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Review of  
**Proposed Regulation to Implement the Low Carbon Fuel Standard**  
California Environmental Protection Agency  
Air Resources Board

The Air Resources Board has made a great deal of progress in modeling and quantifying the greenhouse gas and other environmental impacts of fuels. This work provides a strong foundation for understanding the impacts of these fuels, and for further development of understanding as experience with alternative fuels increases.

The five issues identified by the ARB to be addressed by the peer reviewers are addressed below.

**1. Greenhouse Gas Modeling**

- a. The description in the text of the greenhouse gas impacts of corn-derived and sugarcane-derived ethanol is solid, and could be emphasized more prominently: "Direct GHG emissions from the production and use of corn and sugarcane ethanol are less than the comparable emissions from gasoline. When land use change emissions are considered, however, the emissions-reduction benefit from corn and sugarcane ethanol is diminished." (p. IV-42)
- b. The lookup table values for carbon intensity for the three gasoline fuels appear to be well justified.
- c. The evaluation of carbon intensity for eleven different corn-derived ethanol is sound practice and provides a basis for encouraging low-carbon production of corn-derived ethanol.
- d. The numerical values assigned to the GHG emissions from production of corn-derived and sugarcane-derived ethanol have some uncertainties that could be reduced through revised analysis and further reduced when more data become available.
  - i. The calculation of the direct GHG emissions from production of corn-derived and sugarcane-derived ethanol is by-and-large solid and consistent with a well-developed body of scientific research. The calculation of the coproduct credits does, in my view, somewhat overvalue these credits, resulting in an underestimate of the direct GHG impacts of corn-derived ethanol of perhaps 10%.

## **2. Land Use Modeling**

The calculation of the indirect, land-use-change GHG emissions from production of corn-derived and cane-derived ethanol has significant uncertainties.

- a. That observed data have not been used to validate the GTAP model findings is a significant weakness. The changes in corn production resulting from the federal renewable fuel standard, and the changes in Brazilian sugar production resulting from increased ethanol production should be measurable, and should be measured to validate the model assumptions. The ARB model should be adjusted to reflect data.
- b. The lack of a time dimension in GTAP results in an awkward match with the question at hand. Corn yields have been increasing largely linearly for some time now in the United States, yet the model appears to use 2008 corn yields to determine land impacts of corn-derived ethanol. The projected steady increase in use of corn for ethanol in the US over the next few years suggests that land use change will be somewhat less than projected here.
- c. The greenhouse gas impact of land use change occurs mainly at the time of land clearing. This suggests that the effect of increased use of corn for ethanol will depend on whether and when total global corn production increases. An increase in use of corn for ethanol in a year in which corn demand decreases or stays constant will have a different greenhouse gas effect than in a year in which total corn demand increases. The increased use of corn for ethanol in one year can result in land clearing in a future year, depending on overall global total corn production and production of other crops. The ARB staff has put a great deal of effort in to thinking about the time dimension of this problem. Nevertheless, time-related issues are still addressed in piecemeal way that makes some unjustified assumptions. A more comprehensive approach to the changes in corn production over time would be simpler and could be more accurate. ARB could develop a more data driven and less model-dependent approach by observing and tracking changes in land use patterns that have been observed to date and that will be observed over the next few years as corn-derived and cane-derived ethanol production increases.
- d. The development of the land use change analysis for Brazilian sugarcane-derived ethanol appears to be less developed than the analysis of US corn-derived ethanol. The Brazilian analysis should be revised using up-to-date yield values, if they were not used in this analysis, and should reflect data on land use changes in Brazil.

## **3. Economic Impacts**

The LCFS staff report predicts that the LCFS will result in an overall savings in the State of California. The economic impacts of the LCFS will depend on future prices of petroleum and the future production costs of alternative fuels and vehicle technologies, which cannot be definitively predicted in advance. Nevertheless, the economic assessment appears reasonable, and the projection that the net economic impact will not be large and may even be slightly positive appears sound.

#### **4. Environmental and Multimedia Impacts**

The LCFS staff report covers many of the environmental impacts well. An important set of environmental impacts that are not mentioned are the increased impacts of nitrogen, phosphorus, and other agricultural inputs from increased corn production. As mentioned in the report, the increase in corn production is not likely to take place in California. Nevertheless, the impacts may be significant at the national and international scale. Hypoxia in the Gulf of Mexico is linked to increased corn production.<sup>1</sup> The use of nitrogen fertilizers and other agricultural inputs have a range of other environmental impacts that should be included in the environmental assessment.

#### **5. Credit Trading**

The credit trading framework and details appear reasonable. Note that the credit trading provisions may help to reduce the actual land-use-change impacts of corn-derived and sugarcane-derived ethanol: When corn or sugar prices are high, regulated parties may choose to use less corn-derived or sugar-derived ethanol, which would help to moderate corn and sugar demand and reduce pressure to increase plantings of corn and sugarcane.

#### **The Big Picture**

a. Are there any additional scientific issues to be addressed?  
No.

b. Taken as a whole, is the scientific portion of the proposed rule based upon sound scientific knowledge, methods, and practices?

Taken as a whole, the scientific portion of the proposed rule is based upon sound scientific knowledge, methods and practices. Use of a non-zero positive value for the carbon intensity due to land use change for ethanol from corn and sugarcane is sound. The direct emission values for ethanol from corn and sugarcane, and the differences in direct carbon intensity values for different ethanol production processes are sound. However, the values used to quantify the carbon intensity due to land use change for ethanol from corn and sugarcane are not yet sufficiently developed to be scientifically confirmed; refinement and validation of those quantities is needed.

#### **Detailed comments:**

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<sup>1</sup> US EPA SAB. Hypoxia in the Northern Gulf of Mexico. December 2007. EPA-SAB-08-003 [http://epa.gov/msbasin/pdf/sab\\_report\\_2007.pdf](http://epa.gov/msbasin/pdf/sab_report_2007.pdf)

Table IV-1, page IV-3. This table appropriately separates the direct emissions from the land use effects, and appropriately shows fewer significant figures for land use effects than for direct emissions. The direct emissions, however, should not be shown to four significant figures because the estimates are not that accurate; these results should be expressed to at most two significant figures.

p. IV-12. Coproduct allocation. Coproduct credits for corn ethanol are allocated in GREET by assuming that the use of coproducts as animal feed results in decreased production of the displaced feed in exactly the amount that is displaced. This effectively assumes completely inelastic demand for the displaced product. This is not consistent with the land use change calculations, which do assume demand elasticities. In other words, the coproduct calculation appears to be overestimated, resulting in a somewhat lower calculation of the direct GHG impact than is probably likely, and indicating uncertainty in the direct emissions results for corn ethanol of at least several percent.

p. IV-17. Among the choices to meet demand for biofuel feedstock, one option not mentioned is to convert existing agricultural lands from non-food crops – such as cotton or tobacco, for example.

p. IV-20. The GTAP model is not time dependent, whereas the land use change from biofuels is time-dependent. In particular, yields of corn and other feedstocks can be expected to increase in time. Although there is extensive discussion of this issue, particularly in Appendix C6, the expected increase in yield of corn beyond 2008 does not appear to be incorporated into the model.

p. IV-24. Of the three time accounting methods described, the first one is by far the most sensible. The Net Present Value calculation is not appropriate here. Net present value calculations are used for money because of the potential to invest money and receive a return over time. That is not true for greenhouse gas emissions. The Fuel Warming Potential also is not appropriate; the greenhouse gases will remain in the atmosphere beyond the project time horizon, and presumably the policy interest is to reduce climate change impacts over a longer time horizon than this project time horizon. Presenting the net present value approach and the fuel warming approach gives the impression that these are valid approaches that could be used. I suggest that discussion of these approaches be dropped from the main body of this report, although retained in the Appendices. Development of these ideas in the peer-reviewed literature would provide a basis for inclusion in future ARB analyses.

p. IV-26. ARB staff appropriately uses the annualized method.

p. IV-29. The results of the GTAP model are for a situation in which 13.25 billion gallons of increased ethanol production is produced in the year 2008. Yield will increase in subsequent years, requiring less land for a given amount of ethanol. If the increases in corn production occur after 2008, the land use impact will be less.

p. IV-31. It should be possible to validate with data the projections of land use change shown in Table IV-10, and especially the projections of US land use change.

p. IV-33, Table. IV-12. It should be possible to validate with data the projections of land use change resulting from cane-derived ethanol production in Brazil. The projections seem to be entirely model-derived, with no reference to studies of actual land use change in Brazil. The results should be validated with data. Also, cane yield in Brazil has increased significantly over time. The cane yield used in the GTAP model is not mentioned, but if the 2001 baseline is used, then the modeled land use change would be larger than if the 2006-08 sugarcane yield were used. And, as discussed elsewhere for corn, sugarcane yields can be expected to continue to increase, suggesting that land use change impacts will decrease over time.

p. IV-34. "As an initial estimate, we assumed a 75 percent coproduct credit for soy meal." ARB staff appropriately flags the uncertainty of this estimate.

p. IV-39. Comparison of GTAP results with Observed Market Behavior. The effects of corn ethanol on land use either are, or are not, large enough to be observable. As this section states, there are many factors that influence corn production and corn exports. If the effects of ethanol production are large enough to be measurable and identifiable, then this effect should certainly be taken into account in the assessment of corn-derived ethanol. Observation of the effect and validation of the model results is critical to validation of the greenhouse gas calculation for corn-derived and cane-derived ethanol. This section indicates that the GTAP model results cannot be validated, or have not yet been validated. Surely there is some aspect of the calculation that could be validated. For example, the changes in US forest and pasture land due to the federal RFS should be measurable.

p. IV-41-IV-42. This entire section expresses more certainty than warranted. Some judicious editing would prevent it from being misinterpreted. For example, in the bulleted list on p. IV-42, the word "about" should also be used in the last two bullets – these numbers are very uncertain.

p. IV-42. This statement is solid: "Direct GHG emissions from the production and use of corn and sugarcane ethanol are less than the comparable emissions from gasoline. When land use change emissions are considered, however, the emissions-reduction benefit from corn and sugarcane ethanol is diminished."

pp. IV-46. Increases in crop yield with time. The adjustments made to convert GTAP results from 2001 yields to 2006-08 yields, as described in Appendix C, do appear to be reasonable. However, the time profile of the land use change implied by the LCFS may warrant additional scaling of the GTAP results. In particular, if the increase in corn-derived ethanol is assumed to scale with the federal RFS, then the amount of corn used for ethanol will increase over time; if corn yields also increase over time then the land use impact of the corn-derived ethanol will decrease over time, although it will still be positive. However, if the amount of corn-derived ethanol used to fulfill the LCFS is

constant, as suggested by the scenarios presented in appendix E, then the land use change would all be concentrated in the very near future (or even recent past). The time scenario for corn-derived ethanol production (how much in which year, and the total change in demand in each year) will affect the actual land use change and the actual greenhouse gas impacts. The land use change impact will occur in the year that land use changes, which will not necessarily be the same as the year of the increased use of corn-derived ethanol.

p. IV-47. Uncertainties associated with time-accounting. As mentioned before, it would be feasible, and add clarity to the model, to do more explicit time-dependent modeling.

p. IV-48. The paragraph at the bottom of page IV-48 is solid. ARB should continue to refine its analysis and adjust the GHG emission values as the analysis develops, and data become available.

Appendices:

p. iii. The word "not" seems to be missing from lines 2.

p. C-5. Energy Economy Ratios. In Brazil, development of flex-fuel vehicle technologies with higher compression ratios has provided an opportunity to increase the efficiency of vehicles using ethanol fuels somewhat. ERB may not want to incorporate this potential into its LCFS EERs, but this potential may warrant at least a one-sentence mention.

p. C-27. A corn yield of 151.3 bushels per acre is mentioned here, but a corn yield of 160 bushels per acre is used in the derivation of the "110,000 acres of U. S. farmland" mentioned on p. IV-42 and derived on page C-41. The 160 bushels per acre may be taking into account future yield increases, as I have advocated above. The yield value assumptions, and the year to which each yield value is associated, should be clarified.

p. C-54. Co-product credit for DDGS. The decision of ARB to not adopt Wang's findings on this issue is solid. However, there is an additional co-product credit issue. In GREET, when a coproduct is used instead of the substitute product, the reduced use of the substitute is assumed to result in exactly that amount of decreased production of that product. This is surely an overestimate, resulting in a small underestimate of the direct GHG impacts of corn-derived ethanol.

p. C-54. "Staff will revisit this issue and make updates to the co-product credit, as appropriate." ARB's commitment to revising the analysis is important and will improve the assessment; increased production of biofuels will provide more data with which to refine the analysis.