Testimony on

The Renewable Fuel Standard

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SUMMARY STATEMENT

I wish to thank the Chairs, Representatives Lummis and Jordan, and the Ranking Members, Representatives Lawrence and Cartwright, as well as the other members of your Subcommittees for inviting me to today's hearing.

My name is John DeCicco and I am a research professor at the University of Michigan Energy Institute, where my main focus is transportation fuel use and its environmental effects. I hold a doctorate in engineering from Princeton University and have worked on America's energy challenges for nearly 40 years, including 21 years at environmental organizations before returning to academia in 2009.

My recent research has included scientifically rigorous evaluations of the Renewable Fuel Standard (RFS) and other policies that promote biofuels such as ethanol and biodiesel. RFS proponents claim that the policy reduces CO_2 emissions. I have found that it does not. In fact, from its inception, the RFS has increased rather than decreased the amount of CO_2 entering the atmosphere compared to petroleum fuels such as gasoline.

My findings contradict the conventional wisdom about biofuels and reveal errors in the computer modeling on which the environmental rationale for the RFS was based. It's no surprise that some biofuel researchers and advocates have criticized these findings and those of other researchers who have found related flaws in studies backing the RFS.

The claims that biofuels reduce CO_2 emissions rely on lifecycle analysis, a method for comparing the so-called carbon footprint of various fuels. When it expanded the RFS through the Energy Independence and Security Act of 2007 (EISA), Congress required EPA to evaluate the lifecycle emissions impact of non-grandfathered biofuels. The agency also adapted the method for its RFS impact assessments. EPA did not originate lifecycle analysis. Rather, the methods used were largely developed by the Department of Energy and academic proponents of renewable energy, and their use was advocated by green groups that back the RFS.

Unfortunately, these lifecycle analysis methods make a serious mistake by assuming that biofuels are automatically carbon neutral. In reality, only under certain conditions does replacing a fossil fuel with a biofuel neutralize the CO_2 leaving the tailpipe. For that to occur, harvesting the corn or other feedstock must greatly speed up how quickly cropland pulls CO_2 from the air. That doesn't happen for the corn ethanol and biodiesel mandated by the RFS.

Examining real-world farm data shows that, in practice, the carbon neutrality condition is not met. My research team evaluated corn ethanol for which lifecycle analysis had claimed a 40% reduction in greenhouse gas emissions compared to gasoline. We found no significant reduction of emissions. Moreover, under typical crop rotations, net emissions could be as much as 70% higher than those of gasoline. These results do not even include indirect land-use change, which would increase biofuel emissions even more.

So, here we are, ten years after the 2005 Energy Policy Act established the RFS and eight years after EISA. The policy has worsened CO_2 emissions and it turns out that the studies used to justify it are flawed. From an environmental perspective, the best outcome would be to repeal the policy. Short of that, helpful reforms would include scaling back the mandate, ideally to well below the blend wall, and striking the RFS lifecycle provisions.

Thank you for letting me share these findings and I'll look forward to your questions.

Examining the Renewable Fuel Standard

INTRODUCTION

The Renewable Fuel Standard (RFS) was first established by the Energy Policy Act of 2005, which amended the Clean Air Act to require that 7.5 billion gallons of renewable ethanol be blended into the nation's gasoline supply by 2012. The RFS was expanded by the Energy Independence and Security Act of 2007 (EISA) to target a total of 36 billion gallons of renewable fuel by 2022. EISA also set specific requirements for certain categories of advanced, cellulosic and biomass-based diesel fuels to meet specified levels of greenhouse gas (GHG) reduction, relative to the petroleum-based fuels they replace, as determined by the Administrator of the Environmental Protection Agency (EPA) through lifecycle analysis (LCA). Starch-based ethanol from facilities placed into operation after the enactment of EISA must also meet a lifecycle GHG intensity ("carbon intensity" or "CI") threshold, specified as being 20% lower than that of baseline 2005 petroleum gasoline.

Three public policy rationales underpin the RFS and other policies to promote biofuels. One is to support the domestic agricultural sector by creating an additional market for corn and soybeans, thereby bolstering prices for these commodities and enhancing farmer and processor incomes. The second is energy security, which some argue can improved by developing domestic sources of liquid fuels to reduce reliance on imported oil. The third rationale, which was elevated in the expanded RFS called for by EISA, is environmental. It rests on the potential for biofuels, which utilize carbon absorbed from the atmosphere through crop growth, to reduce net carbon dioxide (CO_2) emissions from transportation fuel use. Such renewable fuels can include biomass-based ethanol and biodiesel as well as potential "drop-in" (fully fungible) fuels derived from biomass that are compatible with existing vehicles and fuel distribution systems.

This discussion focuses on the environmental rationale for the RFS. It examines the methodologies that EPA, the Department of Energy (DOE) and other agencies have used to assess the GHG emissions impacts of renewable fuels and addresses the question of whether the RFS has reduced CO_2 emissions to date.

METHODOLOGICAL ISSUES

The environmental impacts of corn ethanol and other biofuels have been disputed for decades. Much of the disagreement hinges on the methods used to assess the impacts and the numerous assumptions that are made in the absence of complete data. Proponents of the lifecycle analysis (LCA) models used for fuels policy, as in the EISA (2007) RFS requirements for non-grandfathered fuels and in California's low-carbon fuel standard (LCFS), claim that these models implement the best available science for comparing transportation fuel alternatives. Such is the case for the DOE-sponsored GREET[1] model, similar LCA tools and the complex modeling apparatus involving commodity trade simulations that have been combined with GREET. However, outside of a certain community of specialists whose work is oriented to promoting biofuels, there never has been scientific consensus regarding the methods, their results or even whether it is appropriate to use LCA for regulation.

My recent in-depth review paper[2] examined over 100 studies dating from the 1970s and documents how the limitations of fuels-oriented LCA (often termed *fuel cycle analysis*, FCA) were pointed out decades ago. It also points out how the more scientifically rigorous method of terrestrial resource analysis (TRA) was developed two decades ago but that its key principles, particularly regarding complete carbon accounting and consistent use of system boundaries, were neglected by the fuels LCA modeling community. When the incorrect treatment of land use was highlighted in key *Science* papers[3] shortly after EISA was passed, established biofuel analysts attempted to mischaracterize the work and dismiss its applicability, leveling particular criticism at the issue of indirect land-use change (ILUC).[4] Subsequently, the fuels LCA community has addressed ILUC and other economic interactions by combining fuel cycle models with economic models. The resulting lifecycle modeling is more complex but still fails to address fundamental shortcomings with the approach.

This dubious method of analysis was widely promoted, particularly by DOE, certain national laboratories and some environmental groups as well as biofuel companies and trade associations. Unfortunately, this community did not adequately validate the methods using real-world data. Instead, the LCA-based claims of GHG reduction benefits for biofuels have been circulated uncritically, often without sufficient attention to the limitations and uncertainties, and broadly disseminated in policy circles.[5] These results about the lifecycle carbon intensity (CI, or "carbon footprint") found wide acceptance due in part to the politically appealing story they told about the environmental benefits of biofuels. Such was the situation when Congress expanded the RFS through EISA and inserted the requirement for EPA to use lifecycle methods to make compliance determinations for certain categories of renewable fuel.

LCA is a marked departure from proven, empirically verifiable methods for defining environmental regulations. EPA itself pointed out that

> "**the GHG reduction thresholds presented in EISA are the first lifecycle GHG performance requirements included in federal law.**"[6]

Since the RFS was passed, recognition of the problems with LCA has only grown. Concerns about food-versus-fuel trade-offs, the realization that highly productive land is a finite resource and the related risks of deforestation have only amplified the large uncertainties regarding the environmental impacts of biofuels. To the extent that a scientific consensus exists, it is that estimates based on LCA models and their augmentations are highly uncertain, particularly when it comes to the complex market interactions involved when using agricultural products for fuel.[7] As one paper concludes, "Obtaining precise estimates of these impacts is likely beyond the reach of current models and data."[8] Although perhaps unwittingly, Congress has put EPA in an untenable position by requiring the agency to use a method that is inherently, and indeed irreparably, inaccurate when writing regulations that have large impacts on costs to consumers and businesses as well as the environment.

In fact, using LCA to determine a specific value for comparing fuels is an abuse of the method. Lifecycle assessment methods were designed to evaluate the diverse sources of environmental impact associated with a product or system. When appropriately used, LCA can help identify problem areas and opportunities for reducing impacts within a given supply chain. Some LCA scholars have now highlighted the increasingly irreconcilable difficulties incurred when the method is used for bioenergy policy.[9] Moreover, in its guidelines for the method, the International Standards Organization (ISO) states that

> "**there is no scientific basis for reducing LCA results to a single overall score or number, since weighting requires value choices.**"[10]

Yet that is exactly what Congress has required EPA to do through the EISA stipulation that certain renewable fuels meet specified thresholds for lifecycle GHG emissions reduction compared to baseline petroleum fuels.

The LCA method is misused when GREET and similar models are used to claim GHG reduction benefits for corn ethanol, biodiesel and other biofuels.[11] It is also abused in the more elaborate modeling done by California to compute lifecycle carbon intensity values for the LCFS. Similarly, when such LCA modeling calculations are used to assert GHG savings due to the RFS either in the past[12] or prospectively,[13] the results cannot be claimed as scientifically valid. Even though legitimate scientific results may be used as inputs for such modeling, the LCA results depend on numerous value judgements about how to combine the available data for the purposes of obtaining the numbers that purport to represent fuel GHG emissions impacts. EPA's RFS analyses, even though they reflect a careful effort to use the best data available, are still burdened with this profound limitation of the LCA method itself.

Although there are many problems with the method, one key problem is that, by construction, the LCA models used for analyzing fuels assume that renewable fuels are inherently "carbon neutral," meaning that the CO_2 emitted when they are burned is fully offset by CO_2 uptake during feedstock growth. That assumption leads many scientists to presume that environmental impact assessments need only consider production-related GHG emissions throughout a biofuel's lifecycle. Although it is merely an accounting convention that is valid only under certain conditions, the carbon neutrality assumption is automatically invoked by GREET, regardless of whether the conditions are met, and it is also assumed by LCA models used for the RFS, as noted in EPA's statement that "CO_2 emissions from biomass-based fuel combustion are not included in their lifecycle emissions results."[14]

The notion that using a renewable fuels automatically reduces CO_2 emissions (short of processing impacts) is based on an incomplete and incorrect understanding of how carbon is recycled through plant growth. Only under limited conditions does substituting a biofuel for a fossil fuel neutralize tailpipe CO_2 emissions. Moreover, it is possible to evaluate the extent to which this condition is met using field data. Therefore, although it is not possible to estimate a scientifically valid single number that reflects the total lifecycle impact of a fuel, it is possible to carry out a scientifically valid test of whether a biofuel's feedstock has removed enough CO_2 from the air enough to offset, and thereby potentially neutralize, the CO_2 emissions from fuel use. My research has involved performing such evaluations using data for actual biofuel production as seen in the United States since the passage of the RFS. We find that the carbon neutrality condition is not met in practice.

To provide background for understanding this finding, the next section of this testimony describes the principles that underpin scientifically verifiable carbon accounting for interactions among the terrestrial biosphere (which is the source of biofuel feedstocks), the geosphere (the source of fossil fuel feedstocks) and the atmosphere (where excess CO_2 concentrations disrupt the Earth's climate).

PRINCIPLES FOR VERIFIABLE CARBON ACCOUNTING

A crucial foundation for any analysis of biofuels is the fact that CO_2 is always cycling between the biosphere and the atmosphere,[15] whether or not biomass-based products are being used for fuel. Figure 1 highlights the basic carbon flows needed to analyze the substitution of biofuels for fossil fuels, based on the "Biofuels Carbon Balance" paper published in *Climatic Change.*[16]

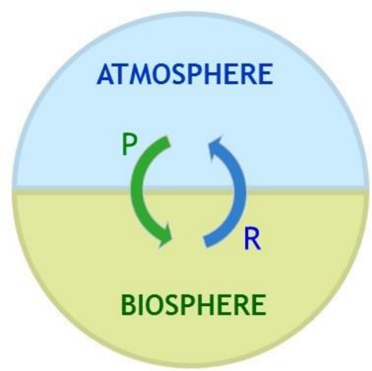

Figure 1. The main flows of the terrestrial carbon cycle: P = net primary production; R = heterotrophic respiration.

In this diagram, P stands for Net Primary Production (NPP), which is the amount of carbon absorbed into plants as they grow after subtracting plants' own metabolic release of CO_2. R stands for heterotrophic respiration (often designated R_h), which is the CO_2 respired by organisms that consume plants. That includes humans and livestock, but the vast majority of such respiration is from soil bacteria, fungi and other organisms collectively known as decomposers. These creatures form a critical part of the food chain that sustains all living things. Carbon is the fuel of life. In nature, no carbon is wasted; it is all put to use whether or not it is used commercially. On average, P exceeds R, which enables carbon to accumulate in the biosphere.

Another key tenet is the fact that the total amount of carbon in the world is fixed. Otherwise put, whether as food for biological processes, CO_2 in the atmosphere, fuel for motor vehicles or in living biomass such as forests, wetlands and other carbon-rich ecosystems, carbon utilization occurs in a closed system. This reflects the law of conservation of mass as applied to carbon. Unfortunately, this basic principle it is neglected in the LCA models used to analyze biofuels. The error is related to the fact that these models were designed without properly accounting for CO_2 uptake (that is, P in the diagram above) even though they track CO_2

emissions throughout a fuel's lifecycle. The failure to respect the law of conservation of mass is one of the reasons why most prior evaluations of the RFS (and biofuel use generally) give results that inconsistent with the realities of the terrestrial carbon cycle.

Using these principles for carbon accounting, rigorous analysis of what happens when a biofuel substitutes for a fossil fuel is straightforward. The situation is depicted in Figure 2, which shows the carbon flows associated with fuel use in addition to the basic carbon flows shown in Figure 1. Also shown is the P-minus-R difference, which is termed Net Ecosystem Production (NEP).[17] It is given as a downward arrow and reflects the net flow of carbon from the atmosphere to the biosphere.

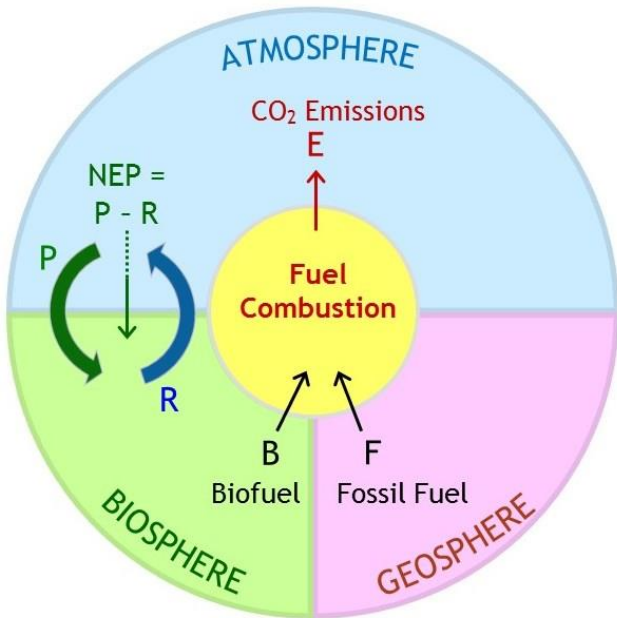

Figure 2. An increase in Net Ecosystem Production (NEP) is needed for biofuels to have a potential climate benefit.

At the center of the figure is fuel combustion. Whether the source of carbon in the fuel is biomass (B) or fossil (F), the amount of CO_2 emitted (E) when burning the fuel is essentially the same per unit of useful energy. In other words, using a biofuel (such as ethanol or biodiesel) instead of a fossil fuel (such as gasoline or diesel from petroleum) does not appreciably change the rate at which CO_2 flows into the atmosphere, e.g., from vehicle tailpipes or jet engines. As a matter of basic chemistry, if biofuels have a benefit, it is not when they are burned.

To reduce CO_2 buildup in the atmosphere, the emissions from fuel combustion must be balanced by *increasing* NEP, that is, speeding up how quickly CO_2 is removed from the atmosphere by cropland. In other words, there must be an acceleration of the net rate at which CO_2 flows from the atmosphere into biosphere. Mathematically, this condition is written as

$$d(NEP)/dt > 0$$

which means that NEP must be higher from one year to the next in order for fuel combustion emissions to be offset. If this condition is not met, biofuels cannot provide a climate mitigation benefit and biofuel use is not carbon neutral. Moreover, this failure to reduce net GHG emissions comes even before considering the emissions involved in growing the feedstock and processing it into fuel. It is also before considering the land-use change impacts that have become so prominent in the biofuels debate.

NEP can be evaluated over any area of land from a farm field up to the entire globe. To determine the potential climate protection benefits of a biofuel, it is necessary to evaluate how NEP changes on the cropland from which the feedstock is harvested. Figure 3 illustrates NEP for a crop such as corn. In annual crops, very little carbon accumulates in the soil from year to year; as NRC (2011) points out, the uncertainties in soil carbon changes are large relative to the magnitudes involved, and so it is fair to assume no change in soil carbon on average. Therefore, NEP is essentially proportional to the harvest (H as shown in the figure).

For example, on a 40 acre farm field that grows corn with an annual yield of 160 bushels per acre, the amount of carbon removed in the harvest is roughly 59 metric tons.[18] That means that the downward rate of carbon flow from the atmosphere into the biosphere over the field (that is, its NEP) is 59 tons of carbon per year. Corn is among the most productive of crops in terms of

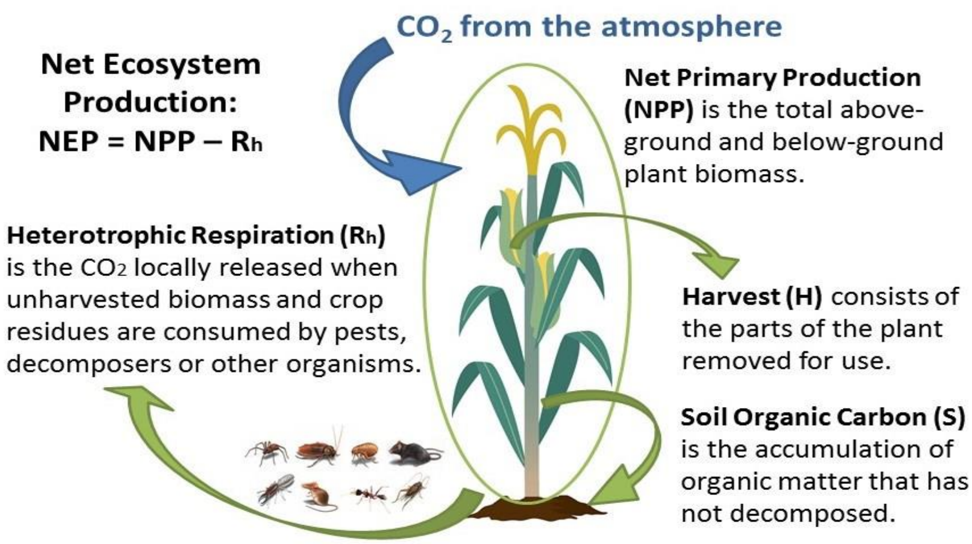

Figure 3. Carbon exchanges associated with an annual crop
Image Credit: Jane Thomas, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/)

yield, and so the NEP on a cornfield is significantly higher than that of other crops. An average soybean yield is 44 bushels per acre, and so a similar calculation for a 40 acre soybean field implies a NEP of roughly 18 tons of carbon per year.[19] As noted in the analysis discussed below, a gain in NEP occurs when rotating from soy to corn; conversely, a loss in NEP occurs when rotating back to soy.

DIRECT CARBON BALANCE EFFECTS FOR ETHANOL PRODUCTION

Measuring the extent to which biofuel feedstock production raises NEP enable an empirical test that of whether the GHG reductions predicted by LCA models actually occur in practice. To answer this question, we examined a case study for a state-of-the-art natural gas dry mill corn ethanol biorefinery and the farmland that serves it. The method we used relies on the directly measurable carbon flows associated with crop growth, refining and other production processes associated with both ethanol and gasoline, and the tailpipe ("end-use") CO_2 emitted when vehicles are driven.

Figure 4 is a schematic illustration of the system examined for a carbon balance analysis. Notably, the system boundary always includes CO_2 uptake on cropland because this uptake occurs whether or not the crops are used for fuel. It also tallies process emissions, including any process-related CO_2 that comes from biomass itself (known as biogenic emissions), which for

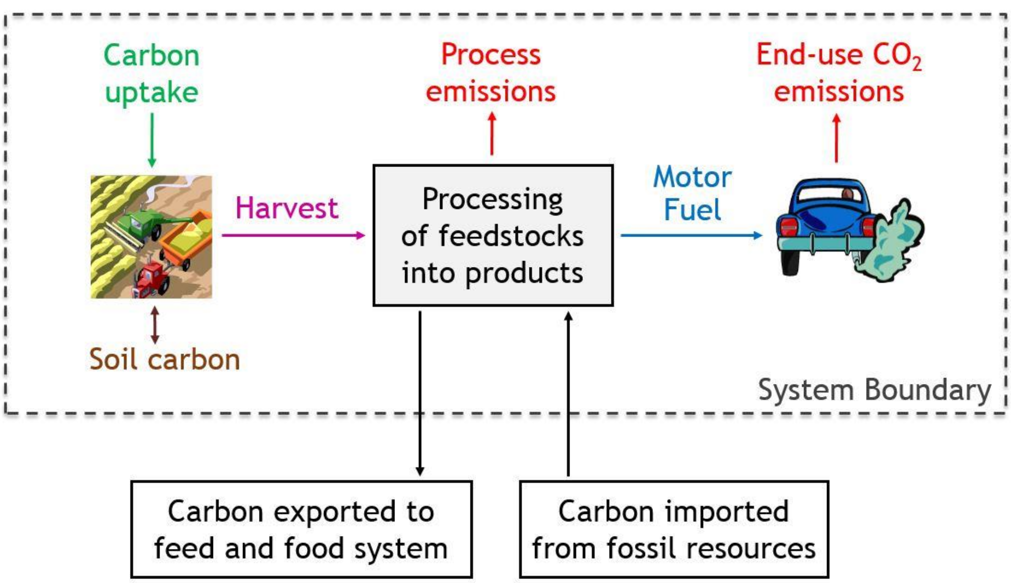

Figure 4. Schematic diagram for direct carbon balance analysis of motor fuel GHG impacts

Table 1. Summary of direct annual basis carbon (ABC) flows for a unified vehicle-fuel system using gasoline in a baseline year and corn ethanol the following year

Carbon-equivalent mass flows, thousand metric tons per year (kt_c/yr)			
	$Year_0$ using gasoline	$Year_1$ using ethanol	$Year_1$ - $Year_0$ Difference
Carbon exchange on cropland	(119)	(189)	(70)
Process emissions	39	115	76
Vehicle emissions	89	87	(2)
Net emissions impact of the system	**10**	**14**	**4**
Biomass carbon exported from system	119	65	(53)
Source: combined pathway results from DeCicco & Krishnan (2015); note that 1 kt_C/yr = (12/44)kt_{CO2}/yr			

ethanol production includes the CO_2 released during fermentation. As shown in the diagram, flows of fixed carbon (as opposed to CO_2) are exported across the fuel system boundary in the form of biomass products (corn, soybeans, other agricultural products and coproducts) and are imported across the system boundary from fossil resources such as crude oil. Changes in these external flows result in displacement effects, such as reduced corn and soybean consumption in the food and feed system, which is partly offset by coproducts such as distillers' grains, and petroleum that remains unused by motor vehicles but which can induce a rebound effect in fuel markets. However, these flows of fixed carbon do not result in CO_2 emissions to the atmosphere from the vehicle-fuel system itself, which is what matters when evaluating the extent to which tailpipe CO_2 emissions are offset by CO_2 uptake on cropland.

Table 1 summarizes what we found in our recent report.[20] The first line gives the carbon uptake on land, shown as a negative emission and reflecting the downward flow of CO_2 from the atmosphere into growing biomass, including carbon removed in the harvest plus any gain in soil carbon; the units are thousand metric tons (10^6 kg) of carbon mass per year, kt_c/yr. The difference column shows the change in carbon uptake; it is negative because the rate of carbon removal from the atmosphere by the cropland went up from the baseline year to the ethanol production year. The main reason for this large gain in uptake is a shift from growing soybeans on nearly half the cropland serving the facility to growing all corn when ethanol was produced. Because corn yields are higher than soybean yields, a corn field removes CO_2 from the atmosphere more rapidly than does a soybean field.

The second line of Table 1 gives process emissions, which are higher for ethanol production than for petroleum refining. These values are consistent with typical LCA estimates of the GHG emissions from feedstock and fuel processing, but for ethanol the ABC method also includes biogenic process emissions, notably the CO_2 released during fermentation. Vehicle tailpipe CO_2 emissions differ only slightly, with ethanol being 2% lower than gasoline.

Summing these values indicates that the net GHG emissions impact of the unified system (cropland, upstream and downstream processing and motor vehicles) is higher when ethanol is used than when gasoline is used. The difference is about 4 thousand metric tons of carbon per year (kt_c/yr), which in relative terms is 4.3% of the baseline 89 kt_c/yr end-use CO_2 emissions from gasoline use. This estimate is not a lifecycle ("well-to-wheels") CI metric, but simply the difference in direct GHG emissions from the circumscribed system of Figure 4 when using corn ethanol instead of gasoline. This increase in direct GHG emissions contradicts the previously published GREET analysis of the facility's first year of operation, which found a lifecycle CI for the corn ethanol that was 40% lower than that of gasoline.

The bottom row of Table 1 shows the changes in the rate at which carbon leaves the system in exported biomass. In the baseline year when gasoline is used, corn and soybeans are supplied to the external food system. When fuel ethanol is produced, only the coproducts are supplied to the food system. This large change in the supply of food-related biomass drives the displacement effects analyzed using the consequential modeling that has become part of LCA for fuels policy. For the case study examined here, the 53 kt_c/yr loss of biomass exports represents 45% of the baseline 119 kt_c/yr of exported biomass. Although not shown in the table, there is a reduction of 111 kt_c/yr of fossil carbon imported into the system as petroleum. Nevertheless, this reduction of fossil fuel use does not result in a direct reduction of CO_2 emissions because vehicle emissions do not significantly change.

This analysis highlights the critical importance of pre-existing CO_2 uptake on the land from which a biofuel feedstock is sourced. In the LCA methods used for the RFS, such baseline carbon uptake is automatically and fully credited against tailpipe CO_2 emissions, a modeling convention equivalent to assuming that uptake was zero before the feedstock was harvested for producing biofuel rather than for feed and food. But CO_2 uptake is never zero on productive land and is in fact substantial for existing cropland, the main source of biofuels produced at commercial scale. For the facility analyzed here, a gain in CO_2 uptake occurred because of the shift from soybeans to corn on nearly half the cropland serving the facility.

Corn-soy is the dominant crop rotation on U.S. farmland, but farms cannot permanently shift from soy to all corn, and so the case illustrated in Table 1 represents a best-case scenario for carbon uptake. We conducted a sensitivity analysis of different baseline conditions for crop rotation and yield; those results are detailed in the aforementioned report.[20] We found that a situation that just involves diverting corn from food and feed markets to the fuel market, and which does not credit a yield gain that would mostly likely have occurred anyway, resulted in an emissions increase of 61 kt_c/yr, implying that using corn ethanol would increase GHG emissions by nearly 70% compared to baseline tailpipe CO_2 emissions using gasoline. This can be considered an upper bound scenario, in contrast to the relatively insignificant 4 kt_c/yr emissions increase shown in Table 1, which can be considered a best-case scenario. The conclusion is that the change in direct CO_2 emissions when using corn ethanol instead of gasoline is insignificant at best, or it could make matters far worse.

In other words, the carbon neutrality assumption built into LCA models does not hold up for real-world biofuel production. Direct accounting of actual carbon flows shows that, at best, corn ethanol production fails to reduce CO_2 emissions relative to petroleum gasoline, and even that result depends on the gain in cropland carbon uptake that occurs with a large shift from growing soybeans to growing corn. If the baseline land use was corn production, then the increase in GHG emissions due to ethanol production would be significantly higher. Finally, if consequential effects including ILUC were included, the result would be a yet even higher estimate of the adverse net GHG emissions impact of biofuel use.

Our next and still ongoing phase of research is performing a data-driven carbon balance analysis of the effect of the RFS nationwide since 2005. To carry out this assessment, we are examining how carbon uptake changed on all U.S. cropland from 2005 through 2013, which was the year of most recently available complete data when we started the project.

The key input to this ongoing analysis is shown in Figure 5, which charts the rate of CO_2 uptake on U.S. cropland in teragrams (10^{15}g) of carbon per year (TgC/yr, which is the same as millions of metric tons of carbon per year).[21] The gain from 2005 to 2013 amounted to roughly 20 TgC/yr, indicating an increase of 10% in the net rate at which CO_2 flows downward from the

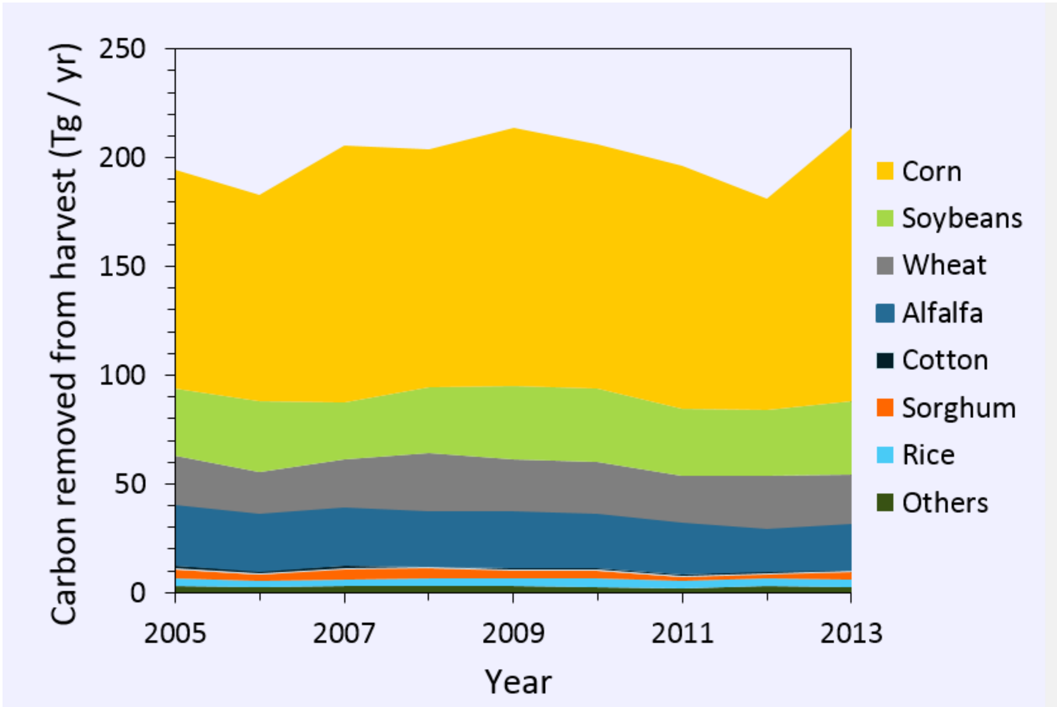

Figure 5. Rate of carbon uptake on U.S. cropland, 2005-2013.
Source: Derived from USDA Crop Production Summary data.

atmosphere into vegetation growing on cropland. It reflects changes in harvested area, crop mix and yield. The estimated 20 TgC/yr gain in CO_2 uptake is essentially an upper bound on the potential offset of end-use CO_2 emissions that might be achieved when substituting biofuels derived from the cropland for fossil fuel products. The amount of this gain in uptake that can be reasonably attributed to the demand for grains created by the RFS is less than the total amount of carbon contained in the harvest supplied to biorefineries. That means that once processing and direct land-use change emissions are factored in, there is no significant reduction in net GHG emissions due to the use of the corn ethanol and soy biodiesel. Using EPA's estimates for indirect land-use change then pushes the total CO_2 impact to a much higher level, implying substantially higher cumulative CO_2 emissions overall.

In theory, the net rate of CO_2 uptake on cropland (i.e., NEP) can be increased by using crop residues to make fuel, as now being pursued at a small scale through cellulosic ethanol production. NEP then increases because R decreases, e.g., by collecting corn stover that would otherwise decompose and thereby reducing the CO_2 emissions from cornfields after grain is harvested. In any case, it is necessary to do a careful, location-specific assessment of how NEP actually changes when biofuel feedstocks are produced; one cannot just assume (as lifecycle models now do) that the carbon in a harvest fully offsets CO_2 emissions during fuel combustion. Ecologically speaking, the extent to which one can safely "starve the decomposers" by harvesting residues is likely to be limited.

The implication is that, while it may be possible for biofuels to contribute to climate mitigation, the conditions under which they actually do so are much more restricted than is commonly assumed. Moreover, because any climate benefit hinges not on biofuel use per se, but rather on raising the net rate of CO_2 removal from the atmosphere, there are other ways to accomplish this task that are less costly and more ecologically sound.

OTHER ENVIRONMENTAL IMPACTS

Although my own studies have focused on the GHG emissions impacts of renewable fuel use, excess CO_2 emissions are not the only environmental harm caused by the RFS.

Other researchers at University of Michigan conducted a detailed, geographically explicit assessment of how the cropland expansion related to the rising mandated demand for corn ethanol has destroyed habit for waterfowl and other wildlife.[22] Expanded corn production to meet the ethanol mandate is worsening water pollution, contributing to algae blooms and oxygen-starved zones in the Gulf of Mexico and Lake Erie.[23] Biofuel processing also releases other forms of air pollution; for example, recent research has found that the country’s third largest corn ethanol refinery emits 30 times more air pollution than was assumed for the RFS regulatory analysis.[24] Ethanol's corrosive properties are also incompatible with many cars already on the road and degrade the operation of lawn mowers, motor boats and other gasoline-powered equipment used by homeowners and businesses alike.

CONCLUSION

My studies have identified serious problems in the lifecycle modeling done for the RFS, raising concerns that have been shared with EPA and other agencies. The EPA Inspector General's investigation of the RFS analysis will hopefully shed further light on these issues. Our empirical research finds that the RFS is harming the environment. The program has caused higher CO_2 emissions than otherwise would have occurred and has also damaged the environment in other ways. Careful scrutiny reveals that the LCA studies used to justify the mandate were deeply flawed and that when passing EISA Congress was misled by claims that the RFS would be environmentally beneficial.

The policy implications of this examination of the Renewable Fuel Standard from an environmental perspective can be summarized as follows:

- The Congressionally imposed requirement to evaluate fuels using lifecycle analysis (LCA) lacks scientific merit. It is legally unprecedented; LCA-based RFS obligations cannot be verified empirically and therefore the method is inappropriate for specifying regulations.
- The use of LCA has resulted in erroneous conclusions regarding the GHG impacts of corn ethanol and other biofuels. Although it is not possible to unambiguously quantify the induced impacts of biofuel production and use, data-driven carbon balance accounting for the directly measurable aspects of a vehicle-fuel system shows that corn ethanol increases GHG emissions compared to gasoline.
- For CO_2 emissions, there is no merit in downstream regulation of motor fuels *per se* (in contrast to CO_2 permits as part of an economy-wide carbon cap, for example).
- Policies such as the RFS or an LCFS are ill-targeted for purposes of climate mitigation. Beyond tailpipe GHG emission standards and other measures that reduce transportation fuel demand, policy should focus on increasing the rate at which CO_2 is removed from the atmosphere in locations outside the transportation sector.
- Environmental harm will be minimized if the RFS is repealed or if the volume mandates are greatly scaled back.
- Environmental integrity will be improved if lifecycle analysis requirements are permanently struck from the law.

ENDNOTES

[1] Wang (1999).

[2] DeCicco (2015).

[3] Fargione et al (2008); Searchinger et al (2008).

[4] Wang & Haq (2008).

[5] An widely-cited meta-analysis from that period was the *Science* paper by Farrell et al (2006); a recent paper by Plevin et al (2014) describes how such attributional LCA studies can be very misleading.

[6] EPA (2009), RFS2 NPRM, *Federal Register* 74(99): 25021.

[7] Plevin et al (2010).

[8] Hertel & Tyner (2013).

[9] McManus & Taylor (2015).

[10] ISO (2006), p. 9.

[11] For example, as done by Wang et al (2007, 2011, 2012), among others.

[12] For example, as by BIO (2015).

[13] For example, as by Markey & Boxer (2014), citing Erickson et al (2014).

[14] EPA (2009), RFS2 NPRM, *Federal Register* 74(99): 25040.

[15] Churkina (2013).

[16] DeCicco (2013).

[17] Lovett et al (2006).

[18] The assumptions for this calculation are that a bushel of corn weighs 56 pounds; that its moisture content is 14% and that its carbon content is 42.1% of the dry mass.

[19] For soybeans, the parameters are a weight of 60 lbs/bu, 12.5% moisture and 42.6% carbon.

[20] DeCicco & Krishnan (2015).

[21] Unless otherwise noted, values are reported on a carbon rather than CO_2 mass basis, where $C:CO_2 = 12:44$; this includes CO_2 equivalences of other GHGs as weighted by 100-year global warming potential.

[22] Brooke et al (2010).

[23] Cho (2011).

[24] de Gouw et al (2015).

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Witness Disclosure Requirement – "Truth in Testimony"
Required by House Rule XI, Clause 2(g)(5)

Name: John M. DeCicco, University of Michigan Energy Institute

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1. Please list any federal grants or contracts (including subgrants or subcontracts) you have received since October 1, 2012. Include the source and amount of each grant or contract.

U.S. Department of Energy, Clean Energy Research Center Award No. DEPI0000012, $25,000,000 over five years, shared among multiple University of Michigan and award partner institutions, administered by the University of Michigan Energy Institute.
U.S. Environmental Protection Agency, SPEED Cooperative Agreement, Grant Number 83594901, $1,000,000 over four years, shared by University of Michigan units including the University of Michigan Energy Institute.
N.B. I was one among many researchers funded under these grants, but not the lead investigator.

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2. Please list any entity you are testifying on behalf of and briefly describe your relationship with these entities.

None.

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3. Please list any federal grants or contracts (including subgrants or subcontracts) received since October 1, 2012, by the entity(ies) you listed above. Include the source and amount of each grant or contract.

n/a

I certify that the above information is true and correct.
Signature: Date: 3/4/2016