15-2-4
Jonathan Lewis

Comments to the California Air Resources Board by the Clean Air Task Force

CLEAN AIR TASK FORCE

On the Proposed Re-Adoption of the Low Carbon Fuel Standard

February 19, 2015

SUMMARY

The Clean Air Task Force (CATF) appreciates this opportunity to comment to the California Air Resources Board on the Low Carbon Fuel Standard (LCFS). CATF is a nonprofit organization that works to help safeguard against the worst impacts of climate change by catalyzing the rapid global development and deployment of low carbon energy and other climate-protecting technologies through research and analysis, public advocacy leadership, and partnership with the private sector.

Our comments focus on the following points:

- ARB should readopt the LCFS through 2020. Achieving compliance with the 2020 target will be difficult, but the LCFS remains the most promising policy tool available for reducing the climate impacts of the transportation sector.
- The LCFS's promise is undermined by the proposed adjustment to the lifecycle emissions for corn ethanol, and by the likelihood that regulated entities will increase their reliance on corn ethanol to meet LCFS targets.
- The proposed adjustment to corn ethanol's lifecycle emissions score rewards corn for its negative impact on global food security. ARB must acknowledge and address this issue before it erodes the legitimacy of the LCFS program.
- The prospects for deep reductions in transportation sector GHG emissions are likely to improve significantly after 2020, particularly if liquid ammonia's potential as an affordable low-carbon fuel is proven out.

READOPTION OF THE LCFS

Consistent with an order issued by the California Court of Appeals in *POET, LLC v. California Air Resources Board*, 218 Cal.App.4th 681 (2013), ARB staff has reviewed and revised the LCFS, and is now

> proposing that the Board re-adopt the LCFS, replacing the current LCFS regulation in its entirety. The proposed LCFS regulation will maintain the basic framework of the current LCFS regulation, including: declining carbon intensity targets; use of life cycle analyses; inclusion of indirect land use change effects; quarterly and annual reporting requirements; and credit generation and trading.[1]

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[1] California ARB, *Staff Report-Initial Statement of Reasons* (December 30, 2014) at ES-3.

CATF urges the Board to readopt the LCFS. California's LCFS is the country's most promising public policy for bringing low-C fuels into the transportation market. It has several key attributes, all of which positively differentiate it from the federal Renewable Fuel Standard (RFS):

- Dynamic requirements: Increasingly stringent annual reduction requirements dissuade regulated entities from investing in marginally effective compliance strategies.
- Dynamic analyses: There are important ongoing debates about the performance of lifecycle GHG analyses—both with respect to specific technologies and their overall effectiveness. Regular reanalysis of compliance strategies prevents "lock-in" of outdated analyses and ineffectual technologies.
- No grandfathering: Under the LCFS, compliance options are measured according to their performance. Under the RFS, corn ethanol—which is largely exempt from the program's GHG reduction requirements—accounted for 83% of the overall volume mandate finalized by the Environmental Protection Agency (EPA) in 2013, the most recent year in which final renewable volume obligations were issued by EPA.
- Not limited to biofuels: Climate change mitigation depends on strategies that are scalable. That poses a problem for biofuels: the climate benefits of conventional biofuels typically diminish as production scales up, and advanced biofuels tend to be difficult (or impossible) to produce at a large scale.
- Clear focus on GHG reductions: The LCFS cannot blind itself to critically important non-climate impacts, especially the effect that increased consumption of biofuels can have on food prices and global food security. With appropriate safeguards in place, however, ARB can pursue the program's singular goal of GHG reductions without having to accommodate related-but-different objectives like price support for the agricultural sector or energy security.

A strong, stringent, flexible, intellectually honest LCFS creates a forum in which to consider new, truly low-carbon fuels, and a key market in which to commercialize them. It needs to succeed. However, that success must be achieved in terms of real GHG reductions, not merely on paper. CATF is concerned that a short-term reliance on conventional biofuels—especially corn ethanol—could pull the LCFS in the wrong direction, and imperil its prospects for long term success.

NET GHG EMISSIONS FROM CORN ETHANOL

When assessing a biofuel's net GHG emissions in the context of a given policy, an important—and complicated—component is the carbon release associated with land use changes. Of particular concern is indirect land use change (ILUC), or the amount of land use change that occurs as agricultural markets accommodate new policy-driven demand for biofuel feedstocks, and the amount of soil and plant-carbon that is released into the atmosphere as a consequence of those changes.

As supply margins for corn and other crops tighten in the face of competition from policy-driven demand for biofuels, the price of foodstuffs increases. The increase in food prices encourages farmers around the world to cultivate previously unfarmed land—a process that results in substantial losses of soil- and plant-carbon to the atmosphere. Accordingly, a biofuel must "pay back" this "carbon debt" (via CO_2 sequestration by subsequent energy crop growth) before it can be credited with any net climate benefits as compared to petroleum-based fuels (which have comparatively insignificant land use-related carbon impacts).

ARB staff have proposed that the ILUC score for corn ethanol should be reduced from the current score of 30 gCO_2/MJ. Adopting the proposed reduction would be wrong, both as a matter of emissions accounting and as a matter of climate mitigation policy. The proposed reduction would make corn ethanol a more viable LCFS compliance strategy. Heavier reliance on corn ethanol would limit the near- and long-term GHG reductions that can be achieved by the LCFS and would undermine the program's innovation-forcing objective—despite corn ethanol's status as an outmoded technology, the significant uncertainty about whether corn delivers any climate benefits, and the concerns about the non-climate environmental damage associated with its production.

Reducing the ILUC score for corn would be wrong from an emissions accounting perspective because it ignores a host of relevant factors that ARB has not yet been able to effectively quantify in CA GTAP-BIO, but which it knows will raise the ILUC score if/when the factors are correctly incorporated into the model. These factors have been identified by ARB staff[2] and in comments submitted by CATF and other stakeholders.[3] They include:

- The effect of water scarcity constraints on projected crop expansion. Researchers from Purdue University who used GTAP to examine the likely role of water scarcity on crop expansion found that earlier ILUC analyses "likely underestimated induced land use emissions due to ethanol production by more than one quarter."[4] As discussed below, ARB has not yet succeeded in sensitizing CA GTAP-BIO to water constraints, so the effect that such constraints have on LUC patterns and resulting emissions are not fully accounted for.
- GTAP's inability to differentiate commercial forest from non-commercial forests, which means that the model wrongly assumes that markets respond to the conversion of both land types in the same way.
- The yield improvement assumptions in GTAP overlook important differences among crops and growing regions, they fail to incorporate new research on future corn yields in the Midwest United States, and they do not adequately address the climate impact associated with the increased use of nitrogen-based fertilizers to sustain yield growth.

These issues are described more fully in the appended comments that CATF submitted to ARB in May 2014.

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[2] John Courtis, Anil Prabhu, Farshid Mojaver, and Kamran Adili. iLUC Analysis for the Low Carbon Fuel Standard (Update), California Air Resources Board, (March 11, 2014).

[3] CATF, Comments on ARB Proposed ILUC Analysis (May 2014) (http://www.catf.us/resources/filings/biofuels/20140519-CATF%20Comments%20on%20ARB%20Proposed%20ILUC%20Analysis.pdf)

[4] Farzad Taheripour, Thomas W. Hertel and Jing Liu. 2013. The Role of Irrigation in Determining the Global Land Use Impacts of Biofuels. ENERGY, SUSTAINABILITY AND SOCIETY.

Even if the fundamental concerns described above are put aside for a moment, the proposed ILUC reduction for corn ethanol is problematic because the materials prepared by ARB staff appear to consider two different reduced scores. The first—19.8 gCO_2/MJ—is the unweighted average of the thirty different production scenarios run on CA GTAP-BIO.[5] ARB's potential reliance on this value implies that it believes all thirty scenarios are equally plausible—a position that ARB has not, and cannot, justify. The second score—21.8 gCO_2/MJ—was derived by performing a Monte Carlo simulation (MCS). ARB's Expert Working Group has urged the use of MCS because of its "ability to represent arbitrary input and output distributions, ... perform global sensitivity analysis (e.g., contribution to variance) to identify which input parameters contribute most to the variance in the output, and ... represent parameter correlations."[6] As between the two scores, the value that was derived from the Monte Carlo simulation—*i.e.*, 21.8 gCO_2/MJ—is superior.

A recent paper by Bruce Babcock and Zabid Iqbal of Iowa State University asserts that ILUC models utilized by ARB and EPA have overestimated land use changes by "attribut[ing] all supply response[s] not captured by increased crop yields to land use conversion on the extensive margin."[7] The paper argues for the use of lower ILUC scores by attempting to prove that "the primary land use change response of the world's farmers from 2004 to 2012 has been to use available land resources more efficiently rather than to expand the amount of land brought into production."[8] The paper has several shortcomings, however:

- Babcock and Iqbal only consider intensification techniques such as double cropping rather than analyzing yield increases over this time period.
- The paper dismisses data on extensive land use changes in Africa on the grounds that the linkage between global food prices and those in rural Africa is weak (implying that biofuel policies in the US and EU have little effect on African food prices and land use change)—even though the authors note a correlation between global food prices and food prices in urban Africa.
- The paper makes overly generous assumptions about the extensiveness of double cropping. As Jeremy Martin of the Union of Concerned Scientists wrote in recent comments to ARB, double cropping is not widely used in Southeast Asia where palm oil plantations have moved into formerly uncultivated areas. Nor is double cropping widely adopted in parts of the Midwest where most U.S. biofuels feedstocks—primarily corn and soybeans—are grown. The Babcock and Iqbal paper also fails to account for increased GHG emissions from increased fertilizer usage where it does assume the use of additional double cropping in response to higher crop prices.
- Finally, the authors assume the "only net contributor to US cropland from 2007 to 2010 was a reduction in [Conservation Reserve Program (CRP)] land," but this too is an inappropriate assumption, because several studies (from South Dakota State University and even U.S. Department of Agriculture Economic Research Service, Farm

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[5] California ARB, *Staff Report-Appendix I: Detailed Analysis for Indirect Land Use Change* (December 30, 2014) at I-25.

[6] *Id.* at I-38, I-17.

[7] *See* Bruce A. Babcock and Zabid Iqbal, *Using Recent Land Use Changes to Validate Land Use Change Models* (Staff Report 14-SR 109) (http://www.card.iastate.edu/publications/dbs/pdffiles/14sr109.pdf)

[8] *Id.*

Service Agency, and Natural Resources Conservation Service data) show that cropland conversions exceeded acres exiting CRP, with huge impacts on GHG emissions.[9]

Reducing the ILUC score for corn ethanol would also be a mistake in terms of climate mitigation policy. The use of highly complex models like CA GTAP-BIO to determine the net emissions associated with biofuels produces values that have the veneer of objective validity. But the modeling outputs are enormously dependent on the data that are fed into the system and on the system's assumptions about how those data affect physical and economic processes.

A recently published paper examines the extent to which subjective decisions about incorporating different assumptions and data into a lifecycle model can affect the outcome.[10] Plevin *et al.* used a Monte Carlo simulation to characterize the parametric uncertainty associated with the two components of the lifecycle analysis that California used to evaluate biofuels: "an economic modeling component that propagates market-mediated changes in commodity production and land use induced by increased demand for biofuel globally, and a carbon accounting component that calculates the GHG emissions associated with (some) of these induced changes."[11]

The authors found that three parameters have particularly strong influences on the uncertainty importance for ILUC emissions intensity:

- Elasticity of crop yield with respect to price (YDEL) (in the economic model);
- Relative productivity of newly converted cropland (in the economic model); and
- Ratio of emissions from cropland-pasture to cropland, as compared to the ratio from converting standard pasture (in the emissions factor model).[12]

Among these factors, "[b]y far, the greatest contributor to variance in the estimate of ILUC emissions was YDEL, the elasticity of crop yield to price;" in fact, in ILUC analyses for corn ethanol, YDEL accounts for "nearly 50%"of the variance among possible modeling results.[13] ARB currently uses a YDEL value of 0.25 in GTAP-BIO—a subjective decision that is

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[9] *See* Christopher K. Wright and Michael C. Wimberly. 2013. *Recent land use change in the Western Corn Belt threatens grasslands and wetlands.* PNAS 4134–4139 (doi: 10.1073/pnas.1215404110) (http://www.pnas.org/content/110/10/4134.abstract); Steven Wallander *et al. The Ethanol Decade: An Expansion of U.S. Corn Production, 2000-09.* Economic Information Bulletin No. EIB-79 (August 2011) (http://www.ers.usda.gov/publications/eib-economic-information-bulletin/eib79.aspx); U.S. Department of Agriculture Farm Service Agency. *Cropland Conversion* (July 31, 2013) (http://www.fsa.usda.gov/FSA/webapp?area=newsroom&subject=landing&topic=foi-er-fri-dtc); U.S. Department of Agriculture Natural Resources Conservation Service and Center for Survey Statistics and Methodology, Iowa State University. *Summary Report: 2010 National Resources Inventory* (September 2013) (http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167354.pdf); *see also* Lark, TJ, Salmon, JM, Gibbs, HK. *Cropland expansion outpaces agricultural and biofuel policies in the United States.* ENVIRONMENTAL RESEARCH LETTERS. Expected Spring 2015.

[10] Richard Plevin, *et al.* 2015. Carbon accounting and economic model uncertainty of emissions from biofuels-induced land use change. ENVIRON. SCI. TECHNOL. (doi: 10.1021/es505481d)

[11] *Id.*

[12] *Id.*

[13] *Id.*

increasingly difficult to justify in light of separate analyses conducted for ARB by Steven Berry and David Locke. Berry reviewed a collection of studies on yield price elasticity (YPE) and, according to an ARB staff report, "concluded that YPE was mostly zero and the largest value that could be used was 0.1."[14] Locke ran a statistical analysis of a similar set of studies and found "that based on methodologically sound analyses, yield price elasticities are generally small to zero."[15] ARB has nonetheless chosen to include YPE values up 0.35 in its ILUC analyses.[16] [[Id. at Attachment 1-6]]

Developing the relevant data and determining which datasets to use (and which to exclude) are highly subjective exercises, as are the processes of choosing and programming the relational assumptions that drive the model. Viewed in this context, the proposal to reduce the corn ethanol ILUC score can be more appropriately understood as the product of a subjective process—one that reflects the current availability of certain data and analyses that would contribute to a lower ILUC score, but fails to account for a host of countervailing factors that ARB does not yet understand how to model.

The Board should recognize these limitations, as well as the necessary role that it and ARB staff play in interpreting and acting upon modeling results. The Board should exercise its best judgment in light of the overarching policy objective of the LCFS, which CATF understands to be a meaningful reduction in GHG emissions from the transportation sector. Because corn ethanol's lifecycle GHG emissions are—at best—only slightly lower than those from gasoline, and because increased reliance on corn ethanol would frustrate the development of more innovative and effective compliance options, the proposal to reduce the ILUC score for corn ethanol undermines the objectives of the LCFS. Accordingly, CATF urges the Board to table the proposal.

CORN ETHANOL'S IMPACT ON FOOD SECURITY

Another critically important way in which ILUC estimates are the product of subjective decisions (and not just objective calculations) relates to the treatment of food price increases associated with policy-induced demand for biofuels. As Plevin *et al.* (2015) write, "ILUC emission estimates depend on various modeling choices, such as whether a reduction of food consumption resulting from biofuel expansion is treated as a climate benefit."[17] ARB currently chooses to count GHG reductions that result from reduced food consumption when analyzing the lifecycle emissions of biofuels, but that—again—is a subjective decision. (Moreover, doing so implies that ARB assumes that national governments would not subsidize food consumption in the face of rising food prices.)

If instead ARB chose to assume that society would limit the extent to which food consumption would decline (especially taking into consideration a growing world population demanding significantly more calories and protein), its ILUC analysis would produce different results. For

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[14] California ARB, *Staff Report-Appendix I: Detailed Analysis for Indirect Land Use Change* (December 30, 2014) at Attachment 1-2.

[15] *Id.* at Attachment 1-5.

[16] *Id.* at Attachment 1-6.

[17] Plevin *et al.* (2015), *supra.*

example, Thomas Hertel *et al.* (2010) found that if food consumption were held constant in GTAP, the estimated emissions from biofuel expansion would increase by 41%.[18]

Similarly, Plevin *et al.* (2015) examine the effect of food consumption assumptions by comparing three model outputs for corn ethanol and other biofuels: the ILUC emissions factor; the non-CO_2 emission factor (*i.e.*, methane and nitrous oxide); and the total emission factor, which sums the ILUC factor and the non-CO_2 factor on a trial-by-trial basis.[19] When food consumption is held constant (or fixed) in non-Annex I countries, ILUC emissions for corn ethanol increase by more than 5 gCO_2/MJ as compared to a scenario in which food consumption is not fixed.[20] Total emissions from corn ethanol under a "food fixed" scenario increase by approximately 10 gCO_2/MJ (from roughly 35 gCO_2/MJ to roughly 45 gCO_2/MJ), while the upper limit of the confidence interval for the total emission factor reaches approximately 70 gCO_2/MJ.[21]

As with the other factors discussed above, the problematic and highly subjective treatment of reduced food consumption reinforces the point that ARB is not obligated to reduce the ILUC score for corn ethanol on the basis of the most recent—but highly incomplete—modeling results.

More generally, CATF urges ARB to reconsider how it accounts for reduced food consumption within the LCFS context, before the issues erodes the legitimacy of the LCFS program.

EMISSION REDUCTION OPPORTUNITIES POST-2020

ARB is appropriately interested in using the LCFS to achieve deep, long-term reductions.

> Although post-2020 goals for the LCFS are not part of this proposed rulemaking, continuing these policies beyond 2020 will ensure that fuel carbon intensity continues to decline and that low-carbon alternatives to petroleum are available in sufficient quantities in the long term. Achieving California's mid and long-term greenhouse gas and air quality goals will require a renewable portfolio of transportation fuels—including electricity and hydrogen—well beyond the current policy trajectories. Accordingly, ARB, in a future rulemaking, will consider extending the LCFS with more aggressive targets for 2030.[22]

An unwarranted reduction to the corn ethanol ILUC score would do more than undermine the actual climate benefits that the LCFS can achieve through 2020; it would lower the ceiling on the long-term effectiveness of the program by extending the period in which marginally beneficial technologies can compete with the far better options that will be available to California after 2020. Chief among these better options may be ammonia, a hydrogen-based energy carrier that CATF has previously discussed with ARB management and staff.

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[18] TW Hertel, *et al.* 2010. *Effects of US Maize Ethanol on Global Land Use and Greenhouse Gas Emissions: Estimating Market-Mediated Responses*. BIOSCIENCE. 60:223-231(doi: 10.1525/bio.2010.60.3.8).

[19] Plevin et *al.* (2015), *supra*.

[20] *Id.* at Fig. S2.

[21] *Id.*

[22] California ARB, *Staff Report-Initial Statement of Reasons* (December 30, 2014) at ES-1.

The potential benefits associated with ammonia fuel ammonia are enormous, both for the environment and for the prospects of the LCFS:

- Zero-carbon ammonia can be produced using air, water, and electricity generated by renewable or nuclear power plants, or by fossil fuel-based generating stations equipped with carbon capture and storage systems.
- A wide range of engines and fuel cells can use ammonia to generate electricity or to power vehicles, and can do so without emitting CO_2.
- Substantial global ammonia production and transport infrastructure is already in place. At 150 million metric tons per year, it is the third largest chemical produced globally.
- At $3.27 per gallon (on an energy equivalent basis to gasoline, at current prices) and $1.78 per gallon (when compared against gasoline's 10-year average price), ammonia is affordable. And as a liquid, it can be more easily transported and stored than hydrogen and natural gas.

The steps that need to be taken before a widespread transition to ammonia fuel can occur are significant—but not insurmountable. These include:

- Building awareness among industry, regulators, and other stakeholders about the economic and environmental advantages of using ammonia fuel for power generation and transportation (especially, at the outset, rail and long-haul truck fleets).
- Helping innovators and investors identify small volume/high profit projects to jumpstart the ammonia energy industry.
- Highlighting opportunities to shift ammonia production to zero-carbon processes (e.g., using stranded or otherwise underutilized wind power assets for ammonia synthesis).
- Detailing ammonia's toxicity risk (which is similar to that of LPG), describing how that risk is managed by farmers globally, and outlining protocols for how it can be managed in the power and transportation sectors.
- Developing a long-term roadmap for building up ammonia production and distribution capacity to the scale of a global energy commodity.

Since CATF briefed ARB on ammonia in July 2014, research in Texas (on ammonia-gasoline blending in internal combustion engines), Toronto (on the use of ammonia to fuel locomotives), and California have continued to validate the concept and develop demonstration projects.

The California project—which involves the University of California at Los Angeles (UCLA), California Energy Commission, and South Coast Air Quality Management District (SCAQMD)—is among the most interesting efforts to date. UCLA is spearheading a comprehensive program to utilize advanced engines from Sturman Industries for a multifuel (gas and ammonia), low NO_x combined-heat-and-power system. The system will be designed, installed, and optimized at a metals foundry in Los Angeles called California Metal-X (CMX). The project goal is to provide power at $0.097/kwh compared to a current base load cost of $0.18/kwh and peak power costs ranging from $0.20-$0.50/kwh from the grid. These cost savings come along with the potential to prove out an ammonia-based, scalable power source that meets the stringent air quality requirements implemented by SCAQMD.

The system will be designed to run in a wide range of modes including pure ammonia as a peak fuel and a variety of combined heat/power modes depending on power pricing, air quality standards, process efficiency, and power export profitability. UCLA, Sturman Industries, and other project partners will instrument the system to test and optimize ammonia engines, emissions, costs, maintenance, safety and other aspects of these types of operations in the real world. This project is being designed to provide a robust prototype for low cost, clean electricity across the California economy. If successful, the project will provide a technology and engineering basis for installing ammonia power in various markets around the world.

CONCLUSION

CATF urges ARB to readopt the LCFS through 2020. Although significant challenges remain, the LCFS is the most promising policy tool available for reducing the climate impacts of the transportation sector.

However, that promise is undermined by the proposed adjustment to the lifecycle emissions for corn ethanol, and by the likelihood that regulated entities will increase their reliance on corn ethanol to meet LCFS targets. The proposed adjustment to corn ethanol's lifecycle emissions score rewards corn for its negative impact on global food security. ARB must acknowledge and address this issue before it erodes the legitimacy of the LCFS program.

An unwarranted reduction to the corn ethanol ILUC score would also lower the ceiling on the long-term effectiveness of the program by extending the period in which marginally beneficial technologies can compete with the far better options that will be available to California after 2020. The prospects for deep reductions in transportation sector GHG emissions are likely to improve significantly after 2020, particularly if liquid ammonia's potential as an affordable low-carbon fuel is proven out.

Respectfully submitted,

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Estimating Indirect Land Use Change Emissions from Biofuels

CLEAN AIR TASK FORCE

Comments by Clean Air Task Force to California Air Resources Board

On the ILUC emissions estimate discussed in ARB's presentation "iLUC Analysis for the Low Carbon Fuel Standard (Update)" (March 11, 2014)

May 19, 2014

Overview

The Clean Air Task Force (CATF) is a non-profit environmental organization that works to protect the earth's atmosphere by improving air quality and reducing global climate change through scientific research, public advocacy, technological innovation, and private sector collaboration. CATF is pleased to submit the following comments to the California Air Resources Board concerning ARB's review of the indirect land use change (ILUC) emissions associated with biofuels and how those emissions are accounted for within the state's Low Carbon Fuel Standard (LCFS).

Although research into the effect that biofuels have on climate change is marked by uncertainty and controversy, it is increasingly evident that the production and consumption of some types of biofuels are undermining efforts to reduce greenhouse gas (GHG) emissions. As compared to other policies being used to promote biofuels—most notably, the federal Renewable Fuel Standard—the LCFS represents a significantly better platform for evaluating net GHG emissions and rewarding the fuels with the lowest carbon intensities. CATF is therefore committed to helping ARB ensure that the best and most current research is used to inform its assessments of the carbon intensities of different fuels, especially biofuels.

These comments highlight three factors that ARB should take into account as it evaluates the ILUC emissions estimate used to calculate the carbon intensity of biofuels in the LCFS context:

- Studies that supposedly demonstrate a trend toward lower ILUC emissions estimates—including versions of the Global Trade Analysis Project (GTAP) model that ARB relies upon to implement the LCFS—typically ignore how water scarcity constraints will impact crop expansion. A recent analysis that takes water scarcity into account finds that earlier studies "likely underestimated induced land use emissions due to ethanol production by more than one quarter."
- GTAP's inability to differentiate commercial forest from non-commercial forests means that the model wrongly assumes that markets respond to the conversion of both land types in the same way.
- The yield improvement assumptions in GTAP overlook important differences among crops and growing regions, they fail to incorporate new research on future corn yields

in the Midwest United States, and they do not adequately address the climate impact associated with the increased use of nitrogen-based fertilizers to sustain yield growth.

Each of these factors separately suggest that the GTAP model is currently under-counting ILUC emissions. Taken together, they indicate that a reduction to the ILUC emissions estimate discussed in ARB's March 11, 2014, presentation, "iLUC Analysis for the Low Carbon Fuel Standard (Update),"[1] would not be appropriate. CATF therefore urges ARB to keep the ILUC estimate at its current level until ARB can more fully account for the issues raised here and at the March workshop.

[I] The "Trend" Toward Lower ILUC Emission Estimates Is Illusory

In California (as in Washington DC), the ethanol industry has aggressively promoted the idea that ILUC emissions estimates for corn ethanol are steadily trending downward as new lifecycle analyses are published. The industry places particularly high value on particular publications by Purdue researchers Wally Tyner and Farzad Taheripour that point toward relatively low estimates of ILUC emissions, e.g., a 2012 paper that reduces the estimated land requirements for US ethanol production by 25%.[2] The cited studies have important shortcomings, however—a problem that is exemplified by the way in which the studies have ignored real-world constraints on the amount of water available for new agriculture.

In fact, more recent work by Taheripour is intended to correct this oversight. In a 2013 study he co-authored by Thomas Hertel and Jing Liu, two other researchers from Purdue, he writes: "[I]n contrast to the recent trend in such studies, incorporating explicit modeling of irrigation, and associated constraints, *significantly raises the land-based emissions associated with biofuel expansion*."[3]

Taheripour *et al.* (2013) opens with two key points. First, water availability is essential to understanding the land use impact of biofuel expansion, especially with water availability projected to decrease over the next two decades.

> [T]he question of whether expansion of global cropland cover involves irrigated or rainfed lands make a significant difference in terms of how much new land will be required to provide the additional production called for in the presence of biofuels … [I]f the expansion of irrigated land is constrained, either due to insufficient water or due to insufficient pumping capacity, then it is likely that more cropland area will be required to meet the additional global demand induced by ethanol production.[4]

The authors cite recent studies that predict large water deficits, including an analysis by McKinsey which estimates that by 2030 water demand will exceed water supply by 40%. "In summary," Taheripour *et al.* write, "it appears that water for agricultural irrigation will become much more expensive in the future – no doubt spurring considerable efficiency gains, but also raising the cost of production and therefore limiting the amount of land on which irrigated crops can be economically grown."[5]

Second, refining land use change models to account for real-world constraints on water availability reveals a greater likelihood that biofuels expansion will drive displaced agricultural production into areas that are rainfed. "These regions tend to be more carbon rich and therefore exhibit higher ILUC emission factors," write Taheripour *et al.* "Therefore, earlier models which ignore the role of irrigation in crop expansion tend to underestimate the ILUC emissions due to biofuel expansion."[6]

One such model is GTAP-BIO, which Taheripour and Tyner used in the earlier 2012 study to assess the land use impacts of the 2015 ethanol mandate in the US Renewable Fuel Standard.[7] (GTAP-BIO, of course, is used to generate the emissions estimates for biofuels that ARB relies upon to implement the LCFS.) The enhancements that Taherpour *et al.* make to GTAP in the 2013 study allow the model to recognize water scarcity constraints and distinguish between rain-fed and irrigated land. Figures 3 and 6 from Taheripour *et al.* (2013) illustrate the extent to which the intensity of global land use change can differ when models are programmed to distinguish between irrigated crops and rainfed crops, and when constraints on water availability are introduced:

Fig. 3 from Taheripour et al. (2013)

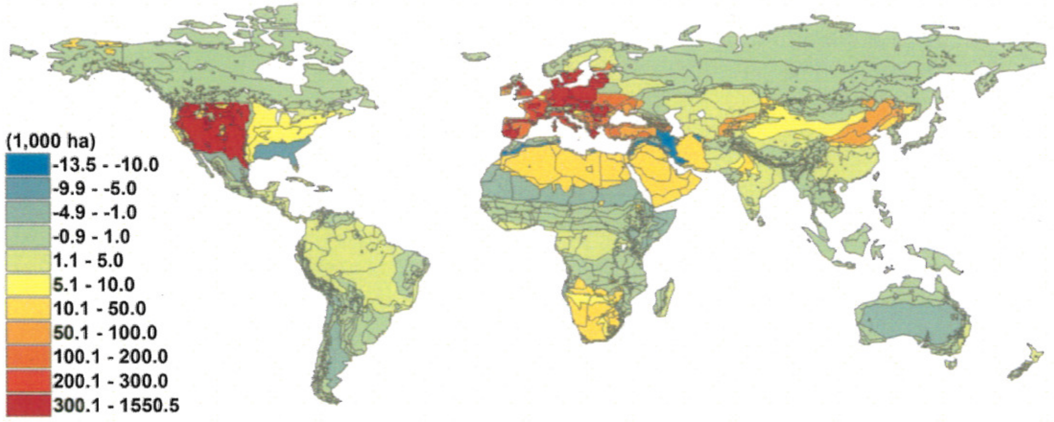

Figure 3 Irrigated cropland cover change, without irrigation constraint.

Fig. 6 from Taheripour et al. (2013)

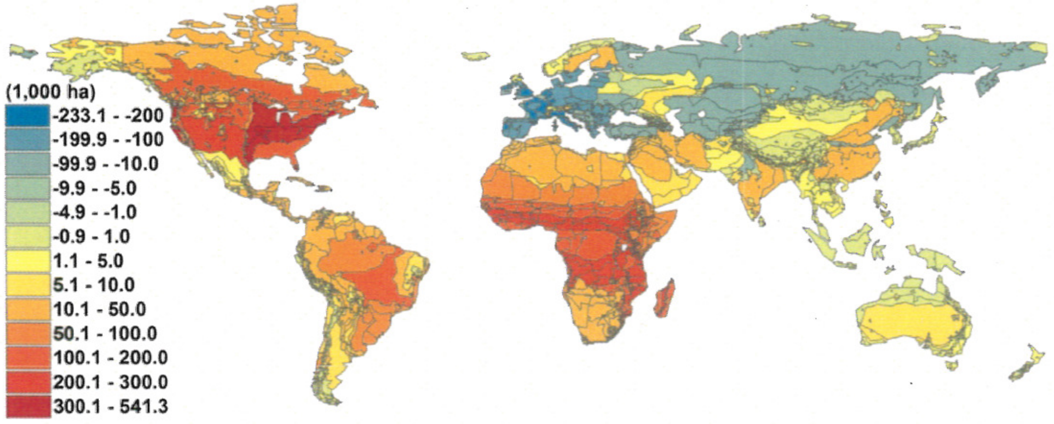

Figure 6 Rainfed cropland cover change, with irrigation constraint. Figures 3, 4, 5, 6 represent change in harvested areas.

By sensitizing the model to these factors, the 2013 study finds that ILUC emissions are likely to be substantially higher than prior estimates:

> [I]ncreasing US ethanol production from its 2001 level to 56.78 billion liters causes about 35.6 g CO2e/MJ emissions if there is no irrigation constraint across the world. Factoring in the physical limitations on irrigation expansion increases the land-based emissions to 45.4 g CO_2e/MJ. This means that the physical water scarcity adds 27.5% to the emissions due to land use changes induced by ethanol expansion. As shown in Table 5 [excerpted below], the constrained case also generates 27.5% more emissions compared to the case wherein we ignore irrigation altogether. This means that earlier studies, which failed to distinguish rainfed from irrigated lands, likely underestimated induced land use emissions due to ethanol production by more than one quarter.[8]

Table 5 from Taheripour et al. (2013)

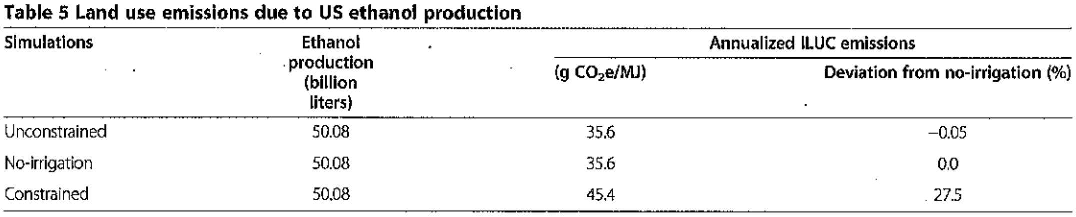

Table 5 Land use emissions due to US ethanol production

Simulations	Ethanol production (billion liters)	Annualized ILUC emissions	
		(g CO_2e/MJ)	Deviation from no-irrigation (%)
Unconstrained	50.08	35.6	−0.05
No-irrigation	50.08	35.6	0.0
Constrained	50.08	45.4	27.5

An additional point worth noting in this context is that both of the values cited in the 2013 study for corn ethanol—35.6 and 45.4 g CO_2e/MJ—are higher than the central values that ARB presented at the March 11 workshop (30.0 and 23.2 g CO_2e/MJ).[9]

In its March 2014 presentation, ARB staff notified the Board that the current version of GTAP fails to differentiate between the irrigated and rain-fed land and assumes that the water availability (or, rather, the unavailability of water) does not affect the model's estimates concerning the conversion of new land for crop production. Staff flagged two of the problems connected with this assumption—water is not an unlimited resource, and it cost money to irrigate newly converted cropland—and pointed out that, "Crop expansion and crop switching decisions will require availability of water resource and may change model predictions."[10] According to the presentation, staff plans to collect data on water availability, productivity differences, and land elasticity, and integrate those data into a revised GTAP model within the next few months.[11]

This effort to incorporate water-related restrictions on biofuel demand-driven cropland expansion is likely to materially affect ARB's estimate of the net GHG emissions associated with the LCFS. The 2013 study by Taheripour *et al.* indicates that ignoring the role of irrigation in cropland expansion "introduces systematic biases in the measurement of the size and pattern of global land use changes and therefore the land use emissions due to production of biofuels."[12]

We therefore encourage ARB to ensure that water constraints are accounted for in the lifecycle emissions analyses used to assess the treatment of biofuels within the LCFS.

[II] GTAP's Treatment of Forest Conversion Artificially Suppresses ILUC Emissions

Currently GTAP represents three land-use classes: forestry, pasture, and cropland. These are economic uses of land, however, not land-cover types. That is, GTAP does not represent forests generally; it represents economically productive timberland. As a result, the model assumes that any conversion of forestry land causes a reduction in timber supply, which in turn creates upward pressure on timber prices. This assumption has two effects that are likely to produce lower projected ILUC emissions.

First, the opportunity cost of converting commercial forestry land is greater than the opportunity cost of converting forestland that is not in economic use. The assumption within GTAP that all forestland is commercially managed therefore exaggerates the economic limits on non-commercial forest conversion. Consequently, the model likely projects less overall forest conversion than it would if it differentiated between commercial and non-commercial forests and made both types available for conversion.

Second, once commercial forestland is converted, there is an *afforestation* response elsewhere that makes up some portion of the lost timber supply. GTAP fails to appreciate that the conversion of non-commercial forestland would not produce a similar afforestation response.

Notably, other models used to estimate land-use change emissions—including IFPRI's MIRAGE, MIT's EPPA, and PNNL's GCAM—allow for the conversion of non-commercial forestland.

ARB staff referenced these concerns in their presentation for the March 2014 workshop, explaining that GTAP's inability to differentiate between forest categories "creates unrealistic deficit from wood products in the forestry sector."[13] A temporary fix involving adjustments to the Land Transformation Elasticity (ETL) values was proposed, with a completion target of April 2014.[14] It is not clear from ARB's website whether this fix has been executed or how the adjustment impacts the ILUC estimate. CATF cannot specifically comment on the proposed fix until we have reviewed the results of the ETL adjustment, but we are encouraged that ARB has identified this problem and is committed to addressing it. We urge ARB to ensure that its ILUC determination is based on land use modeling that effectively differentiates between commercial and non-commerical forestland.

[III] Aspects of GTAP's Treatment of Yield Problematically Affect ILUC Analysis

Several of the ways in which GTAP treats future crop yields are suppressing the model's ILUC emission projections. These include the model's assumption that price-induced yield improvements for all crops in all regions will match the improvement rate projected for Midwestern US corn, the model's current failure to accommodate new research suggesting that future corn yield improvements in the Midwest US could decelerate, and model's ongoing failure to adequately address the climate impact associated with the increased use of nitrogen-based fertilizers to sustain yield growth.

[A] GTAP's Handling of Yield Price Elasticity Suppresses ILUC Estimates

Yield price elasticity is perhaps the most controversial parameter in the GTAP model. GTAP utilizes a single number which determines how much yields—of all crops, in all regions—increase in response to price increases. Most arguments about price-induced yield improvements have focused on the "correct" value for this parameter, while failing to recognize that no such parameter exists in the real world: no single value can properly capture the substantial variability across crop types, climatic conditions, and economic conditions.

In practice, nearly all of the discussion about this parameter is informed by studies of one crop grown in one region—*i.e.*, corn grown in the US Corn Belt. There is little reason to expect that the yield effects measured for corn in the Midwest, a growing region characterized by fertile soil and readily available capital, to be representative of the effect that minor price increases have on, say, rice yield in developing regions.

When setting a range of values to consider for yield price elasticity within GTAP, ARB must treat this parameter as representing the *average* yield elasticity for all crops, in all regions, which is likely to be lower than what has been achieved by corn growers in the United States. The high values suggested for the US corn should be treated as the maximum obtainable. If GTAP assumed (appropriately) that not all crops grown around the world will achieve the same level of yield price elasticity as US corn, estimated ILUC emissions would likely increase.

[B] GTAP Does Not Incorporate New Research on Future Corn Yields

The assumptions made in GTAP about future crop yields do not yet take into account important new research by David Lobell and others on the impact that future drought conditions will have on Midwest US corn yields over the next 50 years. According to the study—Lobell *et al.*, "Greater Sensitivity to Drought Accompanies Maize Yield Increase in the U.S. Midwest," SCIENCE (May 2, 2014)—a greater incidence of midsummer drought conditions will slow the steady improvement in corn yields that farmers have historically achieved by increasing their cropping density. Assuming that finding is corroborated, it should be incorporated into GTAP's assumptions about future yield improvement.

According to the study, a handful of factors have allowed farmers to increase the density at which they plant corn and soy—e.g., no-till agricultural, higher ambient CO_2 concentrations, and genetic enhancements. Increased density has contributed to yield improvements, but it also "can be detrimental under drought conditions because of excessive stress exposure for individual plants."[15] The authors examined how corn and soy respond to various environmental stresses to determine "the net effect of recent genetic, agronomic, and environmental changes on drought sensitivity." They find that corn yields are particularly sensitive to increases in daytime vapor pressure deficit (VPD), "a widely used measure of atmospheric water demand that depends on air temperature and humidity." VDP increases appear to be especially impactful when they occur 2-3 months after a corn crop is sowed.[16] As Figure 4(B) from Lobell *et al.* shows, VDP during that timeframe (July, approximately) is expected to climb significantly over the next forty years:

Fig. 4 from Lobell et al. (2014)

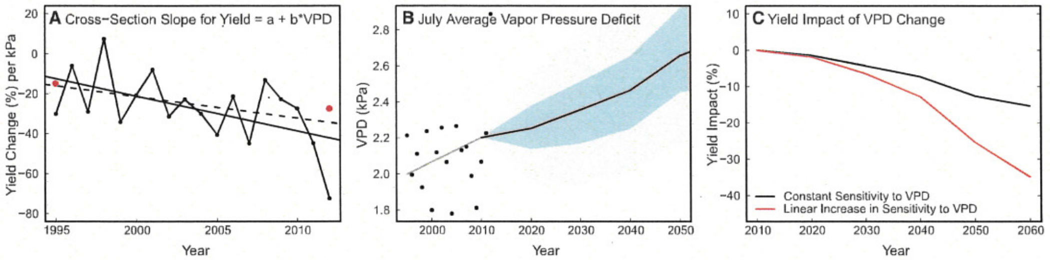

Fig. 4. Changes in vapor pressure deficit and its impacts. (**A**) Estimates of maize yield sensitivity to VPD 61 to 90 days after sowing from a cross-sectional regression for each year in the study period, along with best-fit trend lines with (solid) or without (dashed) including 2012 for computing the trend. Red dots indicate sensitivity estimates from APSIM simulations with sowing densities corresponding to the start and end of the study period. (**B**) Average July VPD in the study region for historical and projected periods. Dots show individual year observations, gray line shows linear trend for 1995 to 2012, black line shows mean VPD projected using 29 climate models, blue shading indicates 25th to 75th percentile of model projections, and gray shading indicates 5th to 95th percentiles. (**C**) Estimated impact of mean VPD projections on average maize yields using either constant yield sensitivity of −27.5% per kPa or a linear increase in sensitivity at the historical rate of 7% per kPa per decade.

The study concludes that if corn-growing regions continue to experience hotter and drier Julys, current projections for corn yield improvements are unlikely to be met:

> One implication is that climate change effects may be more severe than predicted by models that assume current crop genetics and management. Climate model projections indicate that July VPD for this region will become more severe, with an expected increase in average VPD of roughly 20% over the next 50 years (Fig. 4B), driven both by higher temperatures and reduced relative humidity. At current VPD sensitivity, these VPD trends would reduce yields by about 15% over the next 50 years. If maize yields continue to become increasingly sensitive to VPD, then yield losses from VPD trends could be as much as 30% (Fig. 4C).[17]

In addition to casting doubt on long-term yield projections for corn (the feedstock used to produce more than 80% of the biofuel consumed in the United States in 2013), Lobell *et al.*'s findings support the point made above that ARB should not use a yield price elasticity value for corn as a proxy for the elasticity of other crops' yields. Lobell *et al.* demonstrate that there are important physical constraints on corn yields that farmers may not be able to overcome through the commitment of additional resources. Accordingly, the study suggests that GTAP's yield price elasticity value for corn may not be appropriate for corn, much less for other crops.

Consequently, ARB should ensure that the new work by Lobell *et al.* informs future yield projections and the effect those projections have on ILUC estimates.

[C] ARB's Modeling Framework Undercounts N_2O Emissions

The modeling framework used by ARB assumes that yields for a wide range of crops will climb in response to increased demand for biofuel feedstocks, but it does not adequately account for the extra emissions associated with the farming techniques that will be utilized to achieve those higher yields. The likely result of ARB's approach is that ILUC emissions are undercounted.

Adding fertilizer, for example, results in additional emissions of nitrous oxide (N_2O), a potent greenhouse gas. ARB's modeling framework currently accounts only for the N_2O emissions that result from fertilization of the feedstock crops used to produce biofuels. This approach ignores the additional use of fertilizer for other crops, even when that additional usage is tied to an overall rise in crop prices brought about by new demand for energy crops. Under the existing modeling framework, therefore, the benefit of price-induced yield increases are counted, while the cost to climate of achieving those increases is not. If ARB accounts for both sides of the equation—*i.e.*, improved yields *and* higher N_2O emissions—as it should, estimated ILUC emissions are likely to increase.

In the March 2014 presentation, ARB staff acknowledged that both crop intensification and crop extensification associated with increased biofuel demand could result in additional N_2O emissions.[18] We urge ARB to fully account for these emissions when estimating ILUC emissions.

[D] GTAP's Treatment of Marginal Crop Yields Increases Uncertainty

One of the recent changes to GTAP that contributed to the proposed reduction in ILUC emissions relates to how the model represents yield on newly converted cropland. GTAP previously relied on a single value of 0.66 to represent the relative productivity of newly converted land,[19] until Taheripour et *al.* (2012) used the Terrestrial Ecosystem Model (TEM) to estimate relative yields on a regional basis.[20] The shift to regionalized estimates is an improvement conceptually, but the implementation of this change creates additional uncertainty—leaving in doubt whether this change produces a better representation of reality.

To implement this change, Taheripour *et al.* estimated the average net primary productivity (NPP) of a single crop—based on corn grown in the US Corn Belt—for land not currently used for crop production in each Region-AEZ combination, and the average NPP of land currently in crop production in that Region-AEZ.[21] The ratio of these NPP values—truncated to a maximum value of 1.0[22]—is used as a proxy for the relative yield of newly converted cropland.[23] This approach implicitly incorporates the following assumptions:

- *That Iowa's 1996 corn season is an appropriate proxy for all crops grown around the world.* (TEM is parameterized using data for corn grown in 1996 in Iowa, one of the world's most productive corn producing regions.)
- *That NPP is a good proxy for yield, and the difference in yield between these two land-use classes is best represented as a constant ratio (A/B) rather than, say, a constant difference (A-B).*
- *That TEM's estimate of NPP is correct.* (Pan et *al.* (1996) performed sensitivity analysis on the TEM model (version 4.0), showing that estimated NPP is sensitive to different assumptions about soil texture, temperature, precipitation, and radiation—all of which may vary within a given Region-AEZ.[24])
- *That the average NPP of all land not in crop production is a good approximation of NPP on the land actually converted.* (This assumption holds true only when land selection is random or there is little variability of NPP across land in the Region-AEZ. Neither of these are claimed to be the case in the study.)
- *That truncating some of the NPP ratios to 1.0 produces a valid estimate of marginal yield.* (Taheripour et *al.* make this adjustment in their 2012 study as a way of recognizing the unlikelihood that yields are better on land not being used for production. It remains unclear, however, why this adjustment is necessary if the basic method of computing

> NPP and using the ratio is valid. In other words, if the method produces values that are believed to be unrealistically high in some cases, what basis is there to believe that the other values produced by TEM (*i.e.*, those <1.0) are not likewise too high?)

In principle, regionalized estimates of marginal yield can produce more accurate model results. Whether this is true in practice, however, depends on how the regionalized values are determined. It is unclear whether the present implementation brings GTAP results closer to reality or further from it.

Conclusion

CATF believes that California's LCFS can play a globally important role in identifying and promoting fuels that can meaningfully reduce GHG emissions from transportation. We therefore appreciate the opportunity to help ARB ensure that the best and most current research is used to assess the carbon intensities of different fuels, particularly biofuels.

In order to develop a more reliable ILUC estimate, CATF urges ARB should ensure that its model fully appreciates the extent to which water scarcity will constrain future crop expansion, effectively differentiates commercial forest from non-commercial forests, and utilizes the most comprehensive and up-to-date data on yield improvements.

Sincerely,

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ENDNOTES

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[2] Farzad Taheripour, Quinlai Zhuang, Wallace E. Tyner, and Xioliang Lu. Biofuels, Cropland Expansion, and the Extensive Margin. ENERGY, SUSTAINABILITY AND SOCIETY 2012 (hereafter "Taheripour *et al.* (2012)")
[3] Farzad Taheripour, Thomas W. Hertel and Jing Liu. The Role of Irrigation in Determining the Global Land Use Impacts of Biofuels. ENERGY, SUSTAINABILITY AND SOCIETY 2013. 3 (emphasis added) (hereafter "Taheripour *et al.* (2013)").
[4] *Id.* at 1-2.
[5] *Id.* at 2.
[6] *Id.* at 2.
[7] Taheripour *et al.* (2012) at 6.
[8] Taheripour *et al.* (2013) at 9.
[9] March 2014 Staff Presentation at 61.
[10] March 2014 Staff Presentation at 42.
[11] *Id.* at 43.
[12] Taheripour et *al.* (2013) at 1.
[13] *Id.* at 45.
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[15] David B. Lobell *et al.* Greater Sensitivity to Drought Accompanies Maize Yield Increase in the U.S. Midwest. SCIENCE 2014. 516.
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[21] *Id.* at 3.
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