Land Use Change Effects for Soy Biodiesel and Renewable Diesel

Comments received from stakeholders during the 30-day period under the Third Notice of Public Availability of Modified Text and Additional Documents and Information ("Third 15-Day Change Notice," released Dec. 14, 2009), as well as staff's own analysis, identified a number of issues related to the land-use change modeling for the soy biodiesel and renewable diesel pathways covered by the Third 15-Day Change Notice. These issues include a time discrepancy between the GTAP database (2004) and the land use database (2001) used in the modeling covered by the Third 15-Day Change Notice. This discrepancy resulted in an inconsistency with the modeling work that was done for corn ethanol using GTAP-BIO (Feb. 2009). Thus, as a result of the comments received and staff's analysis, staff concluded that a complete reevaluation of the land-use change effects portion of the supporting documents for soy biodiesel and renewable diesel was warranted.

For consistency with the modeling done for corn ethanol, staff took the GTAP-BIO model for corn ethanol as a starting point and modified its inputs and parameters to generate a customized GTAP model for soy biodiesel and renewable diesel. This new customized model, GTAP-SOY (January 2010), along with its component files, replaces the previous customized model (GTAP-SOY, Dec. 2009) that was released for public comments pursuant to the Third 15-Day Change Notice. Accordingly, this document replaces the document titled, "Land Use Change Effects for Soy Biodiesel," dated December 14, 2009, which was appended to the Third 15-Day Change Notice.

Because of time constraints on completing the pathway reevaluation, it was necessary for this latest modeling development to be conducted independently from the prior analysis in December 2009 using a different contractor. Nevertheless, it should be noted that, despite the use of two different contractors applying two different GTAP approaches, the modeling done by both contractors yielded essentially identical values for carbon intensity from land-use changes associated with soy biodiesel and renewable diesel. Working with researchers at Purdue, staff has estimated a new LUC carbon intensity value for soy biodiesel which is presented in this report.

We also note that, although the following specifically discusses the LUC analysis for soy biodiesel, the same discussion and analysis applies to soy renewable diesel. This is because both soy biodiesel and soy renewable diesel are derived from the same feedstock and, therefore, would reflect the same LUC effects. Thus, this analysis yields a LUC-effects carbon intensity value for soy biodiesel that also applies to soy renewable diesel.

1. GTAP Model Updates for Soy Biodiesel Modeling

ARB uses the Global Trade Analysis Project (GTAP) model for estimating LUC impacts of increased biofuel production. For the preliminary modeling presented in the ISOR, GTAP was limited in its ability to represent the soy biodiesel sector. Some key GTAP model limitations were as follows:

- The model assumed that biodiesel is produced directly from oilseeds. In actual practice, biodiesel producers usually use crude vegetable oil to produce biodiesel.

- The model did not account for market effects of oilseed meals and therefore an external adjustment for soy meal co-product credit was required.

- The model was aggregating all food products including vegetable oil under one category. Hence, the model was not able to properly distinguish impacts of biodiesel on food and vegetable oil markets.

Since publication of the ISOR in March 2009 and release of the prior analysis, "Land Use Change Effects for Soy Biodiesel" (Dec. 14, 2009), several improvements to the modeling of soy biodiesel were made to address these limitations[1]. Major revisions to the model are as follows:

- New sectors/commodities have been added to the model to represent production, consumption and trade of key commodities for biodiesel analyses. In particular, an aggregated commodity which was representing all processed food, feed, and vegetable oil products (called "OthFoodPdts") is now divided into five distinct commodities of: processed food, processed feed, crude vegetable oil, refined vegetable oil, and oilseed meals.

- In the new model, crude vegetable oil industry produces two commodities: crude vegetable oil and oilseed meals.

- Refined vegetable oil and biodiesel industries use crude oil in their production process.

- The model is modified to better take into account consumption of meals in livestock feed rations.

Based on these changes, staff believes the model results for soy biodiesel are now sufficiently robust to be included in the Lookup Table.

[1] For details about these modifications see Taheripour, F., T. Hertel, and W. Tyner. 2009. "Implications of the Biofuels Boom for the Global Livestock Industry: A Computable General Equilibrium Analysis."

2. Results and Discussion of Land Use Change Effects.

In this section, we present land use change results for soy biodiesel. Results include a sensitivity analysis performed on key model inputs. All land use change carbon intensity values were calculated using the annualized method with a 30 year project horizon.

a. Key Inputs into the GTAP model

Table I summarizes the key inputs for the GTAP analysis. The parameters appearing in this table are briefly described below and more fully described in Appendix C of the ISOR. The primary input to computable general equilibrium models such as GTAP is the specification of the changes that will, by moving the economy away from equilibrium, result in the establishment of a new equilibrium. Parameters such as elasticities are used to estimate the extent which introduced changes alter the prior equilibrium.

Table I
Key Inputs into the GTAP model

Inputs/Parameters	Ranges (if appropriate)
Baseline Year	2001
Biodiesel production increase (billion gallons)	.995
Crop Yield Elasticity	0.2 to 0.4
Elasticity of Harvested Acreage Response	0.5
Elasticity of land transformation	0.1 to 0.3
Elasticity of crop yields with respect to area expansion	0.5 to 0.75
Trade elasticity	Central Values*

*see Table C5-2 in Appendix C of the ISOR

- Fuel production increase: We modeled a production increase from 0.005 billion gallons in 2001 to 1.0 billion gallons of biodiesel. A final volume of 1.0 billion gallons is consistent with the Renewable Fuel Standard mandate for biomass based diesel.

- Crop yield elasticity: This parameter determines how much the crop yield will increase in response to a price increase for the crop. Agricultural crop land is more intensively managed for higher priced crops. If the crop yield elasticity is 0.25, a P percent increase in the price of the crop relative to input cost will result in a percentage increase in crop yields equal to P times 0.25. The higher the elasticity, the greater the yield increases in response to a price increase.

- Elasticity of crop yields with respect to area expansion: This parameter expresses the yields that will be realized from newly converted lands relative to yields on acreage previously devoted to that crop. Because almost all of the land that is well-suited to crop production has already been converted to agricultural uses, yields on newly converted lands are almost always lower than corresponding yields on existing crop lands.

- Elasticity of harvested acreage response: This parameter expresses the extent to which changes occur in cropping patterns of existing agricultural land as land costs change. The higher the value, the more cropping patterns will change (e.g. soybean to corn) in response to land costs.

- Elasticity of land transformation across cropland, pasture and forest land: This elasticity expresses the extent to which expansion into forestland and pastureland occurs due to increased demand for agricultural land (driven by higher crop prices).

b. Sensitivity Analysis Results

As shown in Table 2, the model results are sensitive to changes in crop yield elasticity, elasticity of land transformation, and elasticity of crop yields with respect to area expansion and are insensitive to reasonable changes in the biodiesel production increase. This model behavior is similar to that presented in the ISOR for corn, sugarcane, and preliminary soy biodiesel results.

Table 2
Sensitivity Analysis Results for Soy Biodiesel

Input variable	Input Variable Ranges		Percent Change in LUC Carbon Intensity
	Low Value	High Value	
Biodiesel production increase (billion gallons)	0.695	0.995	4.2
Crop Yield Elasticity	0.2	0.4	-21.6
Elasticity of land transformation	0.1	0.3	31.6
Elasticity of crop yields w.r.t. area expansion	0.50	0.75	-40.9

c. Calculating the LUC carbon intensity for soy biodiesel

In order to select an appropriate central value for the land use change impact of soy biodiesel production, seven scenarios were performed with varying elasticity values. For these scenarios, staff utilized elasticity value ranges consistent with the corn ethanol analysis presented in Chapter IV and Appendix C of the ISOR. These ranges are as follows:

- Elasticity of crop yield with respect to area expansion: 0.5 to 0.75

- Crop yield elasticity: 0.2 to 0.4
- Elasticity of land transformation: 0.1 to 0.3
- Trade elasticity: central case

Table 3 shows the LUC and carbon intensity results for seven scenarios. As shown in the rightmost column of Table 3, the mean global land conversion value across the range of runs is 0.94 million hectares. When the total GHG emissions from the conversion of these lands are annualized over a 30-year period, the result is a mean land use change impact of 66 gCO_2e/MJ.

Table 3
GTAP Modeling Results for Soy Biodiesel Indirect Land Use Change

Scenario	A	B	C	D	E	F	G	Mean
Economic Inputs								
Soy Biodiesel production increase (bill. gal.)	0.995	0.995	0.995	0.995	0.995	0.995	0.995	
Elasticity of yield wrt area expansion	0.50	0.75	0.50	0.50	0.50	0.66	0.75	
Crop yield elasticity	0.40	0.40	0.20	0.40	0.40	0.25	0.20	
Elasticity of land transformation	0.20	0.20	0.20	0.30	0.10	0.20	0.20	
Elasticity of harvested acreage response	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Trade elasticity of crops	Central							
Model Results								
Total land converted (million ha)	0.98	0.66	1.30	1.12	0.73	0.91	0.86	0.94
• Forest land (million ha)	0.33	0.16	0.43	0.31	0.29	0.25	0.21	0.28
• Pasture land (million ha)	0.66	0.50	0.87	0.81	0.44	0.66	0.66	0.66
U.S. land converted (million ha)	0.19	0.13	0.23	0.22	0.13	0.16	0.15	0.17
• U.S. forest land (million ha)	0.12	0.08	0.13	0.12	0.09	0.09	0.08	0.10
• U.S. pasture land (million ha)	0.07	0.05	0.10	0.10	0.04	0.07	0.07	0.07
LUC carbon intensity(gCO_{2e}/MJ)	73	43	93	77	58	61	55	66

In the preliminary estimates, several external adjustments were made to the GTAP model results to account for missing oilseeds meals; the difference between the average yield for aggregate oilseeds biodiesel and yield for soybean based biodiesel; and crop yield increase. There is no need to make the first two adjustments with the new analysis. The model now takes into account production and consumption of oilseed meals. The new model uses crude vegetable oil to produce biodiesel. Since biodiesel can be produced from all types of vegetable oils with the same conversion rate, the type of oil is not an issue here. In addition, the US average oil extraction rate from oilseeds (i.e., produced vegetable oil / oilseeds used) is equal to the oil extraction rate from soybean (i.e., produced soybean oil / soybeans used). Hence, the model results represent biodiesel production from soybean, and there is no need to make any adjustment for this reason. Therefore, the only external adjustment needed is an adjustment for yield growth.

In applying an external adjustment to account for crop yield increases since 2001, an overriding consideration was consistency with the similar yield adjustment that was applied to the corn ethanol land use change results.[2] That approach was vetted during the 45-day comment period held on the LCFS and approved by the Board when it approved the regulation as a whole on April 23, 2009. The Board-approved approach called for adjusting the land use change carbon intensity value from the GTAP analysis by the percentage increase in U.S. corn yields between 2001 and the corresponding average yield for the years 2006, 2007, and 2008.

The approach taken here departs from that method only slightly. Rather than applying the soybean yield increase, we apply the oilseed increase. Although both GTAP analyses were run on the crop group rather than the individual crops (coarse grains rather than corn, and oilseeds[3] rather than soybeans), corn usually comprises a somewhat higher proportion of the coarse grain harvest than the proportion contributed by soy to the oilseed harvest. In addition, all oilseeds can be converted to biodiesel using the same fatty-acid-to-methyl-ester process used on soy oil. Rapeseed is currently used to produce biodiesel, for example.

According to the USDA[4], the U.S. oilseed yield was 2.41 metric tons per hectare in 2001. The corresponding average yield for the years 2006 through 2008 was 2.58 metric tons per hectare—a seven percent increase. Applying this yield increase to the 66 g CO_2e/MJ from the GTAP analysis reduces that value to 62 g CO_2e/MJ. The full lifecycle carbon intensity of soy biodiesel, therefore, will consist of the sum of the direct fuel pathway carbon intensity (determined using the CA-GREET model) and the adjusted land use change carbon intensity of 62 g CO_2e/MJ.

[2] Please see page IV-29 of the Low Carbon Fuel Standard Initial Statement of Reasons (March 5, 2009). Yield adjustments are also discussed in appendix C (see sections C5 and C7).
[3] The oilseeds group consists of soy, peanuts, rapeseed, sunflower, and cottonseed).
[4] USDA Foreign Agricultural Service, Production, Supply, and Distribution Online (http://www.fas.usda.gov/psdonline/psdhome.aspx)