating all fuel options.

The most recent GREET model shows no increase in PM2.5 emissions or other criteria pollutants when gasoline with 10% corn ethanol is compared to conventional gasoline without ethanol.

The RFA statement is incorrect. GREET actually shows increased life cycle emissions of criteria pollutants with 10% corn ethanol gasoline blends as compared to gasoline without ethanol. Moreover, the RFA's statement fails to reflect that $PM_{2.5}$ can be emitted (primary $PM_{2.5}$) or formed (secondary $PM_{2.5}$). Consideration of the total impacts to $PM_{2.5}$ concentrations from fuels must account for emissions of primary $PM_{2.5}$ and also of $PM_{2.5}$ precursors such as VOCs, NO_x, SO_x, and NH_3.

Further, when E85 from corn ethanol is compared to conventional gasoline, GREET1_2014 shows that using E85 decreases urban emissions of volatile organic compounds (VOC), nitrous oxide (NOx), coarse particulates (PM10), fine particulates (PM2.5), and sulfur oxide (SOx).

The RFA statement mentions urban emissions but fails to mention rural emissions. For multiple pollutants, GREET shows decreased urban emissions but higher total life cycle emissions because of higher rural emissions. It is necessary to account for both urban and rural emissions, as our study does. People live in rural areas and in urban areas, and air pollution can travel from rural to urban areas, and vice versa. Our study accounts for the transport of air pollution in the atmosphere.

The high levels of PM2.5 and ozone concentration attributed to corn ethanol in the Minnesota study appear to be mostly related to assumed upstream agricultural practices, such as fertilizer application. However, the paper and the supporting material do not clarify what assumptions were used for fertilizer production and application, or other agricultural activities.

RFA is correct that agricultural emissions are important. All of the assumptions for fertilizer production, application, and other agricultural activities are provided in our

report and in its supporting material. Unless otherwise noted in our report, all of the assumptions used are those of the GREET model. Peer review by other experts in the field and by the editorial staff of the journal concluded that our methods and assumptions were sufficiently documented and justified.

Further, the study omits NOx and SOx emissions for other fuels if those emissions occur "far from population centers." Yet, it appears all NOx and SOx emissions associated with agricultural production of biofuel feedstocks are included even though most feedstock production occurs in sparsely populated rural areas.

The statement that our "study omits NOx and SOx emissions for other fuels if those emissions occur 'far from population centers'" is false. Within our modeling domain of the continental United States and surrounding waters, we account for all emissions occurring in both urban and rural areas. We exclude a fraction of life cycle pollutant emissions from our estimates of health impacts, as we show in Figure S2, but not because they are "far from population centers"; rather, it is because they are outside of our modeling domain (that is, outside of the continental United States and its surrounding waters). We state that their effect, which is largely over open oceans or far from population centers, is not likely to impact our overall conclusions. We treat ethanol the same as we do petroleum; we exclude emissions from international fertilizer production and transport, and we exclude emissions from international extraction and transport of petroleum used in ethanol production.

OTHER RESEARCH SHOWS ETHANOL REDUCES THE POTENTIAL FOR OZONE AND PM2.5

Urban ozone formation occurs from rather complex atmospheric photochemistry, as volatile organic compounds (VOC) and carbon monoxide (CO) react in the presence of nitrogen oxides (NOx). Both the EPA and National Research Council have recognized that CO is a precursor to ozone formation. There is a substantial body of evidence proving that ethanol reduces both exhaust hydrocarbons and CO emissions, and thus can help reduce the formation of ground-level ozone. Indeed, ethanol's high oxygen content and ability to reduce exhaust hydrocarbons and CO emissions is the primary reason it is used as an important component of reformulated gasoline in cities with high smog levels.

Further, research has shown that increasing the oxygen content in gasoline reduces primary exhaust particulate matter (PM2.5) from the tailpipe. Because ethanol is 35% oxygen by weight, blending ethanol with gasoline increases the oxygen content of the fuel and thus reduces PM2.5 emissions.

Ozone chemistry is complex, and our study accounts for this complexity. We accounted for all of the factors stated in this comment from RFA, but we note that while ethanol may decrease tailpipe emissions of some hydrocarbons, it may increase emissions of others. Furthermore, the argument presented by RFA above ignores emissions caused by fuel production. It is important to consider total life cycle impacts from air pollution, not just tailpipe emissions.

Our study uses emissions factors from the GREET model. We note that EPA has concluded that the use of ethanol as mandated by the Renewable Fuel Standard is likely to increase ozone concentrations over the United States by as much as 1 ppb.[3]

THE STUDY USES QUESTIONABLE ASSUMPTIONS REGARDING OTHER FUELS

The Minnesota study's lifecycle emissions estimates for electric vehicles (EVs) do not include emissions associates with battery production, a glaring omission that creates an inconsistent framework for comparing various fuel/vehicle options. The authors admit that emissions associated with battery production account for "about half" of total EV lifecycle emissions—yet those emissions are excluded from the central scenario.

This statement by RFA is simply false; our study does include battery production. Our article states this fact several times: in the introduction, materials and methods, results, and discussion sections. See, for example, Figure 2 on page 18492, where "$PM_{2.5}$ from battery production" is clearly labeled. We are unsure how RFA's close reading of our report could have missed this aspect of our work.

Contrary to RFA's assertion, we do not "admit that that emissions associated with battery production account for 'about half' of total EV lifecycle emissions." Rather, we state that about half of the emissions from battery production occur outside of our modeling domain (that is, they are international) and thus are excluded from the analysis. We test the sensitivity of our model runs to this assumption in a complementary analysis in which we double the impacts from battery production. As we describe in our paper (p. 18492), this modification does not change the relative impacts of any of the fuel options we considered.

The study also excludes NOx and SOx emissions associated with crude oil extraction, a decision that grossly underrepresents the actual lifecycle emissions impacts of gasoline. These emissions were excluded because the authors assume they occur outside the geographical boundaries of their study area. The authors also assumed all crude oil in 2020 is extracted using conventional methods, which entirely ignores the emissions impacts of unconventional extraction techniques. According to the paper, "oil extraction from oil sands occurs outside of our geographic modeling domain," and thus they assume "all oil is extracted conventionally (0% oil sands oil)."

Omitting key emissions sources from the lifecycle assessment of EVs and crude oil inappropriately skews the paper's results for the overall emissions impacts of these fuels and vehicles.

Again, this statement by RFA is false. We do not exclude NO_x and SO_x emissions associated with crude oil extraction and transportation, except for the fraction that occurs internationally, which is primarily over oceans or far from population centers. Our assumption concerning conventional extraction techniques is justified by the primary source of unconventional oil imported into the United States being Canadian oil sands, which themselves are in sparsely populated areas far from population centers. A similar simplifying assumption was made for ethanol, in which emissions from the production and transportation of imported fertilizers were likewise excluded.

Response to GROWTH ENERGY

Following the recent report released by the University of Minnesota, "Life Cycle Air Quality Impacts Of Conventional And Alternative Light-Duty Transportation In the United States," which contains significant flaws in regards to their analysis of ethanol, Tom Buis, CEO of Growth Energy, released the following statement:

“Clearly this study was published with an agenda and without regard to the facts. It is misleading, inaccurate and runs counter to a large body of expert research.

> **We reviewed other expert research in the preparation of our report. We conducted our own research objectively and without outside influence. Our funding was solely from competitive grants awarded from federal or state agencies. Our research underwent peer review in the *Proceedings of the National Academy of Sciences.* We are unaware of the “large body of expert research” to which our work runs counter; Growth Energy offers no support of their claim.**

“This report also fails to account for the numerous environmental benefits ethanol provides. According to Argonne National Laboratory, ethanol reduces greenhouse gas (GHG) emissions by an average of 34 percent compared to gasoline, even when the highly controversial and disputed theory on Indirect Land Use Change (ILUC) is factored into the modeling. However, the study by the University of Minnesota specifically excludes ILUC impacts, and Argonne has found that without ILUC included, ethanol reduces GHG emissions by 57 percent compared to gasoline.

> **Indirect land-use change is a widely accepted principle whereby increased demand for crops for biofuels leads to higher crop prices, which in turn leads to global expansion of cropping area. The values from Argonne National Laboratory cited by Growth Energy are among a wide range of estimates from various research groups that show higher or lower greenhouse gas emissions of corn ethanol compared to gasoline.[4] Furthermore, Argonne National Laboratory’s estimates ignore the fuel market rebound effect, whereby additional ethanol production does not completely displace gasoline production, resulting in increased net greenhouse gas emissions.[5] Notably, EPA’s own analysis of the Renewable Fuel Standard found that corn ethanol produced through at least the year 2017 has higher greenhouse gas emissions than gasoline, even without consideration of the fuel market rebound effect.**

“In fact, in 2013, the 13.2 billion gallons of ethanol blended into gasoline in the United States helped reduce GHG emissions by approximately 38 million metric tons, which is the equivalent of removing roughly 8 million automobiles from the road.

> **This claim is debatable for the reasons provided above. Even if it were to be the case, it does not address the new information added by our study, namely the increased health impacts caused by $PM_{2.5}$ air pollution from corn ethanol production and use relative to gasoline.**

“In addition, another critical component that was unsurprisingly left out of the University of Minnesota’s report is that ethanol, with its high octane content, reduces the need to add toxic aromatics to gasoline to bolster octane and engine performance such as benzene and 1-3 butadiene that are known carcinogens. Additionally, ethanol plays a major role in reducing ultra-fine particulates in exhaust emissions that are linked to a large number of adverse health outcomes."

> **The overwhelmingly dominant environmental health impact of fuel choice is cardiovascular related mortality caused by exposure to atmospheric fine particulate matter ($PM_{2.5}$). Growth Energy's comments concern pollutants other than fine particulate matter that have relatively insignificant or less-proven health impacts. Thus, their comments do not affect our analysis of monetized health impacts.**
>
> **Growth Energy refers to ultrafine particulate matter, whereas we studied fine particulate matter. Despite these two pollutants having similar-sounding names, they are different. The epidemiological evidence regarding the health impacts of fine particulate matter is many-fold more robust than that of ultrafine particulate matter.**
>
> **Furthermore, Growth Energy does not provide evidence or citations for their assertions about ethanol reducing ultra-fine particulate matter. It also appears that they are referring to tailpipe emissions rather than to life cycle emissions. As our research demonstrated, comparisons of tailpipe-only emissions are incomplete and fail to account for non-tailpipe emissions from fuel production and for the transport and transformation of those emissions.**

Response to MINNESOTA BIO-FUELS ASSOCIATION

The recent report released by the University of Minnesota, "Life Cycle Air Quality Impacts Of Conventional And Alternative Light- Duty Transportation In the United States," contains several inaccuracies and misleading information.

In particular, its conclusion that corn-based ethanol contains more harmful pollutants than gasoline runs contrary to findings from the Argonne National Laboratory (which is a non-profit research laboratory operated by the University of Chicago for the U.S. Department of Energy), the U.S. EPA and the Energy Information Administration (EIA).

> **The Minnesota Bio-Fuels Association's statement is false. Our findings do not run contrary to the model from Argonne National Laboratory. In fact, we use their model, GREET, in our analysis. We note that the issue is not whether "corn-based ethanol contains more harmful pollutants than gasoline," but rather whether corn-based ethanol causes greater human health damage from air pollution than gasoline.**

The authors of the report state that corn-based ethanol emits more ozone and particulate matter than gasoline. Ozone is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) while particulate matter is an air pollution term for a mixture of solid particles and liquid droplets in the air.

> **The Minnesota Bio-Fuels Association's statement contains a minor error related to the *emission* versus the *formation* of a pollutant. As they mention, ozone is created in the atmosphere, not emitted. When the Minnesota Bio-Fuels Association summarizes our results, however, they say that we state that ozone is emitted. Their**

statement is false. We do not state that ozone is emitted; rather, we consistently describe it as being formed in the atmosphere.

Both ozone and particulate matter can trigger health problems. While the U Of M's report states that these two pollutants increase with ethanol usage, data from the EPA suggests otherwise. According to the EPA, the amount of ozone in the air has decreased 18 percent from 2000 to 2013. In the Upper Midwest, ozone levels have fallen 11 percent during the same time period. Similarly, particulate matter has decreased 34 percent nationwide from 2000 to 2013. It is important to note that the drop in ozone and particulate matter coincide with the increase in ethanol blended gasoline which took off on a large scale after the implementation of the Renewable Fuel Standard in 2005.

The Minnesota Bio-Fuels Association's text confuses correlation with causation. Air pollution improved during 2000–2013, which were the years during which ethanol use increased most rapidly, but during that time there were also many other changes in our economy, including major environmental regulations impacting power generation, industry, and motor vehicles. Indeed, it is quite possible that air pollution during 2000–2013 improved *despite* the increase in ethanol use, not *because* of it.

Moreover, the Argonne National Laboratory's GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model – which was also used by the authors of the report – shows total urban life cycle emissions of VOC, NOx and particulate matter in a vehicle using E10 (gasoline that contains 10 percent ethanol) is lower than in a vehicle using gasoline which contains no ethanol.

If compared with a vehicle running on E85 (gasoline that contains 85 percent ethanol), GREET shows that the urban emission reductions are even more significant at 5 percent (VOC), 7.8 percent (NOx) and 20 percent (particulate matter).

The values cited here by the Minnesota Bio-Fuels Association are for urban emissions only and ignore rural emissions. For multiple pollutants, GREET shows decreased urban emissions with E10 or E85 compared to E0, but GREET also shows higher total life cycle emissions of these pollutants because of higher rural emissions. It is necessary to account for both urban and rural emissions, as our study does. People live in rural areas and in urban areas, and air pollution can travel from rural to urban areas, and vice versa. Our study accounts for the transport of air pollution in the atmosphere.

Interestingly, the report did not address CO2 emissions which dominates greenhouse gas emissions. According to the EIA, a gallon of gasoline that does not contain ethanol produces 19.64 lbs of CO2. A gallon of ethanol , on the other hand, emits 12.72 lbs of CO2.

As such, E10 produces 18.95 lbs of CO2 while E85 emits 13.75 lbs of CO2. Thus, it is quite clear that using ethanol reduces the level of CO2 in the air.

The Minnesota Bio-Fuels Association's statement that we did not address CO_2 emissions is false. We included a detailed analysis of greenhouse gas emissions from

the fuel options we considered. See, for example, Figure 3 of our report, which includes a clear label for climate change impacts.

The estimates of greenhouse gas emissions that the Minnesota Bio-Fuels Association presents are misleading. They are tailpipe emissions of CO_2 from burning gasoline and ethanol,[6] not life cycle emissions; that is, they do not account for emissions released during the production of these fuels. Furthermore, presenting tailpipe emissions on a per gallon basis rather than on an energy-equivalent basis ignores the mileage penalty with ethanol, which is a result of ethanol being only about two-thirds as energy dense as gasoline; that is, vehicles burn more ethanol than gasoline to go the same distance.

In 2012, some 2.45 billion gallons of gasoline was consumed in Minnesota. If we assumed that all 2.45 billion gallons were E10, it would mean 766,571 metric tons of CO2 was prevented from being released into the air thanks to ethanol.

That, according the EPA's greenhouse gas equivalencies calculator, is the equivalent of removing 161,383 cars from the road for a year in Minnesota.

These calculations are incorrect. As stated above, they do not account for the emissions released during fuel production and for the lower energy density of ethanol.

Considering the above, it is clear that ethanol is a much cleaner fuel than gasoline. Moreover, it is important to note that the authors of the study did not factor emissions from Canadian oil sands in their analysis of life cycle emissions from gasoline. This in itself casts more doubts on their findings as 70 percent of oil imported from Canada (which would include oil sands from Alberta) are brought into the Midwest.

Alberta oil sands extraction was excluded because it occurs outside of our modeling domain of the continental United States and its surrounding waters. Furthermore, Alberta oil sands extraction occurs in sparsely populated, remote areas and is unlikely to cause health impacts that are sufficiently larger than conventional oil extraction health impacts to affect the results of our study. A similar simplifying assumption was made for ethanol, in which emissions from the production and transportation of imported fertilizers were likewise excluded.

Even if the Minnesota Bio-Fuels Association's calculations were correct, they are regarding greenhouse gases, which does not address the new information added by our study, namely the increased health impacts caused by $PM_{2.5}$ air pollution from corn ethanol production and use relative to gasoline.

References

1. Tessum, C., J. Hill, and J. Marshall (2014) Life cycle air quality impacts of conventional and alternative light-duty transportation in the United States. *Proc. Natl. Acad. Sci. USA* **111**: 18490–18495.

2. U.S. Environmental Protection Agency (2004) The Particle Pollution Report: Current Understanding of Air Quality and Emissions Through 2003. EPA-454-R-04-002.
3. Cook, R., *et al.* (2011) Air quality impacts of increased use of ethanol under the United States' Energy Independence and Security Act. *Atmos. Environ.* **45**: 7714–7724.
4. National Research Council (2011) The Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy.
5. Rajagopal, D., and R. Plevin (2013) Implications of market-mediated emissions and uncertainty for biofuel policies. *Energy Policy.* **56**: 75–82.
6. U.S. Energy Information Administration (2015) Frequently Asked Questions: How Much Carbon Dioxide Is Produced by Burning Gasoline and Diesel Fuel? Accessed at <www.eia.gov/tools/faqs/faq.cfm?id=307&t=11>.