Advancing Biofuels Research
NCERC at SIUE

May 24, 2013

The Honorable Fred Upton
Chairman
Committee on Energy and Commerce
U.S. House of Representatives

The Honorable Henry Waxman
Ranking Member
Committee on Energy and Commerce
U.S. House of Representatives

Dear Chairman Upton and Ranking Member Waxman:

The NCERC at SIUE is a nationally-recognized research center dedicated to the development and commercialization of biofuels, specialty chemicals, and other renewable compounds. Established through federal and state initiatives, with support from the Illinois and National Corn Growers Associations, the Center promotes rural development and economic stimulus and is providing tomorrow's workforce with the skills needed to meet the challenges of a changing energy environment. Designated as a Biorefining Center of Excellence, the Center assists in developing the technologies needed to reduce U.S. reliance on foreign oil and provide consumers with economically sound and environmentally responsible fuel options.

The NCERC appreciates the opportunity to offer its experiences in response to a relevant question posed in the third white paper, "Greenhouse Gas Emissions and Other Environmental Impacts," as part of the Committee's review of the Renewable Fuel Standard (RFS).

1b. Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels?

According to the U.S. EPA, corn ethanol facilities reduce GHG emissions by up to 60% compared with baseline petroleum through the utilization of "modeled advanced technologies" including corn fractionation, corn oil extraction, membrane separation, raw starch hydrolysis, and combined heat and power. The NCERC can attest to the impact of the RFS on incentivizing the development of these technologies based on its contractual and collaborative research, which has included projects in each of these areas. This research is not stopping at the pilot scale; in fact, more than 50 technologies that have passed through the doors of the NCERC are now in the commercial marketplace.

NCERC researchers successfully produced ethanol from the cellulosic portion of the corn kernel using corn fractionation technologies, which reduce GHG emissions. This NCERC-patented process has significant implications for the ethanol industry as a whole. Any of the 211 existing ethanol plants in the United States could be retrofitted with existing bolt-on technologies to produce cellulosic ethanol from corn without the need to build new facilities. This translates into reduced greenhouse gas emissions and opportunities for jobs and economic development, particularly in rural areas.

The Renewable Fuel Standard encourages industry investment in research, development, and ultimately, implementation in existing generation one ethanol plants. For example, Edeniq and Pacific Ethanol have partnered to install advanced technology at Pacific Ethanol's generation-one ethanol plant in Stockton, California, where Edeniq's patented corn oil extraction process will be used to increase corn oil recovery. This type of collaborative investment would not be possible without the RFS.

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Thank you again for the opportunity to share our comments. Please do not hesitate to contact me with any questions or requests for further information.

Sincerely,

John Caupert

John Caupert
Executive Director
NCERC at SIUE

May 22, 2013

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The Honorable Henry Waxman
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Dear Chairman Upton and Ranking Member Waxman:

On behalf of Nebraska's 23,000 corn farmers, we appreciate the opportunity to comment on your committee questions related to the Renewable Fuels Standard (RFS).

Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?

The RFS has accomplished many positives since the original passage in 2005 and expanded within the 2007 Energy Bill. Specifically to your question on greenhouse gas (GHG) emissions, the use of renewable fuels such as ethanol has reduced GHG emissions. This is documented in not only the RFS2 Final Rule released by EPA that calculated a greater than 50% reduction in GHG emissions (excluding indirect land use change [ILUC]), but additional studies have documented such reductions in GHG emissions. Studies include Wang, et al[1] that show that corn ethanol reduces GHG emissions by an average of 44% compared to gasoline when excluding ILUC using the updated GREET model. Liska, et al[2] modeled that different corn ethanol processes reduced GHG emissions from 17% to 67% compared to gasoline using the BEES model.

The corn ethanol industry is continually making additional improvements in their production processes and we believe this is being driven two fold; first by the RFS and secondly by pure economics. First within the RFS, it sets benchmark reductions that various biofuels have to meet to be classified as advanced and cellulosic. Although corn ethanol cannot be classified as such due strictly by the restrictions within the RFS definitions, the industry clearly believes that it can attain such reductions in GHG emissions to meet the benchmarks.

Secondly, economics are a continual driver in reducing input costs within the production process. This is captured in a recent survey publication by Mueller et al[3] that showed that yield

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[1] *Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use*, Wang, et al
[2] *Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol*, Liska, et al
[3] *2012 Corn Ethanol: Emerging Plant Energy and Environmental Technologies*, Mueller, et al

(gallons per bushel) is up 1.4% between 2008 and 2012. Energy use is down nearly 9% and water use is down also. With continued increases in efficiencies of today's biofuels and expansion of new biofuels, further GHG emission reductions are expected.

Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?

When the EPA released its initial draft of the regulations governing the RFS, it utilized the GREET model with data that was outdated. Since that time, the GREET model has went through continual updates and we believe this is necessary for EPA to adopt also. As our comments show to the question above, efficiencies have been gained within the ethanol process and this needs to be updated within EPA's modeling also.

Our comments are similar to those submitted by Liska and Cassman[4] to EPA during the open comment time period of June 2009 when they stated…*Accurate LCA [life cycle analysis] is based on empirical data to the fullest extent possible. The RFS2 methodology for the LCA of biofuels relies more heavily on hypothetical data derived from complex models that predict "expected" future technological improvements in different classes of biorefineries.* Their comments went on to say *we therefore recommend that the RFS2 LCA methodology first focus on optimizing LCA methods for the existing corn-ethanol industry, using an empirical approach wherever possible.*

Additionally, in the same survey referenced above by Mueller et al, the authors found that farmers are using new technologies that have improved feedstock production efficiencies. Those include the use of global positioning systems, remote sensing, fertilizer technologies and soil testing.

Our recommendation is that EPA revisit the data sets within their version of GREET and update with new data sources and surveys. Additionally, we recommend that EPA visit with the U.S. Department of Agriculture's (USDA) National Agriculture Statistics Service (NASS) about additionally surveys that need to be completed on such issues as fertilizer use and efficiency and co-product (distillers grains) usage and replacement rates.

Since the inclusion in the RFS on considering ILUC, the debate has continued on whether models can accurately pinpoint whether ILUC is actually happening or whether biofuels can be pinpointed as a cause for ILUC. Although EPA utilized different modeling, California adopted the GTAP model when finalizing their low carbon fuel standard. Since that time, GTAP has been updated and has reduced their estimated impact ILUC by nearly 50 percent.

Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?

Although we believe that the definition adequately protects against unintended consequences, as mentioned above, we recommend that EPA revisit their total "402 million acres" with USDA – NASS to be sure that it accurately represents all possible feedstock options.

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[4] *Recommendations for Life Cycle Assessment Methodology in the Renewable Fuel Standard Program (RFS2) of the U.S. EPA,* Liska and Cassman

What is the optimal percentage of ethanol in gasoline?

Although we don't have a specific blend percentage to recommend, we will answer it a couple of different ways. First, Hanna et al[5] completed a study on a small number of vehicles that were available to them from the State of Nebraska fleet. The study concluded that *from an overall operational standpoint, the medium- and heavy-loaded vehicles maintained or improved maximum torque and horsepower with the E20 and E30 ethanol fuel blends*.

Anecdotal information from retailers in Nebraska that have installed blender pumps across the state show that among the various mid-level blends of ethanol the most popular is a 30% blend of ethanol that is available to flex fuel vehicles.

What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?

Longer term our recommendation is that EPA look at taking into account the requirements of the RFS, along with considering the updated CAFÉ (Corporate Average Fuel Economy) requirements of fuel efficiency and release a recommended blend percentage. This recommendation will allow fuel retailers, automobile manufactures and the ethanol industry to plan for what we consider to be a blend that is above the currently approved E15 level. Concurrent to this discussion, we recommend that ethanol and other biofuels inherent octane content be considered as an avenue to meeting both the RFS and CAFÉ requirements.

Clearly, as answered above, ethanol and other biofuels have been and will continue to provide GHG emission reductions. To expand on this impact, we believe looking at increasing the blend of ethanol allowed in transportation fuels will further this impact. Again this is a balance that needs to be addressed when considering both the RFS and CAFÉ requirements.

In closing, we appreciate the efforts of the House Energy and Commerce Committee in requesting input on the value of the renewable fuels standard.

Regards,

Tim Scheer,
Chairman

[5] *Mid-level Ethanol Blend Study: Chassis Dynamometer Study of Flex Fuel Vehicles*, Hanna, et al

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May 24, 2013

Dear Chairman Upton and Ranking Member Waxman:

Novozymes, a leader in biotechnology and innovation, is pleased to respond to the U.S. House of Representatives Committee on Energy and Commerce's (Committee) third Renewable Fuel Standard (RFS) assessment white paper[1] reviewing the RFS's Greenhouse Gas (GHG) Emissions and Other Environmental Impacts.

In terms of environmental benefits, the RFS has several objectives:

- Increase the use of renewable resources.
- Decrease the nation's greenhouse gas emissions – and protect the environment.
- Listen to the science and data on impacts of fossil fuel.
- Improve air and water quality – and therefore people's health.

On all those objectives, the RFS is working.

The RFS is America's only Congressionally-authorized greenhouse gas program. Production of biofuels under the RFS is subject to strict lifecycle GHG reduction requirements of up to 60 percent less compared to traditional petroleum-derived fuel. In 2012, using renewable fuel slashed greenhouse gas emissions by 33.4 million metric tons.[2] EPA has estimated that renewable fuels use under the RFS will reduce greenhouse gas emissions by 138 million metric tons when the program is fully implemented in 2022. [3] The reductions would be equivalent to taking about 27 million vehicles off the road.

[1] U.S. House of Representatives Energy and Commerce Committee. 9 May 2013. *RENEWABLE FUEL STANDARD ASSSESSMENT WHITE PAPER: Greenhouse Gas Emissions and Other Environmental Impacts* *http://energycommerce.house.gov/sites/republicans.energycommerce.house.gov/files/analysis/20130508RFSWhitePaper3.pdf*
[2] Renewable Fuels Association, "Battling for the Barrel: 2013 Ethanol Industry Outlook." Washington, DC: February 2013, p.18.
[3] US EPA, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis." Washington, DC: EPA-420-R-10-006, February 2010.

If left to keep working, the RFS will do even more to bring increasingly low carbon alternatives to market. The RFS sets forth ambitious targets through 2022 for the production of cellulosic and advanced renewable fuel that meet stringent, specific minimum thresholds of lifecycle greenhouse gas emissions reductions reaching 60 percent, depending on the type of fuel, as determined by EPA.

Novozymes is making those benefits come alive. Our business is built on the idea that we, the world, can do more with less. Our technology enables our customers to use less energy and water, results in better and products – and leaves countries with less pollution.

Novozymes is a technology and science company; we embrace and encourage both. We have nearly 6,000 employees worldwide, and cellulosic biofuels is our largest global R&D effort with more than 150 employees dedicated to its development. We have more than 7,000 patents and 700 products at work in 130 countries. Our US biofuels investment – and that of many industry peers – is driven in large part by the Renewable Fuel Standard. In May 2012, Novozymes opened the largest enzyme plant dedicated to renewable fuels in the United States – its advanced manufacturing plant in Blair, Nebraska. Funded with more than $200 million in private investment, the plant created 100 career positions and 400 construction jobs, and specializes in enzymes for both the conventional and advanced biofuel markets. Biorefineries across the world – in the United States, China, Italy and Brazil – are using enzymes made at our Nebraska Plant. In fact, global production capacity of advanced biofuels is estimated to reach approximately 15 million gallons in 2012 and 250 million gallons by 2014.

Our sustainability and life cycle assessment experts help guide our business and their work is internationally recognized. We actively support international initiatives to develop certification for sustainable renewable fuels.

White Paper Responses:

Greenhouse Gas Reduction

The science is clear: fossil fuels funnel carbon into the atmosphere. Carbon in the atmosphere causes problems, for people and the environment.

Conversely, biomass feedstocks essentially *recycle* carbon, so the carbon released into the atmosphere is not "new." Biogenic carbon emissions should thus be considered "carbon neutral" based on the feedstock's carbon uptake.

Beyond EPA data, independent reviews document the tremendous GHG reduction potential of biotechnology.[4,5,6,7,8]

- Existing and new ethanol plants are improving efficiency thus producing ethanol with lower GHG emissions profiles than before.
- Corn ethanol can help reduce CO_2 emissions by 30–60%[9].
- Cellulosic ethanol can reduce GHGs by up to 90% when compared with gasoline. [10]

Under a stable RFS, advances like these will continue as the industry matures.

The RFS, by mandating use of renewable biofuels in transportation fuel, can also replace marginal production with ethanol, reducing GHG's further. As petroleum becomes scarce, gasoline from marginal production will increase emissions relative to gasoline from sweet crude.

LCA Modeling

A significant body of new work has emerged since EPA developed its methodology, casting doubt on the existence or magnitude of indirect land use change impacts. [11,12,13,14,15,16,17] In addition to the indirect models, significant updates and improvements have been made to the GREET model, used to calculate direct emissions for biofuels since 2008. These changes are documented in thirty eight publications from Argonne National Lab.[18] Instead of discounting the RFS, a more proactive approach is EPA's: to update the assessment of direct emissions to include the latest data and information.

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[4] WWF, "Industrial Biotechnology, More Than a Green Fuel in a Dirty Economy?" http://www.bio-economy.net/reports/files/wwf_biotech.pdf, 2009.

[5] The European Association for Bioindustries ("EuropaBio"), "How Industrial Biotechnology Can Tackle Climate Change" http://www.europabio.org/sites /default/files/facts/how_industrial_biotechnology_can_tackle_climate_change.pdf, 2008.

[6] German Advisory Council on the Environment, "Climate Change Mitigation by Biomass" http://eeac.hscglab.nl/files/D-SRU_ClimateChangeBiomass_Jul07.pdf, 2007.

[7] Biotechnology Industry Organization ("BIO"), "New Biotech Tools for a Cleaner Environment", http://www.bio.org/sites/default/files/CleanerReport.pdf, 2004.

[8] Brookes and Barfoot, "GM crops: global socio-economic and environmental impacts 1996-2011, PG Economics, Ltd, 2013 www.pgeconomics.co.uk/pdf/2013globalimpactstudyfinalreport.pdf

[9] A. Liska, et al. In: Journal of Industrial Ecology (2008): Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn Ethanol

[10] Macedo I.C. et al (2008), "Biomass and Bioenergy," p. 32

[11] Kim, Hyungtae, Kim, Seungdo, Dale, Bruce E., *Biofuels, Land use Change and Greenhouse Gas Emissions: Some Unexplored Variables*

[12] Marshall, E. et al. "Measuring the Indirect Land-Use Change Associated With Increased Biofuel Feedstock Production: A Review of Modeling Efforts. (Report to Congress)" Washington: Economic Research Service, February 2011.

[13] Wicke, B., P. Verweij, et al. (2012). "Indirect land use change: review of existing models and strategies for mitigation." Biofuels 3(1): 87-100.

[14] Oladosu, G., K. Kline, et al. (2012). "Global economic effects of US biofuel policy and the potential contribution from advanced biofuels." Biofuels 3(6): 703-723.

[15] Taheripour, F. and W. E. Tyner (2013). "Induced Land Use Emissions due to First and Second Generation Biofuels and Uncertainty in Land Use Emission Factors." Economics Research International 2013: 12.

[16] Farzad Taheripour and Wallace E. Tyner (2013). "Biofuels and Land Use Change: Applying Recent Evidence to Model Estimates." Applied Sciences 2013 (3): 14-38.

[17] Kim, Hyungtae, Kim, Seungdo, Dale, Bruce E., *Biofuels, Land use Change and Greenhouse Gas Emissions: Some Unexplored Variables*

[18] http://greet.es.anl.gov/index.php?content=publications&by=date&order=down#GREET_Model_Reports

As data and information for renewables looks more promising, data and information for petroleum looks worse. Lifecycle GHG emissions for petroleum continue to increase as unconventional, high-carbon sources such as tar sands become a larger part of the U.S. transportation fuel mix. In order to best understand their current and potential impact, we believe emissions reductions for biofuels should be evaluated against those for present-day petroleum.

Congress afforded EPA the flexibility to make these and other methodological adjustments in the program's annual rulemaking. EPA is taking a science- and data-driven approach. No action is required, nor should it be pursued, by Congress.

Biomass

We have a partner called Fiberight that is already making cellulosic renewable fuel from trash in Lawrenceville, VA. Instead of taking trash to the land fill, trucks take that trash to Fiberight's plant – where it is separated, processed and turned into fuel. Despite the narrow definition of renewable biomass, pioneering industrial biotechnology leaders are helping to make advanced and cellulosic biofuels a reality.

Environmental Impacts

The substitution of biofuels for petroleum-derived fuels provides a host of environmental benefits beyond GHG reductions. A 2011 review by the National Academy of Sciences identifies potential environmental benefits from biofuel substitution across a range of metrics, including air quality, water quality, water use and biodiversity.[19]

What the science says clearly is that while agriculture and biorefining continues to contribute to a better environment, traditional oil production's negative impacts continues to contribute to a more challenged one.

Air Quality

Adding ethanol to gasoline reduces air contamination. Ethanol reduces emissions of carbon monoxide, hydrocarbons, aromatics, particulate matter and greenhouse gasses - resulting in better

[19] "Renewable Fuel Standard: Potential Economic and Environmental Effects of U.S. Biofuel Policy" The National Academies. 2011

overall air quality than when cars burn conventional gasoline. [20] Imagine how much healthier our children, families and cities could be with cleaner air.

Car manufacturers can help by improving on the technologies they use to reduce emissions. Ethanol acts as a fuel additive to raise the octane level of gasoline, resulting in a fuel that burns more cleanly, cutting down on emissions of carbon monoxide and other air pollutants. It is especially suitable to lower emissions of CO, hydrocarbons, aromatics and particulate matters (PM). As an example, ethanol decreases emissions of benzene, a hydrocarbon classified by the EPA as a known human carcinogen. Benzene accounts for about 70% of the total toxic emissions from vehicles running on conventional gasoline.[21]

Biodiversity

The loss of biodiversity is caused by the increasing impact of human activities on the environment. As we increasingly look to agriculture to deliver food, feed and energy it is important that we work to make these needs more sustainable.

Novozymes provides technical solutions for this including increasing crop yields, and reducing pre- and post-harvest waste of agricultural production. One of the most important drivers of forest loss in Africa is subsistence agriculture often using slash-and-burn techniques. In Latin America and Southeast Asia a majority of deforestation is the result of industrial activities, notably cattle ranching in the Amazon and large-scale agriculture and intensive logging in Southeast Asia. [22]

An example of biofuels fighting deforestation and increasing biodiversity is Clean Star Mozambique. The company is working with smallholder farmers to implement sustainable farming practices and produce sustainable biofuel for household cooking replacing thousands of charcoal-burning cook-stoves.

It is intended that by 2014, CleanStar Mozambique will supply 20% of local households in Mozambique's capital Maputo with ethanol. This will protect 4,000 ha of indigenous forest per year. Furthermore, 2.4 million indigenous trees will be planted in rural communities as part of the agro-forestry systems and 6000 ha of degraded land will be rehabilitated.

Water

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[20] Based on among others: EPA (2009), Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program http://www.epa.gov/orcdizux/renewablefuels/420d09001.pdf and Krzyzanovski M. et al (2005), Health effects of transport related air pollution (WHO/Europe)

[21] Gary Whitten, "Air Quality and Ethanol in Gasoline," December 2004.

[22] www.mongabay.com

It takes about 1.8 liters of water to produce one liter of conventional biofuel. Questions about water scarcity must be viewed locally; it is a mistake to generalize. While water resources may be scarce in an area of a region or country, they are abundant in others. Advanced biofuel from agricultural residues requires no additional water usage within agriculture and only limited amounts in the production process. Novozymes participates in development of biofuels certification programs including water footprint. When debating water footprint of ethanol or any other product, it is essential to be clear about what is measured and how it is measured.

In addition, ethanol is rapidly biodegraded in water and soil, and is the safest component found in gasoline today. A study conducted for the Massachusetts Department of Environmental Protection concluded that "…biodegradation [of ethanol] is rapid in soil, groundwater and surface water, with predicted half-lives ranging from 0.1 to 10 days. Ethanol will completely dissolve in water, and once in solution, volatilization and adsorption are not likely to be significant transport pathways in soil/groundwater or surface water."[23]

Renewable Fuel Use

Drop-in replacement biofuels can be substituted directly for petroleum-based products, and should be blended at the highest rates achievable. High octane biofuels, such as ethanol, complement drop-in alternatives by offering a pathway to meet the higher mileage CAFÉ standards in the 2012 rulemaking "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." High octane ethanol can be operated at substantially higher compression ratios than standard gasoline, allowing for smaller, lighter, and more efficient engines. Additionally, in its Tier III rulemaking, EPA acknowledged that higher octane fuels "could help manufacturers that wish to raise compression ratios to improve vehicle efficiency, as a step toward complying with the 2017 and later light-duty greenhouse gas and CAFE standards. This in turn could help provide a market incentive to increase ethanol use beyond E10 by overcoming the disincentive of lower fuel economy associated with increasing ethanol concentrations in fuel, and enhance the environmental performance of ethanol as a transportation fuel by using it to enable more fuel efficient engines."

The RFS assures that the US consumer will have choice at the gas pump and our country will have diversification in our fuel supply. But both outcomes are necessary if America is to achieve these environmental goals and reduce its reliance on foreign imports.

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[23] http://www.mass.gov/eopss/docs/dfs/emergencyresponse/special-ops/ethanol-spill-impacts-and-response-7-11.pdf

Conclusion

America's best option for substantially further reducing greenhouse gas emissions from the transportation sector is to leave the RFS at work – as is. We are just 1/3 of the way through the timeline Congress laid out in 2007 – we must stay the course or risk losing the progress we've made.

New research shows that ethanol significantly reduces CO_2 emissions compared to fossil fuels, even when ILUC is accounted for. The International Food Policy Research Institute estimates savings from conventional ethanol between 48 and 65%.[24] Options to produce biofuels without ILUC risk or to mitigate ILUC include biofuels from residues and household waste, biofuels produced additionally from yield increase, biofuels produced on land that has become available by integrated food and energy system, biofuels produced on degraded or marginal land. [25]

The RFS is vital to growing the biofuel markets, including adoption of a higher-octane blend as the gasoline base fuel, and expedited approval of new drop-in fuel molecules. It enables engine manufacturers to optimize beneficial characteristics of biofuels in engine design, and expedited approval of new pathways provides obligated parties with additional options for compliance, several of which could alleviate blending limitations.[26] Rapid approval of alcohol-to-jet fuel pathways would also create additional markets for ethanol not subject to blending limits.[27]

The RFS provides exactly the type of long-term, regulatory stability that is required to send a signal to investors. The most important action Congress can take to reduce our nation's dependence on oil and cut greenhouse gas emissions is to leave the RFS in place and let it work.

Thank you for this opportunity for input, if there is any additional information Novozymes can provide, please do not hesitate to ask. We invest in the US in large part because of the RFS.

novozymes®
Rethink Tomorrow

Cc: Congressman Lee Terry
Congressman G.K. Butterfield

[24] Laborde (2011): Assessing the Land Use Change Consequences of European Biofuel Policies, Final Report, October 2011, IFPRI.
[25] Goodwin et al (2012): Is Yield Endogenous to Price? An Empirical Evaluation of Inter- and Intra-Seasonal Corn Yield Response
[26] http://www.afdc.energy.gov/fuels/emerging_dropin_biofuels.html
[27] http://www.safug.org/case-studies/

POET | DSM
Advanced Biofuels

May 24, 2013

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Submitted via email at: *rfs@mail.house.gov*

RE: POET-DSM Advanced Biofuels, LLC comments on the U.S. House of Representatives Committee on Energy and Commerce white paper on the Renewable Fuel Standard (RFS) and "Greenhouse Gas Emissions and Other Environmental Impacts"

Dear Chairman Upton and Ranking Member Waxman:

POET-DSM Advanced Biofuels, LLC (hereinafter, "POET-DSM") is pleased to comment on the white paper on the RFS and "Greenhouse Gas Emissions and Other Environmental Impacts" that the Energy and Commerce Committee released on May 9, 2013 (hereinafter, White Paper).[1] The White Paper is the third in a series of analyses by the Committee on the RFS.

About POET-DSM

POET-DSM Advanced Biofuels is a 50/50 joint venture, created by POET, LLC ("POET"), based in Sioux Falls, South Dakota, and Royal DSM ("DSM"), based in the Netherlands. This joint venture is targeted to begin operation in early 2014 of its first commercial-scale cellulosic ethanol facility, located in Emmetsburg, Iowa, called Project LIBERTY. The capital expenditure by the joint venture in Project LIBERTY amounts to approximately $250 million.

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[1] *See* "Renewable Fuel Standard Assessment White Paper: Greenhouse Gas Emissions and Other Environmental Impacts," available at http://energycommerce.house.gov/sites/republicans.energycommerce.house.gov/files/analysis/20130508RFSWhitePaper3.pdf.

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DSM is a global life-sciences and materials-sciences company. DSM has more than 140 years of experience in biotechnology development and a proven track record of scaling up industrial operations. With its integrated technology package the company is the industry technology leader in converting cellulosic biomass to ethanol using proprietary enzymes and yeasts.

POET, the largest ethanol producer in the world, is a leader in biorefining through its efficient, vertically-integrated approach to production. The 25+ year-old company produces more than 1.6 billion gallons of ethanol annually from 27 production facilities nationwide. POET is also the world's largest producer by volume of distillers' dried grains with solubles (DDGS), a highly nutritious animal feed produced as a coproduct of ethanol production.[2] POET also owns and operates a pilot-scale cellulosic ethanol plant in Scotland, South Dakota, which uses corn stover as a feedstock.

The POET-DSM joint venture intends to extend cellulosic technology to the remaining 26 plants in the POET network and to license this technology to build other plants co-located with grain ethanol plants in the United States and globally. With this joint venture, POET and DSM expect to lead the industry in fulfilling one of the central goals of Congress when it created the RFS program—the large-scale development of cellulosic ethanol and the dramatic reduction of greenhouse gas emissions as compared to petroleum.

Preface

The RFS has begun to have its intended impact of increasing the use of domestically-produced renewable fuels. Furthermore, the RFS is meeting Congress' goals for the standards of enhancing our nation's energy security, providing a much-needed source of rural employment, and reducing the emissions of greenhouse gases and other harmful pollutants from petroleum. As currently structured (and if allowed to work *as-is*), the RFS will continue to provide the benefits that Congress desired when it strengthened the RFS requirements in 2007.

POET-DSM appreciates the opportunity to comment on this White Paper on "Greenhouse Gas Emissions and Other Environmental Impacts." Responses to the specific questions raised in the White Paper are below.

Discussion of specific questions

1. **Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower**

[2] For more information on POET, *see* http://www.poet.com.

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greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?

Yes, the RFS is reducing greenhouse gas emissions below that of baseline petroleum fuels. For instance, in 2012 using renewable fuel has been calculated to have reduced greenhouse gas emissions by over 33 million metric tons, according to the data assessed by the Renewable Fuels Association.[3] Furthermore, the U.S. Environmental Protection Agency (EPA) estimates that by 2022, the RFS will reduce greenhouse gas emissions by 138 million metric tons or the equivalent of taking *27 million* passenger vehicles off the road.[4]

Additionally, the RFS is incentivizing the development of a new generation of lower greenhouse gas-emitting fuels. Numerous companies, including POET and DSM, have made significant investments in cellulosic ethanol production. A recent EPA proposed rule regarding RFS obligations for 2013 recognizes that companies are "continuing to invest significant sums of money" in cellulosic biofuel production.[5] EPA also accurately recognizes the likelihood of robust growth in cellulosic biofuel commercial production:

- "The cellulosic biofuel industry in the United States continues to make significant advances in its progress towards large scale commercial production."[6]
- It is reasonable to expect that cellulosic biofuel "production costs and capital costs will continue to decline."[7]
- "If these first commercial-scale cellulosic biofuel production facilities are successful, the potential exists for a rapid expansion of the industry in subsequent years."[8]

By statute under the RFS, advanced biofuels must reduce greenhouse gas emissions by at least 50% compared to petroleum fuels, and cellulosic biofuels must reduce greenhouse gas emissions by at least 60%.[9] With this in mind, Congress set aggressive targets for advanced biofuels and cellulosic biofuel through 2022. Left alone to work as-is, the RFS has been and will

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[3] Renewable Fuels Association, *Battling for the Barrel: 2013 Ethanol Industry Outlook* (February 2013), p.18, available at http://ethanolrfa.org/page/-/PDFs/2013%20RFA%20Outlook.pdf?nocdn=1.

[4] EPA final rule, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program*, 75 Fed. Reg. 14,670, 14,683 (March 26, 2010).

[5] EPA proposed rule, *Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards*, 78 Fed. Reg. 9,282, 9,284 (February 7, 2013).

[6] *Id.*

[7] 78 Fed. Reg. 9,288.

[8] 78 Fed. Reg. 9,289.

[9] *See* CAA section 211(o)(1), definitions of "Advanced biofuel" and "Cellulosic biofuel."

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continue to drive investment in projects that significantly reduce greenhouse gas emissions below baseline petroleum fuels.

Doing its share, POET-DSM has heavily invested in next-generation cellulosic ethanol that on a lifecycle basis can eliminate or reduce the GHG emissions attributed to gasoline use, while also generating surplus clean energy. As noted above, POET-DSM's Project LIBERTY is slated to begin operating in early 2014. According to a third-party study, Project LIBERTY will reduce GHGs by 111% compared to gasoline—i.e., the cellulosic ethanol will *more than* offset the GHG emissions of gasoline.[10] This is achieved by eliminating the need for fossil fuel at an adjacent, grain-based ethanol facility by selling extra biogenic power generated by Project LIBERTY to that adjacent facility.

POET-DSM also is actively pursuing a licensing and investment strategy to rapidly increase the scope of cellulosic ethanol production at its existing facilities. POET-DSM is interested in scaling up these operations as rapidly as the market will permit. In fact, the POET-DSM joint venture aims to extend cellulosic technology to the remaining 26 plants in the POET network and, beyond that, to other corn ethanol plants in the United States. POET-DSM can cost-effectively expand cellulosic production through a "bolt-on model" whereby a cellulosic facility is sited next to an existing grain-based facility, thereby making use of existing infrastructure, including electricity, water, railroad access, and biomass supply (e.g., corn stover from a similar footprint of farms that supplies corn to the pre-existing ethanol facility). This bolt-on model provides for potential rapid expansion of cellulosic ethanol production by making use of the existing infrastructure of the pre-existing ethanol facility.

To achieve these aggressive cellulosic production goals, POET-DSM notes that market support and regulatory predictability consistent with Congressional intent in enacting the RFS is essential to promoting the widespread use of low-emitting, domestically-sourced cellulosic ethanol.

POET and DSM are pursuing production of a number of important advanced biofuels, in addition to the companies' significant investments in cellulosic biofuel. POET provides corn oil to the biodiesel market, and the biodiesel market has been rapidly growing. POET is also exploring the production of ethanol as an advanced biofuel, through the use of sorghum.

Responding to the final subpart of this first White Paper question, yes, the RFS will produce further greenhouse gas emissions reductions when it is fully implemented. The RFS sets targets through 2022 for increased use of cellulosic and advanced renewable fuels that meet specific minimum thresholds of lifecycle GHG emissions reductions, with these reductions

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[10] *See* Air, Inc., *Lifecycle Emissions of POET's LIBERTY Cellulosic Ethanol Plant*, available at http://poet.com/media/LCA-exec-summary.pdf.

exceeding 60% for cellulosic production. As demonstrated regarding the above POET-DSM information on Project LIBERTY, the future involves even greater emission reductions from ethanol facilities.

2. **Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?**

POET-DSM supports full "well to wheels" lifecycle greenhouse gas calculations, which show the significant emission reduction benefits of ethanol compared to gasoline. However, EPA should avoid over-stated and unsupported impacts of indirect land use change (ILUC) when calculating the lifecycle greenhouse gas emissions of ethanol. Recently, researchers from Michigan State University (including the well-known Dr. Bruce Dale) used an empirical approach that suggests that, based on available data, U.S. biofuels production has not caused indirect land use change either in the United States or internationally.[11] Indeed, a variety of studies suggest that direct and international land use change effects are not as large as once assumed. Ethanol continues to be unduly penalized, including by EPA, based on simulations used to find ILUC that are not supported by proven scientific data.[12] Lifecycle analysis should not penalize ethanol, but instead should recognize the science that shows how biofuels are better for the environment compared to fossil fuels.

The context of international agriculture must also be properly understood, to recognize just how small of an issue ILUC change caused by ethanol is. The World Bank has noted that worldwide biofuels account for only about 1.5% of the area under grains/oilseeds, which "raises serious doubts about claims that biofuels account for a big shift in global demand."[13]

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[11] *See* Seungdo Kim and Bruce Dale, *Indirect Land Use Change for Biofuels: Testing Predictions and Improving Analytical Methodologies*, 35 Biomass and Bioenergy 3,235 (2011).

[12] Indeed, EPA's own EPA report to Congress on the RFS states that "potential" impacts of biofuel production on land use conversion are "not yet observed" in reality and "it is not possible at this time to predict with any certainty what type of land use change in other countries will result from increased U.S. demand for biofuel." *See* EPA's *Biofuels and the Environment: First Triennial Report to Congress* (December 2011), pp. xv and 5-10. This report is available at http://nepis.epa.gov/EPA/html/DLwait.htm?url=/Exe/ZyPDF.cgi?Dockey=P100ELNF.PD.

[13] World Bank, *Placing the 2006/08 Commodity Price Boom into Perspective* (July 2010), p. 12, available at http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2010/07/21/000158349_20100721110120/Rendered/PDF/WPS5371.pdf.

Moreover, according to Stanford University research, more than a billion acres of agricultural land has gone idle worldwide in the last century.[14] This further diminishes the potential impact of U.S. biofuels production on international land use; significant idled cropland is available for agriculture.

Importantly, another leading study by Dr. Bruce Dale and a team from Michigan State University, found that the United States "can replace a large fraction of [its] petroleum consumption without indirect land use change."[15] For instance, this analysis found that 80% of U.S. imported petroleum can be replaced through "a more land efficient approach which uses that same acreage to generate an equal amount of food and animal feed while also providing much larger quantities of biofuels."[16] This study concluded that, even with conservative assumptions, "Large scale biofuel production can be successfully reconciled with food production while also accomplishing significant GHG reductions and promoting biodiversity."[17] Taking this and other learned studies into account, EPA's methodology for calculating lifecycle greenhouse gas emissions should be improved and not include over-stated values for indirect land use changes for ethanol. Congress provided EPA the flexibility to make these methodological adjustments, and EPA should do so. No further steps are required regarding this issue by Congress at this time; should EPA fail to act, Congressional oversight may be appropriate.

3. **Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?**

POET-DSM does not believe there is a substantial need to revise the definition of renewable biomass at this time. The current definition has protected environmental conservation values, and while the definition of qualified biomass is narrow in that regard, the definition has not unduly restricted POET-DSM operations.

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[14] *See* J. Campbell et al., *The Global Potential of Bioenergy on Abandoned Agriculture Lands*, 42 Environmental Science & Technology 5,791 (2008), available at https://eng.ucmerced.edu/czo/files/public/elliott_campbell/Campbell-etal-Biofuels-EST-2008.pdf.

[15] Bruce Dale et al., *Biofuels Done Right: Land Efficient Animal Feeds Enable Large Environmental and Energy Benefits,* 44 Environmental Science & Technology 8,385 (September 2010), available at http://pubs.acs.org/doi/ipdf/10.1021/es101864b.

[16] *Id*. at 8,386.

[17] *Id*. at 8,387.

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4. **What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels? Is there evidence of a need for air quality regulations to mitigate any adverse impacts of the RFS?**

The non-greenhouse gas impacts of the RFS are favorable compared to petroleum derived fuels. By definition, the RFS involves renewable fuels, as opposed to petroleum that is often obtained from resource-intensive and environmentally-damaging extraction processes, of which the BP disaster in the Gulf of Mexico would be one example. Furthermore, imported oil often comes from politically instable regions or countries with limited environmental controls.

By comparison, as the White Paper notes, EPA's first triennial report on the RFS has not found significant adverse environmental impacts resulting from the RFS. Moreover, the report notes that "Second-generation feedstocks have a greater potential for *positive* environmental outcomes relative to first-generation feedstock."[18] POET-DSM agrees that second generation feedstocks, including cellulosic feedstocks, are likely to have significant environmental benefits, in addition to the various benefits of current ethanol facilities. And current ethanol facilities are widely undergoing efficiency improvements, such that ethanol greenhouse gas and other benefits are improving even further.

Various environmental protections are built into the statutory RFS provisions, including a requirement that all renewable fuel must come from "renewable biomass." For instance, to reduce land conversion, crop lands must be "from agricultural land cleared or cultivated at any time prior to December 19, 2007, that is either actively managed or fallow, and nonforested."[19]

Furthermore, no additional air quality regulations are necessary to mitigate impacts of the RFS. To the contrary, the increased use of ethanol *reduces* critical types of air pollution. For instance, ethanol can reduce highly harmful particulate matter emissions, particularly in next-generation engines.[20] Ethanol can also reduce emissions of air toxics such as benzene and polycyclic aromatic hydrocarbons.[21] Overall, ethanol is a clean transportation fuel, and cleaner than gasoline in important ways. Notably, ethanol replaces other octane boosters in gasoline that include harmful benzene, toluene and xylene. Ethanol is an inherently less toxic substance than gasoline.

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[18] EPA, *Biofuels and the Environment: First Triennial Report to Congress*, *supra*, p. xv (emphasis added).

[19] CAA 211(o)(1)(I).

[20] *See e.g.*, M. Maricq et al., *The Impact of Ethanol Fuel Blends on PM emissions from a Light-Duty GDI Vehicle*, 46 Aerosol Science & Technology 576 (January 2012), available at http://www.tandfonline.com/doi/pdf/10.1080/02786826.2011.648780.

[21] *See e.g.*, M.A. Costagliola et al., Combustion efficiency and engine out emissions of a S.I. engine fueled with alcohol/gasoline blends, Applied Energy (2012), available at http://www.sciencedirect.com/science/article/pii/S0306261912006836.

The air emissions that should be more closely regulated are those of petroleum-derived products, not biofuels. In fact, EPA has recognized as much, by recently proposing extensive "Tier 3" motor vehicle and fuel regulations. In particular, EPA regulations for transportation fuels have focused on fuel sulfur and benzene, neither of which is contained in ethanol in any substantial quantities.[22] Ethanol provides a critical pathway to cleaner vehicles; accordingly, its use should be encouraged, rather than hindered through unnecessary regulation.

5. **Has implementation of the RFS revealed any environmental challenges or benefits not fully anticipated in the statute?**

The RFS has delivered on the greenhouse gas reductions sought by Congress through the RFS, as discussed above. Furthermore, the RFS has spurred the development of cellulosic ethanol and other advanced biofuels technology, as also discussed above. The implementation of the RFS has not revealed any significant environmental challenges not fully anticipated in the statute.

6. **What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?**

There is not necessarily a single "optimal" percentage of ethanol in gasoline, as different blend levels serve different purposes, particularly for the vehicle fleet of today versus the near future. Currently, 10% ethanol blends are the predominant fuel type throughout the United States, providing valuable octane and low emissions of key pollutants throughout virtually the entire United States gasoline supply. EPA has recently approved the use of E15 for vehicles in model years 2001 and later. E15 provides similar benefits as E10, and additional octane, with a slightly lower Reid Vapor Pressure that is also beneficial. E15 provides a means of increasing the use of ethanol consistent with the RFS targets. And flex-fuel vehicles capable of running on any blend of ethanol from E0 to E85 have been widely deployed in the marketplace and may be particularly useful for fleet vehicle operations. An estimated 14 million flex fuel vehicles are on the road today.[23]

Perhaps most significantly, even more ethanol in "mid-level ethanol blends" (MLEBs, such as E30) can cost-effectively reduce GHGs and provide a superior automotive fuel that has higher octane (allowing vehicles to run more efficiently) and lower toxic air pollutants than regular gasoline. These MLEBs are particularly critical as they enable the use of high-efficiency

[22] *See* EPA proposed rule, *Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards*, 78 Fed. Reg. 29,816 (May 21, 2013).

[23] *See e.g.*, http://www.ffv-awareness.org.

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engines needed to meet EPA's recent CAFE/GHG standards. As EPA has recognized, MLEBs can "help manufacturers that wish to raise compression ratios to improve vehicle efficiency, as a step toward complying with the 2017 and later light-duty greenhouse gas and CAFE standards."[24] While E30 is not necessarily the only "optimal" ethanol blend level, its high octane provides an excellent fit with "next generation" engines, and MLEBs are likely to be a critical fuel of the future.

7. **What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?**

Yes, the RFS is an important component of reducing greenhouse gas emissions from the transportation sector. Given the significant success of the RFS in reducing greenhouse gas emissions—and the even greater benefits that the RFS will bring—it is critical that Congress allow the existing RFS to continue to work as intended. Fortunately, the RFS as currently designed contains the measures that it needs to significantly reduce GHG emissions. In particular, the RFS sets strong targets through 2022 for increased use of cellulosic and advanced renewable fuels that meet specific minimum thresholds of lifecycle GHG emissions reductions, including a minimum 60% greenhouse gas reduction threshold for cellulosic production. POET, DSM and others have invested billions of dollars in bringing new cellulosic ethanol facilities on line, with production significantly increasing this year and next. POET is also actively pursuing various advanced biofuels production, including by providing feedstock to the biodiesel market, and by pursuing additional, next-generation biofuels from a variety of feedstocks.

MLEBs such as E30 also enable another signature greenhouse gas reduction program impacting cars and trucks--the EPA/NHTSA greenhouse gas and CAFE light-duty vehicle standards. As stated above, MLEBs enable the use of high-efficiency engines needed to meet the recent greenhouse gas/CAFE standards.

Unfortunately, non-market-based barriers are currently preventing the greater use of ethanol. In particular, current EPA regulations have impeded the use of ethanol in amounts over 10% by volume in gasoline, creating a "blendwall" when E10 in the market has reached a saturation point.[25] Put short, incumbent oil interests fear losing market share and have attempted to make this blendwall a reality by opposing ethanol blends greater than 10%. However, these blend wall issues can be addressed through the continued widespread use of

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[24] EPA Tier 3 proposed rule, 78 Fed. Reg. at 29,825.

[25] EPA has described this blendwall situation follows: as "the volume requirements of the RFS program increase, it becomes more likely that the volume of ethanol that must be consumed to meet those requirements will exceed the volume that can be consumed as E10." *See* 78 Fed. Reg. 9,301. Blendwall issues were also the focus of the first in this series of Energy & Commerce Committee white papers.

E10, an increased use of E15, the expanded use of E85 and MLEBs, and the deployment of additional flex-fuel vehicles and pumps.

Importantly, targeted action by EPA under its existing statutory authority could help to remove barriers to the wider use of MLEBs such as E30, allowing for the distribution of a superior transportation fuel. If EPA fails to act, then Congress should undertake relatively targeted measures to remove these barriers. In short, if barriers to MLEBs are removed, "blendwall" concerns can be eliminated, and our nation can cost-effectively reduce GHGs while dramatically improving our energy security.

In particular, Reid Vapor Pressure (RVP) barriers to greater ethanol use must be removed. EPA should promote higher-ethanol blends by extending the RVP waiver that currently only applies to E10. Notably, MLEBs such as E30 lower the RVP versus existing in-use fuels (thus reducing evaporative emissions and improving air quality); however, despite this improvement, MLEBs may still be in excess of certain RVP limits without an extension of the RVP waiver. In its Tier 3 rulemaking, EPA is taking comment on this issue and "whether it might be an appropriate reading of our regulatory and statutory authority to allow E16 to E50 blends to have higher RVP levels than otherwise required by our regulations for gasoline."[26] POET-DSM submits that E15 and mid-level ethanol blends should be given the same regulatory vapor pressure treatment as E10 blends. The Tier 3 rule also takes comment on incorporating higher ethanol blends in test fuels used for vehicles, as well as other measures that should facilitate the use of increased ethanol blends, and EPA should finalize those measures that promote increased ethanol use.

Other targeted measures should also be undertaken by EPA to recognize the full promise of the enhanced use of biofuels. These include a strong flex-fuel vehicle (FFV) credits program under the EPA's light-duty vehicle greenhouse gas rules that maintain volumes of FFV production so that RFS biofuels targets can be achieved.[27]

Importantly, ethanol is a critical, *cost-effective* means of reducing greenhouse gas emissions from the transportation sector. The 2017-2025 light-duty vehicle greenhouse gas and CAFE final rule stated that "owners of ethanol FFVs do not pay any more for the E85 fueling

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[26] *See* 78 Fed. Reg. at 29,938.

[27] *See e.g.*, EPA's Draft Guidance Letter on *E85 Flexible Fuel Vehicle Weighting Factor for Model Year 2016-2019 Vehicles*, available at http://www.epa.gov/otaq/regs/ld-hwy/greenhouse/documents/draft-ffv-guidance-letter.pdf. Numerous entities, including POET and the Alliance of Automobile Manufacturers, commented on how this draft guidance under-incentivized FFVs. POET comments, submitted in conjunction with Growth Energy, are available at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0120-0011.

capability."[28] This implies that greenhouse gas reductions from FFV E85 usage come at a nominal cost to the consumer. By comparison, the EPA and NHTSA greenhouse gas and CAFE rule estimated that the technology cost to create a midsize/standard car with an electric range of 75 miles would be over $17,000 *additional* in 2017.[29] Both ethanol-fueled vehicles and electric vehicles (EVs) can result in important greenhouse gas emission reductions. However, the substantial additional cost of EVs, their limited driving range, and unresolved technology issues for EVs (including various battery issues), create substantial barriers to consumer acceptance of EVs. Accordingly, ethanol-fueled vehicles—with their cost-effective, significant emission reductions using reliable technology—provide a critical means of reducing greenhouse gas emissions.

Cellulosic ethanol can even further reduce these greenhouse gas emissions, and mid-level ethanol blends can provide not only greenhouse gas benefits but octane improvements that can enable more efficient engines. But regulatory consistency, including maintaining the RFS targets *as-is*, is critical to recognizing these substantial benefits.

<u>Conclusion</u>

In conclusion, the RFS has been a significant success and—left as it is—will provide even more of the economic, energy security, and environmental benefits that Congress intended to promote, including significant greenhouse gas and other environmental benefits, including reducing toxic air emissions from gasoline.

POET-DSM would welcome the opportunity to further discuss these issues and solutions to the nation's transportation energy needs, and the significant greenhouse gas and environment benefits of the RFS.

Sincerely,

Steve Hartig
General Manager
POET-DSM Advanced Biofuels Licensing

James Moe
Chairman of the Board
POET-DSM Advanced Biofuels

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[28] *See* EPA/NHTSA final rule, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards*, 77 Fed. Reg. 62,624, 62,829 (October 15, 2012).
[29] *Id*. at 62,848.

May 24, 2013

Via Electronic Filing

Committee on Energy and Commerce
U.S. House of Representatives
Washington, DC

ATTN: Ben Lieberman & Alexandra Teitz

Re: Request for Comment on Renewable Fuel Standard Greenhouse Gas Emissions and Other Environmental Impacts

Dear Sir or Madam:

Renewable Energy Group, Inc. (REG) appreciates the opportunity to present comments to the Committee on Energy and Commerce regarding "Greenhouse Gas Emissions and Other Environmental Impacts" of the Renewable Fuel Standard (RFS). The RFS was expanded as part of the Energy Independence and Security Act of 2007 (EISA) (P.L. 110-140), which also created specific requirements for advanced biofuels, including biomass-based diesel. In so doing, Congress sought to further incentivize U.S. production and use of these fuels such as biodiesel. This policy has been an overwhelming success in the biodiesel sector, and has resulted in significant job creation, energy security, and environmental benefits.

As the nation's leading advanced biofuel producer, REG has a strong interest in the continued success of the RFS and we support efforts to fully implement RFS program requirements. REG currently has more than 225 million gallons of annual biodiesel production capability at seven biorefineries and distribution capabilities at nineteen terminals across the country. We plan to build upon our leadership in the biodiesel industry and expand into the production of additional advanced biofuels. The experience REG has gained over the last 17 years in the biofuels industry uniquely qualifies us to share comments on the RFS with you.

The Committee solicited comment on greenhouse gas emissions (GHG) and other RFS-related environmental impacts. REG will weigh in on select issues and, as we share many of the concerns articulated by the National Biodiesel Board (NBB), REG incorporates their comments by reference.

Specifically, the Committee requested comment on the following issues:

1. **Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower**

greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emission reductions when it is fully implemented?

Absolutely, yes the RFS has resulted in a dramatic increase in the use of biodiesel, an advanced biofuel with significant GHG emissions reduction benefits, depending on the feedstock utilized, ranging from 57% for soy biodiesel to 86% for waste grease biodiesel. Annual use in the United States, from 2005 to 2012, has more than doubled to 1.1 billion gallons due to the RFS. The dramatic increase in biodiesel consumption has reduced greenhouse gas emissions by 74.3 billion pounds. That is the equivalent of removing 5.4 million vehicles from America's roadways. Moreover, the consumption of total advanced biofuels increased to 2 billion gallons in 2012. These fuels are required to meet a minimum 50% reduction relative to gasoline or diesel fuel and many of them perform significantly better.

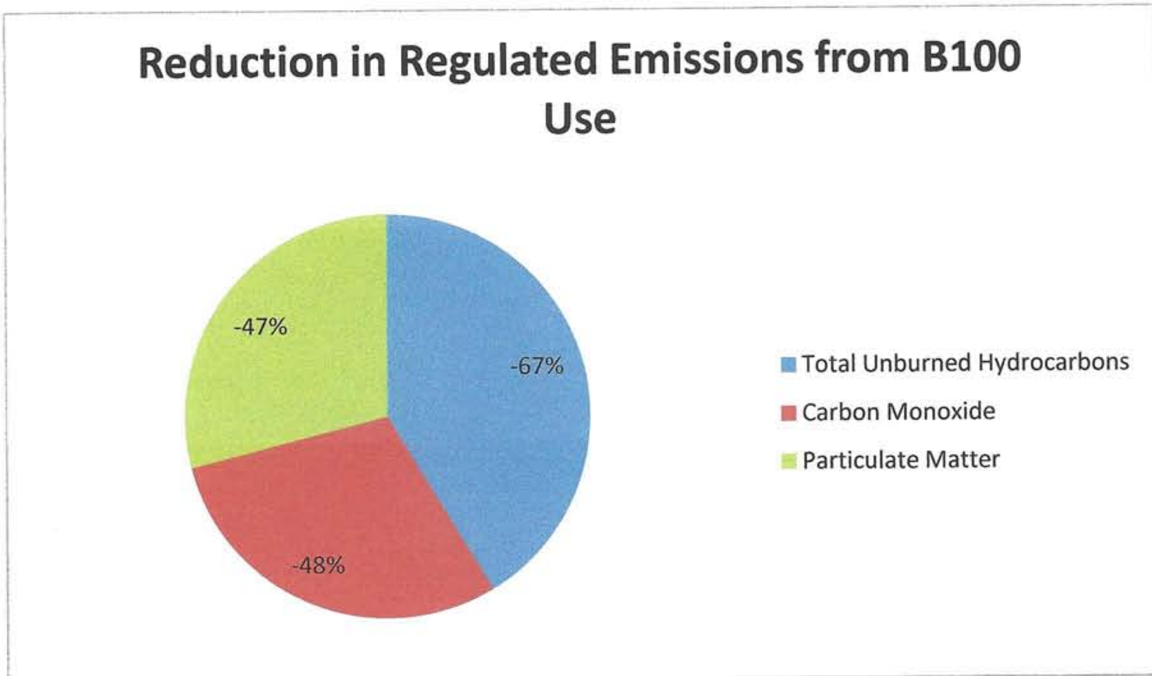
Biodiesel's origins arose out of a desire by American soybean farmers to add value to the surplus oil produced from soybean crushing facilities. REG was born out of one such agricultural cooperative, West Central, in 1996 with the establishment of a 1.3 million gallon a year biodiesel refinery next to a soybean crushing facility. One of REG's core strengths that we've developed over the past several years is our ability to utilize a wide-variety of feedstocks in the production of biodiesel. We now use products ranging from inedible corn oil, tallow, used cooking oil, yellow grease, and even ship waste products from some of our plants to our state-of-the-art refineries to turn them into biodiesel. RFS has been a key driver in incentivizing companies like our own to innovate and expand production. In short, it has been making a clean fuel even cleaner and more abundant.

4. **What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels? Is there evidence of a need for air quality regulations to mitigate any adverse impacts of the RFS?**

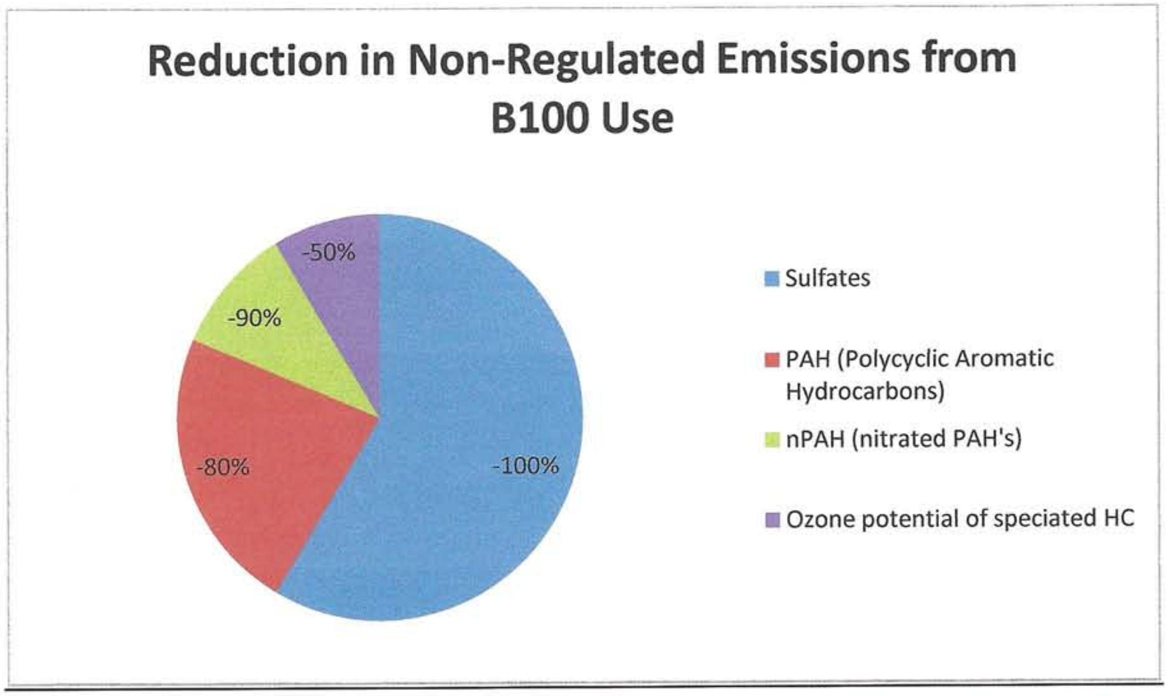
The use of biodiesel results in significant health benefits for Americans by reducing harmful regulated and non-regulated emissions. Specifically, biodiesel use has been cited as an effective method of reducing conventional diesel emissions. As the National Institute of Health notes, "Numerous studies have shown that burning biodiesel compared with petroleum diesel reduces

PM, CO and total hydrocarbons in tailpipe exhausts."[1] The negative health effects that are associated with exposure to these emissions include "increased emergency room visits, reduced lung function, exacerbation of asthma, arrhythmia, hypertension and increased mortality rates."[2] The use of biodiesel also reduces other non-regulated emissions, which have been identified as potential cancer causing compounds.[3]

Data provided by the National Biodiesel Board highlights the air quality benefits of B100 relative to petroleum-based diesel[4]:



[1] NORA TRAVISS, Breathing easier? The known impacts of biodiesel on air quality, U.S. NATIONAL LIBRARY OF MEDICINE, (2012) http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3622266/.
[2] *Id.*
[3] *Id.*
[4] Biodiesel Emissions, NATIONAL BIODIESEL BOARD (Last visited May 21, 2013), http://www.biodiesel.org/docs/ffs-basics/emissions-fact-sheet.pdf?sfvrsn=4.



In addition, biodiesel does not have any special handling requirements. It is less toxic than table salt, biodegrades as quickly as sugar and can also be utilized as a cleaning agent for marine oil spills. In short, the environmental performance of biodiesel is even better than anticipated when RFS was expanded in 2008.

5. **Has implementation of the RFS revealed any environmental challenges or benefits not fully anticipated in the statute?**

Please see response to question #4.

6. **What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?**

Biomass-based diesel is a versatile fuel. It is utilized in on-road fuel, heating oil and a diesel fuel substitute for power production. Each of these applications has a range of common blend rates. It is also important to note that EPA does not place a limit on biodiesel blends into diesel fuel, unlike ethanol into gasoline. As an on-road transportation fuel, it is typically utilized in blends ranging from 5 to 20 percent, mostly in medium and heavy duty trucks. Over 2/3 of engine manufacturers currently certify their engines for B20 including Cummins, Ford Motor Co., General Motors, John Deere and Mack Trucks.[5] In some cases, biodiesel is utilized as a total substitute. For example, New Holland certifies farming equipment to run on B100 blends. [6] On-road fuel marketers have taken note and are incorporating biodiesel into their fuel mix. For example, in Texas, Musket Corporation, an affiliate of Love's Truck Stops, stated that the value of the RINs creates sufficient value to make biodiesel cheaper than clear diesel."[7]

To provide some context into biodiesel's current market penetration, it makes up less than 3% of the on-road diesel market. In other words, biodiesel consumption could more than triple and still have room for growth in on-road diesel fuel markets. Moreover, contrary to gasoline demand, diesel fuel consumption has been increasing in recent years. Some analysts predict that this trend will continue as an attractive compliance option to meet heightened Corporate Average Fuel Economy requirements in future years. These trends do not take into account other growing markets for biodiesel in heating oil and power production markets.

Biodiesel has also been increasingly utilized in heating oil, often referred to as Bioheat™. Heating oil vendors in the Northeast are rapidly adopting biodiesel blending in order to improve the emissions profile of their product. New York City recently enacted a 2% biodiesel mandate in heating oil and other states in the region have established similar mandates. In addition, some power plants utilize biodiesel as a substitute for petroleum-diesel. For example, REG supplies Hawaii Electric Company with biodiesel to generate power to meet local fuel diversification goals. In short, the use of biomass-based diesel has multiple uses and is utilized all over the country at different blend rates with plenty of room for growth from New York to Texas to Hawaii.

7. **What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?**

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[5] Biodiesel Benefits and OEM Positions, NATIONAL BIODIESEL BOARD (last visited May 21, 2013), http://www.biodiesel.org/docs/default-source/ffs-engine_manufacturers/biodiesel-benefits-and-oem-positions.pdf?sfvrsn=4.

[6] *Id.*

[7] Hearing on RIN Fraud: EPA's Efforts to Ensure Market Integrity in the Renewable Fuels Program Before the H. Subcomm. on Oversight and Investigations of the H. Comm. on Energy and Commerce, 112th Cong. 2 (2012) (statement of Jon P Fjeld-Hansen, Managing Director, Musket Corporation).

The Renewable Fuel Standard was designed to accomplish multiple goals – not just to reduce GHG emissions from the transportation sector. The program, however, is the only significant Federal policy the United States has in place in order to address this problem. Moreover, as noted in our response to question #1, these emissions reductions significantly increase as the conventional fuel requirements are reached in 2015 and advanced biofuel requirements, the bulk of the RFS, are implemented. Many observers have suggested there may be more efficient methods to reduce in transportation fuel and are currently discussing and experimenting with policy alternatives. Historically, states have been utilized as policy laboratories to thoroughly vet innovative methods of addressing public policy problems such as transportation sector GHGs before being implemented at the Federal level. Unfortunately, there isn't enough implementation data available right now to determine whether these policy alternatives are better GHG reduction measures.

The biodiesel industry has demonstrated its capability and capacity to meet increasing biomass-based diesel targets beyond the 1.28 billion gallons called for in 2013. REG also looks forward to continuing to work with all stakeholders, public and private, as we move forward with RFS goals and requirements. Please don't hesitate to contact Anthony Hulen (Anthony.Hulen@REGI.com) or myself (Jonathan.Hackett@REGI.com) if you have any questions.

Sincerely,

Jonathan W. Hackett
Director, Federal Affairs & Policy
Renewable Energy Group, Inc.

RENEWABLE FUELS ASSOCIATION

May 24, 2013

The Honorable Fred Upton
Chairman
Committee on Energy and Commerce
U.S. House of Representatives

The Honorable Henry Waxman
Ranking Member
Committee on Energy and Commerce
U.S. House of Representatives

Dear Chairman Upton and Ranking Member Waxman:

The Renewable Fuels Association (RFA) is the national trade association representing the U.S. ethanol industry. The RFA appreciates the opportunity to respond to the questions posed in the third white paper, "Greenhouse Gas Emissions and Other Environmental Impacts," as part of the Committee's review of the Renewable Fuel Standard (RFS).

An important policy objective of the RFS2, as adopted by Congress as part of the Energy Independence & Security Act of 2007, was to reduce greenhouse gas emissions (GHG) and displace petroleum imports with cleaner, renewable fuels. As demonstrated in these comments, the RFS has succeeded in reducing GHG emissions, decreasing other harmful tailpipe pollutants, and displacing crude oil imports with more sustainable renewable transportation fuels.

When assessing the environmental impacts of renewable fuels, it is absolutely imperative to make appropriate comparisons to the impacts associated with the use of petroleum fuels. In other words, it is inappropriate to examine the environmental effects of the RFS without simultaneously examining the effects of *not having the RFS*. It is also important to compare new renewable fuels entering the market to the actual sources of marginal petroleum they are delaying and displacing. In that regard, the questions posed by the Committee appear woefully incomplete. By focusing exclusively on the environmental impacts of ethanol and other biofuels used for the RFS, the Committee is missing the significant environmental and public health consequences of increased petroleum production and use in the absence of ethanol and the RFS. The RFA would respectfully suggest that for a complete understanding of this important program, the following questions should also be asked and answered:

1. **What are the environmental effects of oil exploration, including seismic surveys, drilling and well logging, deployment of marine platforms, and infrastructure development?** Please discuss among other issues the potential environmental effects resulting from disturbing ecologically sensitive areas including wetlands and tundra, loss of natural vegetation, functional habitat loss, reduced populations and densities of birds and animals, perforations in cap rock

formations, air and groundwater contamination from disposal of drill cuttings, structural impacts on marine life, seabird mortality from collision, oiling, incineration by flame, hydrologic alteration through long term surface water mining for ice roads, and decline in aquatic macro invertebrate density and taxonomic diversity due to siltation.

2. **What are the environmental effects of oil extraction, including fracturing, pumping, and additional infrastructure establishment?** Please include a discussion about the potential health and environmental effects associated with chemicals used in fracturing, alteration of groundwater flow and quality, surface and subsurface contamination from improperly abandoned wells, seismic events, bird fatalities in produced water ponds, fires from terrestrial oil spills, loss of saltmarsh vegetation from oil spills, air pollution from flaring, permanent depletion of subsurface deposits of petroleum, loss of wetlands or habitat, species decline, and animal avoidance.
3. **What are the environmental effects of crude oil distribution, including transportation (ocean tanker, rail and/or truck) and pipeline?** Please discuss specifically the potential effects of marine oil spills, aquatic and shoreline biological effects of spills, land clearing for pipeline construction, disturbance of remote areas such as the North Slope tundra and Ecuadorian Amazon, and the biological effects of spills.
4. **What are the environmental effects of gasoline production at the refinery?** Please discuss specifically among other things the potential impacts of air pollution from refining, water pollution, soil pollution, petroleum coke and radioactive solid waste streams due to buildup of naturally occurring radioactive materials.
5. **What are the environmental effects resulting from gasoline distribution, including transportation, pipeline shipment and storage?** Please discuss specifically the air pollution from trucks and rail, gasoline spills, freshwater spills from pipeline ruptures leading to fish kills and species fragmentation, the toxicity of spills to terrestrial plants and soils, evaporative emissions from storage facilities, and leaking of underground storage tanks and associated groundwater contamination.
6. **What are the environmental and public health effects of gasoline use, including fuel blending, fuel dispensing and driving?** Please discuss specifically the potential environmental and health effects of tailpipe pollutants from gasoline combustion, spills and evaporation at retail locations, leaking underground storage tanks and associated groundwater contamination. Also, please discuss specifically the impact on gasoline toxicity, aromatics content generally and the level of benzene, toluene and xylene specifically resulting from reduced ethanol use under a scenario where the RFS didn't exist.
7. **What are the GHG emissions impacts of increased unconventional oil production from Canadian oil sands, tight oil from fracking, thermally enhanced oil recovery, and gasoline production, distribution and use?** Please discuss specifically the direct and indirect emissions, such as land use change and methane releases, resulting from unconventional oil production.
8. **How has the composition of gasoline and resulting emissions changed since 2005?** Please discuss specifically the toxicity, ozone-forming potential and carbon profile of today's marginal

gallon of gasoline (unconventional tight oil and oil sands) relative to the 2005 baseline fuel used by EPA for RFS comparison and compliance.

9. **What are the GHG and other environmental impacts of our dependence on imported oil and the national security implications of that dependence?** Because 40% of our oil imports come from OPEC nations, please address specifically the emissions of the Fifth Fleet that protects international oil shipping lanes from the Persian Gulf, the emissions attributable to the transportation, re-supply and training of ground and air forces staged in the region to keep stability amongst oil producing states, and the GHG emissions attributable to the burning of oil fields and deliberate spills following the Gulf War.

10. **Do current lifecycle analysis tools and models fully capture the environmental and carbon effects of oil exploration, extraction, processing, transportation and combustion?** Please discuss how existing analytical tools can be improved.

Context is important. As Congress assesses the merits of ethanol and the RFS, a clear understanding of the fossil fuels being displaced by ethanol and other renewable fuels is imperative. Changes to the RFS would undoubtedly lead to increased use of marginal petroleum, fuels that have their own distinct environmental, public health and carbon effects.

Below please find RFA's responses to questions set forth by the Committee on environmental impacts.

1. **Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels (a)? Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels (b)? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented (c)?**

    a. *Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels?*

Yes, the RFS is unquestionably reducing GHG emissions today compared to baseline petroleum. As an initial matter, it is important to understand there is a fundamental difference between the carbon cycle of renewable fuels and the carbon cycle of fossil fuels. As highlighted in a recent paper in which scientists from Duke University, Oak Ridge National Laboratory, and the University of Minnesota compared the lifecycle environmental impacts of ethanol and gasoline:

> A critical temporal distinction exists when comparing ethanol and gasoline life-cycles. Oil deposits were established millions of years in the past. *The use of oil transfers into today's atmosphere GHGs that had been sequestered and secured for millennia and would have remained out of Earth's atmosphere if not for human intervention*. While the production and use of bioenergy also releases GHGs, there is an intrinsic difference between the two fuels, for GHG emissions associated with biofuels occur at temporal scales that would occur naturally, with or without human intervention. …Hence, a bioenergy cycle can be managed while maintaining atmospheric conditions similar to those that allowed humans to evolve and thrive on Earth. In contrast, *massive release of fossil fuel carbon*

alters this balance, and the resulting changes to atmospheric concentrations of GHGs will impact Earth's climate for eons. [1] (emphasis added)

Indeed, one of the major benefits of using biofuels is that they essentially *recycle* atmospheric carbon. In the case of corn ethanol, for instance, the amount of CO_2 released when the fuel is combusted in an engine has been previously removed from the atmosphere via photosynthesis during growth of corn plant. Although there may be temporary shifts between atmospheric and terrestrial stocks of carbon within the active carbon cycle, the carbon released into the atmosphere during this process is not "new" carbon being introduced into the earth's carbon cycle. Biogenic carbon emissions then are considered "carbon neutral" based on the feedstock's carbon uptake. For annual crops like corn, this carbon cycle occurs every year with each new harvest.

While CO_2 emissions from fuel ethanol combustion are carbon neutral, there are some GHG emissions associated with the production and distribution of the fuel. These supply chain emissions are the subject of "lifecycle analysis." A recent lifecycle analysis paper by Wang et al. published in the journal *Environmental Research Letters* (Attachment 1) found that corn ethanol produced in the 2008-2012 timeframe reduced GHG emissions by an average of 34% compared to baseline gasoline.[2] Importantly, that figure *includes hypothetical emissions from indirect land use change* (ILUC) for corn ethanol and uses a carbon intensity value for baseline gasoline that is nearly identical to the value used by EPA for the RFS2. If ILUC emissions are excluded from the calculation (i.e., if an equitable comparison of only direct emissions is made), today's average corn ethanol reduces GHG emissions by 44% relative to gasoline, according to Wang et al. (Figure 1).

The results from Wang et al. are consistent with several other independent lifecycle analyses of corn ethanol. For example, Liska et al. (2009) found modern corn ethanol reduces direct GHG emissions by 48-59% compared to gasoline.[3] Meanwhile, a report by O'Connor for the International Energy Agency found 2005-era corn ethanol reduced direct GHG emissions by 39% compared to gasoline, with reductions of up to 55% expected in the near future.[4] Further, the California Air Resources Board (CARB) has certified individual pathways for nearly 30 grain ethanol plants that serve the California market for the state's Low Carbon Fuels Standard (LCFS). The ethanol produced by these plants reduces direct GHGs by an average of 40-45% relative to baseline gasoline, according to CARB.[5] Incidentally, CARB recently reported that ethanol has provided 80% of the GHG emissions reductions required under the LCFS to date.[6]

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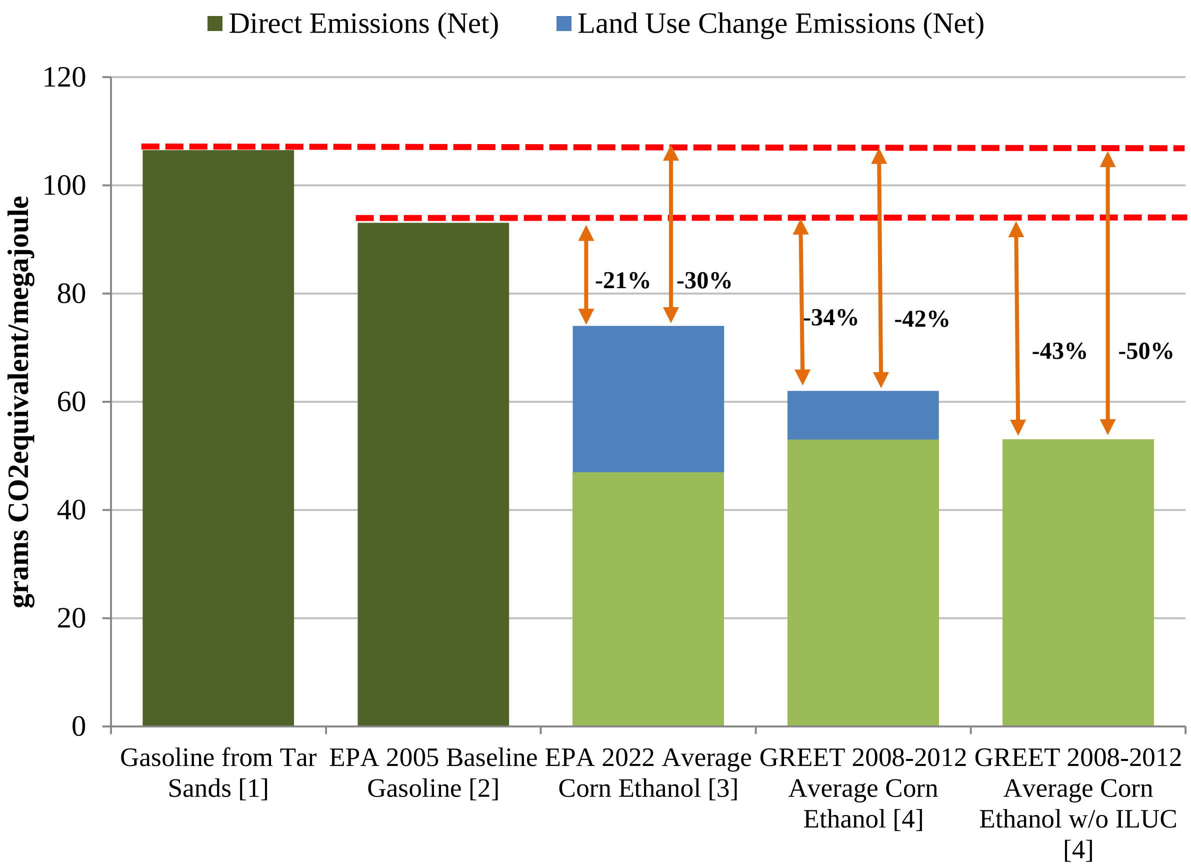
[1] Parish et al. (2012). "Comparing Scales of Environmental Effects from Gasoline and Ethanol Production." *Environmental Management*, 50 (6): 979-1246.
[2] Wang et al. (2012). "Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use." *Environ. Res. Lett*., 7 (2012) 045905 (13pp).
[3] Liska, A.J., H.S. Yang, V.R. Bremer, T.J. Klopfenstein, D.T. Walters, G.E. Erickson, and K.G. Cassman (2009). "Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol." *Journal of Industrial Ecology*. 13(1): 58-74.
[4] O'Connor, D., for International Energy Agency (2009). "An examination of the potential for improving carbon/energy balance of bioethanol." IEA Task 39 Report T39-TR1, 72 pp.
[5] See CARB (2013). "Method 2A-2B Carbon Intensity Applications. " http://www.arb.ca.gov/fuels/lcfs/2a2b/2a-2b-apps.htm
[6] See CARB (2013). "LCFS 2012 Q4 Data Summary." http://www.arb.ca.gov/fuels/lcfs/20130329_q4datasummary.pdf

Figure 1. Lifecycle GHG Emissions: Corn Ethanol and Gasoline



[1] NETL (2009), An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact of Life Cycle Greenhouse Gas Emissions, March 27, 2009, U.S. Department of Energy, DOE/NETL-2009/1362.
[2-3] EPA (2010). RFS2 Final Rule.
[4] Wang et al. (2012). "Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use." *Environ. Res. Lett*., 7 (2012) 045905 (13pp).

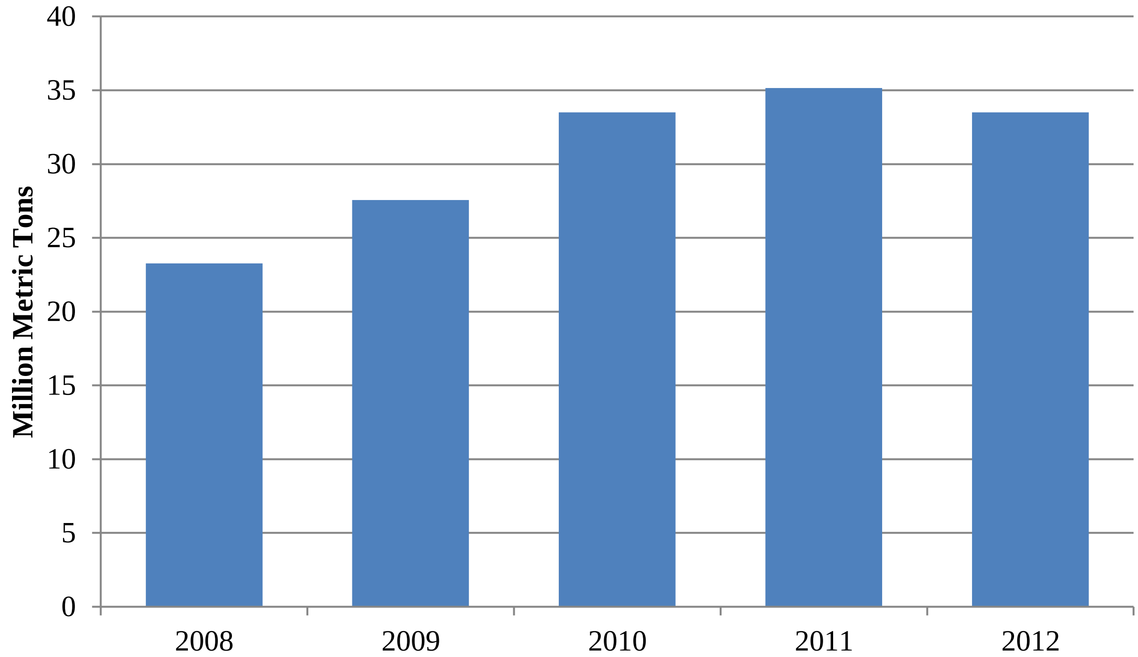
The latest results presented by Wang et al. were obtained from an updated and re-structured version of the Department of Energy's "GREET" model.[7] Recent versions of the GREET model have incorporated updated data and assumptions from the 2008-2010 timeframe regarding emissions related to ethanol plant energy use, grain production, and land conversion. Unfortunately, these updates to the GREET model were conducted shortly after EPA finalized its RFS2 lifecycle analysis, meaning the versions of the GREET model used by the Agency were already obsolete by the time the RFS2 final rule was promulgated.

Based on the lifecycle emissions reported for ethanol and gasoline in the Wang et al. paper, substitution of corn ethanol for gasoline in the 2008-2012 time period has conservatively reduced GHG emissions from the transportation sector by 153 million metric tons of CO_2-equivalent (CO_2e), or an average of 30.6 million metric tons per year (Figure 2). The GHG emissions reduction associated with substituting

[7] **G**reenhouse Gases, **R**egulated **E**missions, and **E**nergy Use in **T**ransportation Model. See http://greet.es.anl.gov/

ethanol for gasoline has been equivalent to removing an average of 6.4 million vehicles from America's roadways annually from 2008 to 2012.[8]

Figure 2. GHG Emissions Reductions From Substituting Ethanol for Gasoline, 2008-2012



Source: Argonne GREET 1 2012 rev2. Corn ethanol emissions = 62 g/MJ (incl. 9 g/MJ ILUC); gasoline emissions = 93 g/MJ. Note ILUC emissions are average values (i.e., variable timing of emissions not considered)

A recent study of 2012-era ethanol and corn production practices by the University of Illinois-Chicago (Attachment 2) reveals additional improvements that would further reduce corn ethanol's lifecycle GHG emissions beyond the levels reported in Wang et al. and shown in Figure 1. The study shows thermal energy use at a typical dry mill ethanol plant has fallen another 9% since 2008, as the amount of ethanol produced per bushel of grain increased 1.4%. Additionally, the study showed increasing adoption of new practices and technologies in the feedstock production phase. Importantly, current energy use by the average ethanol plant is *already* below the levels assumed by EPA for an average plant in 2022.

While the renewable fuels used for RFS compliance today are clearly reducing GHG emissions relative to 2005 baseline petroleum, the comparison to a 2005 petroleum baseline understates the *actual* GHG savings associated with using renewable fuels. As corn ethanol's lifecycle GHG emissions have trended downward over the past decade, the lifecycle GHG emissions associated with petroleum have increased. A 2009 study by DOE's National Energy Technology Laboratory showed that gasoline from tar sands has

[8] Assumes annual average CO_2e. emissions of 4.8 metric tons per light duty vehicle (EPA). See www.epa.gov/cleanenergy/energy-resources/refs.html

lifecycle GHG emissions of 106.4 g CO_2e/megajoule (MJ).[9] This is 14% higher than the lifecycle GHG emissions assumption of 93.1 g/MJ for EPA's 2005 baseline gasoline. Because unconventional crude oil sources like tar sands and tight oil from fracking make up a much larger share of the U.S. crude oil slate today than in 2005, ethanol's true GHG benefits are significantly understated by EPA's analysis. When ethanol is compared directly to the unconventional petroleum sources it is displacing a the margin of today's fuel market, the actual GHG savings are much greater than when ethanol is compared to a static gasoline baseline from eight years ago.

b. *Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels?*

Yes, the RFS is providing the economic incentive and market certainty necessary for development of the next generation of feedstocks and biofuels. Based on various lifecycle analyses, advanced and cellulosic are likely to provide even greater GHG savings than first-generation biofuels. According to Wang et al., for example, cellulosic ethanol derived from feedstocks like switchgrass, corn stover, and miscanthus will reduce GHG emissions by 77-115% compared to gasoline.[10] The first commercial-scale gallons of biofuel from these feedstocks and others are likely to be produced in 2013, while several additional commercial-scale cellulosic biofuel facilities are slated to begin operations in 2014. The RIN credits associated with production and consumption of lower-emitting advanced biofuels have consistently carried superior value to RINs for conventional biofuels, thus providing a strong economic incentive for development and commercialization. Already, 40 companies have submitted petitions to EPA for approval of 42 new and unique renewable fuel production pathways, the majority of which are related to second-generation feedstocks and biofuel technologies.[11] Unfortunately, only 10 of the 42 new pathways have been approved by EPA so far, meaning the uncertain and lengthy petition process is hindering commercialization of new, lower-emitting advanced and cellulosic biofuels.

c. Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?

Yes, GHG emission reductions will be accelerated as the RFS requires increased consumption of advanced and cellulosic biofuels. As described above, GHG emissions reductions associated with the use of corn ethanol have averaged 30.6 million metric tons CO_2e annually over the past five years. EPA conservatively estimates that the annual GHG reductions associated with full implementation of the RFS in 2022 will be on the order of 138 million metric tons CO_2e.

2. Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?

Yes, EPA's lifecycle GHG methodology and key assumptions could be greatly improved. As noted earlier, much of EPA's lifecycle GHG analysis is now obsolete based on the availability of better modeling tools and methodologies, as well as more current and robust data sets. Better methods and data

[9] NETL (2009), An Evaluation of the Extraction, Transport and Refining of Imported Crude Oils and the Impact of Life Cycle Greenhouse Gas Emissions, March 27, 2009, U.S. Department of Energy, DOE/NETL-2009/1362.
[10] Wang et al. (2012). "Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use." *Environ. Res. Lett*., 7 (2012) 045905 (13pp).
[11] See http://www.epa.gov/otaq/fuels/renewablefuels/compliancehelp/rfs2-lca-pathways.htm

are now available for assessment of both hypothetical indirect emissions (e.g., ILUC) as well as direct (supply-chain) emissions. RFA outlined many of the important new developments in corn ethanol lifecycle GHG analysis and ILUC estimation in a letter to former EPA Administrator Lisa Jackson (Attachment 3) dated Nov. 30, 2012 (note that the letter was submitted before the aforementioned study by Wang et al. was made available). The RFA letter demonstrates that improved modeling and better data show that the corn ethanol process is more efficient and producing less GHG emissions *today* than EPA assumed would be in the case *in 2022*.

In the pre-amble for the RFS2 final rule, EPA acknowledged that lifecycle GHG analysis is an evolving science, and that updates to the Agency's analysis would be undertaken as better data and methodologies became available. Further, EPA recognized that technology adoption and efficiency improvements in biofuel production may also necessitate periodic reassessments of the RFS2 lifecycle analysis. For example, EPA wrote that it "…recognizes that as the state of scientific knowledge continues to evolve in this area, the lifecycle GHG assessments for a variety of fuel pathways will continue to change."[12] The Agency further stated that it "…plans to continue to improve upon its [lifecycle] analyses, and will update it in the future as appropriate…"[13] and "…the Agency is also committing to further reassess these determinations and lifecycle estimates."[14] Unfortunately, EPA has so far failed to follow through on its commitment to update its analysis to reflect the most current data and studies, despite the breadth of new information available. This failure has resulted in the ongoing mischaracterization of ethanol's actual GHG impacts.

Additionally, the analysis of indirect GHG emissions remains highly controversial. As the Committee noted in its white paper, there remains a substantial lack of consensus in the scientific and regulatory communities about the proper methodologies, appropriate analytical boundaries, and suitability of model input data for assessment of indirect GHG effects. According to Parish et al. (2012), "…little consensus exists on how to quantify the indirect effects or even on how to determine whether such effects might be positive or negative."[15] Further, retrospective analyses of land use patterns since adoption of the RFS have concluded that there is little or no evidence that the program has induced ILUC.[16]

While predictive ILUC analysis remains highly uncertain and assumption-driven, the methods and data associated with ILUC estimation have somewhat improved since EPA finalized the RFS2. These improvements have resulted in corn ethanol ILUC emissions estimates that are much lower than EPA's estimate for the RFS2. The improved estimates primarily result from better data and enhanced understanding of: the types of land most likely to be converted, the most likely location of predicted conversions, crop yields on newly converted lands, crop yield responses to changes in prices, carbon stocks and emissions from land conversion, the effects of animal feed co-products on land use, and crop switching/cross-commodity effects. New and improved methodologies for accounting for land use

[12] 75 Fed. Reg. 14,765
[13] 75 Fed. Reg. 14,677
[14] *Id*.
[15] Parish et al. (2012). "Comparing Scales of Environmental Effects from Gasoline and Ethanol Production." *Environmental Management*, 50 (6): 979-1246.
[16] See, for example, Oladosu et al. (2011). "Sources of corn for ethanol production in the United States: a decomposition analysis of the empirical data." *Biofuels, Bioprod. Bioref*. 5:640–653 (2011).

emissions over time (i.e., "time accounting") have also been established.[17] EPA's time accounting method was a particularly controversial element of its ILUC analysis.

Important revisions have been made to Purdue University's GTAP model, which was used by EPA to "cross-check" its LUC results from the FASOM/FAPRI framework. Specifically, improvements were made to the model's energy elasticities, treatment of distillers grains, land conversion factors for new cropland, treatment of endogenous yield for cropland pasture, handling of cropland switching, and availability of cropland pasture and CRP. The result of these improvements was a reduction in estimated LUC emissions for corn ethanol from 30 g/MJ to 14.5-18.2 g/MJ.[18] Subsequent work by Purdue researchers lowered corn ethanol LUC emissions further to 12.9-17 g/MJ.[19]

Meanwhile, LUC modeling conducted in 2011 by the International Food Policy Research Institute (IFPRI) for the European Commission estimated corn ethanol LUC emissions at 10 g/MJ.[20] IFPRI utilized the MIRAGE model for this research. In a report released in May 2012, researchers at Argonne National Laboratory and University of Illinois Chicago built upon Purdue's recent GTAP work to develop a Carbon Calculator for Land Use Change from Biofuels Production (CCLUB) that is included in the newest version of the GREET model.[21] The CCLUB estimates corn ethanol LUC emissions at 8-9.1 g/MJ. Most recently, Kim, Dale, and Ong estimated corn ethanol LUC emissions at 3.9-8.6 g/MJ using a new allocation method that more accurately assigns LUC emissions among the various drivers of conversion.[22] Thus, based on newer data and improved methodologies, the independent estimates of corn ethanol LUC produced since the RFS2 was finalized have generally trended in the range of 7-15 g/MJ (Figure 3). This compares to EPA's net LUC emissions estimate for corn ethanol of 28.4 g/MJ. Because the FASOM/FAPRI modeling system used by EPA is not readily available to stakeholders, it is unclear whether these models have been similarly updated to reflect more current data and advanced scientific understanding of LUC.

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[17] See, for example, Kloverpris, J. & Mueller, S. (2012). Baseline time accounting: Considering global land use dynamics when estimating the climate impact of indirect land use change caused by biofuels. *Int J Life Cycle Assess*, online Sep. 11, 2012.

[18] Tyner, W., Taheripour, F., Zhuang, Q., Birur, D., & Baldos, U. (2010). Land Use Changes and Consequent CO2 Emissions due to US Corn Ethanol Production: A Comprehensive Analysis, Final Report. Available at: http://www.transportation.anl.gov/pdfs/MC/625.PDF

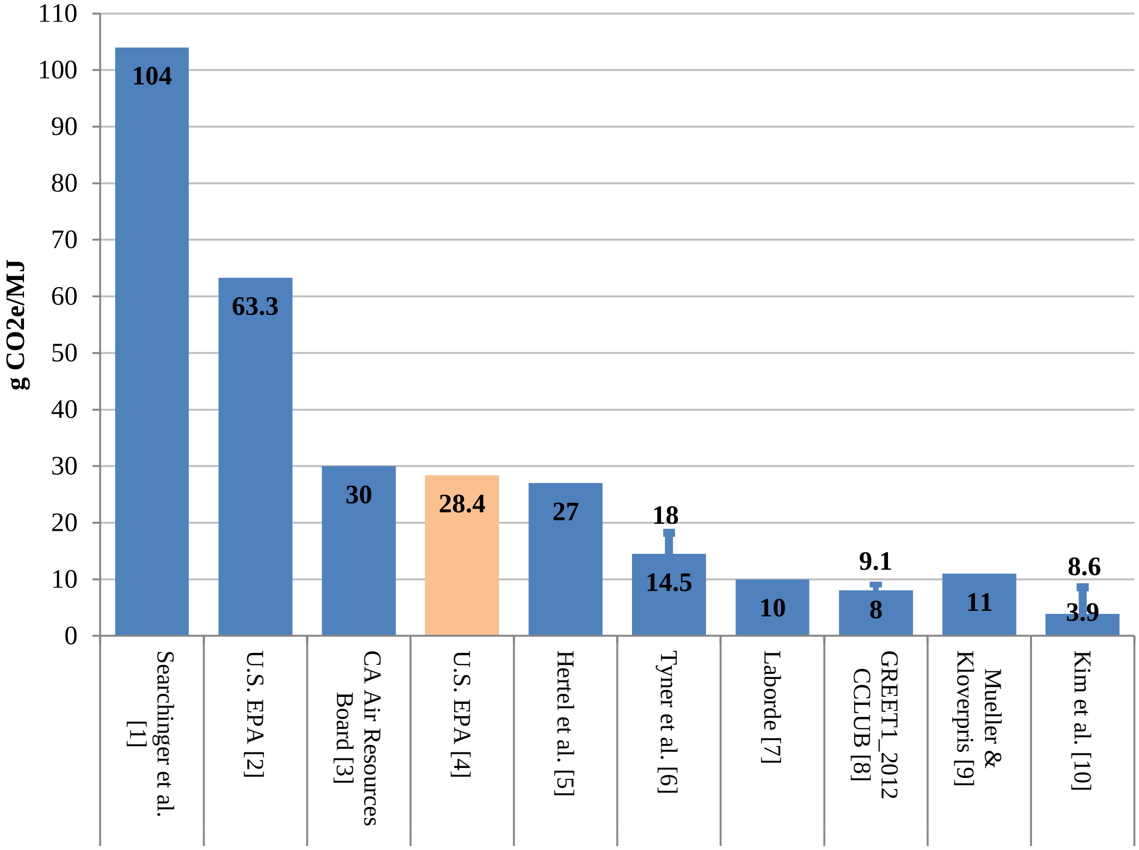
[19] Taheripour, F. & Tyner, W. (2012). Induced land use emissions due to first and second generation biofuels and uncertainty in land use emissions factors. Agricultural & Applied Economics Association's 2012 Annual Meeting, Seattle, Washington, August 12-14, 2012. Available at: http://ageconsearch.umn.edu/bitstream/124407/2/AAEA_2012%20paper-taheripour%20tyner2.pdf

[20] Laborde, D. (2011). Assessing the Land Use Change Consequences of European Biofuel Policies, Final Report. Available at: http://trade.ec.europa.eu/doclib/docs/2011/october/tradoc_148289.pdf

[21] Mueller, S., Dunn, J., & Wang, M. (2012). Carbon Calculator for Land Use Change from Biofuels Production (CCLUB): Users' Manual and Technical Documentation. ANL/ESD/12-5. Available at: http://greet.es.anl.gov/publication-cclub-manual

[22] Kim, S, Dale, B.E., & Ong, R.G. (2012). An alternative approach to indirect land use change: Allocating greenhouse gas effects among different uses of land. *Biomass & Bioenergy, 46*, 447-452.

Figure 3. Corn Ethanol LUC Emissions Estimates, 2008-Present

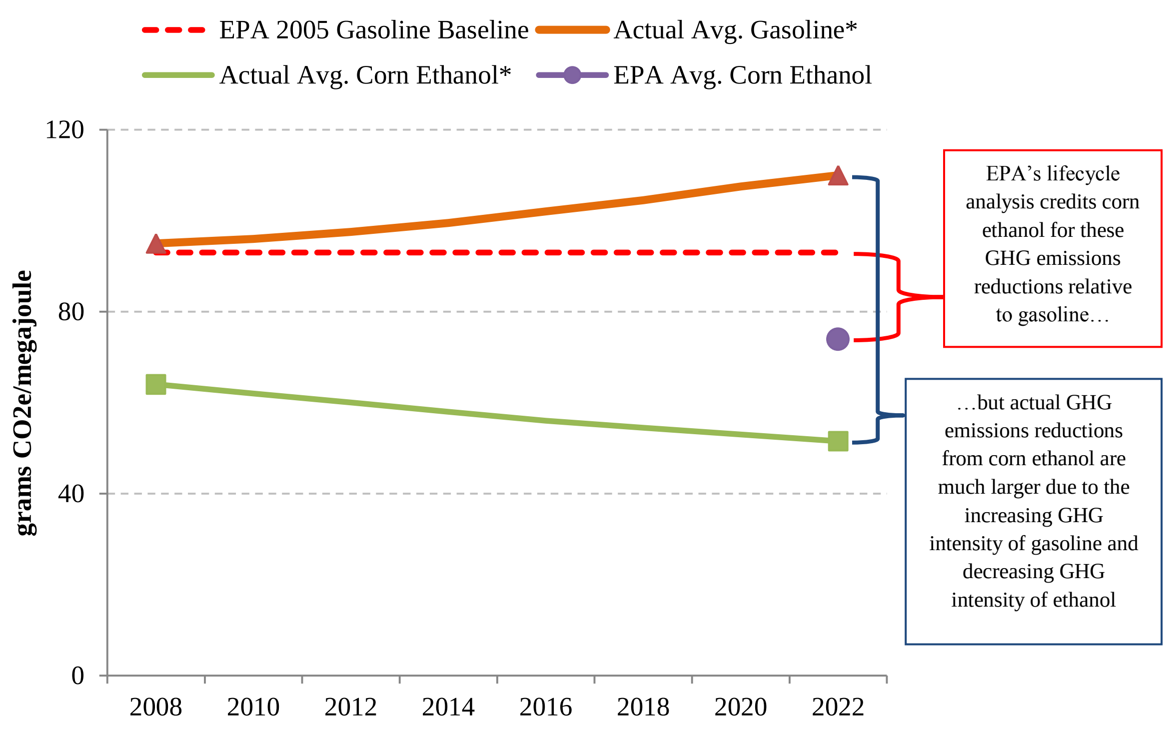


1. Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., & Fabiosa, J.(2008) Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science, 319,* 1238-1240.
2. U.S. EPA (2009). Notice of Proposed Rulemaking: Changes to Renewable Fuel Standard Program
3. California Air Resources Board (2009). California's Low Carbon Fuel Standard, Final Statement of Reasons.
4. U.S. EPA (2010). Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule.
5. Hertel, T.W., Golub, A.A., Jones, A.D., O'Hare, M., Plevin, R.J., & Kammen, D.M. (2010). Effects of US Maize Ethanol on Global Land Use and Greenhouse Gas Emissions: Estimating Market-mediated Responses. *BioScience, 60*, 223-231.
6. Tyner, W., Taheripour, F., Zhuang, Q., Birur, D., & Baldos, U. (2010). Land Use Changes and Consequent CO2 Emissions due to US Corn Ethanol Production: A Comprehensive Analysis, Final Report.
7. Laborde, D. (2011). Assessing the Land Use Change Consequences of European Biofuel Policies, Final Report.
8. Mueller, S., Dunn, J., & Wang, M. (2012). Carbon Calculator for Land Use Change from Biofuels Production (CCLUB): Users' Manual and Technical Documentation. ANL/ESD/12-5.
9. Kloverpris, J. & Mueller, S. (2012). Baseline time accounting: Considering global land use dynamics when estimating the climate impact of indirect land use change caused by biofuels. *Int J Life Cycle Assess,* published online. [Value shown is from Hertel et al., corrected for time accounting]
10. Kim, S, Dale, B.E., & Ong, R.G. (2012). An alternative approach to indirect land use change: Allocating greenhouse gas effects among different uses of land. *Biomass & Bioenergy, 46*, 447-452

Another area of significant concern in EPA's existing lifecycle analysis is the use of a static 2005 petroleum baseline. As indicated earlier, the petroleum used in the U.S. today is far more GHG intensive than the 2005 petroleum slate. Thus, comparing today's biofuels to yesterday's petroleum results in a skewed assessment that misrepresents the actual GHG benefits of using renewable fuels in place of petroleum today. This problem is illustrated in Figure 4. We fully understand EPA is bound by the statute to use a 2005 petroleum baseline as the basis for its lifecycle GHG comparisons; however, we believe it is within EPA's authority to treat avoidance of high-emitting unconventional petroleum sources as an indirect effect of using renewable fuels and assign marginal petroleum GHG "avoidance credits" to the lifecycle analysis results for biofuels. A method for estimating avoidance credits was proposed in a 2009 analysis (Attachment 4) by RFA:

> …substituting biofuels for marginal fossil-based liquid fuels results in the avoidance of significant GHG emissions that are not currently accounted for in lifecycle analysis. These avoided emissions are *in addition to* the emissions reductions relative to average petroleum fuels that are already counted in traditional analysis. In this analysis, avoided emissions resulting from displacement of unconventional liquid fuels range from approximately 8 to 22 grams of CO_2 equivalent per mega joule (g CO_2e/MJ) of energy delivered by biofuels.

Figure 4. A Static Gasoline Baseline Misrepresents Actual GHG Savings from Corn Ethanol



*Actual avg. gasoline and actual avg. ethanol values are illustrative only

EPA's analysis also fails to assign any indirect GHG emissions whatsoever to baseline petroleum; only biofuels are penalized for potential indirect GHG emissions. As a result, EPA's analysis is comparing apples to oranges. Recent research and analysis have underscored that all energy options engender indirect effects.[23] Therefore, if indirect effects are included in the lifecycle assessment for one particular energy source (e.g., ILUC emissions for ethanol), then potential indirect effects also should be included in the assessments for competing energy options (e.g., petroleum). According to a landmark 2009 report by Lifecycle Associates, "…to the extent that economic effects are considered a part of the life cycle analysis of alternative fuels, as is the case with iLUC for biofuels, their effect vis-à-vis petroleum is also of interest."[24] The Lifecycle Associates report identified a number of potential indirect effects associated with petroleum that should be considered in the context of lifecycle analysis. Further, a comprehensive paper by Liska & Perrin (Attachment 5) published in *Environment Magazine* argued that military emissions related to securing and transporting oil from the Persian Gulf region should be included in assessments of petroleum's GHG impacts.[25] Military emissions tied to securing and transporting Persian Gulf oil are in the range of 78 million metric tons CO_2e, the report found. When these emissions are properly attributed to crude oil imported from the Persian Gulf, the lifecycle GHG emissions of gasoline rise by 19% over baseline gasoline. EPA's current analysis ignores these and other important indirect effects related to petroleum consumption.

3. Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?

Yes, the statutory definition of "renewable biomass" and EPA's implementation of the statutory provisions have adequately guarded against adverse environmental consequences. As proven by USDA data, agricultural land use has not expanded as a result of the RFS. The definition should not be modified.

With regard to planted crops and crop residues used as feedstocks for RFS-qualifying renewable fuels, the Energy Independence and Security Act allows only feedstocks from agricultural land cleared or cultivated at any time prior to Dec. 18, 2007 that is either actively managed or fallow, and nonforested. In consultation with USDA, EPA determined that there were 402 million acres of agricultural land under active management or fallow as of Dec. 18, 2007. Thus, the Agency determined if agricultural land use remains below the 2007 "baseline," regulated parties are compliant with the renewable biomass provision. This provision, along with numerous existing conservation and agricultural laws designed to protect sensitive lands, has ensured that agricultural land use has not expanded in response to the RFS. Indeed, agricultural land use since 2007 has been below the baseline every year, demonstrating that farmers have not expanded cropland in response to demand for biofuels under the RFS. In 2012, for example, agricultural land use was determined to be 384 million acres, 18 million acres (4.5%) below the 2007 baseline.[26]

Further, all biofuel producers must submit a renewable biomass report on a quarterly basis to ensure ongoing compliance with the program's requirements. For feedstock s that do not qualify for EPA's "aggregate compliance" determination, quarterly reports must be submitted individually for each separate

[23] See California Air Resources Board LCFS Expert Work Group sub-group report on indirect effects for other fuels: http://www.arb.ca.gov/fuels/lcfs/workgroups/ewg/010511-final-rpt-alternative-modeling.pdf
[24] Unnasch. S., et al. (2009). "Assessment of Life Cycle GHG Emissions Associated with Petroleum Fuels." Life Cycle Associates Report LCA-6004-3P. Prepared for New Fuels Alliance.
[25] Liska, A., & Perrin, R. (2010). "Securing Foreign Oil: A Case for Including Military Operations in the Climate Change Impact of Fuels." *Environment* 52:4, pp. 9–22.
[26] 78 Fed. Reg. 9287.

plot of land from which feedstocks were harvested, and additional electronic files that identify each plot of land by coordinates of the points defining the boundaries of each plot simultaneously submitted.

4. What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels? Is there evidence of a need for air quality regulations to mitigate any adverse impacts of the RFS?

In addition to reducing GHG emissions, the renewable fuels used for compliance with the RFS offer many other environmental benefits relative to petroleum use. In particular, ethanol has long been recognized for its substantial air and water quality benefits relative to gasoline. Unlike gasoline, ethanol is non-toxic and biodegradable.

Ethanol has been used over the past two decades as a gasoline oxygenate to reduce smog formation and low-level ozone pollution in urban areas across the country. Ethanol reduces tailpipe carbon monoxide emissions by as much as 30%, toxics content by 13% (mass) and 21% (potency), and tailpipe fine particulate matter (PM) emissions by 50%. Further, ethanol is the cleanest and most affordable source of octane on the market today, displacing toxic and carcinogenic aromatics such as benzene and toluene.

Ethanol is also rapidly biodegraded in water and soil, and is the safest component found in gasoline today. A study conducted for the Massachusetts Department of Environmental Protection concluded that "…biodegradation [of ethanol] is rapid in soil, groundwater and surface water, with predicted half-lives ranging from 0.1 to 10 days. Ethanol will completely dissolve in water, and once in solution, volatilization and adsorption are not likely to be significant transport pathways in soil/groundwater or surface water."[27]

Moreover, the previously cited study by scientists at Duke University, Oak Ridge National Laboratory, and the University of Minnesota directly compared the lifecycle environmental effects of ethanol and gasoline, taking into consideration a broad range of potential impacts on air, water, land, and human and animal welfare. The authors found that gasoline has significantly more negative impacts on the overall environment than ethanol. Further, the potentially adverse impacts associated with ethanol use are "more easily reversed" and "of a shorter duration" than effects associated with gasoline use. Additionally, the authors found:

> Effects of the gasoline pathway have distinctive spatial extents involving remote and fragile ecosystems, the significant subterranean dimension of disturbances, and the temporal shifting of huge volumes of GHGs from prehistoric times to today's atmosphere. Ethanol expansion has the potential to reduce environmental impacts when compared to current gasoline production and its support systems…[28]

In comparing the overall environmental impacts of gasoline to ethanol, the authors performed an extensive literature search and identified nearly 70 distinct adverse environmental effects related to the gasoline production supply chain (Attachment 6). The temporal duration of many of the identified

[27] http://www.mass.gov/eopss/docs/dfs/emergencyresponse/special-ops/ethanol-spill-impacts-and-response-7-11.pdf
[28] Parish et al. (2012). "Comparing Scales of Environmental Effects from Gasoline and Ethanol Production." *Environmental Management*, 50 (6): 979-1246.

gasoline impacts is *centuries to millennia*, while the geographic scale of several of the impacts is regional to global. By comparison, potential environmental impacts associated with ethanol use were found to be far fewer, of shorter temporal duration, and of a narrower geographic scope.

In regard to air quality regulations, the weight of evidence shows the renewable fuels used for the RFS improve air quality relative to comparable volumes of petroleum-derived fuels. Additionally, both mobile source and stationary source emissions are already tightly regulated by EPA and state regulatory agencies.

5. Has implementation of the RFS revealed any environmental challenges or benefits not fully anticipated in the statute?

We do not believe RFS implementation has revealed any environmental challenges that were not anticipated. The statutory GHG reduction requirements and renewable biomass provisions have effectively safeguarded against adverse environmental impacts. In terms of unanticipated benefits, we believe the GHG reductions resulting from the RFS have been greater and have occurred more quickly than was anticipated by EPA's analysis.

6. What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?

The optimal percentage of ethanol in gasoline has yet not been definitively determined. It will depend on numerous factors, including light duty vehicle engine design, refueling infrastructure certification and compatibility, emissions performance, and other considerations. Recent research conducted by automakers has shown ethanol's unique properties—including its exceptionally high octane content—may be best utilized by modern internal combustion engines at a blend of 20-30%vol. ethanol (E20-E30). A recent paper published by Ford Motor Company (Attachment 7) concludes that one means of meeting new and increasingly rigid CAFE/GHG standards is through the use of direct injection and higher compression ratio engines. Such engines would require a higher octane motor fuel, and the most cost effective octane booster available today is ethanol. According to the Ford paper:

- "The physical properties of ethanol provide important benefits when added to gasoline. Ethanol has both a higher octane rating and a higher heat of vaporization than typical gasoline."
- "Ethanol improves octane ratings when added to gasoline. The RON and AKI of pure ethanol are approximately 109 and 99, respectively, much higher than regular or premium-grade US gasoline."
- "Higher minimum octane ratings for regular-grade fuel would enable higher compression ratios in future vehicles and is an opportunity to provide greater engine efficiency and meet increasingly stringent fuel economy regulations and expectations."
- "…it appears that substantial societal benefits could be obtained by capitalizing on the high octane rating of ethanol through the introduction of higher octane number ethanol–gasoline blends to the US marketplace."

Additionally, if ethanol accounts for most of the renewable fuel used to meet the long-term RFS requirements (as assumed by EPA in its "high ethanol" case in the RFS2 Regulatory Impact Analysis), the average blend rate will need to be in the range of E22-E27. This means the approximate level of ethanol in gasoline needed to comply with the long-term required RFS2 volumes generally coincides with the level of ethanol in gasoline that is thought to be optimal based on initial research by automakers.

7. **What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?**

The RFS is absolutely the best policy option available for further reducing GHG emissions from the transportation sector—but such reductions will only be achieved if the RFS is left intact and investors are assured that there will be a lasting market for renewables. The RFS program has already demonstrated its ability to encourage widespread use of lower-emitting renewable fuels. As discussed above, it is generally believed that the next generation of biofuels from cellulosic feedstocks will further reduce GHG emissions relative to gasoline. Broad commercialization of these cellulosic biofuels likely will not be possible in the absence of the RFS and the market certainty it provides.

* * * * *

Thank you again for the opportunity to comment. If there is any additional information you would like RFA to provide, please do not hesitate to ask.

Sincerely,

Bob Dinneen
President & CEO

Shell Oil Company
Government Relations
1050 K Street, NW, Suite 700,
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202 466 1495

May 24, 2013

Representative Fred Upton
Chairman
Committee on Energy and Commerce
2125 Rayburn House Office Building
Washington, DC 20515

Representative Henry Waxman
Ranking Member
Committee on Energy and Commerce
2125 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Upton and Ranking Member Waxman:

Thank you for the opportunity to comment on the Committee's third white paper concerning the Renewable Fuels Standard (RFS) and its environmental impacts. Below, we provide input on four of the questions asked by the Committee.

1. **Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?**

Answer: The RFS has already encouraged some development of lower greenhouse gas emitting fuels. Indeed, there is now some commercial production. Looking forward, we expect that due to the cellulosic renewable fuel provision of the RFS, which requires a minimum of a 60-percent greenhouse gas emissions reduction relative to gasoline or diesel fuel, this will continue. With sufficient regulatory certainty, Shell intends to continue its efforts to develop commercially available biofuels, particularly drop-in biofuels.

To continue the progress that has already been made, it is critical that investors have confidence in the RFS. Unfortunately, the blend wall has created tremendous uncertainty. As explained in our responses to the Committee's first two white papes, unless it is revised, the RFS will limit supplies of gasoline and diesel fuel for U.S. consumption resulting in severe adverse impacts on consumers and the economy. This uncertainty will continue to slow investment and development rates for cellulosic renewable fuels unless it is addressed. As we've explained in our previous submissions to the Committee, EPA's use of waivers on an annual basis does not provide the certainty needed for continued investment and development in alternative lower greenhouse gas emitting fuels.

2. **Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?**

Answer: At the time EPA promulgated the RFS2 rules, EPA committed to ask for the expert advice of the National Acadamy of Science to evaluate EPA's methodology for calculating greenhouse gas emissions, including indirect land use change. 58 Fed. Reg. 14670, 14677 (March 26, 2010) ("As part of this ongoing effort, we will ask for the expert advice of the National Academy of Sciences, as well as other experts, and incorporate their advice and any updated information we receive into a new assessment of the lifecycle GHG emissions performance of the biofuels being evaluated in this final rule. EPA will request that the National Academy of Sciences evaluate the approach taken in this rule, the underlying science of lifecycle assessment, and in particular indirect land use change, and make recommendations for subsequent lifecycle GHG assessments on this subject. At this time we are estimating this review by the National Academy of Sciences may take up to two years."). We are not aware of any progress on this to date even though EPA made that commttment in 2010.

As part of that evaluation, we believe that the following should be considered:

- EPA should consider ways to simplify their methodology, looking to combine their models, and make them more accessible to the public. At present, EPA's methodology is complicated, with integration of a large number of models.
- EPA's current modelling does not consider the dynamic nature of indirect land use change (iLUC). Imposing high iLUC factors on some biofuels increases the demand on those with low iLUC factors and causes a different type of iLUC. EPA should consider this dynamic for future greenhouse gas emission calculations.
- EPA should expand their models to include evaluations of iLUC from cellulosic biofuels.
- N2O and CH4 emissions from agriculture have a big effect on overall GHG emissions. The GHG emissions inventory including N2O and CH4 emissions, in particular regarding fertiliser inputs/use needs to be improved in EPA's calculations.
- EPA should seek to improve consistency between its models and other models used to calculate lifecycle greenhouse gas emissions. At present, there is a large difference in the way EPA's models handle assumptions on price-yield elasticities for crops compared to other models.
- EPA should improve how land cover is defined in international land use change modelling (in FAPRI). They have a more detailed model for Brazil but other countries are just aggregated together. It is important that they include the correct allowance of regional unused land in these models. The carbon stock database used for calculating carbon losses from the modelled land use changes could also be improved.
- EPA should improve how they handle potential yield improvements and co-products and how they handle crop yields on new land compared to yields on existing land

8. What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?

Answer: At present the vast majority of vehicles and retail infrastructure are only compatible with up to 10-percent ethanol. E15 and E85 are not compatible with most retail fueling station infrastructure in the country. Additionally, E15 and E85 are currently compatible with less than approximately 5-percent of cars on the road. The use of biodiesel is also constrained by vehicle compatibility issues. Most vehicles today are only compatible with up to 5-percent biodiesel. Renewable diesel (i.e., hydro-treated vegetable oil/animal fats) and cellulosic drop-in biofuels, which are also both considered “biomass-based diesel” under the RFS program do not have the same vehicle compatibility issues as biodiesel.

We urge Congress to expand its thinking beyond ethanol and biodiesel. While there are considerable practical problems expanding ethanol and biodiesel use beyond levels that are compatible with vehicles, these are not the only renewable fuels. Congress should also consider that with the right incentives, the prospects for drop-in biofuels -- i.e., gasoline or diesel -- might increase, thus allowing the country to meet its long-term renewable fuel objectives without incurring all of the vehicle and retail infrastructure costs that expanding the use of ethanol or biodiesel imply.

9. What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?

Answer: We believe fuels from biomass, which can deliver greenhouse gas emission savings, and economic and energy security benefits, and that are both affordable and sustainable, play a linchpin role in the long-term future of lower carbon energy systems. The RFS is an important component of such efforts and is a better option than other constructs such as the Low Carbon Fuel Standard adopted in California. However, the RFS must be revised to address the blend wall to align the mandates with vehicle and infrastructure compatibility, and provide the right incentives to provide the substantial investment certainty needed to support cellulosic biofuel development and commercialization.

* * *

In closing, although we generally support the RFS, we continue to strongly advocate for revising it to lower the mandates to levels that are consumable by vehicles on the road today and existing infrastructure. If the RFS is not revised, the blend wall will continue to limit the supply of gasoline and diesel in the U.S., have adverse impacts on consumers and the economy, and undermine the intent of the law, as well as investments in cellulosic biofuels that can deliver substantial greenhouse gas emission reduction benefits.

Sincerely,

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Steptoe
STEPTOE & JOHNSON LLP

May 24, 2013

TO: House Energy and Commerce Committee

FROM: Society of Independent Gasoline Marketers of America

RE: Renewable Fuel Standard Assessment White Paper – Greenhouse Gas Emissions and Other Environmental Impacts

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The Society of Independent Gasoline Marketers of America ("SIGMA") applauds the Energy and Commerce Committee for conducting its review of the Renewable Fuel Standard ("RFS"). SIGMA represents a diverse membership comprised of approximately 260 independent chain retailers and marketers of motor fuel. SIGMA members know first-hand the legal and logistical complexities associated with the RFS, and are pleased to provide answers to the following questions set forth in the Committee's White Paper on the RFS's impacts on greenhouse gas emissions and other environmental issues. SIGMA has provided answers to only those questions that are pertinent to SIGMA members' operations.

#1. *Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?*

As fuel marketers, SIGMA is not qualified to say whether or not the RFS is reducing greenhouse gas emissions below that of baseline petroleum-derived fuels. However, SIGMA is confident that the RFS is at least providing incentives to develop a new generation of lower greenhouse gas ("GHG")-emitting fuels. The success of this effort, however, will depend on the robust development of those advanced biofuels and the fuels' ability to be commercially competitive with petroleum-based fuels and corn-based ethanol. **SIGMA is unaware of the production of commercially viable and economically competitive cellulosic ethanol in the United States at this time.**

Indications are that to be economically competitive with (and displace) corn ethanol and gasoline, cellulosic ethanol must be produced from feedstocks that produce at least 15 tons of dried biomass per acre per year. Feedstocks that have currently been approved as "pathways" under the RFS (such that resulting ethanol generates RINs) are incapable of such high-volume cultivation per acre. If a pathway is granted for new feedstocks that are capable of generating cellulosic ethanol on a basis that is competitive with gasoline and corn ethanol, the cellulosic biofuels provisions will succeed in diversifying the RFS. If such additional pathways are not approved, cellulosic ethanol will not come to market as Congress anticipated when developing the RFS.

#4. *What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels? Is there evidence of a need for air quality regulations to mitigate any adverse impacts of the RFS?*

SIGMA believes that the implementation of the RFS to date has been problematic. Before EPA even considers promulgating additional air quality regulations, it should resolve the following outstanding issues with RFS implementation:

- **RIN Fraud –** SIGMA supports the Committee's examination of the RIN fraud cases and how to manage better the RIN process to limit future fraud. EPA's proposed rule to mitigate RIN fraud[1] does not go far enough to solve this problem. As SIGMA noted in its comments to EPA, unless the proposal is revised substantially, RIN fraud's ripple effects on the overall RIN market will continue largely unabated.
- **Litigation Surrounding the Cellulosic Renewable Volume Obligations –** SIGMA believes the litigation stemming over the appropriate method for EPA to establish the cellulosic RVO is causing substantial market uncertainty and should be resolved.
- **Blend Wall –** Finally, the approaching blend wall—when volume obligations will require blending more than E10 into every gallon of gasoline sold—puts significant stress on the market. (Please refer to SIGMA's April 5, 2013 comments on the Committee's first RFS White Paper for more information on the Blend Wall.)

SIGMA believes the EPA should not issue *additional* regulations before these issues are resolved. SIGMA supports making the current regulatory scheme work well before adding to its complexity.

#6. *What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?*

As fuel marketers, SIGMA supports allowing the market to determine the optimal percentage of biofuel within the transportation fuel mix. And, with ethanol currently the lowest cost octane fuel additive available, it will be blended wherever possible to generate incremental margin for the blender. However, before the market can function adequately, current legal and logistical impediments precluding retailers from introducing ethanol blends above E10 must be addressed. Until those obstacles are removed, we will be unable to know what the market dictates is the "optimal" percentage.

Fuel retailers face three distinct risks associated with expanded use of E-15 or any higher than E10 blend, all of which are addressed in H.R. 1214, the Domestic Fuels Protection Act of 2013. Please see SIGMA's April 5, 2013 White Paper comments.

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[1] 78 Fed. Reg. 12158 (Feb. 21, 2013).

#7. ***<u>What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?</u>***

The answer to these questions relies on cellulosic ethanol's success in the United States. This will likely determine whether the RFS will be an important component of efforts to reduce greenhouse gas emissions from the transportation sector.

The RFS assumes cellulosic ethanol is more environmentally friendly than fossil fuels, and further assumes that it will be commercially available. If cellulosic ethanol is produced on a cost-effective basis, *i.e.*, at a cost that is competitive with corn ethanol and gasoline, cellulosic ethanol has the potential to *displace* corn ethanol and thereby help limit RFS effects on corn prices. Under the RFS, cellulosic RINs can satisfy corn ethanol obligations, but corn ethanol RINs cannot satisfy cellulosic obligations. Thus, if cellulosic ethanol is produced at a price that is equal to or less than corn ethanol, cellulosic ethanol will displace corn ethanol because cellulosic RINs are more valuable. (Indeed, several originators of the RFS intended for this to be the outcome when they developed the program and expanded it in 2007.)

Cellulosic ethanol must be cost competitive with gasoline because otherwise no consumers will purchase it. While the RFS contains a number of affirmative obligations on a number of different parties, the RFS does <u>not</u> require consumers to purchase anything. Therefore, unless cellulosic ethanol can be produced on a cost-effective basis, consumers will not purchase it and it will never displace gasoline.

Indications are that to displace corn ethanol and gasoline, cellulosic ethanol must be produced from feedstocks that produce at least 15 tons of dried biomass per acre per year. Feedstocks that have currently been approved as "pathways" under the RFS (such that resulting ethanol generates RINs) are incapable of such high-volume cultivation per acre. If new feedstocks capable of competing with corn ethanol and gasoline are approved as RFS pathways, the cellulosic biofuels provisions will succeed in diversifying the RFS and presumably reducing overall GHG emissions. If, however, such additional pathways are not approved, cellulosic ethanol will not diversify the RFS because consumers will not purchase it at a price that exceeds those of competing products.

Again, SIGMA appreciates the opportunity to provide these comments and looks forward to working with the Committee as its White Paper process continues.

Respectfully Submitted,

R. Timothy Columbus
David H. Fialkov

Counsel

syngenta

David Morgan
President, Syngenta Seeds, Inc.

11055 Wayzata Boulevard
Minnetonka, MN 55305

May 24, 2013

Subject: **Comments on U.S. House of Representatives Energy and Commerce Committee, Renewable Fuel Standard Assessment White Paper: Greenhouse Gas Emissions and Other Environmental Impacts**

Syngenta is one of the leading agricultural product companies in the world with 26,000 employees in 90 countries. Our broad portfolio of safe and efficient crop protection products helps farmers improve crop yields and health in all stages of plant development. Through modern plant breeding and biotechnology, Syngenta has developed high quality seed varieties that reduce loss from insect pressure and increase tolerance to drought to further boost crop yields. This same expertise was employed to develop corn containing the Enogen trait, a revolutionary technology specifically developed to enhance the productivity and efficiency of converting starch to biofuel. Enogen exemplifies the innovation and technological advancement stimulated by the Renewable Fuel Standard (RFS) that not only enhances ethanol production but also significantly reduces the emission of greenhouse gasses in the process. Please accept the following comments from Syngenta in response to the third House Energy and Commerce white paper on the RFS.

On May 9, the National Oceanic & Atmospheric Administration reported worldwide levels of CO2, the chief greenhouse gas causing global warming, reached 400ppm, an amount never before encountered by humans[1]. The potential effects of increased global warming have been well documented, yet the United States lacks a comprehensive multi-sector policy to reduce greenhouse gas emissions. Since enactment in 2005, the RFS has served as the United States principal legislation to reduce the emission of greenhouse gasses from the transportation sector, which is responsible for 28 percent of the U.S. total, or 1.8 billion metric

[1] CO2 at NOAA's Mauna Loa Observatory reaches new milestone: Tops 400 ppm. http://www.esrl.noaa.gov/gmd/news/7074.html

tons of CO_2[2]. During the past seven years the RFS has been responsible for reducing 205 million metric tons of CO2, the equivalent of taking 39 million cars off the road[3]. If this important policy remains in place and the ultimate target is achieved of replacing 36 billion gallons of fossil with renewable transportation fuels, this cumulative reduction could exceed 900 million metric tons by 2022[4].

In the process of achieving this goal, private and public research labs will continue to invest in the development of new technologies that further enhance the efficiency of conventional biofuels and the realization of second generation advanced and cellulosic biofuels. Such investment in conventional biofuels has resulted in the development of combined heat and power, corn oil separation, cold-cook processing, corn expressed enzymes like Enogen and many others[5]. These advancements will continue to reduce the CO2 emissions of conventional biofuels in comparison to gasoline, which is getting more carbon intense as petroleum requires increasingly more energy to extract from sources such as oil sands.

Stability of the RFS provides incentive for continued investment in the development of advanced and cellulosic biofuels. However, were the RFS repealed, these low carbon fuels would struggle to compete against oil. Therefore, investment in feedstocks as diverse as algae, wood chips, corn stover, switchgrass, camelina, sorghum and corn stover, and the process technology to convert them into biofuels would essentially be lost. Along with that loss is the corresponding reduction in carbon emissions renewable transportation fuels enable.

It is important to note that the RFS is also a key contributor to the success of other policies that will contribute to lowered emissions of CO2 and other transportation related pollutants such as SOx, NOx and particulate matter. These policies include the corporate average fuel economy or CAFE standards, recently finalized by the National Highway and Transportation Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) and the Tier

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2 http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html

3 Renewable Fuels Association calculation

4 Extrapolation using information from Renewable Fuels Association

5 2012 Corn Ethanol: Emerging Plant Energy and Environmental Technologies; Issued April 29, 2013; available at http://www.erc.uic.edu/PDF/mueller/2012_corn_ethanol_draft4_10_2013.pdf

III Standard to reduce sulfur in transportation fuel in development by EPA. Both of these regulations will further reduce CO2 emissions but will require renewable fuels to achieve their goals.

The CAFE standards will result in market year (MY) 2025 light-duty vehicles with nearly double the fuel economy, and approximately one-half of the GHG emissions compared to MY 2010 vehicles[6]. High octane fuels such as ethanol are a critical factor contributing to the development of lighter but higher compression engines by the auto industry. Ethanol blends of 25 to 30 percent are considered optimal for this use and will contribute to meeting the RFS requirements in the same time frame[7]. Likewise, the proposed Tier III emission standard targets the reduction of sulfur in transportation fuels to 10 ppm. Sulfur has been linked to the fouling of automobile catalytic converters that reduce NOx, particulate matter and other pollutants from fossil fuels[8]. Ethanol does not contain sulfur and increased use of this renewable fuel would contribute to the meeting of this important environmental policy goal as well.

In summary, the RFS is not only one of the best options to substantially reduce greenhouse gas emissions from the transportation sector but it also is a critically important component to the development of new technologies and other efforts that will contribute to doing the same. Therefore, Syngenta strongly urges Congress to carefully and fully consider the attendant effects of maintaining the RFS in its present form.

Sincerely,

David Morgan
President, Syngenta Seeds, Inc.

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[6] 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule. Federal Register / Vol.77, No. 199 / Monday, October 15, 2012.

[7] **Tier 3 Vehicle Emission and Fuel Standards Program**, Proposed Rule. http://www.epa.gov/otaq/documents/tier3/tier3-nprm-20130329.pdf

[8] Ibid.

THE COALITION FOR
RENEWABLE
NATURAL GAS

Friday, May 24, 2013

The Honorable Fred Upton
Chairman, House Energy & Commerce Committee
United States House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Upton:

Thank you for the opportunity to offer stakeholder comment regarding Green House Gas Emissions and other environmental considerations of the Renewable Fuel Standard.

The Coalition For Renewable Natural Gas is a 501(c)6 nonprofit organization dedicated to the advancement of renewable natural gas (RNG, or biomethane) as a clean, low-carbon, renewable energy resource for generation of electric power, thermal heat application and transportation fuel purposes.

The Coalition's diverse membership and partner organizations include small businesses, renewable energy developers, engineers, financiers, marketers, transporters, environmental advocates, organized labor, law firms, consumers and utilities.

Given the scope of our membership, we offer comment on only those questions where we have experience as an industry.

Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?

Yes. The RFS is reducing GHG emissions below that of baseline petroleum-derived fuels.

Yes. The RFS is incentivizing the development of a new generation of lower greenhouse gas emitting fuels.

Yes. The RFS is poised to produce further GHG reductions when fully implemented.

Let us explain.

▶ www.RNGcoalition.com ▶ 916-520-4764
▶ 1017 L Street, #513 Sacramento, CA 95814

The term Renewable Natural Gas (RNG) refers to pipeline quality biogas that has been scrubbed from its raw form and possesses properties similar to fossil natural gas. Whereas fossil natural gas ranges at 80%-95% methane, RNG is typically 95-97% methane.[1] When combusted as a transportation fuel, RNG achieves a significant reduction in lifecycle GHG emissions due to the predominate cellulosic nature of its feedstock.[2]

The most common sources for collection of biogas are landfills, waste water treatment plants, and dairy waste digesters. Landfill gas is most commonly conditioned to RNG because the quantity of gas that can be collected is typically much greater, thereby making the expense of building the conditioning plant more feasible. EPA regulations currently require municipal solid waste landfills designed to collect at least 2.5 million megagrams (Mg) and 2.5 million cubic meters of waste and emitting at least 50 Mg of non-methane organic compounds per year to capture and control their biogas.[3] Absent a productive and financially viable use, these larger landfills combust their biogas in a flare, converting the methane to CO2.

State Renewable Portfolio Standards for electricity generation have created some market demand for RNG. Thus, electricity has historically been the preferred productive use of renewable natural gas. In 2010, 29% of methane generated at landfills was flared and 29% was used in electricity generation.[4]

With EISA's adoption in 2007, the RNG industry began looking toward transportation fuels as a potential driver to increased collection and productive use of leaked or flared biogas. Regulations on RFS Pathways are still being developed[5], but as they solidify our Members have and are continuing to increase dedication of their time, attention, and resources towards developing ultra-low carbon transportation fuel.

It is no secret that the shale gas plays throughout the country have flooded the U.S. with a domestic supply of fossil natural gas. Ultimately, we believe this reality, coupled with the implementation of RFS2, has the potential to help bridge a transition to increased utilization of renewable natural gas. Regardless of the origin of natural gas (renewable or fossil), the method of utilization as a transportation fuel is through a compression (CNG) or liquefaction (LNG) of gas. Cheep natural gas prices in the market are causing companies and local governments to

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[1] Renewable Gas - Vision for a Sustainable Gas Network: A paper by National Grid (2010).

[2] Barlaz, M.A., R.K. Ham, and D.M. Schaefer. 1989. Mass-balance analysis of anaerobically decomposed refuse. Journal of Environmental Engineering, 15(6) 1088-1102.

[3] Standards of Performance for New Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills, 61 FR 9905, 9944 (March 12, 1996).

[4] Environmental Protection Agency. 2012. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010, Annex 3: Methodological Descriptions for Additional Source or Sink Categories.

[5] U.S. EPA released its Notice of Proposed Rulemaking on 05/20/2013. Docket No. EPA-HQ-OAR-2012-0410.

convert their diesel fleets to clean natural gas vehicles. With that, fueling infrastructure is being installed throughout the U.S. at unprecedented speed. Several of our Members have developed fleet specific fueling stations. Clean Energy Fuels, an RNG Coalition Member, has developed a network of public LNG fueling stations along major trucking routes.[6]

Unfortunately, these same low natural gas prices also create barriers to development of renewable natural gas projects. The financing of a multi-million dollar collection and conditioning RNG plant does not balance on $4 natural gas prices alone. And as our Chairman, Evan Williams of Cambrian Energy, often reminds us, “the secret formula to developing an RNG project is rather simple: Revenues Must Exceed Expenditures, Predictably.”

With EISA, Congress made a policy decision (and we believe a very good one) that renewable, ultra-low carbon fuels are important to the economic, environmental and security interests of the United States and should be incentivized. RFS2 creates a market based system of RINs that, when fully implemented, can meet these goals.

Predictability and stabilization of RFS2 is essential to success. When our members seek financing to develop a new project for transportation fuel purposes, one of the first thing they hear are questions about the long term viability of the RFS. The longer track record the RFS has as an established, bedrock policy, the better it will work.

The Coalition For Renewable Natural Gas is supportive of the EPA’s continuing RFS2 rule making process, especially as they make technical and clarifying refinements to reflect the original intent of the policy. Beyond their actions, the best thing that could be done for the program to work effectively, to meet the goals of GHG emission reductions, would be to lock in the program long term and thereby create future predictability for the market.

What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?

Yes, RFS is vital to reducing GHG emissions from the transportation sector. Renewable Natural Gas has a lifecycle carbon footprint lower than any vehicle fuel commercially available today.[7] The fleet conversation and building of fueling infrastructure is happening as a natural outflow of fossil natural gas supply. With a stable RIN premium under RFS2, renewable natural gas projects can meet the economics necessary for development and ultimately displace fossil natural gas or significant qualities of high-GHG polluting vehicle fuels with clean, ultra-low carbon renewable natural gas.[8]

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[6] Clean Energy Fuels, America’s Natural Gas Highway, http://www.cleanenergyfuels.com/pdf/CE-OS.ANGH.012412.pdf.

[7] CARB: Low Carbon Fuel Standard Report 2009. http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

[8] Renewable Natural Gas (RNG): The solution to a Major Transportation Challenge, Energy Vision (2012) http://energy-vision.org/wordpress/wp- content/uploads/2012/05/EV-RNG-Facts-and-Case-Studies.pdf

Thank you again for receiving stakeholder comments. We appreciate the opportunity to participate in this process.

Sincerely,

//dc//

David Cox
Director
Coalition For Renewable Natural Gas

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

May 24, 2013

The Honorable Fred Upton
Chairman
Committee on Energy and Commerce
United States House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515

The Honorable Henry Waxman
Ranking Member
Committee on Energy and Commerce
United States House of Representatives
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Washington, DC 20515

Dear Chairman Upton and Ranking Member Waxman:

Thank you for the opportunity to share our views on the future of the Renewable Fuels Standard (RFS) as part of your white paper series. The Union of Concerned Scientists (UCS), the nation's leading science-based nonprofit putting rigorous, independent science to work to solve our planet's most pressing problems, is working to cut our nation's oil consumption in half over the next 20 years[1], and better biofuels are an important part of that plan.

1. ***Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels? Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?***

   The implementation of the RFS to date has had at best a limited positive impact on greenhouse gas (GHG) emissions for two reasons. First, the conventional biofuels the RFS has brought to market at higher volumes have primarily been food-based biofuels such as corn ethanol and biodiesel made from soybean oil. These offer limited direct GHG benefits, and when their indirect impact on the US and global agricultural system is considered, the benefits are further reduced. Second, because the availability of corn and vegetable oil to make these fuels is limited, the opportunity to expand the use of these resources to a much larger scale is also limited. Moreover, the consequences of diverting an ever larger share of agricultural output to energy markets has serious negative impacts on both food markets, on agricultural expansion and deforestation, and this limits the GHG benefits we can obtain from these fuels.

   By contrast, cellulosic biofuels, made from biomass, can achieve very large GHG reductions on a per gallon basis. Also, because biomass resources are large and largely underutilized, cellulosic fuels have the potential to scale up to tens of billions of gallons with putting undo pressure on US agriculture (see our report on Biomass Resources in the United States[2]). The combination of

[1] See the UCS Half the Oil plan, at halftheoil.org.
[2] Union of Concerned Scientists (UCS). 2012. Biomass Resource Assessment. Online at http://www.ucsusa.org/assets/documents/clean_vehicles/Biomass-Resource-Assessment.pdf

low carbon intensity and opportunity for scale are the reason that cellulosic biofuels are the largest GHG opportunity in the RFS. However, deploying this technology is obviously more challenging than increasing the use of conventional technologies like grain or sugar ethanol or biodiesel made from oils and fats. It will take longer than 2022 to reach the 16 billion gallons of cellulosic biofuels originally called for in the RFS, and thus it will also take longer to realize the full GHG benefits of the RFS. But the RFS was smart to shift beyond an early scale up of food based fuels to a major focus on biomass based fuels in the second half of the program.

The level of incentive or technology forcing the RFS has for cellulosic biofuels is limited, with a cost cap allowing obligated parties to comply using paper credits sold at a predetermined rate ($0.78/gal-RIN in 2012), and mandate levels set each year based on projected capacity for the coming year. This provides a concrete financial incentive to potential investors in cellulosic biofuel production facilities, but it is not a very large incentive relative to the scale of investment required. The difficulty cellulosic companies have had raising money in the stock market over the last couple years, and the fact that oil companies have backed out of previously announced[3] projects demonstrates that the RFS is not "technology forcing" so much as providing an assurance that any cellulosic fuel that does get produced will be purchased at predictable and reasonable prices. That said, it is our feeling that the framework of the RFS, including a system of categories, scientific lifecycle analysis of different fuels and a tracking system for each gallon of biofuel are an extremely valuable framework that additional policies can build upon. We have laid out several ideas for how this can work in our report, "The Billion Gallon Challenge."[4]

2. *Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?*

We submitted comments[5] to EPA together with several other groups on their proposal back in 2010 before the RFS2 was finalized. There are many good elements to the EPA lifecycle analyses, and several we objected to then and continue to object to.

Lifecycle elements we especially support:

- Comprehensive consideration of emissions from fuel production, including emissions from agriculture associated with feedstock production.

[3] Elgin, B and P. Waldman. Chevron defies California on carbon emissions. *Bloomberg*, April 18, 2013. Online at http://www.bloomberg.com/news/2013-04-18/chevron-defies-california-on-carbon-emissions.html and B. Lefebvre. BP ends plans for U.S. cellulosic-ethanol plant. *Wall Street Journal*, October 25, 2012. On;ine at http://online.wsj.com/article/SB10001424052970204076204578078972049166166.html

[4] Union of Concerned Scientists (UCS). 2010. The Billion Gallon Challenge. Online at http://www.ucsusa.org/assets/documents/clean_vehicles/The-Billion-Gallon-Challenge.pdf

[5] Environmental Community Comments. 2009. Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Extension of Comment Period Online at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2005-0161-2129

- The inclusion of a thorough analysis of indirect land use changes (ILUC) caused by competition of biofuels production for feedstocks previously used for food and other markets.

Lifecycle analysis elements we object to:

- The overly broad favorable treatment of secondary products and pseudo wastes such as animal fats used to make biodiesel.

- The decision to based ILUC analysis on projections to 2022, rather than a more immediate timeframe.

Opportunities for additional lifecycle analysis that should be conducted by EPA:

- Analysis of the indirect GHG (and food competition) implications of incremental volume adjustments to the mandates beyond what was studied in the analysis for the 2010 final rule.

3. ***Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?***

The definition of renewable biomass in the RFS provides an important assurance that policy will not inadvertently support expansion of unsustainable and counterproductive demand for agricultural and forest products. For more details on our position on renewable biomass definitions, see our principles for sustainable bioenergy[6]. While the existing biomass definitions are by no means perfect, we will continue to work with the agency to ensure proper implementation of these protections. We are not advocating for any legislative changes to the biomass definitions in the RFS at this time, and would oppose efforts to weaken them.

4. ***What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels? Is there evidence of a need for air quality regulations to mitigate any adverse impacts of the RFS?***

We have no specific analysis to contribute on this point.

5. ***Has implementation of the RFS revealed any environmental challenges or benefits not fully anticipated in the statute?***

The implementation of the RFS has brought into much clearer focus the implications of biofuels policy for food policy worldwide. Policy driven demand for biofuels is now a top-line concern in global agricultural markets, rather than a footnote. The recent FAO-OECD Ag Outlook

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[6] Union of Concerned Scientists. 2007. Principles for Bioenergy Development. Online at http://www.ucsusa.org/assets/documents/clean_energy/ucs-bioenergy-principles.pdf.

highlights that decisions EPA has to make on seemingly obscure RFS implementation decisions will be major drivers for some of the world's largest commodities (corn, sugar, vegetable oil)[7]. Making sure these decisions are based on a sound analysis of these implications is the focus of our recent comments[8] to EPA on the 2013 volume rule, and we anticipate continued engagement along these lines going forward.

The impact of the RFS implementation on water quality has also become increasing apparent as the water pollution caused by larger acreage of corn and the water pollution benefits of perennial bioenergy crops like switchgrass and miscanthus illustrate the importance of moving from corn based biofuels to cellulosic biofuels. These issues are discussed in our report "The Energy-Water Collision: Corn Ethanol's Threat to Water Resources[9]".

6. ***What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?***

This is an important question which is not yet been definitively settled. At the present time our vehicle and fueling infrastructure make E10 convenient, but the cars we will be driving in 2035 have not yet been designed, and the gas stations at which we will power these cars will all be substantially renovated if not replaced in that timeframe, so there is no reason to assume that what is optimal today is optimal going forward.

There are at least five distinct pathways through which additional biofuel could enter the marketplace, and each has pros and cons.

- Higher penetration of Flex Fuelled Vehicles (FFVs). This option provides an important flexibility that allows biofuel use to expand and contract in response to relative prices of substitutes in both food and fuels markets. We can learn from Brazil in this regard. In response to poor sugar harvests and relatively low domestic gasoline prices, Brazil was able to dramatically reduce the share of ethanol in its fuel mix over the last few years, but retains the capacity to rapidly shift back to ethanol as sugar harvests improve and sugar prices drop.

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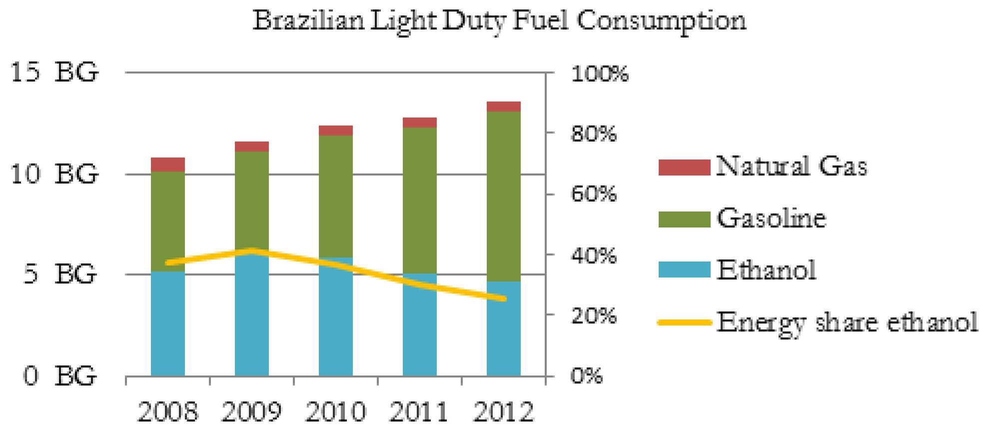
[7] Organization for Economic Co-operation and Development (OECD) and Food and Agriculture Organization of the United Nations (FAO) Agricultural Outlook 2012-2021. 2012a. Increased productivity and a more sustainable food system will improve global food security. Online at http://www.oecd.org/site/oecd-faoagriculturaloutlook/.
[8] Union of Concerned Scientists. 2013. Comments to EPA's Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards. Online at, http://www.ucsusa.org/assets/documents/clean_vehicles/UCS-Comments-on-RFS-2013-Volumes.pdf
[9] Union of Concerned Scientists. 2011. The Energy-Water Collision: Corn Ethanol's Threat to Water Resources. Online at http://www.ucsusa.org/assets/documents/clean_energy/ew3/corn-ethanol-and-water-quality.pdf



Data source: UNICA[10]; BG = billions of gallons

While definitive analysis is lacking, it is not unreasonable to speculate that if a significant share of US ethanol consumption was consumed through FFVs, the market would have had more flexibility to reallocate reduced corn stocks in light of the drought that dramatically reduced corn availability in 2012/13. For additional information, see the comments we submitted to EPA on their draft guidance on E85 FFV weighting factor[11].

- Use of mid-level ethanol blends in specially tuned engines. There are potential vehicle efficiency gains that are enabled by marketing ethanol at specific midlevel blends for vehicles that are optimized to take advantages of its properties. In theory, using ethanol in this fashion would provide more miles per gallon of ethanol than using ethanol in FFVs that must be designed to operate with a broad range of fuel blends. However, moving forward with the technology requires careful coordination of the deployment of the vehicle technology, the fueling infrastructure, and the capacity of the agricultural system to deliver sufficient ethanol to meet these higher level blends without putting undo pressure on other users of the crops or leading to damaging changes in land use, such as accelerating deforestation in the tropics. To the extent that ethanol was used primarily in these specially optimized engines, the demand for ethanol would lack the flexibility available in the FFV scenario described above.

- Alternative blending components such as butanol. Technology exists to substantially increase the blending rates of biofuel in today's infrastructure using other alcohols like butanol. Because butanol has both a lower oxygen content per gallon, and a higher energy density than ethanol, more than twice as much butanol could be blended into a

[10] Uniao Da Industria De Cana-De-Acucar. 2013. Online at http://www.unica.com.br/.

[11] Union of Concerned Scientists. 2013. Comments to "Draft Guidance for E85 Flexible Fuel Vehicle Weighting Factor for Model Years 2016-2019 Vehicles Under the Light-duty Greenhouse Gas Emissions Program" 78 Fed. Reg. 56 (March 22, 2013) [EPA–HQ– OAR–2013–0120]Online at http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0120-0005

fixed volume of gasoline (on an ethanol equivalent basis) than ethanol. This has the potential to push out the blend-wall significantly.

- Biodiesel and bio-based diesel fuel is constrained primarily by the availability of feedstocks, and for this reason the opportunity to use much more than is currently used is limited by the available feedstocks rather than by production or blending capacity. Most biodiesel is made from food grade vegetable oil, and the supply of these oils is quite limited. Our analysis, described more fully in the comments we submitted to EPA during the last rulemaking process,[12] suggests that even if US biodiesel is made from US soybean oil, it will not primarily affect production of US soybeans (the demand for which depends on soy meal rather than oil) but will indirectly lead to expanded production of palm oil in Southeast Asia. Palm oil is driving deforestation and is a major source of GHG emissions (see our recent report on the role of vegetable oils on deforestation[13]). A small share of biodiesel is made from waste oils, and if recovery of waste oils increases, it may be sensible to support the use of more biodiesel. The potential to expand use of other potential feedstocks, such as inedible oils and animal fats, is constrained by competing uses as animal feed, soaps, detergent, and other chemicals.

- Drop-in cellulosic biofuels. Over the longer term the capacity to use abundant and environmentally friendly cellulosic feedstocks to make replacements for gasoline, diesel or jet fuel may render the blending questions above less relevant. In theory these fuels offer the best of both worlds, with the lowest carbon feedstocks producing fuels compatible with current infrastructure, but it is too early to judge the winner of the competition between long established pathways to ethanol and more novel pathways to other fuel molecules.

The design of the RFS currently allows each of the pathways described above to compete to satisfy the mandates. Bio-based diesel fuels can satisfy either the advanced or conventional mandate. Drop-ins cellulosic fuels can compete with cellulosic ethanol to satisfy the cellulosic mandate. In present market conditions the RIN values provide a clear incentive that the various pathways above can compete for. If it turns out the economic incentive required to sell E85 is higher than the price premium for butanol, the market will support an expansion of butanol at the expense of E85. But these technologies cannot be scaled up overnight, and this competition will take at least 5-10 years to play out. Administering the RFS in a manner that provides that stability and allows for the gradual expansion of biofuels markets consistent with availability of underlying agricultural commodities and the

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[12] Union of Concerned Scientists. 2013. Comments to EPA's Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards. Online at http://www.ucsusa.org/assets/documents/clean_vehicles/UCS-Comments-on-RFS-2013-Volumes.pdf

[13] Union of Concerned Scientists. 2012. Recipes for success: solutions for deforestation-free vegetable oils. Online at http://www.ucsusa.org/assets/documents/global_warming/Recipes-for-Success.pdf

constraints of US vehicle and fueling infrastructure will therefore foster the most productive outcome.

7. ***What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?***

We have articulated our vision in this regard in our Half the Oil plan – it is a combination of efficiency, in our vehicles and fleets, and innovation, with advanced vehicle and fuel technologies[14]. A smart implementation of the RFS is key to the success of these efforts, together with additional policies aimed at accelerating the commercialization of cellulosic biofuels.

The RFS has already had a profound impact on global agricultural markets, and failure to administer the RFS in a prudent manner going forward will cause additional problems. Fortunately EPA has the flexibility they need to reduce the impact going forward, as we describe in detail in our comments on the 2013 volume rulemaking.[15]

Additional policies could speed the realization of the goals of the RFS. For example, support for investment in the first billion gallons of cellulosic biofuel production capacity through an investment tax credit would allow cellulosic production to reach the 16 billion target sooner. Establishing a performance based tax credit that uses the RFS tracking system and analysis but rewards GHG reductions beyond those required in the RFS could reduce the GHG emissions of all fuels produced under the RFS. Both of these proposals are described in more detail in our report, "The Billion Gallon Challenge."[16]

Again, thank you for the opportunity to share our analysis on the RFS. On behalf of UCS's more than 400,000 supporters, and network of more than 23,000 scientists, engineers and public health professionals, we urge you to maintain and support policies that support cellulosic biofuels and other oil saving solutions.

Regards,

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[14] See the UCS Half the Oil plan, at halftheoil.org.

[15] Union of Concerned Scientists. 2013. Comments to EPA's Regulation of Fuels and Fuel Additives: 2013 Renewable Fuel Standards. Online at, http://www.ucsusa.org/assets/documents/clean_vehicles/UCS-Comments-on-RFS-2013-Volumes.pdf

[16] Union of Concerned Scientists (UCS). 2010. The Billion Gallon Challenge. Online at http://www.ucsusa.org/assets/documents/clean_vehicles/The-Billion-Gallon-Challenge.pdf

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#2. Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?

A key consideration within EPA's methodology for calculating GHG emissions would be to assess how approved or petitioned feedstocks impact U.S. ecological regions. To increase the availability of feedstocks to be used under the RFS and minimize feedstock invasiveness potential, EPA should include both an invasiveness analysis of feedstocks, and an approval of feedstocks based upon ecological region analysis. In prior regulatory rulings, EPA has summarily dismissed invasiveness concerns regarding some potential feedstocks on the basis that the feedstocks did not appear on either state or national noxious weeds lists (78 Fed. Reg. 14201 (March 5, 2013)). Unfortunately, EPA's reliance upon state and federal lists is largely misguided, as shown through empirical analysis by researchers out of the University of Illinois' Energy Biosciences Institute (Quinn et al. 2013, McCubbins et al. 2013). The analysis emphasized that states largely fail to add invasive plant species to their regulated plant lists (Quinn et al. 2013, McCubbins et al. 2013). Therefore, EPA dismissal of biofuel feedstock invasiveness potential by a faulty reliance upon state and federal lists creates the possibility that invasive feedstocks would be approved for biofuel pathways under the RFS. By including invasiveness analysis within the lifecycle GHG assessment, EPA would be able to minimize negative impacts potential feedstocks would have on ecosystems and obtain more accurate assessments.

Plant invasiveness in one area, however, does not necessarily implicate invasiveness in another. For example, *Arundo donax* (commonly known as giant reed) has received much attention as a potential biofuel feedstock with excellent agronomic traits. However, *A. donax* is considered invasive or noxious within some states. As a result, EPA's current regulatory approval process for *A. donax* has been suspended. In January 2012, EPA issued a direct final rule to approve *A. donax* as an approved biofuel pathway to generate RINs to meet RFS mandates. (77 Fed. Reg. 700) However, objections, (Lewis et al. 2012) some of which included the invasiveness of *A. donax* and EPA's failure to consider the implications of E.O. 13112, forced EPA to withdraw the plant species from consideration at this time. (77 Fed. Reg. 13009) EPA approval or disapproval of feedstocks based upon whether a plant species is invasive in some areas generates unnecessarily broad overregulation. The U.S. is not ecologically homogenous. (Omernik 2004, Omernik et al. 2000) A more nuanced analysis of lifecycle GHGs could incorporates ecoregional evaluations where EPA assesses feedstock invasiveness within the ecoregions of proposed development. As a result, lifecycle GHG analyses will be more accurate. The concept of applying different regulatory standards for dissimilar U.S. regions is already contemplated under the Clean Air Act. (See 42 U.S.C. § 7407) Congress should implement statutory language that authorizes EPA to improve lifecycle GHG analysis by assessing feedstock invasiveness within ecoregions. This authority would introduce increased flexibility into the biofuel pathway approval process, while at the same time, reduce environmental group concerns about increased ecological and economic impacts posed by feedstocks with invasiveness potential (Lewis et al. 2012).

CITATIONS:

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#3. Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?

The definition of renewable biomass currently protects against undesirable land-use change, but is inadequate to protect against other unintended environmental consequences. One of these is the potential for invasion by non-native biomass crops. It has been pointed out that several non-native biomass crops pose a high risk of invasion outside of cultivation (Barney and DiTomaso 2008, Glaser and Glick 2012, Gordon et al. 2011, Gordon et al. 2012, Quinn et al. 2010, Raghu et al. 2006). An improved definition would include language similar to that in Executive Order 13112, which is intended to prevent the invasion of non-native species. Accordingly, a modified RFS definition of renewable biomass would stipulate that feedstocks must be native to or noninvasive in the ecosystem of introduction. Unfortunately, definitions of "invasive" vary in common scientific parlance (Colautti and MacIsaac 2004, Richardson et al. 2000, Valéry et al. 2008), and tend to be vague in related legal statutes. Therefore, in a modified definition, it should be further stipulated that "invasive" refers to those species that cause, or have the potential to cause, a net negative impact on the ecosystem surrounding the area of introduction.

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#5. Has implementation of the RFS revealed any environmental challenges or benefits not fully anticipated in the statute?

One environmental challenge not fully anticipated in the statute is that of potential invasiveness of bioenergy feedstocks. Invasive species can cause major damage to natural ecosystems (Simberloff 2005), and cost the US economy billions to manage each year (Pimentel et al. 2005). While the EPA's First Triennial Report to Congress concluded that invasiveness was of limited concern for the feedstocks in the report, new feedstocks will be continually developed by the industry, driven by a desire to market products that can promise the highest possible yield. Several feedstocks under consideration are non-native to their target ecosystem, and are known invaders in our country and around the world. These include *Arundo donax*, *Eucalyptus* spp., *Miscanthus* spp, *Pennisetum purpureum*, *Phalaris arundinaca*, and others. For example, fertile *Miscanthus* species have escaped from ornamental cultivation in a large area of the Eastern US, in some cases forming extensive monospecific stands (Quinn et al. 2010). This provides an example of a worst-case scenario for deployment of novel fertile feedstocks. Sterility does not guarantee containment, however, as many plants can reproduce asexually. *Arundo donax*, a sterile species, is a major invader in riparian systems throughout California, Texas, and other warm coastal regions (Dudley 2000, Spencer et al. 2008). This species not only competes with and excludes native vegetation (Quinn et al. 2007), it reduces habitat availability for endangered fauna (Bell 1997). Because adequate regulations protecting natural areas from invasive species do not exist in most states (McCubbins et al. 2013, Quinn et al. 2013), it is important that this protection should be built in to the revised RFS. As argued in #3 above, we believe it would be useful to modify the definition of renewable biomass to include a clause that stipulates a feedstock should be native or noninvasive in the target ecosystem. And as pointed out here, sterility should not be considered an adequate proxy for non-invasiveness.

The original RFS, in overlooking the invasive species issue, also created a challenge for commercial entities that wish to develop and commercialize novel biomass crops. The petition process for evaluation of new renewable fuel pathways does not include language relating to invasiveness, and therefore the backlash against approval of *Arundo donax* as a new feedstock (Dorminey 2013, Foster 2012) could not have been anticipated or avoided by Chemtex Group. To avoid this in the future, there needs to be greater awareness of this issue as part of the approval process for new fuel pathways. Modifying the definition of renewable biomass in a revised RFS, as suggested above and in #3, should accomplish this goal.

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URBAN **AIR** INITIATIVE INC.

A KANSAS NOT-FOR-PROFIT CORPORATION

May 24, 2013

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Dear Chairman Upton and Ranking Member Waxman:

Urban Air Initiative Inc. (UAI) respectfully submits its responses to the U.S. House of Representatives Committee on Energy and Commerce's White Paper Series on the Renewable Fuel Standard Questions for Stakeholder Comment. We are submitting our responses to Paper 3 released on May 9, 2013: Greenhouse Gas Emissions and Other Environmental Impacts.

UAI serves as an educational resource on urban air pollution and health problems caused by toxic emissions from motor vehicles. Supporters of UAI include alternative fuels producers, elected officials, medical experts, and anyone concerned about the harmful health effects caused by poor quality gasoline.

Please contact me at 316-927-4230 or via email at UrbanAirInitiative@gmail.com if you have questions.

Thank you for the opportunity to respond.

Sincerely,

Gregory P. Krissek, Director

Energy and Commerce Committee, RENEWABLE FUEL STANDARD ASSESSMENT WHITE PAPER, [Blend Wall/Fuel Compatibility Issues], Questions for Stakeholder Comment

1. ***Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels? Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels?***

Urban Air Initiative responds to these two questions with an emphatic "yes." Contrary to what ethanol's detractors have claimed, even first-generation ethanol has a much smaller carbon footprint than baseline petroleum-derived fuels. In addition, ethanol's carbon benefits will grow substantially as its next-generation technology improvements are compared to the next generation of tar sands, oil shale, and fracking technologies.

The link referenced below is a recent essay published in the Physicians for Social Responsibility newsletter[1] which makes two important arguments: 1) an acre of corn, even after the starch portion of the grain is converted to nearly 500 gallons of "Clean Octane" ethanol,[2] yields the same amount of animal protein as does an acre of soybeans; and 2) an acre of corn—which is a highly efficient C4 crop compared to less efficient C3 crops—is a major carbon sink, rather than a carbon source, and makes the soil more fertile, more resistant to drought, and a more efficient user of water and nutrients. http://www.psr.org/environment-and-health/environmental-health-policy-institute/responses/corn-based-ethanol.html

Additional support for corn's role as a major carbon sink and contributor to increased soil organic matter (SOM) comes from recent USDA multi-year studies which were conducted and peer-reviewed by credible academic institutions. (**Attachment A** contains a spreadsheet listing the various studies and their findings. The Soil Organic Carbon sequestration data was assembled by Ron Alverson, Corn Producer, Chairman of Lake Area Corn Processors LLC, and President of the American Coalition for Ethanol).

As illustrated by the data, corn acres using minimum and no-till cultivation practices—which are used on more than 70% of U.S. corn acreage and increasing rapidly—have been shown to rebuild SOM--and sequester carbon--even better than switch grass, which has been highly touted as a sustainable feedstock for cellulosic ethanol production. Unfortunately, EPA and CARB modeling has thus far neglected to consider the deep root structure benefits of corn, and thus under-predicts corn's carbon sequestration benefits by 60–100%.

[1] Authored by Lt. Col. William C. Holmberg (USMC, ret.), American Council on Renewable Energy (ACORE)

[2] It may be useful to define two terms we use throughout the rest of this discussion. UAI uses the term "Clean Octane" to describe octane-boosting components (such as ethanol) that do not include carcinogenic aromatic compounds derived from crude oil. Conversely, we use the term "Dirty Octane" to describe the octane-boosting compounds known as aromatics, which refiners synthesize from crude oil, and which are the most toxic, carbon intensive, and expensive portion of gasoline. In the U.S., an average gallon of gasoline contains approximately 20–25% aromatics.

2. ***Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?***

Yes. See the response to Question 1 above. We believe that EPA should conduct a thorough reassessment of the assumptions that were used five or more years ago concerning shifts in land use patterns and crop productivity trends. Most importantly, we urge the EPA to incorporate the new science that proves corn's ability to sequester carbon and restore SOM and vitality.

3. ***Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?***

Urban Air Initiative does not have additional information to respond to this question.

4. ***What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels? Is there evidence of a need for air quality regulations to mitigate any adverse impacts of the RFS?***

UAI respectfully objects to the Committee's use of the word "mitigate" in question 4: "...to mitigate any adverse impacts of the RFS." We believe use of the word 'mitigate' in this context suggests that the Committee has already pre-determined that the increased use of ethanol is worse for the environment, "relative to a comparable volume of petroleum-derived fuels."

Last year, when EPA denied the petition to waive the RFS, the agency explained how petroleum refiners are taking advantage of ethanol's excellent octane properties to produce finished motor gasoline at the terminal, and reduce carcinogenic gasoline aromatics in the process.[3] EPA noted that "over the past 10 years, the economics of blending ethanol into gasoline have been such that many refiners have transitioned from producing primarily finished gasoline to producing primarily blendstocks for oxygenate blending (BOBs) which require the addition of ethanol in order to meet the specifications of finished gasoline." Later, EPA asserted that "Morgan Stanley argues that there would be significant impediments from moving away from ethanol because it is widely available and is the least expensive source of octane/oxygenates for most refineries." The good news is that the nationwide use of E10 as an octane booster has established a solid foundation for advancing to the next level as an octane-boosting transportation fuel. It is imperative to consider splash-blending higher volumes of ethanol in addition to the E10 base fuel to produce high quality performance E30+ blends to accommodate for the advanced engine technologies that will soon be dominating the U.S. light duty vehicle (LDV) fleet.

Upon request, Urban Air Initiative would be pleased to submit various peer-reviewed auto industry and health effects studies that have shown how higher levels of ethanol use—such as E30 blends (30% ethanol)—can substantially reduce the most potent pollutants. These criteria pollutants include NOx and fine and ultrafine particulate matter and the highly carcinogenic toxics that coat them (e.g., the polycyclic aromatic hydrocarbons, PAHs, which are hazardous air pollutants ["air toxics"]). Numerous experts have confirmed that E30 blends reduce particulate matter (PM), particulate number (PN), and black carbon (a climate change agent many times

[3] "Notice of Decision Regarding Requests for a Waiver of the Renewable Fuels Standard", EPA, Federal Register/Vol.77, No. 228, November 27, 2012, 70759 – 70760.

more powerful than carbon dioxide) by 45–80% or more in both direct injection and port fuel injection engines. Other studies warn that unless EPA improves gasoline composition by reducing aromatic concentrations (which Congress directed it to do in the 1990 Clean Air Act Amendments), particle-borne PAH emissions will increase as advanced engine technologies like direct injection (DI) dominate the light duty vehicle fleet in order to meet stricter fuel economy standards in coming years.

On May 16, 2013, the Wild Earth Guardians sued EPA for its failure to properly control urban PM2.5 levels in Salt Lake City, Utah, where more than 50% of the particulates originate from motor vehicles. Urban Air Initiative believes that EPA's failure to act on enforcing the control of urban PM2.5 levels is that its models substantially under-predict the secondary organic aerosol (SOA) formation that originates primarily from gasoline aromatics, something that EPA publicly admitted more than seven years ago.

The attached study titled, "Combustion efficiency and engine out emissions of a spark-ignition engine fueled with alcohol/gasoline blends," by M.A. Costagliola et al, is labeled as **Attachment B**. This study explains the relative toxicity of the PAHs compared to other air toxics such as acetaldehydes. EPA's draft Tier 3 rulemaking acknowledges that PAHs are potent MSATs, and that PAH emissions have been increasing in recent years due to increased gasoline use. In addition to their ubiquitous presence in urban air sheds, the increased deposition of PAHs in the nation's waterways is an increasingly serious problem. Inexplicably, however, EPA's models continue to exclude PAHs, even though these compounds are thousands of times more toxic than acetaldehydes.

5. ***Has implementation of the RFS revealed any environmental challenges or benefits not fully anticipated in the statute?***

Urban Air Initiative does not have additional information to respond to this question.

6. ***What is the optimal percentage of ethanol in gasoline?***

Increasingly, automakers such as Mercedes Benz are recommending the widespread use of E30 blends to provide Clean Octane for higher compression, more efficient, and cleaner burning engines of the future. [See May 3, 2013 *New York Times* article by Matt Wald, "Squeezing more out of ethanol".] http://www.nytimes.com/2013/05/05/automobiles/squeezing-more-from-ethanol.html

Many experts believe that the E30 blend range represents the "sweet spot" for ethanol's superior octane properties. Multiple performance studies conclude that E30 provides optimum octane boost, avoids most of the energy density penalties of E85, and ensures substantial reductions in a wide range of harmful emissions. As E30 blends become widely available, ethanol's inherent high-octane rating will allow automakers to optimize their engines by increasing compression ratios to levels not possible with standard gasoline blends, thereby avoiding any mileage loss due to ethanol's energy content.

The 2012 Costagliola et al study cited in Attachment B and the 2012 Maricq/Ford et al. study cited in **Attachment C** elaborate on the many performance and emissions benefits of E30.

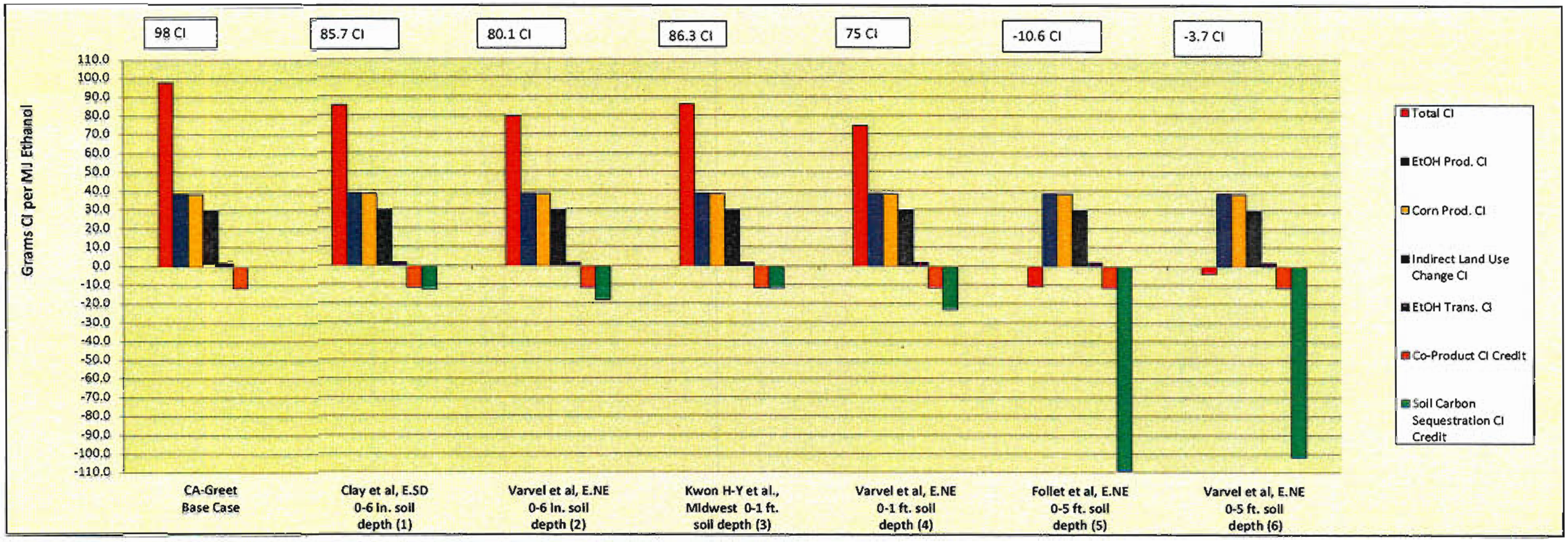
In addition, E30 blends would also save motorists at the fuel pump, since ethanol is an octane provider that costs much less than energy-intensive aromatics, which only get more expensive as crude oil costs increase.

7. ***What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector?***

As public comments submitted by UAI to both the Greenhouse Gas (GHG)–Corporate Average Fuel Economy (CAFE) and PM2.5 rulemaking dockets made clear, gasoline aromatics are not only the most toxic and expensive gasoline components, they are also the most carbon intensive. By replacing the "dirty octane" elements that are in aromatics with "clean octane" in E30+ blends, the U.S. transportation sector would achieve substantially more GHG emission reductions, and these carbon benefits would grow over time as the much more carbon intensive tar sands and oil shale crude feedstocks increase their market share. Coupled with the new science referred to in Question 1 that proves corn's substantial ability to sequester carbon, E30+ blends offer one of the most cost effective, commercially available, and environmentally safe ways to reduce gasoline's carbon footprint in the near- to mid-term.

The Effect of Soil Organic Carbon Sequestration Credits on Corn Ethanol Life Cycle CI (Carbon Intensity)

(A comparison of calculated credits from 6 recent midwest SOC sequestration studies, with the California GREET Model Base Case Carbon Intensity)



(1) https://www.agronomy.org/publications/aj/abstracts/104/3/763
(2) http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1224&context=usdaarsfacpub&sei-redir=1&referer=http%3A%2F%2Fwww.google.com%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3Dsoil%2520carbon%2520levels%2520in%2520irrigated%2520western%2520corn%2520belt%2520rotations%26source%3Dweb%26cd%3D1%26sqi%3D2%26ved%3D0CDQQFjAA%26url%3Dhttp%253A%252F%252Fdigitalcommons.unl.edu%252Fcgi%252Fviewcontent.cgi%253Farticle%253D1224%2526context%253Dusdaarsfacpub%26ei%3DSV5rUcTaH-eBygHF14GQAg%26usg%3DAFQjCNGZtydWf7_gWzem0MO39gOayo_dUw#search=%22soil%20carbon%20levels%20irrigated%20western%20corn%20belt%20rotations%22
(3) http://www.sciencedirect.com/science/article/pii/S0961953413000950
(4) https://www.soils.org/publications/sssaj/abstracts/74/3/915?access=0&view=pdf
(5) http://link.springer.com/article/10.1007%2Fs12155-012-9198-y#page-1
(6) http://digitalcommons.unl.edu/agronomyfacpub/591/

Chart notes of explanation:

Starting on the left side of the chart, the first set of bars are the corn EtOH life cycle emissions calculated using the default values from the California GREET model. Note that total Carbon Intensity is 98. The 98 is a total of the next 6 bars in the group. - 1) emissions from EtOH production at the plants, 2) emissions from corn production on farms, 3) emissions from Indirect Land Use Change, 4) emissions from EtOH transportation and distribution, 5) emissions credits for co-products, and 6) emission credits for soil carbon sequestration. Each succeeding set of bars is described by the footnote and shows the same exact emissions for ethanol production, corn production, ILUC, EtOH transportation and distribution, co-product credits, and the variable (soil carbon sequestration credits) found in that study. So, the only variable is the credit for soil carbon sequestration. I thought it would be helpful to show where all the sources of emissions are from on the chart, but perhaps that adds unnecessary information? Anyway, you will undoubtedly notice that studies that only quantified soil carbon sequestration in topsoils, reduce CI significantly (10-15%) and those that tested full soil profiles resulted in dramatic reductions in CI.

Ron Alverson

Corn Yields and No-Tillage Affects Carbon Sequestration and Carbon Footprints

David E. Clay,* Jiyul Chang, Sharon A. Clay, James Stone, Ronald H. Gelderman, Gregg C. Carlson, Kurtis Reitsma, Marcus Jones, Larry Janssen, and Thomas Schumacher

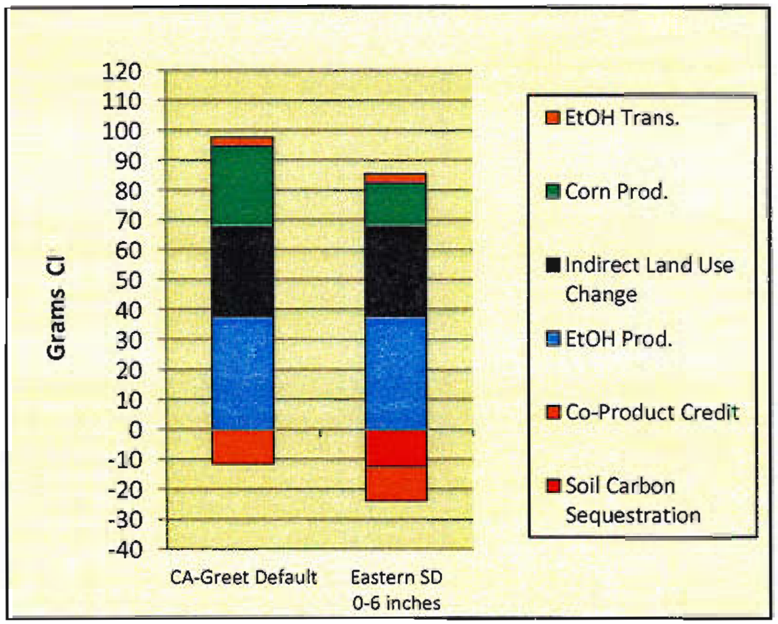
Published in Agronomy Journal, Volume 104 issue 3, 2012

Table 4. The influence of sampling region and the short-term sequestered C rates on partial C footprints for the 2004 to 2007 and 2008 to 2010 time periods - from South Dakota State University soil test lab database - 0-6 inch soil sampling depth

S.D. Region	2004 to 2007 Sequestered Carbon kg SOC/ha/yr	2004 to 2007 Partial Carbon Footprint g CO2eq/Mj	2008 to 2010 Sequestered Carbon kg SOC/ha/yr	2008 to 2010 Partial Carbon Footprint g CO2eq/Mj		2004 to 2007 Estimated Ethanol Value Increase @ $38/Mg Carbon Credit $/gallon	2008 to 2010 Estimated Ethanol Value Increase @ $38/Mg Carbon Credit $/gallon
North Central	229	-14.9	412	-19.6	-16.9143	$ 0.045	$ 0.060
Central	69	-5.1	329	-14.8	-9.25714	$ 0.016	$ 0.045
Northeast	182	-8.9	231	-12.0	-10.2057	$ 0.027	$ 0.036
East-central	125	-6.3	264	-11.4	-8.49143	$ 0.019	$ 0.035
Southeast	266	-14.9	454	-19.2	-16.7429	$ 0.045	$ 0.058
					-12.3223		

Table 4 from page 769

Carbon footprint values reported as negative numbers in this study to represent a CI reduction



Soil Organic Carbon Levels in Irrigated Western Corn Belt Rotations

G.E. Varvel and W.W. Wilhelm
Published in Agronomy Journal, 100:1180–1184 (2008).

Change in SOC (1991-2005) in the 0-15 cm topsoil

(@ 200 kg/ha Nitrogen application rate (corn))

Tillage system = Disk 2X

Site had been in irrigated continuous corn for more than 10 yrs prior

	14 Year increase in SOC Mg/ha	Annual increase in SOC Mg/ha	Annual increase in SOC lb/ac	1991 Organic Matter %	2008 Organic Matter %	Corn Ethanol Annual Carbon Intensity Reduction gCO2eq/Mj	Estimated Corn Ethanol Value Increase (@ $38/Mg) $/gal
Continuous Corn	6	0.429	382	1.54%	2.00%	17.9	$ 0.054
Corn - Soy	3.5	0.250	223	1.54%	1.81%	10.4	$ 0.032
Continuous Soy	1.8	0.129	115	1.54%	1.68%	5.4	$ 0.016

From figure 1 on page 1183

Modeling state-level soil carbon emission factors under various scenarios for direct land use change associated with United States biofuel feedstock production

Ho-Young Kwon, Steffen Mueller, Jennifer B. Dunn, Michelle M. Wander

Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, W-503 Turner Hall, MC-047, 1102 South Goodwin Avenue, Urbana, IL 61801; United States Energy Resources Center, University of Illinois at Chicago, 1309 South Halsted Street, 2nd Floor, Chicago, IL 60607; United States Center for Transportation Research, Argonne National Laboratory, 9700 South Cass Avenue, Building 362, Argonne, IL 60439, United States
Accepted 15 February 2013

Projected Soil C Emission Factors (Sequestration rates in Mg C ha yr in 0-30 cm soil depth)
Cropland conversion to corn for bioenergy production in 11 corn belt states
Figure 3. page 9

Scenario	Practice	Soil C Emission Factors Mg C ha yr	Soil C Emission Factors Lbs C ac yr	Corn Ethanol Annual Carbon Intensity Reduction gCO2eq/Mj	Estimated Corn Ethanol Value Increase (@ $38/Mg) $/gal
	No till Corn - 30% stover harvest	-0.25	-223	10.4	$ 0.032
Baseline	**Reduced till corn - 30% stover harvest**	-0.18	-161	7.5	$ 0.023
2010	**Conventional till corn - 30% stover harvest**	-0.1	-89	4.2	$ 0.013
current	**No till Corn - zero stover harvest**	-0.36	-321	15.0	$ 0.046
conditions	**Reduced till corn - zero stover harvest**	-0.28	-250	11.7	$ 0.036
	Conventional till corn - zero stover harvest	-0.25	-223	10.4	$ 0.032
	No till Corn - 30% stover harvest	-0.49	-437	20.5	$ 0.062
Yield-up	**Reduced till corn - 30% stover harvest**	-0.4	-357	16.7	$ 0.051
2040	**Conventional till corn - 30% stover harvest**	-0.36	-321	15.0	$ 0.046
Future	**No till Corn - zero stover harvest**	-0.64	-571	26.7	$ 0.081
trendline	**Reduced till corn - zero stover harvest**	-0.56	-500	23.4	$ 0.071
yields	**Conventional till corn - zero stover harvest**	-0.51	-455	21.3	$ 0.065
	No till Corn - 30% stover harvest	-0.16	-143	6.7	$ 0.020
Decay-up	**Reduced till corn - 30% stover harvest**	-0.11	-98	4.6	$ 0.014
(increased	**Conventional till corn - 30% stover harvest**	-0.04	-36	1.7	$ 0.005
cultivation &	**No till Corn - zero stover harvest**	-0.28	-250	11.7	$ 0.036
fertilization)	**Reduced till corn - zero stover harvest**	-0.21	-187	8.8	$ 0.027
	Conventional till corn - zero stover harvest	-0.14	-125	5.8	$ 0.018
	No till Corn - 30% stover harvest	-0.37	-330	15.5	$ 0.047
	Reduced till corn - 30% stover harvest	-0.28	-250	11.7	$ 0.036
Yield-up	**Conventional till corn - 30% stover harvest**	-0.25	-223	10.4	$ 0.032
Decay-up	**No till Corn - zero stover harvest**	-0.5	-446	20.9	$ 0.064
	Reduced till corn - zero stover harvest	-0.4	-357	16.7	$ 0.051
	Conventional till corn - zero stover harvest	-0.35	-312	14.6	$ 0.044

Negative factors indicate Soil C sequestration
Positive factors indicate Soil C emissions

Long-term Soil Organic Carbon as Affected by Tillage and Cropping System

G.E. Varvel, W.W. Wilhelm

Published in the Soil Science Society of America Journal: Volume 74: Number 3 • May–June 2010

Table 4. Change in soil organic C concentrations from 1989 to 2004 in the 0 to 7.5, 7.5 to 15, and the 15 to 30 cm depths as affected by five tillage treatments in plots in the first three replications planted to corn at the Rogers Memorial Farm near Lincoln, NE.

Continuous corn portion of study

Tillage	Change in SOC (1989-2004) 0-7.5 cm	7.5-15 cm	15-30 cm	Total Increase SOC	Annual Increase	Corn Ethanol Carbon Intensity Reduction	Estimated Ethanol Value Increase @ $38/Mg
	---- g C kg ----			Lbs/Ac.	Lbs/Ac.	gCO2eq/Mj	$/gallon
Chisel	2.24	1.24	1.3	6,080	405	19	$ 0.058
Disc	3.38	1.3	1.12	6,920	461	22	$ 0.066
Plow	0.33	0.47	1.43	3,660	244	11	$ 0.035
No-till	4.65	1.83	1.71	9,900	660	31	$ 0.094
Sub-till	3.17	1.39	2.91	10,380	692	32	$ 0.098

Table 4 on page 921

Soil Carbon Sequestration by Switchgrass and No-Till Maize grown for Bio Energy

Ronald F. Follett, Kenneth P. Vogel, Gary E. Varvel, Robert B. Mitchell, John Kimble
Published 4 May 2012 in BioEnergy Research ISSN 1939-1234, Volume 5, Number 4

9 Year study (1998-2007)
C sequestration in 0-150 cm soil profile
Study site has extremely variable soils including several sand lenses mixed throughout

Crop	SOC Sequestration 1998 - 2007 Mg C/ha	Annual SOC Sequestration Mg C/ha	Annual SOC Sequestration lbs/ac	Corn Ethanol Sequestration Credit (gCO2eq/Mj)	Estimated Ethanol Value Increase @ $38/Mg ($/gallon)
Switchgrass	18.0	2.0	1,785	84	$ 0.25
No-Till Maize	23.4	2.6	2,320	109	$ 0.33

From Discussion on page 873

No-Tillage increases soil profile Carbon and Nitrogen under long-term rainfed cropping systems

G.E. Varvel, W.W. Wilhelm

Published in Soil & Tillage Research 114 (2011) 28–36

Table 3
Total SOC values as affected by tillage treatment and cropping system at the 0-15, 15-30, 30-60, 60-90, and 120-150-cm depths in 1999 at the Roger's Memorial Farm near Lincoln, NE.

Table 5

Tillage	Depth (cm) 0-15	15-30	30-60	60-90	90-120	120-150	Table 5 Depth (cm) 0-30	0-60	0-90	0-120	0-150	Difference Mg/ha	% OM	Difference % OM	Annual Difference Lbs/ac	gCO2 eq/Mj Annual CI diff.	Estimated Corn Ethanol Value Increase (@ $38/Mg) $/Gal
	Total SOC (Mg ha)																
Chisel	33.3	24.0	27.4	15.3	12.9	9.8	57.3	84.7	100.0	112.9	122.7	0.0	2.01%	0.00%	0	-	
Disk	34.9	26.6	37.3	27.1	21.6	13.6	61.5	98.8	125.9	147.5	161.1	38.4	2.64%	0.63%	8,975	115	$ 0.35
Plow	31.8	28.3	28.6	17.1	14.8	11.0	60.1	88.7	105.8	120.6	131.6	8.9	2.15%	0.15%	2,080	27	$ 0.08
No-till	37.7	31.3	41.5	27.2	21.0	12.6	69.0	110.5	137.7	158.7	171.3	48.6	2.80%	0.80%	11,359	145	$ 0.44
Ridge Till	36.3	30.0	38.2	24.6	18.8	12.6	66.3	104.5	129.1	147.9	160.5	37.8	2.63%	0.62%	8,835	113	$ 0.34
Subtill	32.4	26.7	36.4	27.7	21.9	14.3	59.1	95.5	123.2	145.1	159.4	36.7	2.61%	0.60%	8,578	110	$ 0.33
Cropping System																102	0.309155
CC	36.6	28.6	36.1	22.6	18.4	12.1	65.2	101.3	123.9	142.3	154.4	7.6	2.53%	0.21%	1,776	23	$ 0.07
SB-C	34.1	28.0	35.6	23.6	18.6	12.1	62.1	97.7	121.3	139.9	152.0	5.2	2.49%	0.14%	1,215	16	$ 0.05
CSB	32.5	26.8	33.0	23.3	18.5	12.7	59.3	92.3	115.6	134.1	146.8	0.0	2.40%	0.00%	-	-	

Table 3 on Page 32

Table 5 on page 33

0.46%
2.85%

0
0
0

Applied Energy xxx (2012) xxx–xxx

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journal homepage: www.elsevier.com/locate/apenergy

Combustion efficiency and engine out emissions of a S.I. engine fueled with alcohol/gasoline blends

M.A. Costagliola, L. De Simio, S. Iannaccone, M.V. Prati *

Istituto Motori, National Council of Research, viale Marconi, 8, 80125 Napoli, Italy

HIGHLIGHTS

- ▶ The effect of ethanol was studied in S.I. engine at standard pressure peak position.
- ▶ A slightly better global efficiency (~5%) was achieved with E85 compared to gasoline.
- ▶ Particle number emissions were reduced (~90%) with ethanol blends.
- ▶ A 50% reduction of benzene and 1,3-butadiene emissions was achieved with E85 blend.

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ABSTRACT

In this experimental work, the influence of some bio-fuels on the spark-ignition engine combustion efficiency and engine-out emissions was investigated. A conventional 1.6 l port injection engine was tested over steady-states, with some bio-ethanol/gasoline blends (0, 10, 20, 30, and 85 vol% of ethanol in gasoline) and with a 10 vol% of n-butanol in gasoline. Study of combustion development was made through the heat release analysis of pressure cycles measured in combustion chamber. Regulated emissions, unregulated organics (Polycyclic Aromatic Hydrocarbons, carbonyl compounds and Volatile Organic Compounds) and particulate were measured. Particulate was characterized in terms of total particle number (PN) and size distribution between 7 nm up to 10 μm. The tests were carried out at stoichiometric conditions in closed loop and spark advance was optimized with a calibration tool software in order to have the same peak pressure position. By fueling the alcohol blends, the engine-out particulate emissions are strongly reduced compared to gasoline. The PN reduction percentage ranges between 60% and 90%. The benefits also concern some gaseous unregulated species very harmful for humans, such as benzene and benzo(a)pyrene (reduction of almost 50% and 70% respectively). The highest oxygen content of alcohol blends, instead, provides an increasing of the total carbonylic emissions.

1. Introduction

In recent years, the strong restrictions applied to emissions from road transport together with the scarce availability of conventional fuels responsible for a constant increasing of fuel prices have encouraged the research activity towards alternative fuels. An increasing use of bio-fuels for transport is emerging as an important policy strategy to replace petroleum fuels. The European Union (EU) was aimed at achieving a 5.75% target of biofuels by 2010 (calculated on the basis of energy content), set by the EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources and adopted by most Member States in their national biofuel objectives. Bio-ethanol is a renewable energetic source, and therefore it can contribute to reduce green house gas emissions. The benefits are as much high as greater is the efficiency of ethanol global productive process, taking into account also land use competition with other human needs. Bioethanol can be produced from various kinds of biomass such as corn, sugarcane, sugar beet, cassava, and red seaweed. It is one of alternative fuels most employed because of its oxygen content which favors the further combustion of gasoline. Besides, gasoline blends well with ethanol, compared to diesel, resulting in lower sulfur and aromatics content, higher octane number, and higher vapor pressure compared to the base fuel. Recently, the attention towards n-butanol as alternative fuel is increasing due to its high affinity with gasoline. Moreover, n-butanol when blended with gasoline is characterized by a high stability; in presence of water, in fact, n-butanol/gasoline blends do not separate. The most negative aspect is toxicity to humans from excessive exposition to n-butanol.

The influence of alcohol/gasoline blends on spark ignition internal combustion engine performance and emission was largely

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investigated. Bibliographic data highlight a general reduction of engine out emissions [1,2]. Also a positive effect of alcohol content on thermal efficiency was noted, both on a single cylinder engine at the test bed [3] and on a vehicle on a chassis dynamometer [4]. In [5] a passenger car equipped with a SI engine showed on a chassis dynamometer a 6% efficiency increasing when 50% of isobutanol/gasoline blend was used at full admission. Instead with pure isobutanol efficiency was reduced by 9%. In [6] the authors have tested oxygenated blends up to 15% by volume in gasoline on a single cylinder motorcycle engine. They highlight benefit on HC and CO emission and increased thermal efficiency. Blending ethanol with gasoline was also found to permit a higher compression ratio without knock occurrence [7]. Oxygenated blends were tested also with new concept strategy like homogeneous charge compression ignition (HCCI) and dual-injection. In [8] the authors found a reduction of NOx emission in a HCCI engine at butanol volume percentage increasing due to a lower maximum in-cylinder temperature. In [9] a two cylinders diesel engine was modified to operate in a HCCI mode in one cylinder with pure ethanol. The other cylinder was retained in normal diesel mode to motor the second cylinder. The authors report a stable HCCI combustion with an air intake temperature of 120–150 °C until a bmep of 4.3 bar. Dual injection (port fuel and direct injection) was tested [10,11] on a single cylinder engine with the aim of emphasizing the cooling-effect of oxygenated fuel with heat of vaporization higher than gasoline. The fossil fuel is port fuel injected while the biofuels is direct injected. This reduces the charge temperature and in turn reduces NOx and knock tendency while increases efficiency. A review of ethanol/gasoline blends impact on internal combustion engine is given in [12]. Besides, few publications are available on the effects of these alternative fuels on harmful emissions such as fine particles and carcinogenic organic compounds. In [13] an increment of ethanol, formaldehyde and acetaldehyde was observed when fueling a S.I. engine with low blend ethanol gasoline blends (maximum E20) at relative low temperature (<900 K). A recent study confirm that the emission of acetaldehyde significantly increased using E3 as fuel at the exhaust of nine four-stroke motorcycle [14]. About particulate, results showed in [15] highlight a PM increment at the exhaust of a direct injection engine by increasing the ethanol content related to a lower mixture homogeneity. According [16] n-butanol addition can decrease particle number concentration emissions compared with that of gasoline. This study has the objective of characterizing the engine behavior with several gasoline/ethanol and butanol blends in terms of emissions and performance (mainly efficiency and combustion development). In particular, steady-state tests were carried out on a conventional port injection spark ignition engine 1.6 l displacement fueled with gasoline, E10, E20, E30, E85 and n-B10 (respectively 10%, 20%, 30%, 85% v/v of ethanol and 10% of normal butanol in gasoline). Comparative studies of combustion development of gasoline and gasoline/ethanol blends at different concentrations have been made through the analysis of pressure cycles measured in combustion chamber. Moreover regulated emissions and unregulated organic emissions (Polycyclic Aromatic Hydrocarbons – PAHs, carbonyl compounds and Volatile Organic Compounds – VOCs) were collected and analyzed. Particulate matter was characterized in terms of particle number (PN) emissions and size distribution by an ELPI (Electrical Low Pressure Impactor) sampling system.

2. Materials and methods

2.1. Engine

The engine used in the tests is a conventional 1.6 l spark ignition (volumetric compression ratio 10.5), timed port injection with a three-way catalyst at the exhaust. For the optimization of engine parameters and ECU (Electronic Control Unit) data storage, the Magneti Marelli HELIOS software was used. The engine was instrumented with a pressure transducer in the combustion chamber of cylinder nos. 3 and 29 thermocouples to monitor the temperature in significant points, such as intake and exhaust manifold, the seat between intake and exhaust valve, and the zone close to the spark plug.

The tests were carried out on a grid of 9 speed/load points, ranging from 1750 to 3000 rpm and from 20 to 80 Nm, besides idle condition. In Fig. 1 the nine experimental points carried out with an evident high repeatability in the mid/low engine speed/load operating area are shown.

2.2. Fuels

Six test fuels were used in this study. A commercial gasoline was used as base fuel for the preparation of all the blends. Bioethanol, obtained from grape pomace produced during traditional wine processing, was provided by I.M.A. srl (Trapani, Italy). Four bioethanol-gasoline splash blends were prepared with 10%, 20%, 30% and 85% ethanol by volume in gasoline, named as E10, E20 E30 and E85, respectively. Also a normal butanol/gasoline blend 10% v/v (nB10) was tested for the higher affinity with gasoline characteristics. Selected fuel properties are shown in Table 1.

A not negligible oxygen content (1.5% by mass) in gasoline and a heat value of 42.7 MJ/kg were considered. Pure ethanol has lower *A/F* mass ratio and heat value, but energy content for mass unit

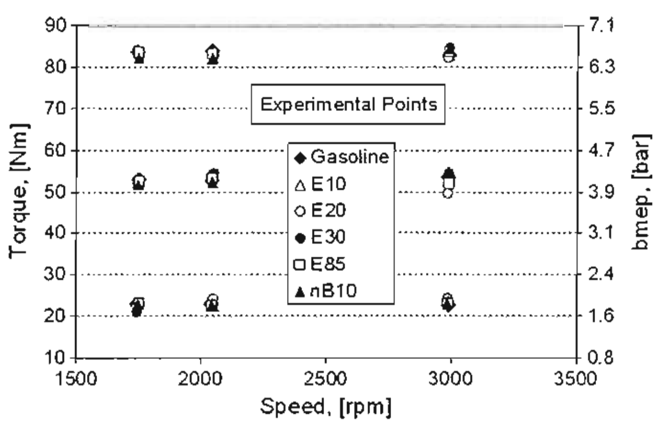

Fig. 1. Experimental points in the mid/low speed/torque area of the 1.6 l spark ignition engine fueled with gasoline and alcohol/gasoline blends.

Table 1
Main characteristics of the tested fuels.

FUEL	*A/F* (kg/kg)	H_i[a] (MJ/kg)	ρ (kg/m^3)	gCO_2/MJ g/MJ	Cooling effect[b] (°C)	$H_{st,mix}$[c] (MJ/kg)	H_v[d] (kJ/kg)
Gasoline	14.3	42.7	750	73	24	2.78	349
nB10	14.0	42.0	756	72	26	2.80	358
E10	13.8	41.0	754	73	30	2.78	409
E20	13.2	39.4	757	73	35	2.77	468
E30	12.7	37.8	761	73	42	2.76	527
E85	9.8	29.2	780	71	86	2.71	840
Butanol	11.2	36.1	810	66	38	2.96	430
Ethanol	9.0	26.9	785	71	102	2.69	923

[a] Heat value.
[b] Estimated considering air as an ideal gas mixture with specific heat at constant pressure of 1 kJ/kg °C.
[c] Heat content of stoichiometric mixture.
[d] Heat of vaporization.

Table 2
List of gaseous unregulated pollutants.

Compound	Group	IARC class[a]	Compound	Group	IARC class[a]
Naphthalene	PAHs	2B	o-Toluoladehyde	Carbonyl.	n.a.
Acenaphtilene	PAHs	3	m-Toluoladehyde	Carbonyl.	n.a.
Acenaphtene	PAHs	3	p-Toluoladehyde	Carbonyl.	n.a.
Fluorene	PAHs	3	Hexaldehyde	Carbonyl.	n.a.
Phenanthrene	PAHs	3	2,5-Dimethylbenzaldehyde	Carbonyl.	n.a.
Anthracene	PAHs	3	Methane	VOC	n.a.
Fluoranthene	PAHs	3	Ethane	VOC	n.a.
Pyrene	PAHs	3	Ethylene	VOC	3
Benzo(a)anthracene	PAHs	2B	Propane	VOC	n.a.
Chrysene	PAHs	2B	Propylene	VOC	3
Benzo(b + k + j)fluoranthene	PAHs	2B	Acetylene	VOC	n.a.
Benzo(e)pyrene	PAHs	3	i-Butane	VOC	n.a.
Benzo(a)pyrene	PAHs	1	Propadiene	VOC	n.a.
Perilene	PAHs	3	n-Butane	VOC	n.a.
Indeno(1,2,3,c,d)pyrene	PAHs	2B	Trans-2-butene	VOC	n.a.
Dibenzo(a,h)anthracene	PAHs	2A	1-Butene	VOC	n.a.
Benzo(g,h,i)perylene	PAHs	3	i-Butene	VOC	n.a.
Dibenzo(a,e)pyrene	PAHs	3	Cis-2-butene	VOC	n.a.
Coronene	PAHs	3	2,2-Dimethylpropane	VOC	n.a.
Dibenzo(a,h)pyrene	PAHs	2B	2-Methylbutane	VOC	n.a.
Dibenzo(a,i)pyrene	PAHs	2B	Propine	VOC	n.a.
Dibenzo(a,l)pyrene	PAHs	2A	1,3-Butadiene	VOC	1
Formaldehyde	Carbonyl.	1	2,2-Dimethylbutane	VOC	n.a.
Acetaldehyde	Carbonyl.	2B	Butine	VOC	n.a.
Acrolein	Carbonyl.	3	2-Methylpentane	VOC	n.a.
Acetone	Carbonyl.	n.a.	3-Methylpentane	VOC	n.a.
Propionaldehyde	Carbonyl.	n.a.	Benzene	VOC	1
Crotonaldehyde	Carbonyl.	3	Toluene	VOC	3
Butyraldehyde	Carbonyl.	n.a.	Ethylbenzene	VOC	2B
Benzaldehyde	Carbonyl.	n.a.	m + p-Xylene	VOC	3
Isovaleraldehyde	Carbonyl.	n.a.	o-Xylene	VOC	3
Valeraldehyde	Carbonyl.	n.a.			

[a] Group 1 carcinogenic to humans; Group 2A probably carcinogenic to humans; Group 2B possibly carcinogenic to humans; and Group 3 not classifiable as to its carcinogenicity to humans.

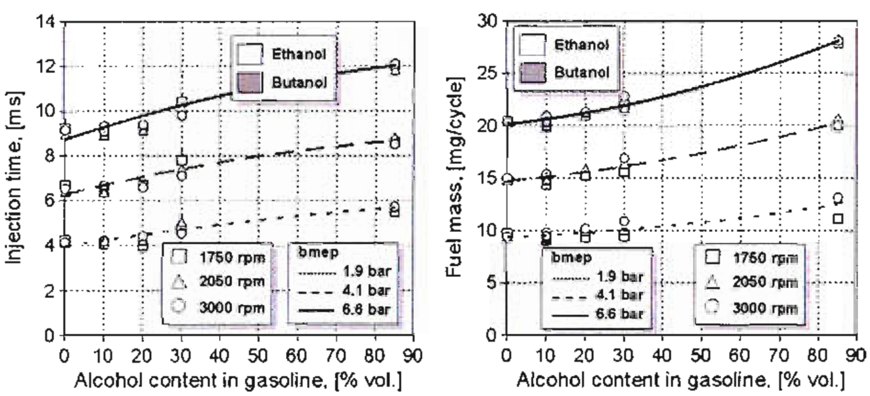

Fig. 2. Injection time and fuel mass injected per cycle bmep trend lines as a function of alcohol content.

of stoichiometric mixture ($H_{st,mix}$) is quite similar and therefore engine power is not affected by fuel composition. Some benefit could derive from mixture cooling effect due to the higher ethanol heat of vaporization (H_v). As a consequence some positive effect on volumetric efficiency is expected at ethanol percentage increasing. Moreover grams of CO_2 per MJ produced are not influenced by oxygenated compounds at the same engine efficiency. Due to molecule type very similar to gasoline composition, n-butanol has better fuel properties than ethanol [17]. It can be blended with gasoline at any percentage without modifying the engine. The energy content (H_i) is higher than ethanol and comparable to gasoline.

2.3. Emission sampling and characterization

For gaseous regulated emissions a hot ABB UV Limas 11 (ultra violet sensor) for nitrogen oxides (NOx), a cold ABB URAS 14 for CO, CO_2 (infra-red sensor) and oxygen (electro-chemical cell), and a hot Beckman 404 FID analyzer (flame ionization detector) for THC were used.

Besides regulated emissions, also particles and some gaseous unregulated pollutants were investigated. All the unregulated pollutants were sampled downstream a double stage dilution device (Fine Particle Sampler – FPS by Dekati Ltd.) which diluted the engine-out raw gas almost 14 times with purified shop air at a temperature of almost 150 °C.

Particle number (PN) and size distribution were measured by an Electric Low Pressure Impactor (ELPI) by Dekati Ltd. It is able to count, in a continuous way, the number of particles with the aerodynamic diameter between 7 nm and 10 μm, collected on twelve dimensional stages. ELPI data were also used to estimate the particulate mass (PM). Considering the particles as spheres, the particle mass was evaluated assuming their density as 1 g/cm^3. This

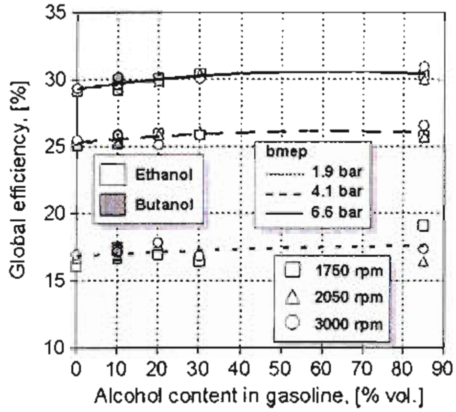

Fig. 3. Global efficiency bmep trend lines as a function of alcohol content.

statement represents a strong hypothesis on the density value which is a function of the particle diameter: higher the diameter, lower the density [18]. The mass calculation starting from the particle numbers could be affected by a great error, mostly for the larger particles that more account for the total volume and mass. In order to limit the inaccuracy, only mass of particles with the diameter lower than 1 μm (PM_1) was estimated.

Polycyclic Aromatic Hydrocarbons (PAHs) were collected by using the sorbent tubes XAD-2 by SKC, connected to a constant volume sampler Bravo H Plus by TCR Tecora (flow rate of almost 10 lpm). After sampling, the sorbent tubes were Soxhlet extracted with cyclohexane for at least 12 h with the addiction of the recovery standard mixture (Dr. Ehrenstorfer Mix 31), and then concentrated to 0.5 ml. PAHs analysis was realized with a gas chromatograph (HP 5890 Series II) coupled with a mass selective detector (HP 5971A) [19]. The chromatographic operative conditions and the internal standard analysis to quantify PAHs from phenanthrene to dibenzo(a,l)pyrene were reported in [20]. Table 2 lists all gaseous unregulated pollutants which were determined. The table indicates the pollutant group (PAHs, carbonylics and VOC) and the IARC (International Agency for Research on Cancer) classification for carcinogenicity [21].

Carbonylic compounds were collected by using the DNPH-cartridges by Waters connected to a sampling pump (flow rate of almost 4 lpm) and a volumetric counter. After sampling, the cartridges were chemically extracted with 3 ml of acetonitrile. Chemical analysis was realized with a HPLC (HP 1050) coupled with an ultraviolet detector [22]. The operative condition are: Supelco column LC-18 (25 cm × 4.6 mm × 5 μm); two mobile phases: A water/acetonitrile/tetrahydrofuran 60/30/10 v/v and B water/acetonitrile 40/60 v/v; constant flow rate of 1.5 ml/min; gradient conditions: 100% A for 1 min and then a linear gradient from 100% A to 100% B in 10 min. Five dilutions of the standard mixture TO11/IP-6A by Supelco were used for the quantitative analysis. Formaldehyde and acetaldehyde are classified by IARC as carcinogenic and probably carcinogenic to humans, respectively.

A chromatographic analysis was carried out directly on the gaseous sample for evaluating the volumetric concentration of some

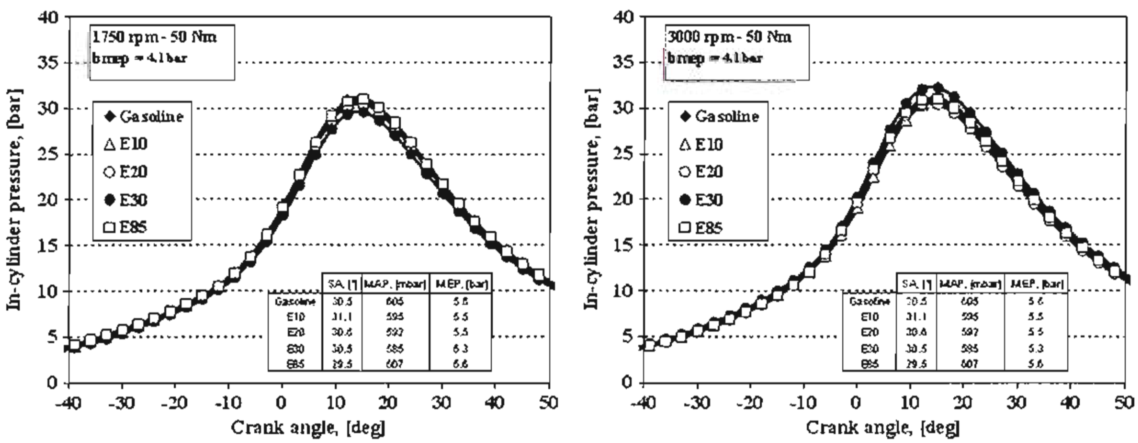

Fig. 4. In-cylinder pressure at 4.1 bmep load at 3000 and 1750 rpm for gasoline and all the tested oxygenated blends.

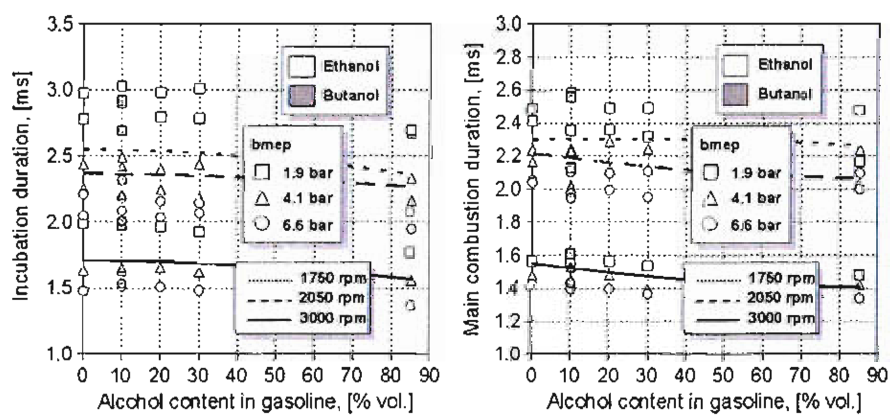

Fig. 5. Incubation and main combustion duration bmep trend lines as a function of alcohol content.

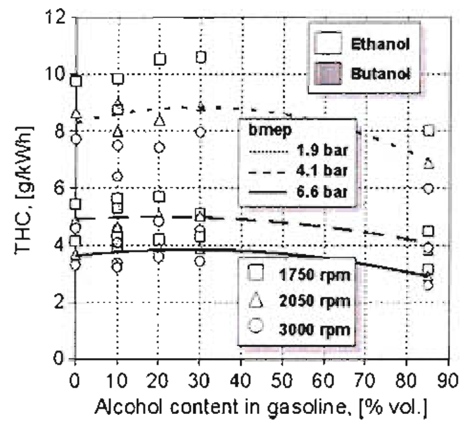

Fig. 6. THC emissions upstream of the catalyst.

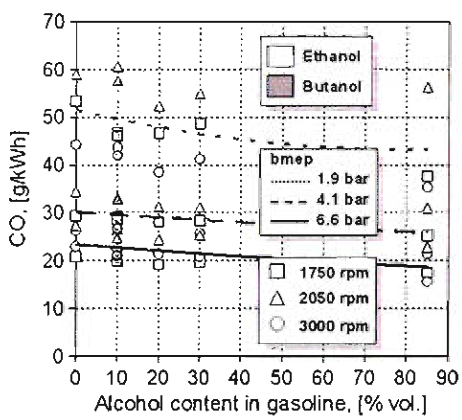

Fig. 7. CO emissions upstream of the catalyst.

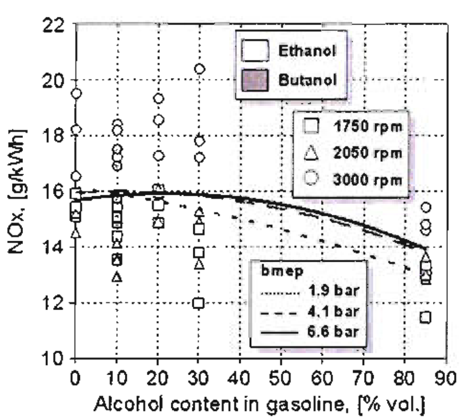

Fig. 8. NOx emissions upstream of the catalyst.

Volatile Organic Compounds (VOCs) with a carbon atoms number between C_1 and C_7. Among these, 1,3-butadiene and benzene cover a relevant role because of their carcinogenic potential (see Table 2). The gaseous sample was injected in the GC with flame ionization detector (FID) through a sample loop of 0.5 ml. The operative conditions are: carrier gas: helium; capillary column: Agilent HP-Al/KCl 50 m × 0.55 mm × 15 μm; Initial head column pressure: 50 kPa; Injector temperature: 250 °C; Initial oven temperature: 80 °C; program of temperature: isothermal for 16 min, 10 °C/min up to 160 °C; 5 °C/min up to 180 °C; 2 °C/min up to 200 °C–50 min at 200 °C. The calibration curves for quantitative analysis were made with five dilutions of a certified gaseous mixture standard.

3. Results and discussion

3.1. Combustion analysis

A stoichiometric operation closed loop was assured by the Electronic Control Unit (ECU) in all tested steady states. Spark advance (SA) has been optimized to have the peak pressure at the same angle position (13–16° ATDC) for the different fuels, while the standard ECU showed a trend to reduce SA increasing the ethanol content. Anyway the spark advance optimization was very small (not higher than 3%). In these optimized conditions, any influence of ethanol content was observed on the manifold absolute pressure and exhaust temperature. Not great variations of the injection time and the fuel mass injected per cycle were noted up to E20, whereas with E30 and E85 a longer injection time was expected due to a lower energy content for mass unit and a relative quite constant density of high content ethanol blends. Fig. 2 reports three constant bmep (Brake Mean Effective Pressure) trend lines of injection time and fuel mass injected per cycle for all the engine speed and alcohol blends. In all the graphs of this paper, n-butanol data are distinguished by ethanol ones by using grey-filled indicators. At each bmep the increase is not depending by speed and it is more evident for E30 and E85.

The observed fuel mass increasing is appreciably lower than predictable one estimated from fuel properties. Experimental data were confirmed by using two different measuring devices (a Coriolis mass flow meter and a precision electronic balance), which gave the same results. The slightly better efficiency with E85 was also confirmed by a mean CO_2 improvement of 7% for E85 vs gasoline.

The global efficiency of E85 estimated from the lower heating values of Table 1 was 4% higher than that of gasoline (Fig. 3) even though the combustion efficiency did not change with the fuel. Therefore the efficiency improvement could be related to other parameters, such as a lower compression work (for lower intake temperatures) and lower thermal losses (for lower maximum in-cylinder temperatures). From these results a "tank to wheel" analysis should give a small CO_2 and consumption reductions in a conventional port injection spark ignition engine. Some effective benefits could derive if a positive global carbon balance from well to tank is achieved.

Combustion analysis carried out by measuring in cylinder pressure confirm that fuel does not influence combustion quality, not giving a reason to justify the engine efficiency improvement shown in Fig. 3. Combustion development was deeply analyzed at 50 Nm (bmep 4.1 bar) at 1750 rpm and 3000 rpm. In Fig. 4 in-cylinder pressure is represented in the "late/compression – combustion – early expansion" crank angle area for the five tested fuels at 4.1 bmep load at 3000 and 1750 rpm. With spark advance optimization in each operative conditions, no great differences among the pressure cycles of the five fuels can be observed.

Intake and exhaust pressure curves did not differ for the five tested fuels since also throttle angle is almost similar. Same behavior was observed for the burned mass fraction, being both incubation time of combustion and main duration combustion substantially the same for all the tested fuels, with the exception of E85 blend. Fig. 5 shows lower incubation and main combustion duration for E85, stating a slightly faster combustion with this blend. Also engine head thermal load does not significantly changes with oxygenated blends, in fact temperature measured in the area between inlet and exhaust valves is almost similar in each operating condition for all the tested fuels. Temperature vari-

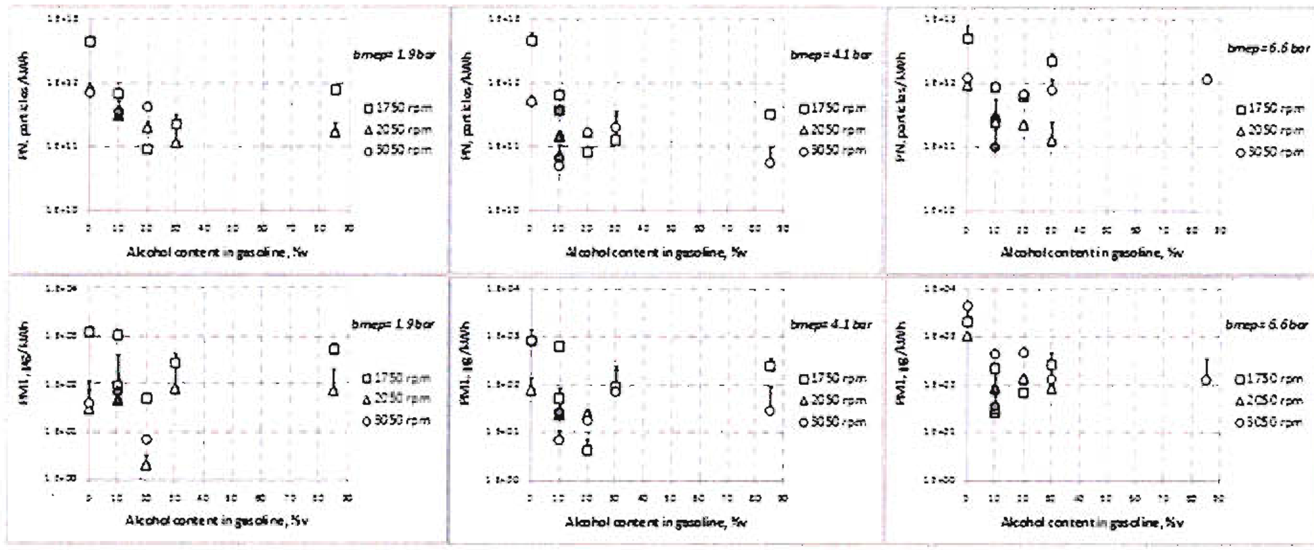

Fig. 9. PN and PM_1 emissions as a function of alcohol content.

ations are only related to the different speed/load operative conditions, but not to the fuel composition. These data are in accordance with pressure cycle development observed for the different fuels.

3.2. Emissions analysis at engine-out

3.2.1. Regulated emissions

In Figs. 6–8 regulated emission results (THC, CO and NOx) upstream the catalyst are shown in each experimental point as load trend line at the three tested speed.

Since FID sensibility towards HC coming from pure ethanol is reduced at 46% [23], measured THC concentration were increased proportionally to the ethanol and butanol fraction in blend (ranging from 10% to 85%) in each point of the experimental grid. For highest alcohol content, a small decreasing of THC was observed (Fig. 6). CO emissions follow alcohol content in the blends. This behavior can be justified by oxygen presence in the molecule, that should improve combustion quality and therefore give a reduction of CO at the exhaust (Fig. 7).

NOx behavior is quite similar to THC. The lower percentage measured (Fig. 8) at ethanol increasing levels is in accordance with higher vaporization heat, typical of oxygenated compounds, giving lower air/fuel mixture temperature at intake and, as a consequence, also lower peak temperatures in combustion chamber. The mixture temperature at intake valve, measured during experiments, is progressively lower with alcohol increasing in blends. The difference is quite small between several fuels, reaching the maximum value between gasoline and E85 (almost 4%); it could be due to the fact that only a small amount of fuel has vaporized into intake manifold, since a larger quantity should vaporize into the cylinder during intake and compression stroke.

3.2.2. Particulate matter characterization

PN and PM_1 emissions were measured at the engine exhaust with gasoline, n-B10 E10, E20 and E85. For each fuel type, an experimental test composed by all the engine experimental points was carried out. Fig. 9 shows PN and PM_1 mean values (expressed as particles/kW h and µg/kW h, respectively) in a semi-log graph as a function of the alcohol content in gasoline for the three tested engine loads (1.9, 4.1 and 6.6 bar as bmep). At the same engine load, PN emissions clearly decrease of almost one order of magnitude when moving from gasoline to E85. The PN reduction percentage of alcohol blends respect on gasoline ranges between 30% and 95% whereas the PM_1 one between 10% and 98%. The influence of engine speed is, instead, not so clear. It has to be noted that, for some fuel formulations and in correspondence of low load experimental points, PN become not measurable (i.e. lower than the ELPI Limit of Detection – LOD).

Fig. 10 represents the particle size distribution for the five fuel formulations over the several engine loads (1.9, 4.1 and 6.6 bar as bmep). For low and medium engine load, gasoline distribution is referred to secondary y axis, due to different values to be plotted.

99% of particle number distribution is included in PM_1 zone (particle diameter lower than 1 µm). The size distributions relative to gasoline are bimodal in almost all conditions; they, in fact, present a first peak in the ultra-fine dimensional zone (less than 20 nm) corresponding to the first ELPI collecting stage, and a second peak around 70 nm (3rd ELPI dimensional stage). The particle size distribution of alcohol blends are, instead, in most cases totally decreasing [24]. In other words, the main difference between gasoline and alcohol blends particle size distribution lies in the number of particles with the smallest diameter belonging to the nucleation mode; for gasoline, the contribution of these particles is stronger than for the tested oxygenated fuels. This observation agrees with the highest HC emissions related to gasoline fuel, which mainly constitutes the volatile particulate fraction included in the nucleation mode.

The different size distribution measured with pure gasoline and gasoline blends also justifies the different estimated reduction in PN and PM_1. These differences are explained by the major contribution of larger particles in particulate mass evaluation respect to the smaller ones.

3.2.3. Unregulated organic emissions

Emissions of carbonylic compounds, VOC and PAHs were measured with gasoline, n-B10, E10, E20, E30 and E85 over the high load engine experiments.

In Fig. 11 the emissions of carbonylic sum (expressed as mg/kW h) are reported as a function of alcohol content in gasoline for all experimental conditions. It is evident an increasing of carbonylics when alcohol percentage in gasoline increases. The carbonylic increment is not dependent by engine speed conditions and it is stronger for E85 blend. For n-B10, E10, E20 and E30, the carbonylic sum is, in fact, almost twice that of gasoline; for E85 this ratio becomes almost 3.5. The aldehydes increasing was already observed by [25].

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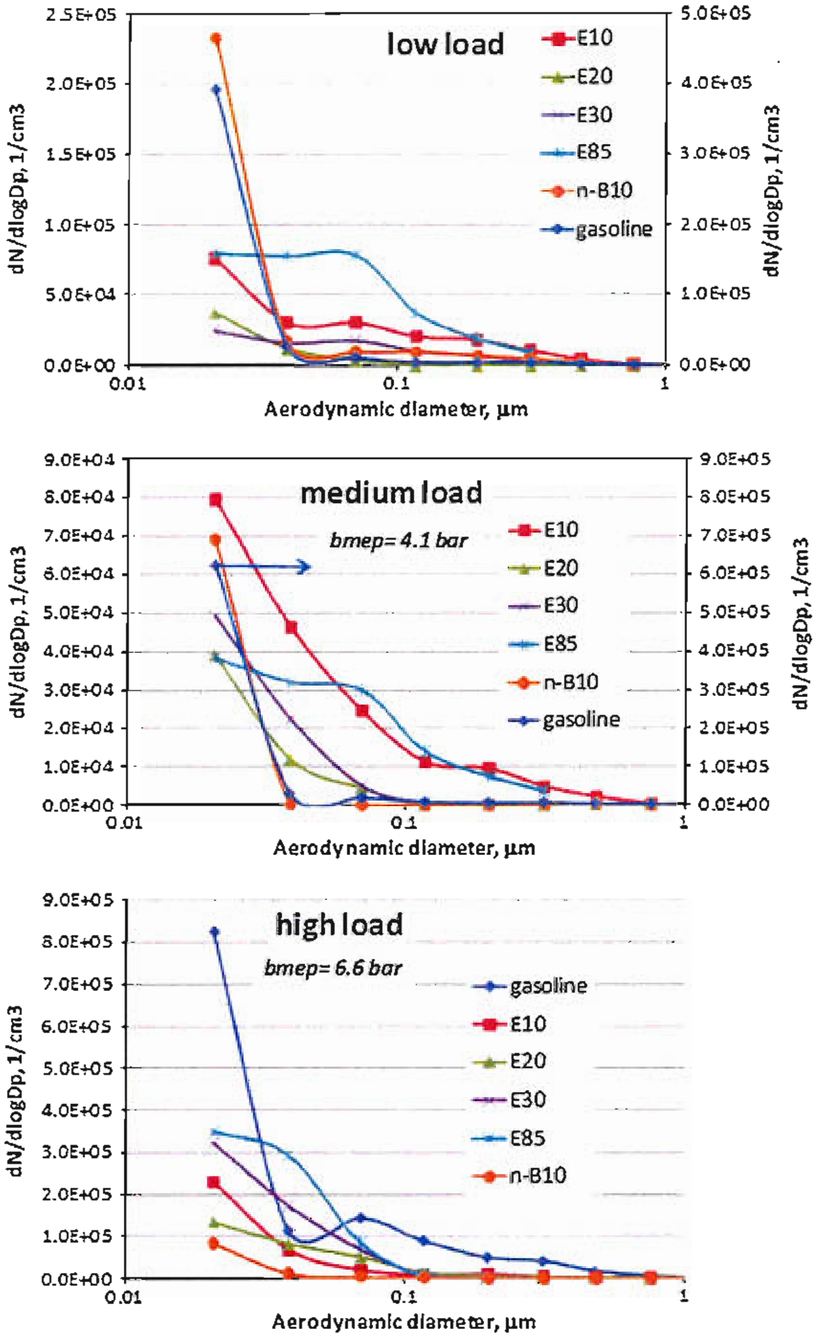

Fig. 10. Particle size distribution.

Fig. 12 reports the speciation of carbonylic compounds. These data are obtained by averaging the emissions measured over 1750–2050–3000 rpm/80 Nm with the same fuel. In all the conditions, the measurable compounds range from formaldehyde to benzaldehyde, in agreement with [26]. The most abundant compounds are formaldehyde and acetaldehyde whose sum covers almost 85% of total. They are followed, as abundance, by benzaldehyde and acetone. The strong increment of carbonylic sum observed for E85 blend is due to acetaldehyde whose emissions become much higher than those relative to the other fuels [27].

The mass percentage of total carbonylics in THC measured by FID analyzer is almost 3% for gasoline fuel, almost 8% n-B10, E10, E20 and E30 fuels and reaches almost 14% for E85.

Sum of VOCs is plotted as a function of the alcohol content in Fig. 13. Data are grouped for the several engine speeds. It is evident a marked reduction for E85 blend (between 50% and 70% compared with gasoline). Two ranges of values are in fact evident: the first between 1500 and 2000 mg/kW h which includes gasoline, n-B10, E10, E20 and E30, and the second between 700 and 1000 mg/kW h referred to E85. The decreasing trend is already visible for E30, even though the reduction percentage is almost 5–10% compared with gasoline emissions.

According to the average VOC speciation (Fig. 14), the most abundant compounds are ethylene and acetylene, followed by methane and propylene. Total quantified VOCs constitute almost 50% of THC measured with FID for gasoline, n-B10, E10 and E20. This percentage decreases to almost 40% for E30 and almost 30% for E85. These percentages are different probably due to increasing carbonylic contribution with increasing alcohol content, taken into account for THC evaluation and obviously not considered in VOC sum. The carcinogenic compounds belonging to VOC list are

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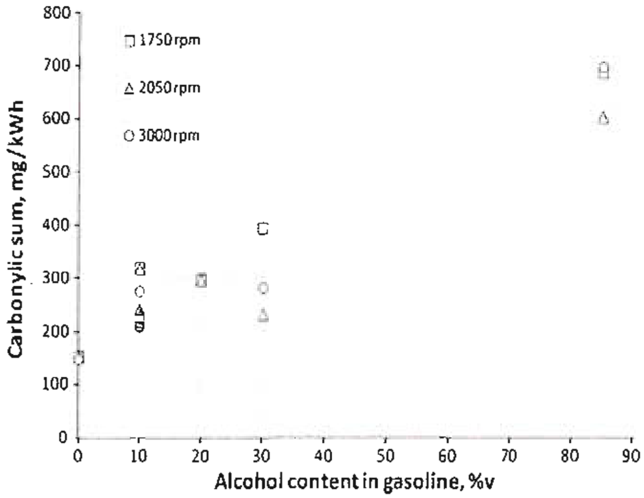

Fig. 11. Carbonylic compounds emissions as a function of alcohol blends.

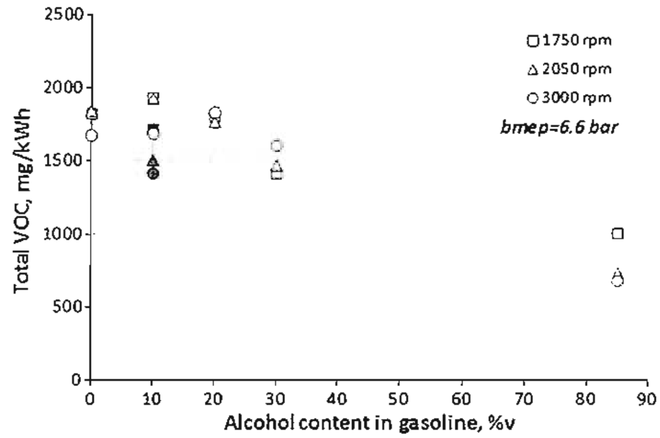

Fig. 13. VOC emissions as a function of alcohol blends.

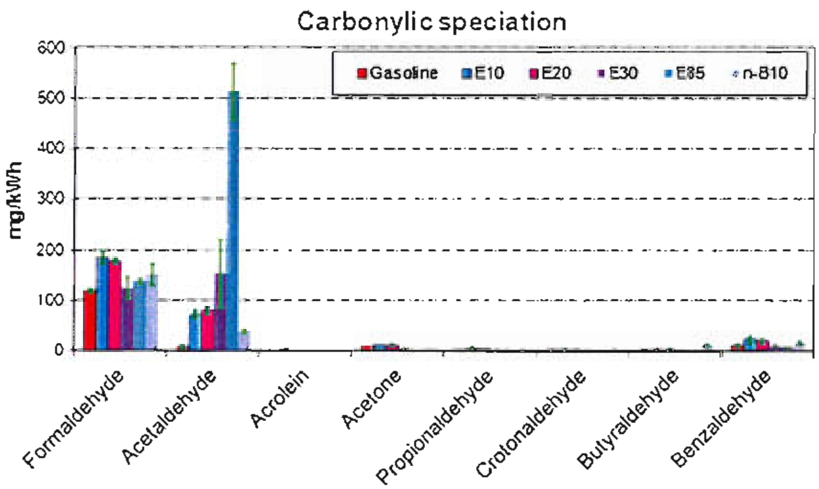

Fig. 12. Carbonylic compounds speciation.

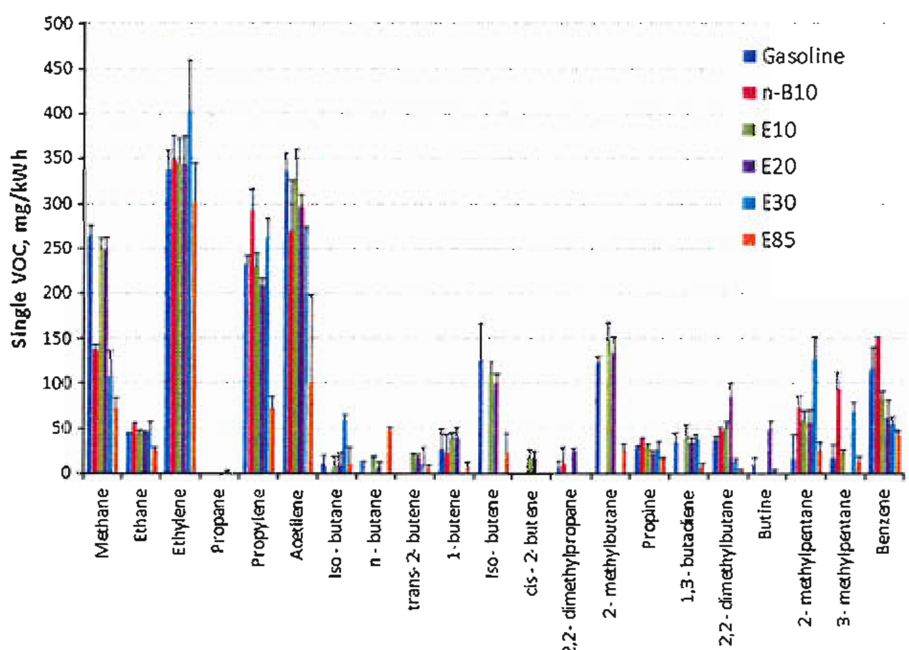

Fig. 14. VOC speciation.

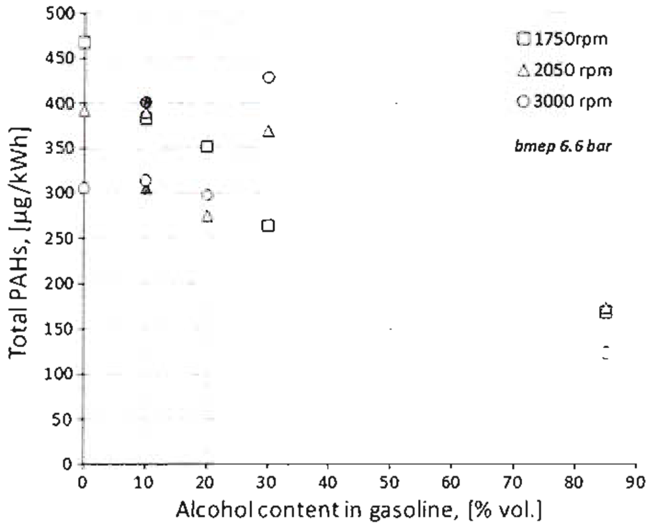

Fig. 15. PAHs emissions vs alcohol content in gasoline.

1,3-butadiene and benzene. The emissions of 1,3-butadiene are lower than those of benzene, and also for these single compounds the reduction is clear for E85 blend.

The sum of PAH expressed as µg/kW h and measured over all experimental points, is summarized in Fig. 15 as a function of alcohol content in gasoline. The PAHs trend showed in this figure is very similar to THC ones (see Fig. 6); for an alcohol content between 0 and 30 vol%, PAHs, in fact, range between 250 and 450 µg/kW h, not showing a clear influence by alcohol content. When looking at emissions referred to same fuel, in fact, the variability associated to the average value does not allow to point out any significant difference. Emissions referred to E85, instead, are almost 150 µg/kW h, stating a marked reduction (from 40% to 70%) respect on the results obtained with the other alcohol/gasoline blends.

Fig. 16 specifies the composition of the PAHs sum, above discussed. It appears that no differences due to fuel type can be highlighted. Major constituent are the lightest compounds (from phenanthrene to pyrene). This is explained by the sampling procedure used during this experimental program. PAHs in fact were collected in the exhaust gas phase, mainly containing the light fraction (from 2 to 4 aromatic rings) of PAHs. The heavier fraction

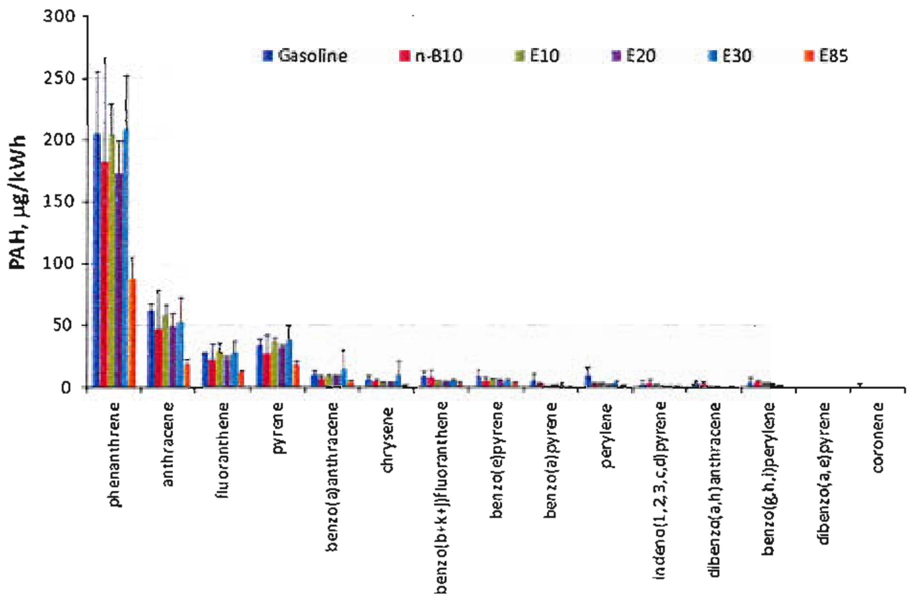

Fig. 16. PAHs speciation.

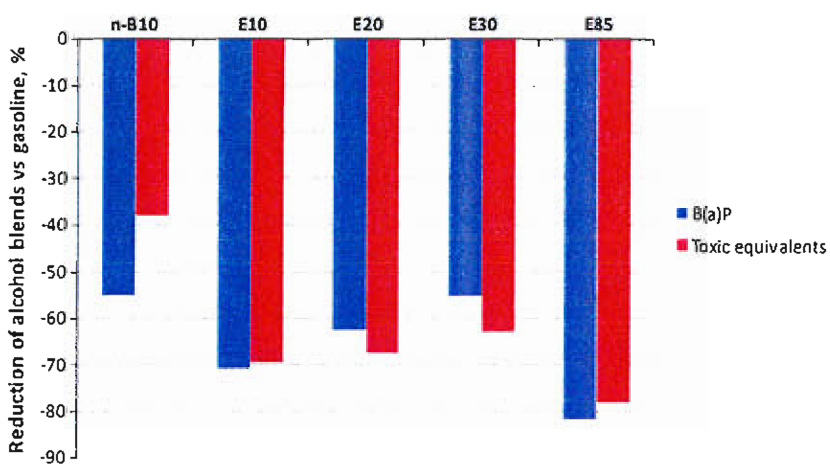

Fig. 17. B(a)P and toxic equivalents percentage reduction of alcohol blends compared to gasoline.

is typically associated to the particulate phase. The sum of carcinogenic PAHs (i.e. PAHs classified as belonging to IARC group 1, 2A and 2B) covers between 5% and 12% of total PAHs.

Benzo(a)pyrene (B(a)p), classified as carcinogenic to humans by IARC, is used as a marker for the carcinogenic risk of PAHs. The Individual PAH method (IPM) estimates a toxic equivalent (TEQ) by summing the emission levels of each aromatic expressed as "B(a)P equivalents". These last quantities are calculated by multiplying the concentration of single PAH for the carcinogenic potency relative to benzo(a)pyrene [28], the so called toxic equivalency factor – TEF. This method applied to PAHs experimental results provides a sensible reduction of toxic equivalents when moving from gasoline to alcohol blends. Fig. 17 reports the reduction percentage of toxic equivalents and benzo(a)pyrene (B(a)P) of alcohol blends compared to gasoline. Both reductions are strong (between 40% and 80%) with E85 showing the greatest percentage.

4. Conclusions

A deep experimental campaign was carried out to study the effect of gasoline/alcohol blends on performance and emissions of a 1.6 port injection spark ignition engine. Comparison between five fuel formulations was realized by modifying the spark advance in order to have an unchanged pressure peak position. In these operative conditions, the standard ECU was able to control air/fuel composition retaining the target stoichiometric value; therefore the engine was run in closed loop condition for all the tested fuels. No appreciable differences in combustion development were found, while a slightly better global efficiency (about +5% as mean values) was achieved with E85. As regard regulated emissions, the alcohol blends generally provide emission reduction respect on gasoline. The strongest reduction is associated to E85 (−20% for THC and about −15% for CO and NOx).

A significant reduction of PN and PM_1 (almost 90%) was achieved with alcohol blends compared to gasoline. Besides particle size distribution is always included in PM_1 dimensional range, distribution referred to oxygenated blends highlights a lower contribution of ultra-fine particles (aerodynamic diameter lower than 20 nm) in agreement with a lower volatile fraction.

The use of oxygenated fuels provides high carbonylic compound emissions; the strong increment compared to gasoline (almost 3.5 times higher) was measured for E85 blend and is mainly due to acetaldehyde. For alcohol content ranging between 10 and 30 vol%, the carbonylic sum becomes almost twice that of gasoline.

A 50% reduction of benzene and 1,3-butadiene emissions, classified as carcinogenic to humans was achieved with E85 blend.

Concerning PAHs, B(a)P and toxic equivalent evaluated for alcohol/gasoline blends reduce between 30% and 70% compared to gasoline. Also for this class of compounds, the best result in terms of PAHs emission reduction is obtained with E85 blend.

Acknowledgements

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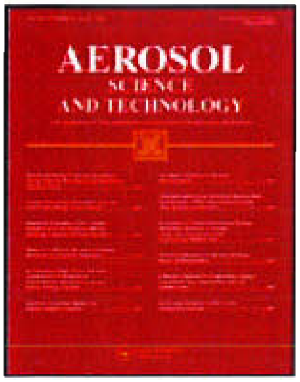

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The Impact of Ethanol Fuel Blends on PM Emissions from a Light-Duty GDI Vehicle

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The Impact of Ethanol Fuel Blends on PM Emissions from a Light-Duty GDI Vehicle

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This study explores the influence of ethanol on particulate matter (PM) emissions from gasoline direct injection (GDI) vehicles, a technology introduced to improve fuel economy and lower CO_2 emissions, but facing challenges to meet next-generation emissions standards. Because PM formation in GDI engines is sensitive to a number of operating parameters, two engine calibrations are examined to gauge the robustness of the results. As the ethanol level in gasoline increases from 0% to 20%, there is possibly a small (<20%) benefit in PM mass and particle number emissions, but this is within test variability. When the ethanol content increases to >30%, there is a statistically significant 30%–45% reduction in PM mass and number emissions observed for both engine calibrations. Particle size is unaffected by ethanol level. PM composition is primarily elemental carbon; the organic fraction increases from ~5% for E0 to 15% for E45 fuel. Engine-out hydrocarbon and NO_x emissions exhibit 10–20% decreases, consistent with oxygenated fuel additives. These results are discussed in the context of the changing commercial fuel and engine technology landscapes.

[Supplementary materials are available for this article. Go to the publisher's online edition of *Aerosol Science and Technology* to view the free supplementary files.]

INTRODUCTION

Three areas related to motor vehicles and air quality are experiencing major changes. The first is fuel composition. Recent energy policy decisions, such as the 2007 Energy Independence and Security Act, mandate increased reliance on renewable fuels, directives to enhance national security and ameliorate climate change impacts (U.S. Environmental Protection Agency 2007). This implies increased blending of ethanol into conventional gasoline fuel. Roughly 90% of gasoline sold in the United States currently contains nearly 10% ethanol (E10) (U. S. Energy Information Administration 2011). This will increase following the United States Environmental Protection Agency (EPA) partial waiver to allow E15 fuel use in 2007+ model year vehicles (U. S. Environmental Protection Agency 2010).

The second is the growth of gasoline direct injection (GDI) engine technology, aimed to offer fuel economy and CO_2 emissions benefits (Fraser et al. 2009; Yi et al. 2009). Direct injection of gasoline into the cylinder allows better combustion control, for example, multiple fuel injections and charge-air cooling. But it risks incomplete fuel volatilization and impingement onto piston and cylinder surfaces, exacerbating particulate matter (PM) emissions. The third is regulatory; California Air Resources Board (ARB) and EPA are both contemplating next-generation emissions standards which would lower tailpipe PM emissions from 10 mg/mi to 6 mg/mi, and then 3 mg/mi, over the next decade (California Air Resources Board 2010).

Consequently, it is important to examine the interplay and potential synergies between fuel composition and engine technology in efforts to reduce emissions. There are ongoing investigations of ethanol's effects on fuel systems, evaporative emissions, and gaseous emissions (Durbin et al. 2007; Kar and Cheng 2009; Knoll et al. 2009; Coordinating Research Council 2011), but few gasoline engine studies have examined its impact on PM emissions. The paucity of data is presumably because stoichiometric combustion in spark ignition engines naturally produces very low PM emissions, a few milligrams per mile (Maricq et al. 1999), and because GDI is a new technology. One exception is the effort by Aikawa et al. (2010) to create a PM index based on fuel properties, which is of interest for GDI because of the potential to help model air fuel mixing and sooting propensity.

Ethanol effects on GDI particulate emissions have been reported by Storey et al. (2010) and He et al. (2010), who observed reductions of about 30% for E20 fuel over the Federal Test Procedure (FTP) drive cycle. However, the detailed characterizations, such as particle number, size, and composition, were undertaken at steady-state engine operation, whereas cold and hot starts and transients are typically of more interest for gasoline engines. Work by Chen et al. (2010) showed that PM

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emissions can either increase or decrease with ethanol content depending on fuel injection timing. Such results point out a difficulty in investigating potential fuel benefits, namely that these might be masked by adjustments in engine calibration when the fuel is changed. Other properties of fuel besides ethanol content can also impact PM emissions; thus, Khalek et al. (2010) noted higher PM levels from a GDI vehicle operated on a commercial E10 fuel relative to two E0 fuels, but attributed this to a higher volatility in the base gasoline.

The goal of this paper is to examine how ethanol–gasoline blends impact PM emissions from GDI vehicles. Six fuels are examined, ranging from E0 (base gasoline) to E45 (45% ethanol). The study utilizes the FTP drive cycle to include the important effects of cold start and transient operation. It addresses measurement variability both by repeat tests and the use of three metrics of PM emissions: mass, number, and elemental/organic carbon composition. The issue of sensitivity to engine parameters is handled in two ways: First, we conduct testing at two different engine calibrations to assess the consistency of ethanol's impact on emissions. Second, we compare the vehicle exhaust results to observations from a study of ethanol–gasoline blend diffusion flames (Maricq 2011).

TABLE 1
Fuel properties

Characteristic	E0	E10 cert	E10 pump	E100
Ethanol (%vol)	0	10.1	9.0	97.3
10% recovery dist. T (°C)	56.7	54.8	48.5	
50% recovery dist. T (°C)	105.6	98.4	69.8	
90% recovery dist. T (°C)	155.8	158.8	165.5	
Density (g/mL)	0.744	0.754	0.734	0.795
Vapor pres. ASTM (kPa)	55.2	54.5	70.6	21.0
Net heating value (MJ/kg)	43.34	41.5		26.73
Research octane	97.3	94.4	91.8	
Carbon weight%	86.41	82.90		52.16
Hydrogen weight%	13.59	13.41		13.08
Oxygen weight%	<0.05	3.69		34.76
Sulfur (ppm)	19	5	58.8	3
Aromatics (%vol)	28.5	24.1	16.9	

EXPERIMENTAL METHODS

Test Vehicle and Fuels

The test vehicle is a light-duty truck equipped with a 3.5-L V6 gasoline turbocharged direct injection engine. It is representative of current GDI products, but contains prototype elements, such as the engine calibrations tested here. It has a compression ratio of 9.8:1 and independent variable cam timing. The fuel injectors are side-mounted and deliver single-fuel pulses, except for split injection (two pulses) during crank and early cold start operation. Exhaust aftertreatment consists of a three-way catalyst to control hydrocarbon (HC) and NO_x emissions.

The study uses four fuels: certification test gasoline (E0), a commercial E10 fuel similar to that expected for future certification, a commercial pump grade E10, and a commercial E100 fuel used for blending. Their properties are listed in Table 1. E100 and E0 were splash-blended to produce the E17, E32, and E45 fuels. All fuels were analyzed by gas chromatography to verify ethanol content. Fuel changes were done by draining the tank, filling with new fuel, and running the vehicle through the FTP drive cycle prior to testing. Emissions were measured over the FTP cycle, consisting of three phases: (1) cold start, (2) urban, and (3) hot start. E0 tests were conducted first and last to confirm that no changes in vehicle emissions performance occurred.

PM Sampling and Measurement

The vehicle was tested on a 48-inch single roll, AC electric, chassis dynamometer. The experimental setup is illustrated in Figure 1. Vehicle exhaust was sampled in two ways: (1) directly from the tailpipe and (2) through a full-flow constant volume sampling (CVS) dilution tunnel, as per the regulatory method (except to substitute quartz filter EC/OC analysis for Teflo filter gravimetric PM mass). In our CVS system, exhaust is diluted with a "remote mix T" connected to the tailpipe via a short (~1 m) extension. The dilution air is filtered, temperature- and humidity-controlled (38°C and −9°C dew point), and actively regulated to maintain a constant total flow of exhaust plus dilution air. This was set to 9.34 m^3/min for E0, E10, and E17 fuels, but raised to 19.8 m^3/min for E32 and E45 because of increased exhaust humidity. The diluted exhaust travels via a ~7-m, 25.4-cm-diameter, conductive coated Teflon tube to a 30.4-cm-diameter stainless steel tunnel.

Direct tailpipe sampling employs a Dekati Fine Particle Sampler (FPS) originally developed to provide standardized dilution conditions for studying nucleation mode formation (Ntziachristos and Samaras 2010). It uses a coaxial perforated tube diluter that allows room temperature dilution, but avoids thermophoretic deposition of PM from hot exhaust. This approach contrasts with the European Union solid particle counting method, which is designed to remove nucleation mode particles by hot dilution and evaporation (Giechaskiel et al. 2008). Instead, the FPS samples both semivolatile and solid particles. It was used at a dilution factor of 25–30. A Dekati ejector pump provides 8.5 times secondary dilution for particle number counting. Room temperature nitrogen from liquid boil-off supplies the diluent for both the FPS and the ejector pumps.

Three PM emissions metrics are examined: (1) mass, (2) elemental/organic carbon (EC/OC), and (3) total particle

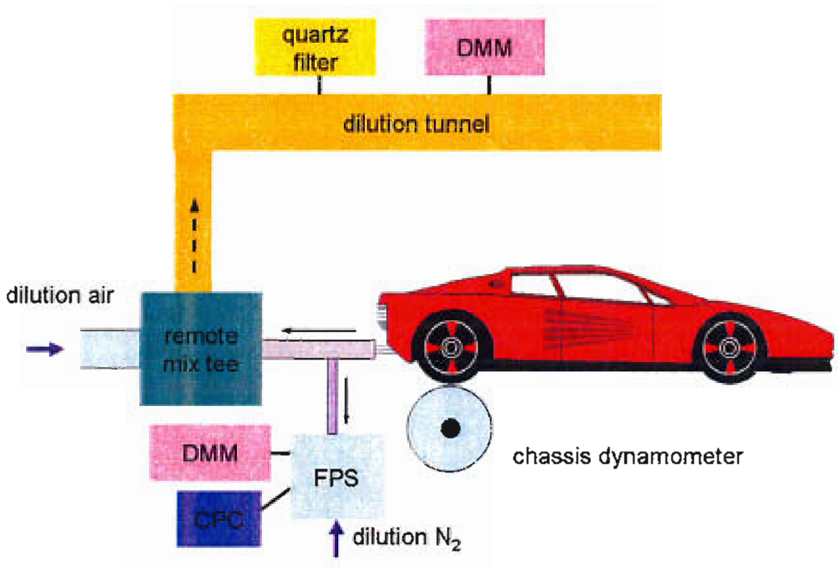

FIG. 1. Schematic diagram of the experimental setup. Solid arrows show exhaust and diluent flows. Dashed arrow indicates diluted exhaust flow. (Color figure available online).

number. Engine-out HC and NO_x emissions are also reported. They are measured using Horiba analyzers based on flame ionization detection (FID) and chemiluminescence detection, respectively.

PM mass is determined by Dekati Mass Monitor (DMM) using a combination of electrical mobility and aerodynamic particle size measurements (Mamakos et al. 2006). Particles are charged in a corona discharge, segregated by mobility (D_{50} = 50 nm), and those penetrating the mobility classifier enter a cascade impactor. The resulting electrical currents and aerodynamic and mobility size information yield estimates for the quantity, volume, and effective density of particles, which are combined to calculate second-by-second PM mass concentration. Two DMMs were used, one at the tailpipe and the second at the CVS tunnel.

EC/OC particulate mass is determined by sampling diluted exhaust through prebaked 47-mm-diameter quartz filters, followed by thermal analysis with a Horiba MEXA 1370PM (Akard et al. 2004). The filters are heated to 980°C, first under nitrogen and then with oxygen present. CO_2 from the oxidation of material evolved under nitrogen is equated with organic carbon, whereas that produced with oxygen is attributed to elemental carbon. The OC mass includes a correction for hydrogen content assuming an H/C ratio of 1.85. A correction is also made for gas phase adsorption, which amounts to about 0.5 mg/mi (Maricq et al. 2011). Unlike the IMPROVE and NIOSH methods (Chow et al. 2001), there is no correction for pyrolysis, which impacts interpretation of EC/OC values. But the total PM mass compares well with gravimetric data (Akard et al. 2004).

Total particle number concentration is measured via TSI 3010 CPC (condensation particle counter). The lower size cutoff, 50% count efficiency, is 12 nm. This is nearly a factor of two smaller than the 23-nm cutpoint adopted by the EU for their solid particle method. The CPC counting efficiency at 70 and 100 nm was calibrated by electrometer to 100%.

Many of the E0 and E10 tests included tailpipe PM measurements by an electrical low-pressure impactor (ELPI) (Keskinen et al. 1992). This is a cascade impactor that measures second-by-second aerodynamic size distributions by first charging the particles in a corona discharge and then recording the electrical currents from the impactor stages. Previous work has shown that analysis of diesel particulate matter ELPI data using a fractal-like effective density results in PM mass and geometric mean mobility diameter estimates in good agreement with gravimetric and scanning mobility particle sizer data (Maricq et al. 2006).

RESULTS

Four engine calibrations (engine computer control of fuel pressure, fuel injection and spark timing, etc.) were initially examined with E0 fuel and found to have FTP cycle-weighted average PM emissions in the range of 3–7 mg/mi. Two of these near the proposed 3 mg/mi LEV III standard were selected for further study, labeled A and B. These differ in that calibration A produces lower cold start but higher urban and hot start PM relative to calibration B. Three to four repeat tests were performed with calibration A for each fuel; whereas, one to three were conducted with calibration B. The calibrations were not altered between fuels, except to adjust the amount of fuel needed to maintain a stoichiometric air/fuel ratio. The two calibrations show similar PM emissions trends with ethanol level; therefore, calibration A data are presented next, whereas those for calibration B are included in Supplementary Information.

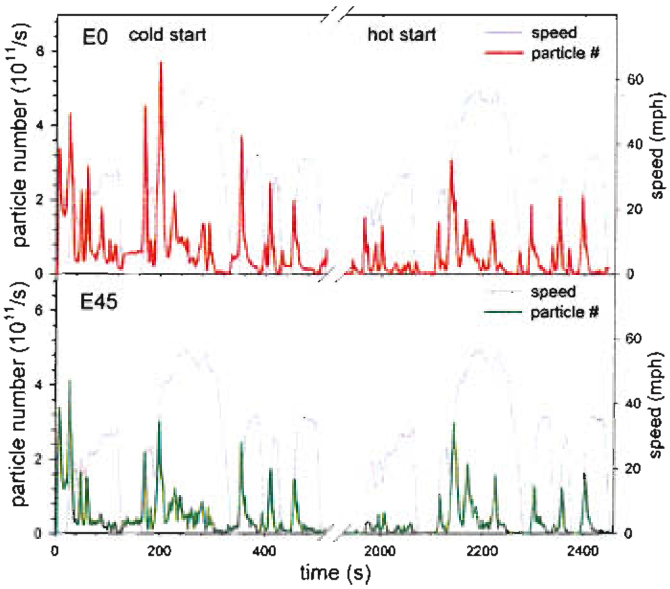

FIG. 2. Transient particle number emissions from the GDI test vehicle for the cold and hot start phases of the FTP drive cycle. Data are recorded by direct tailpipe sampling. Top panel: E0 fuel. Bottom panel: E45 fuel. (Color figure available online).

PM Mass and Number Emissions

Figure 2 illustrates tailpipe particle number emission rates over the cold and hot start FTP phases. Mass emissions (Figure S2 in Supplementary Information) exhibit a similar pattern.

When measured at the tailpipe, the particle concentrations recorded by DMM or CPC are multiplied by the time-aligned exhaust flow volume to derive emissions rates. Concentrations recorded via CVS sampling are simply scaled by the dilution tunnel flow. Not surprisingly, PM emissions correlate with vehicle acceleration owing to the increased fueling. But one also observes smaller emissions peaks during decelerations, likely a consequence of fuel shut-off. Emissions with E45 fuel are consistently below those for E0, but the decrease is not uniform, as seen from the accentuated reduction in particle emissions at the beginning of the hot start.

The effect of ethanol on PM emissions is summarized by Figures 3 and S3. These portray five parallel measurements: (1) mass from the tailpipe DMM, (2) mass from CVS tunnel DMM, (3) EC/OC mass from CVS, (4) particle count at tailpipe, and (5) ELPI PM mass for a subset of tests. The 1σ error bars represent test-to-test variability. Differences between the five methods reflect measurement uncertainty. This includes both systematic and random effects, but the data scatter points to random noise as the major contributor at these low emissions levels. The variability between the five PM methods is comparable to test-to-test variability in any given method. No statistically significant differences are observed between direct tailpipe and CVS sampling.

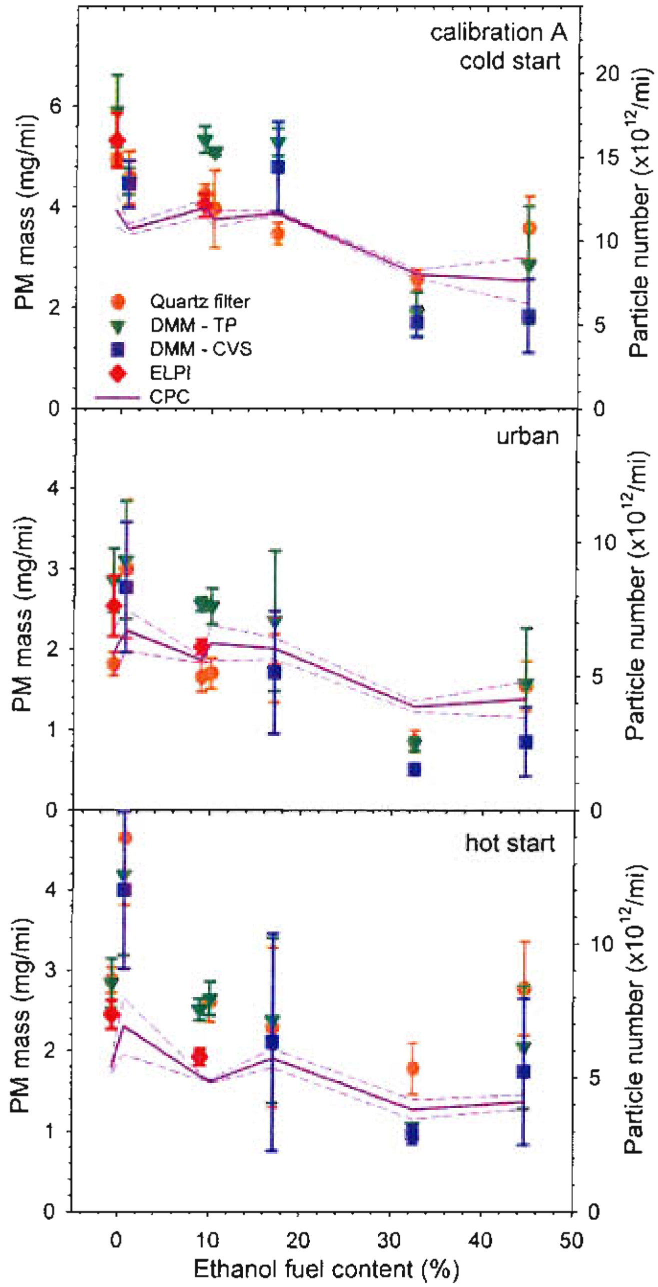

FIG. 3. GDI vehicle exhaust particle number and mass emissions versus ethanol content of fuel. Emissions are measured over the three-phase FTP drive cycle using calibration A. Symbols = mass. Lines = particle number. E0 data recorded at the beginning and end of the study are distinguished by plotting them slightly below and above 0% ethanol, respectively. Error bars are 1σ of the test repeatability. (Color figure available online).

All three metrics indicate a statistically significant reduction in particulate emissions with E32 and E45 fuels compared to base gasoline, relative to the average measurement uncertainty of approximately ±0.7 mg/mi. The decrease from E0 to these fuels is on average ~30% by particle number and ~45% by mass. This distinction is likely within the uncertainty, but could also originate from differences in nuclei mode particle emissions. Since E85 fuel further reduces PM (not part of this study), the small increase from E32 to E45 is likely from vehicle variability.

Figures 3 and S3 suggest a small (~20%) PM benefit for the lower ethanol blends relative to E0, but the data are mixed. Averaged over the parallel measurements, PM mass decreases 10–30% from E0 to E10 fuel using calibration A, but then remains constant from E10 to E17. For calibration B, there is a 10–20% PM increase from E0 to E10, but a ~10% decrease from E0 to E17 fuel. However, the individual DMM and EC/OC data are not always consistent in their trends for the lower-ethanol blends, reflective of the difficulties in measuring PM at the ~1 mg/mi level. Particle number measurements show a similar circa 20% improvement from E0 to E17 fuel. But even with somewhat lower variability than the PM mass data, this ~20% falls within the overall measurement uncertainty.

Figure 4 shows that engine-out HC and NO_x emissions exhibit similar dependences on fuel ethanol content. The decreases are more modest, about 20%. For calibration A, they occur already for the E17 blend, but calibration B data in Figure S4 indicate the decreases to occur above E17. The HC decrease should be interpreted with caution. Adding ethanol to gasoline changes HC composition, increasing the proportion of alcohols and aldehydes. These compounds are less efficiently detected by FID, which by itself can lead to an apparent emissions reduction. Additional measurements to correct under-determination of these compounds were not conducted in this study.

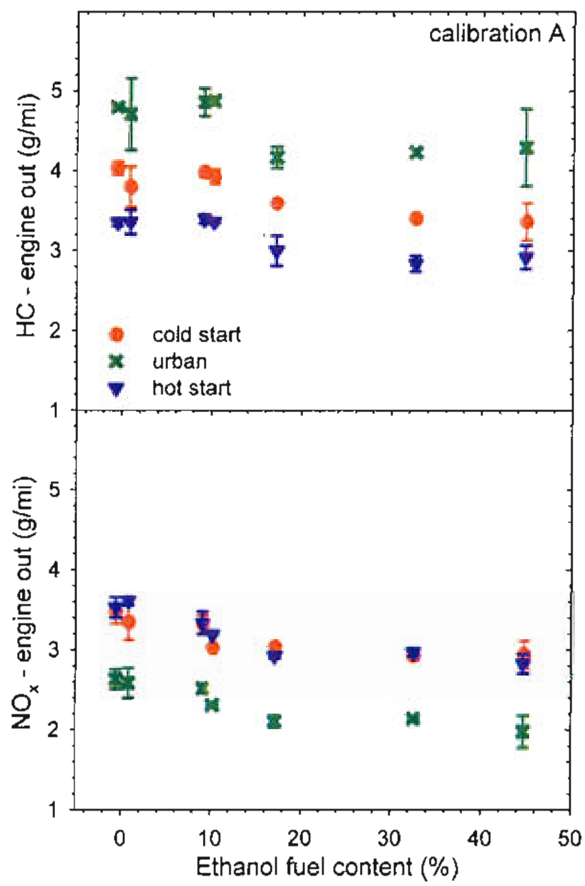

FIG. 4. FTP engine-out (feedgas) total hydrocarbon and NO_x emissions versus fuel ethanol content for calibration A. Initial and final E0 tests are distinguished as in Figure 3. (Color figure available online).

PM Mode and Size

Engine exhaust particles have an agglomerate morphology; thus, their size is characterized by the notion of an equivalent diameter. The DMM employs a combination of mobility and aerodynamic analysis, but does not directly measure either equivalent diameter. Rather, we derive estimates of geometric mean mobility diameter by assuming a bimodal lognormal distribution of particle number concentration versus mobility diameter and fitting the DMM impactor and mobility currents to the calculated currents. This is similar to the procedure described previously for the ELPI (Maricq et al. 2006). The number of adjustable parameters is reduced to three by fixing the nucleation mode geometric mean diameter to 20 nm, its standard deviation to 1.3, and by assigning the universal value of 1.8 to the accumulation mode geometric standard deviation (Harris and Maricq 2001). Best fits of the DMM data and a typical OC density of 0.8 g/cm^3 yield nucleation mode masses increasing from 2% to 5% of the total PM as the ethanol content rises. Choosing a different nucleation mode diameter or standard deviation alters the calculated mass, but it remains a small fraction of the total PM mass.

The influence of ethanol level on accumulation mode diameter is illustrated in Figure 5. This shows three estimates of the geometric mean mobility diameter (μ_g): (1) ELPI, (2) fits of DMM currents, and (3) calculated from the PM mass and number measurements via:

$$M = N_0 \frac{\pi}{6} \rho_0 d_0^{(3-D_f)} \mu_g^{D_f} e^{(D_f \ln \sigma_g)^2/2}. \quad [1]$$

Equation (1) assumes a log-normal mobility distribution of N_0 particles with geometric mean μ_g and standard deviation σ_g, an aggregate morphology with mass-mobility exponent $D_f = 2.3$, a primary particle density of $\rho_0 = 2$ g/cm^3, and a primary particle diameter of $d_0 = 20$ nm typical of engine soot (Maricq et al. 2006). Fits of DMM data yield mean mobility diameters of ~150 nm, roughly double the size normally expected for combustion engines. This discrepancy is systematic but independent of the agreement between DMM and filter-based PM mass values. Figures 3 and S3 show that PM mass measurements from the two DMMs, ELPI, and EC/OC agree within the test-to-test variability. The question of size is discussed further in the Supplementary Information. Here, scaling the DMM values by 0.5 provides a consistent estimate of mean mobility equivalent particle diameter. The results reveal that accumulation mode particle diameter is essentially independent of ethanol level. For the E0–E17 fuels, average size may decrease a bit (~5 nm)

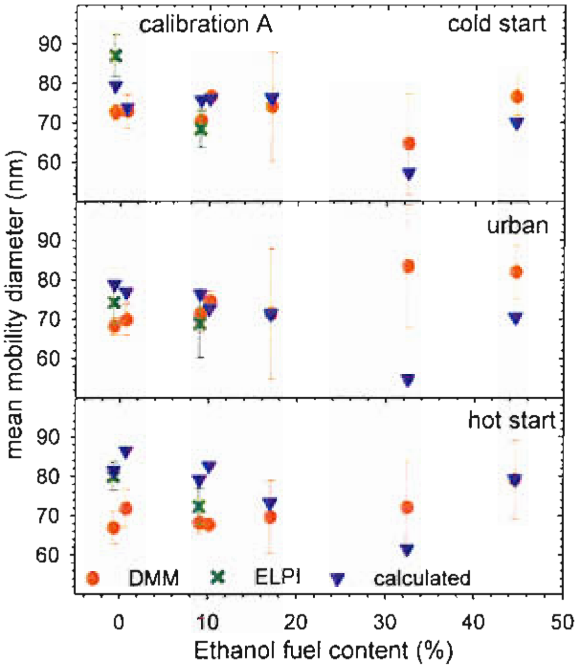

FIG. 5. Geometric mean mobility diameter of GDI particle emissions versus fuel ethanol. (Color figure available online).

from cold start to warmed-up operation and from calibration A to calibration B (Figure S5). For E32 and E45, such changes are within measurement uncertainty.

EC/OC Composition

Figures 6 and S6 plot the elemental and organic carbon fractions of the PM emissions versus ethanol blend. EC is clearly the predominant component and follows the same trend as total PM mass, namely it decreases slightly from 0% to 17% ethanol, but falls by ~45% for E32 and E45. In contrast, the OC component increases from about 0.1 mg/mi to 0.4 mg/mi from E0 to E45.

The low OC fraction is consistent with the small (<5%) nucleation mode mass determined from DMM data. However, this result should not be interpreted too literally. First, pyrolysis during thermal evolution of the OC introduces a bias toward a higher EC/OC ratio. Second, the ~0.5-mg/mi correction for gaseous HC adsorption by quartz filters is only approximate. Nevertheless, OC constitutes a small fraction of the GDI vehicle PM emissions.

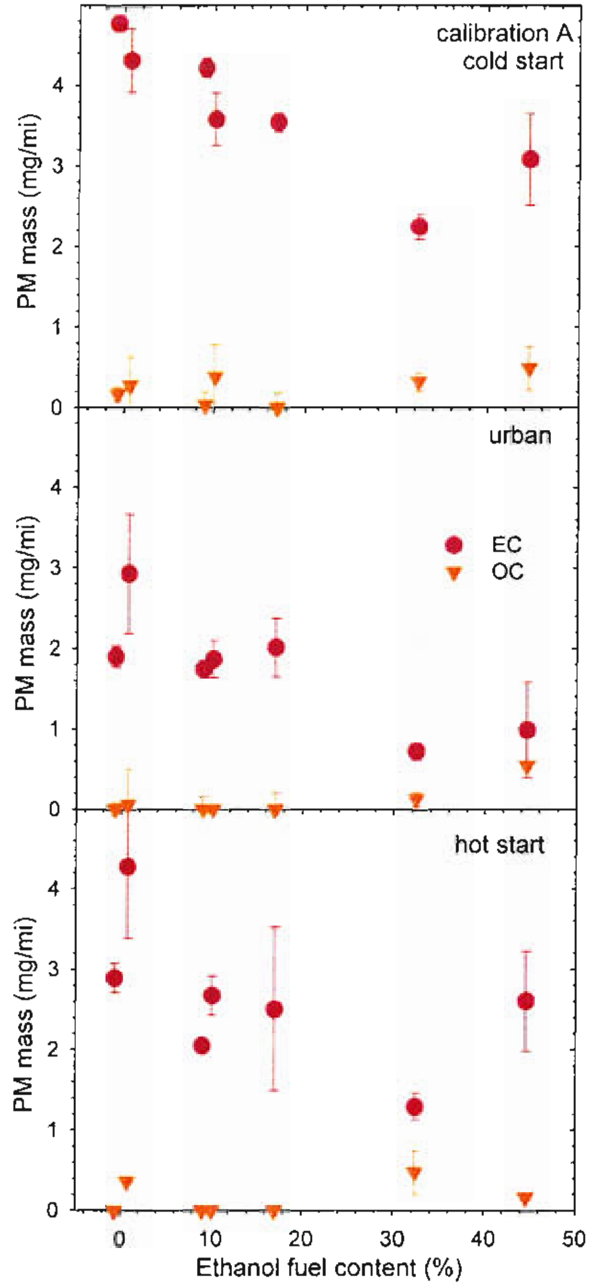

FIG. 6. Elemental carbon/organic carbon PM emissions versus fuel ethanol. (Color figure available online).

DISCUSSION

Overall, the effects of ethanol blends on GDI vehicle PM emissions described above agree with previous work. The data in Storey et al. (2010) show a 30% PM decrease for E20, but as for the present study, this decrease lies within measurement uncertainty. In He et al. (2010), there is likewise no clear distinction between E0 and E10, but they report a statistically significant 20% PM reduction for E20. Interestingly, He et al. (2010) observe bimodal size distributions in their fast mobility particle sizer data, with peaks at 10 nm and 70 nm. The latter value coincides with the ~70-nm mean accumulation mode mobility diameter depicted in Figure 5. They further report that a three-way catalyst reduces nucleation mode emissions, consistent with the present DMM data, which indicate that this mode contributes little to the total PM mass from the three-way catalyst-equipped test vehicle.

The present study of GDI vehicle exhaust PM reveals interesting features not typically associated with gasoline vehicles:

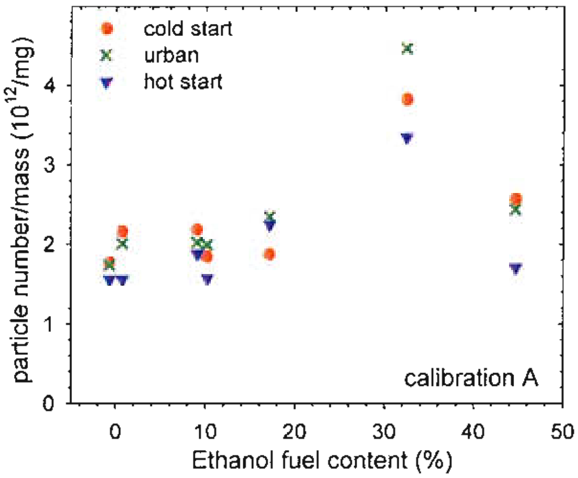

FIG. 7. Particle number to PM mass ratio versus fuel ethanol. (Color figure available online).

(1) a high fraction of elemental carbon and (2) a correlation between particle mass and number emissions. Normally, gasoline vehicle PM is considered primarily organic in nature; for example, EPA's Kansas City Study reports that OC accounts for about 80% of the particulate emissions (U.S. Environmental Protection Agency 2008). The explanation is that tight control of air/fuel stoichiometry allows little chance for sooting conditions to develop and, therefore, the observed PM largely derives from organic combustion byproducts and fugitive low-volatility fuel and lube components. But this reasoning applies to port fuel injection, where the fuel is vaporized at the intake port. Direct injection provides less opportunity for fuel vaporization and increases the likelihood of fuel impingement onto piston and cylinder surfaces, and the resulting combustion of liquid fuel produces soot. HC precursors to organic PM, though, are removed by the three-way catalyst, leaving the tailpipe PM with a high EC/OC content.

Figures 7 and 7S demonstrate the correlation between particle number and mass emissions. The ratio of $\sim 2 \times 10^{12}$ particles/mg for E0–E17 fuels is the same as found for solid particles emissions from both GDI and diesel vehicles (Kirchner et al. 2010; Maricq et al. 2011). Since in the present work, we did not purposefully remove liquid droplets, this similarity indicates that there is virtually no nucleation mode. Apparently, pool fires and liquid droplet combustion in GDI engines produce PM sufficiently similar to the 60- to 80-nm geometric mean mobility diameter soot in diesel exhaust to yield a comparable number to mass correlation (Harris and Maricq 2001). The increase of the ratio toward 4×10^{12} particles/mg in some tests, particularly E32, suggests the possibility of a small nucleation mode.

The high soot content and likely formation by liquid fuel combustion suggest that a comparison of GDI vehicle PM to soot in ethanol–gasoline diffusion flames may be interesting (Maricq 2011). These flames fall into two characteristic groups: (1) open flames, orange in color and emitting soot from their tips, and (2) closed flames, yellow in color with no smoke emitted from the tip. E0 and E20 flames belong to the first group. They exhibit little difference in how soot size and number density develop with height of the flame. E50 is similar, but shows signs of reduced soot formation. In contrast, the E85 flame falls into group 2. In effect, ethanol blend combustion fundamentally follows a similar trend as found in the GDI vehicle emissions, namely a minimal impact on soot up to about E20, but then, larger reductions for high-level blends.

The present study suggests that substantial PM emissions benefits are not expected for low-level ethanol blends; at least not more than the ~0.7-mg/mi measurement uncertainty. But, neither is there a PM disadvantage as the commercial light-duty fuel composition moves to E10, and possibly E20. The specific conclusions from this study might change as GDI engine designs evolve, but the reproducibility of the fuel effects at two different calibrations, plus the similar behavior in flames, suggests a measure of robustness to these conclusions.

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VIRENT

May 24, 2013

The Honorable Fred Upton
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U.S. House of Representatives
2125 Rayburn House Office Building
Washington, DC 20515

The Honorable Henry A. Waxman
Ranking Member
Energy and Commerce Committee
U.S. House of Representatives
2322A Rayburn House Office Building
Washington, DC 20515

Dear Chairman Upton and Ranking Member Waxman:

Virent is pleased to comment on the U.S. House of Representatives Committee on Energy and Commerce's third white paper reviewing the Renewable Fuel Standard (RFS2).

Virent is a Madison, Wisconsin based company that uses patented catalytic technology to convert plant-based materials into a range of products identical to those made from petroleum, including gasoline, diesel, jet fuel, and chemicals used to produce plastics and fibers. Key investors and partners include Shell, Cargill, Honda and The Coca-Cola Company. Please visit www.virent.com for more information.

As the committee is aware, the Renewable Fuel Standard was expanded as part of the Energy Independence and Security Act of 2007, which created specific requirements for advanced biofuels, including the biomass-based diesel, advanced, and cellulosic biofuels pools. The clear vision of Congress in drafting this statute was to encourage the production of an entirely new range of fuels from a broad and diverse array of feedstocks. We agree that many factors such as potential impacts to the environment and the potential of second generation biofuels to meet these challenges makes this an appropriate time to assess the course and implementation of the RFS2 program. We applaud the committee's efforts in this regard.

Based on Virent technology and positioning within the biofuels and biobased chemicals industry, we feel it is appropriate for us to comment on six (excluding question 5) of the seven questions posed by the white paper.

Question 1: Is the RFS reducing greenhouse gas emissions below that of baseline petroleum-derived fuels?

Yes, it is likely that the aggregate biofuels currently produced under the RFS have a net positive effect with regard to reducing GHG emissions from the transportation sector. Unfortunately, these positive effects are greatly diminished by the "grandfathering" provisions that exempted

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existing ethanol facilities from demonstrating the minimum 20% GHG baseline that defines a renewable fuel.[1] *As the nation's only policy directly targeted to reduce GHG creation, a plan to phase out the grandfathering of these ethanol facilities should be strongly considered. A provision that would incentivize ethanol producers to either meet the 20% GHG reduction standard or be replaced by better performing, advanced biofuels should be implemented.*

Is the RFS incentivizing the development of a new generation of lower greenhouse gas emitting fuels?

Not as well as it could. In addition to ending the grandfathering policy as discussed above, we would recommend the incorporation of performance based metrics that would reward products produced under the RFS with increased RIN value for incremental increases in GHG reduction above the 20% baseline. The current thresholds for advanced (50% GHG reduction) and cellulosic (60% GHG reduction) are laudable, but in light of the apparent difficulty in delivering the mandated volumes these thresholds should be re-examined. Rewarding incremental performance above the 20% baseline with additional RIN value (similar to the provisions that reward the increased BTU content of drop-in fuels), along a sliding scale, would incentivize production of better GHG performing products and reward continuous improvement. This incremental additional RIN value would also promote compliance with the mandate, delivering increased GHG performance with the same or even fewer gallons of biofuels.

Additionally, consideration should be given to including some level of mandatory annual volumes in every pool of the RFS. This would send a strong signal to investors and promote investment by private capital toward increasing the manufacturing capacity in the advanced and cellulosic biofuel sectors.

Will the RFS produce further greenhouse gas emissions reductions when it is fully implemented?

Certainly, with even greater impact if the above changes are implemented.

Question 2: Could EPA's methodology for calculating lifecycle greenhouse gas emissions be improved, including its treatment of indirect land use changes? If so, how?

Overall, the current EPA methodology for calculating GHG emissions could benefit from more clarity in the description of how direct and indirect emissions should be calculated. There is room for improvement in the EPA's methodology for calculating lifecycle greenhouse gas emissions and they include the treatment of indirect land use change (ILUC). The value of GHG

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[1] EPA 40 CFR Part 80, Regulation of Fuel and Fuel Additives: Changes to renewable Fuel Standard Program, *Federal Register*, Vol. 75, No. 58, March 26, 2010.

emissions due to global agricultural production and commodity economics is not static and it should not be treated as such. Furthermore, there is still a lack of scientific consensus on how to calculate ILUC, though some models have emerged as potentially useful given the proper data.[2] *The dynamic and location-specific calculation of ILUC should be allowed and preferred in the EPA methodology when possible instead of the application of static ILUC factors. Additionally, national averages do not reflect the potential benefits of growing a feedstock in one region or another. Therefore, more region-specific calculations of GHG emissions from crop production in general should be used. Finally, cropping systems continue to evolve and, therefore, it is important to look at a comprehensive timeline for the actual cropping rotations. The lack of a comprehensive cropping system perspective leaves open the opportunity for cherry-picking one crop in a system because it gets minimal direct input since other inputs were added for other crops in the rotation.*

Question 3: Is the definition of renewable biomass adequate to protect against unintended environmental consequences? If not, how should it be modified?

The current definition of renewable biomass is not adequate to protect against unintended environmental consequences for two primary reasons. First, the current way that the definition is written is not well-suited to new feedstocks that are not currently under large-scale production. For example, many cellulosic feedstocks (e.g. switchgrass) are not under large-scale production in the US. This makes it difficult to assess the environmental consequences of its production at the large scale. The definition should include a requirement to study the effects of the production of new crops to prevent unintended consequences from the production of such feedstocks. Second, the definition should not exclude the use of crops planted on land newly converted to agricultural use unless the prior use was as some sort of sensitive habitat or land otherwise not suitable for agricultural use. Lastly, the RFS rules for woody materials should be simplified, and improved sustainability criteria should be applied more equitably within the woody materials themselves as well as relative to other agricultural biomass materials.

Question 4: What are the non-greenhouse gas impacts of the RFS on the environment relative to a comparable volume of petroleum-derived fuels?

There are significant potential impacts other than GHG impacts from the implementation of the RFS2. Recent research has identified the potential increase in other emissions to air which are

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[2] See Kløverpris, JH and Mueller, S. 2012. Baseline time accounting: Considering global land use dynamics when estimating the climate impact of indirect land use change caused by biofuels. Int J Life Cycle Assess. DOI 10.1007/s11367-012-0488-6, and Hertel, TW., Golub, AA., Jones, AD., O'Hare, M., Plevin, RJ and Kammen, DM. 2010. Effects of US maize ethanol on global land use and greenhouse gas emissions: Estimating market-mediated responses. BioScience. 60(3): 223-231 and Kim, S and Dale, BE. 2011. Indirect land use change for biofuels: Testing predictions and improving analytical methodologies. Biomass and Bioenergy. DOI 10.1016/j.biombioe.2011.04.039.

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human health hazards from the production and combustion of ethanol in transportation fuels. [3] *Additionally, many advanced drop-in fuels contain virtually zero sulfur, and would be instrumental in reducing emissions of this form.*

Finally, the 2005 petroleum baseline should be re-assessed to include the potential water use, water quality, air quality and land impacts of emergent sources of petroleum-based fuels (e.g. tar sands)[4,5]*. This new baseline should then become the basis for assessing performance of RFS eligible bio-based fuels and other product streams.*

Question 6: What is the optimal percentage of ethanol in gasoline? What is the optimal percentage of biomass-based diesel in diesel fuel?

Based on the current US transportation infrastructure (engines, storage facilities, pipelines and distribution network) and lower relative energy content, the optimum percentage of ethanol in the US gasoline market is no greater than 10%. Any changes to the RFS should be designed to increase development and commercialization of "drop-in" biofuels, which have the same properties and composition as petroleum-based fuels and may be used in existing infrastructure.

Question 7: What are the best options for substantially further reducing greenhouse gas emissions from the transportation sector? Is the RFS an important component of such efforts?

Substantial reductions in GHG emission in the transportation sector will be best effected through a portfolio approach. This will include increased fuel efficiency as mandated in the new Corporate Average Fuel Economy standards, electrification (albeit limited by cost, lack of infrastructure and current battery technology), and the use of alternative and renewable fuels.

The RFS is an important component of such efforts. In its nascent stages, these reductions were achieved through the use of ethanol and bio-based diesel, but the future reductions in GHG emissions from the RFS will come from the increased use of drop-in fuels. Though not directly tied to the transportation sector, an obvious next step would be to expand RFS eligibility to incentivize and credit the production of bio-based renewable chemicals. This would acknowledge the intimate connection between the production of fuels and chemicals in modern integrated biorefineries and allow a holistic approach to GHG emissions reductions in the future.

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[3] See Tessum, CW., Marshall, JD and Hill JD. 2012. A spatially and temporally explicit life cycle inventory of air pollutants from gasoline and ethanol in the United States. Envi Sci & Tech. 46(20): 11408-11417 and Hill, J., Polasky, S., Nelson, E., Tilman, D., Huo, H., Ludwig, L., Nuemann, J., Zheng, H. and Bonta, D. 2009. Climate and health costs of air emissions from biofuels and gasoline. PNAS. 106(6): 2077-2082.

[4] Woynillowicz, D., Severson-Baker, C., Raynolds, M. 2005. Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush; Pembina Institute, http://pubs.pembina.org/reports/OilSands72.pdf (accessed September, 2008).

[5] Kim, H., Kim, S. and Dale, BE. 2009 . Biofuels, land use change, and greenhouse gas emissions: some unexplored variables. Envi Sci & Tech. 43(3): 961-967.

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Once again, we appreciate the opportunity to comment and hope this information is beneficial to the Committee as it continues its review of the RFS. If there are any questions please do not hesitate to contact me at (202) 507-1316 or david_hitchcock@virent.com.

Sincerely,

David M. Hitchcock
VP, Government Affairs