Indirect Land Use Analysis and Review of EPA's Proposed RFS-2 Rules for Biodiesel

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Overview

In May 2009, EPA released a series of reports documenting their life cycle analysis of green house gas emissions associated with the production of biofuels, including international indirect land use calculations. This report focuses on the models and the process used in their calculation of international indirect land use, specifically for biodiesel. In addition, this report presents alternative scenarios that incorporate the most recent history of biodiesel production and more current projections of crude oil prices, biodiesel technology parameters, and crop technology. As detailed in the report, the impact of the biodiesel mandate on indirect land use depends heavily upon the assumptions made regarding the price of crude oil, the extension of the blenders' credit, and technology growth. In general, IHS Global Insight finds that with current projections of crude oil prices, biodiesel production exceeds mandated levels and, therefore, there is no indirect land use change associated with the implementation of the biodiesel mandate.

In order to make the process EPA followed more transparent, a brief overview of the process is described, followed by a more-detailed evaluation of those models for which documentation is available. EPA utilized three models to compute the indirect land use associated with biofuels because they were unable to find one model that could provide all of the metrics needed in their analysis. Each of these models was developed independently of one another without the anticipation of being used collaboratively. The first of these models is the National Energy Modeling System (NEMS) model, which was developed the Energy Information Administration, a division of the Department of Energy. The NEMS model is designed to forecast energy supply, demand, and prices. The EPA states that the energy prices from the Department of Energy's 2008 Annual Energy Outlook (AOE) were used for the two scenarios they simulated (EPA-420-D-09-001 page 659). But the EPA also created another version of the NEMS to simulate the fuel volumes with and without the biofuels mandates in the RFS 2. The EPA refers to this modified model as the NEMS-EPA model although no documentation is provided of the specific changes that they made. The NEMS-EPA model was used to simulate two types of scenarios for each mandate. In the case of biodiesel, the first scenario was called the reference case and excluded the biodiesel mandate and removed the biodiesel blenders' credit. The second scenario, called the control case, included the biodiesel mandate, but continued to assume the biodiesel blenders' credit was removed. This method of analysis assumes that biofuels have no impact on energy prices. In addition, EPA makes a specific note on the difficulties of simulating fuel volume changes unique to each type of biofuel mandate in the RFS 2. With regard to the simulation of the reference case and control case for ethanol, they state: "Both cases also include modifications to the cost of soy-based biodiesel as a device that keeps the biodiesel production only at the minimum EISA-mandated level in both cases." (EPA-420-D-09-001 page 315). No specific comments are made regarding restrictions for the biodiesel mandate runs. It is not clear why it would be necessary to restrict soy-based biodiesel production in the ethanol runs, nor if any restrictions were made in the biodiesel runs. It is also unclear why EPA did not ask DOE personnel to make the runs since they have more experience with the NEMS model.

To examine the effects of biofuels mandates on the agricultural sector, EPA used the Forest and Agriculture Sector Optimization Model (FASOM) and the CARD-FAPRI model. (CARD is acronym for the Center for Agriculture and Rural Development and FAPRI is an acronym for the Food and Agricultural Policy Research Institute.) The EPA states that the energy prices from the 2008 AOE were used in the FASOM and CARD-FAPRI model scenarios.

The CARD-FAPRI model is a partial equilibrium econometric model that estimates supply and demand for agricultural commodities, including biofuels, in the major trading countries. The CARD-FAPRI models include corn, sorghum, barley, wheat, rice, cotton, sugar, soybeans, sunflowers, rapeseed, palm, peanuts, beef, pork, and poultry; although the rice and cotton models were not included in the CARD-FAPRI model set provided by EPA. Curiously, the biofuels portion of the CARD-FAPRI model was not utilized; instead, the EPA-NEMS model results for biofuels were used to overwrite the CARD-FAPRI model equation results. This allowed no simultaneity between crop prices (biofuels feedstocks) and biofuels production within the CARD-FAPRI model. In order to isolate the impacts from the RFS 2 biodiesel mandate, the CARD-FAPRI model utilized the reference case volume projections from the EPA-NEMS model to establish a projection to 2022. A "control" scenario, including the biodiesel mandate required in the Energy Independence and Security Act of 2007 (EISA), was then run to determine the impact on crop acreage globally. In both scenarios, the EPA used their version of the NEMS model to simulate the volumetric effects. The West Texas Intermediate Prices and the Refiner's Acquisition crude oil prices reported in the CARD-FAPRI model are not consistent with the 2008 AOE. Closer examination of these prices suggests that they drive the biofuels equations in the CARD-FAPRI model, which were shut off for the EPA simulations. Of greater importance is whether the 2008 AOE assumptions were used to formulate the variable costs of crop production used in the CARD-FAPRI model. Comparison of the cost of production numbers in the CARD-FAPRI simulations with the FAPRI 2008 deterministic baseline forecast reveals that these are the same numbers, which means that the 2008 AOE projections were not used since FAPRI used IHS Global Insight macroeconomic projections for their January 2008 baseline.

The CARD-FAPRI model does not include a component to convert crop acreage changes into GHG emissions, so GHG emissions were calculated using the GREET model defaults and IPCC emission factors.

Finally, the FASOM model was also run independently from CARD-FAPRI model. FASOM is a quadratic programming model that includes many environmental measures such as GHG emissions. The model includes regional coverage of the United States and coverage of 37 international countries/regions. It incorporates broader commodity coverage and includes a forestry component, although that was not available for the EPA analysis in their proposed rule-making process. The FASOM model was used to provide acreage impacts for the United States, as well as GHG emissions.

The NEMS Model

As mentioned above, the NEMS-EPA model was used to simulate the volumetric effects of each of the biofuel mandates, although energy prices used in the scenarios are supposed to be consistent with the DOE's AOE 2008. This means the supply and demand impacts of the mandates on biodiesel, ethanol, and cellulosic ethanol were simulated by EPA, but energy prices were supposed to be based on the DOE's AOE 2008. EPA does not specifically describe how their version of the NEMS model is different from the existing NEMS model operated by EIA. A reference is made in the EPA reviewer comments that the EPA designation was added to make it clear that EPA ran the energy scenarios used in the analysis, not the EIA division of the Department of Energy. This implies that the NEMS-EPA may be the same as the NEMS model.

The DOE version of the NEMS model is also extremely large and not parsimonious, either in documentation or structure. The NEMS was developed in FORTRAN primarily for analysis of the traditional energy sources such as crude oil, natural gas, and coal. The model is a combination of engineering and economic relationships regarding the supply, demand, and prices for energy commodities. The biofuels component of the NEMS model is found within the petroleum market module, which utilizes all the NEMS submodels to solve for energy prices.

The EIA has continuously reviewed the performance of the NEMS model since its adoption in 1994, with the latest review in September 2008. The average percent errors in forecasting world oil prices are presented in Table 1 taken from that study (Labeled Table 4 in the EIA study). As expected, near-term forecasts have lower error than longer term forecasts. Utilizing the data in Table 1 beginning in1994 (when the NEMS model was introduced), projections one year out for world oil prices have an average percent error of 2.4%, while projections two and three years out have average percent errors of 15.9 and 24.6, respectively. The EIA analysis also shows the tendency of the NEMS model to underestimate world oil prices since 2000.

A review of forecasts made by the EIA using the NEMS model over the 2006 through 2009 period also points to the difficulty in projecting oil prices. Oil price projections have been edging higher since the February 2006 EIA forecast with the exception of the slight downward revision in the June 2008 forecast after the impacts of EISA were included. The substantial upward revision in March 2009 reflects "market volatility and different assumptions about the future of the world economy" according to the Department of Energy. Comparing the most recent EIA forecast with the IHS Global Insight forecast of crude oil prices: the IHS Global Insight forecast is a bit more conservative than EIA's most recent projection, but both forecasts point to significantly higher fuel prices in the long run. There is also a considerable contrast between the current forecasts and the AOE 2008 forecast used by EPA for their analysis. Global recession, supply issues, and political stability all contribute to the uncertainty in forecasts of crude oil prices. This uncertainty necessitates that sensitivity analysis not only be performed, but also reported by EPA for the various scenarios they have considered. As will be illustrated, crude oil prices substantially influence the competitiveness of biodiesel.

It is also unclear what assumptions were made by EPA regarding the productivity of the biodiesel sector in feedstock conversion. These assumptions are very important in determining the competitiveness of the sector.

Figure 1. Crude Oil Average Import Prices, Various EIA forecasts

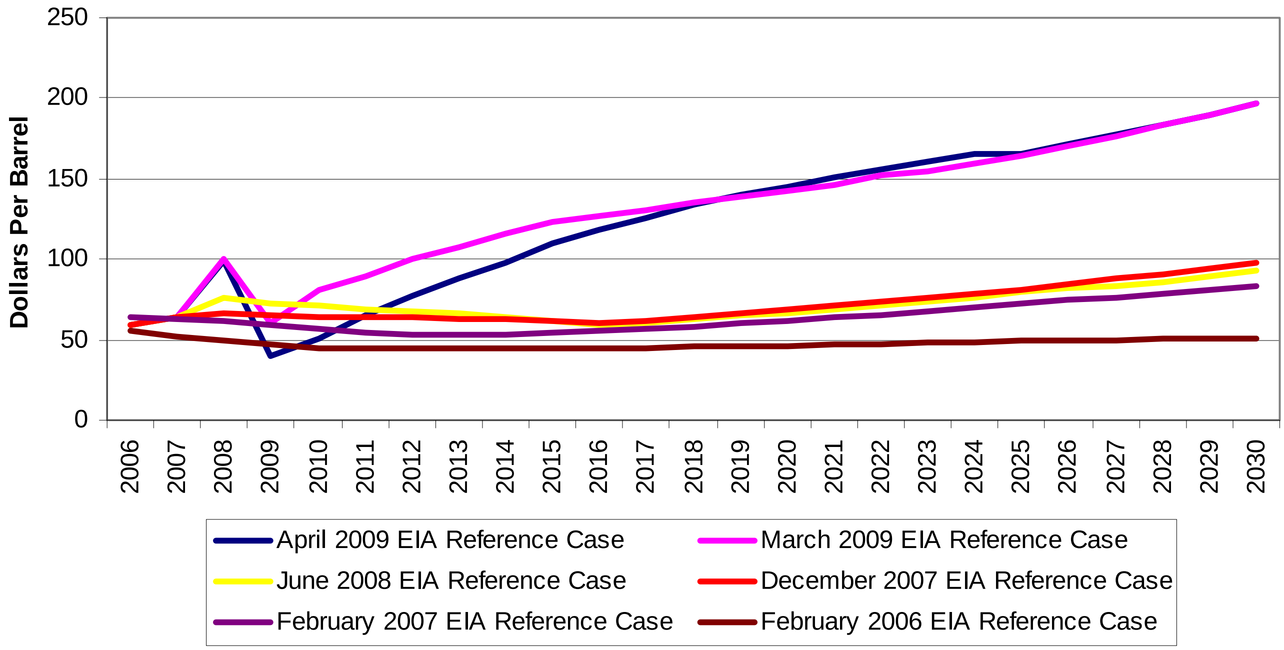

Figure 2. Crude Oil Refiners' Acquisition Price

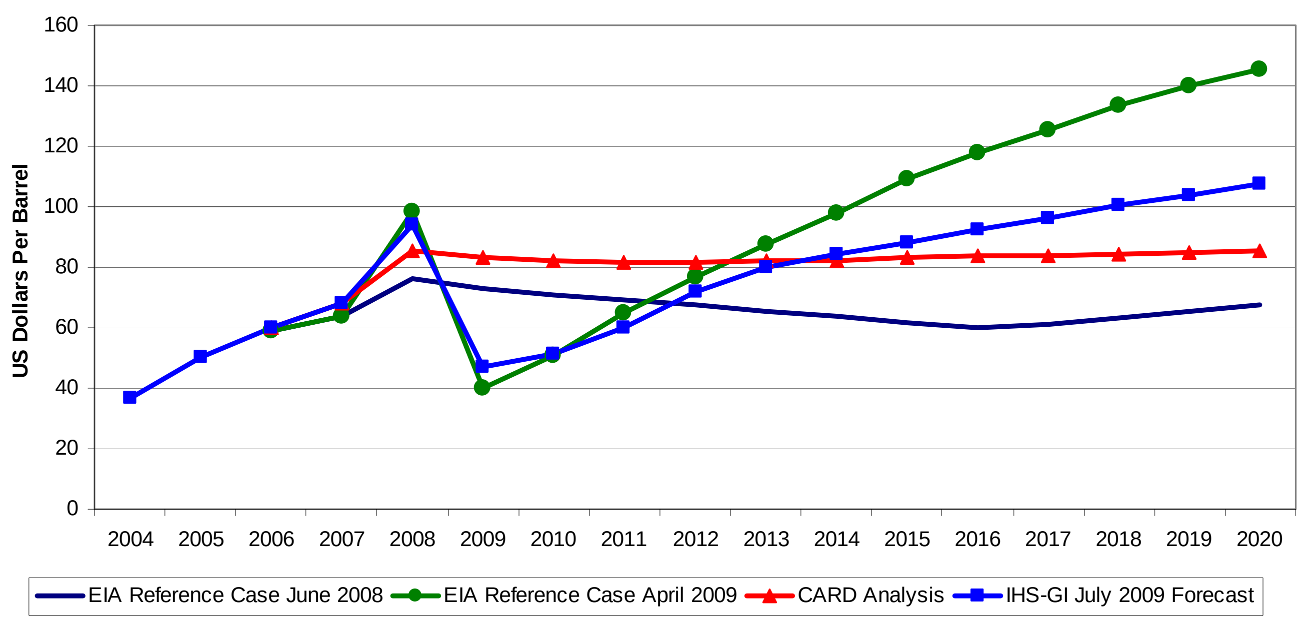

Figure 3. Daily West Texas Crude Oil Prices

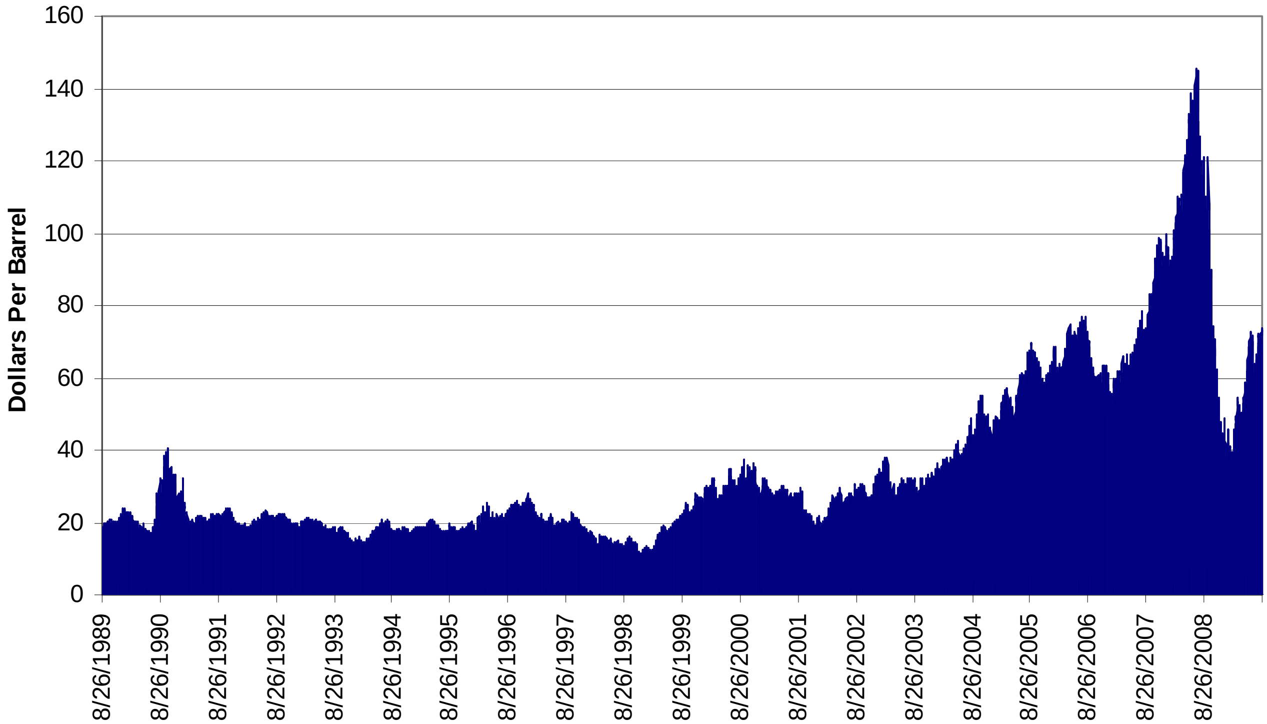

Table 1. World Oil Prices, Projected vs. Actual
(percent difference)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
AEO 1982	9.9	148.7	128.5	229.9	197.3	171.4																	
AEO 1983	7.4	110.0	80.2	170.0	154.8	144.6					492.7												
AEO 1984	7.7	110.0	70.8	133.2	105.9	87.6					331.0												
AEO 1985	0.0	84.7	36.9	78.9	64.2	55.1	97.7	122.7	165.8	202.5	189.6												
AEO 1986		4.1	-12.5	18.8	4.3	-5.2	19.0	39.4	84.3	124.7	132.9	117.3	168.3	351.0	241.7	132.5							
AEO 1987			-0.1	18.8	4.6	-8.4	11.8	19.6	48.7	77.3	86.9					108.4							
AEO 1989*				1.0	-17.4	-24.9	-5.1	5.2	34.3	62.5	68.7	61.3	104.1	252.7	168.6	80.4							
AEO 1990					-2.1	-19.6					55.1					66.7					41.4		
AEO 1991						1.1	32.4	40.6	63.9	76.3	65.5	42.6	64.8	166.0	98.6	33.2	81.1	82.8	69.9	42.0	13.0	0.6	-5.2
AEO 1992							1.8	10.2	28.0	43.6	41.2	27.5	54.7	158.9	96.7	33.4	81.4	81.2	66.2	37.0	7.5	-5.3	-11.3
AEO 1993								3.6	25.5	36.9	31.0	14.7	35.0	121.8	65.9	12.0	52.2	53.0	40.4	14.8	-10.7	-21.4	-26.1
AEO 1994									5.7	10.9	6.4	-5.9	11.4	83.7	37.7	-7.9	25.0	25.1	15.0	-5.3	-26.2	-35.0	-39.2
AEO 1995										-1.8	0.8	-11.7	4.0	69.4	25.1	-17.1	10.6	8.8	-1.6	-19.7	-37.8	-45.5	-49.4
AEO 1996											0.1	-14.0	0.3	63.8	21.5	-19.3	8.2	6.5	-3.6	-21.4	-38.9	-46.6	-50.6
AEO 1997												-3.1	4.8	62.4	16.3	-25.7	-1.5	-4.2	-14.3	-31.0	-47.1	-54.3	-58.1
AEO 1998													0.0	56.1	15.1	-24.4	-1.0	-5.0	-15.3	-32.2	-48.3	-55.9	-59.7
AEO 1999														3.8	-21.0	-47.0	-25.7	-24.6	-29.1	-41.1	-53.8	-59.0	-61.6
AEO 2000															0.5	-21.3	-4.6	-9.2	-20.4	-37.0	-52.5	-59.6	-63.4
AEO 2001																1.8	13.0	-3.7	-19.3	-35.8	-51.6	-58.9	-62.9
AEO 2002																	4.5	-7.3	-13.4	-30.8	-47.5	-55.1	-59.2
AEO 2003																		-0.3	-2.9	-28.4	-48.0	-55.8	-60.1
AEO 2004																			-0.2	-31.7	-50.0	-57.4	-61.4
AEO 2005																				-0.4	-27.6	-46.2	-56.0
AEO 2006																					4.3	-4.4	-18.3
AEO 2007																						7.8	-6.5
AEO 2008																							-4.9
Average Absolute Percent Difference (All AEOs)	6.3	91.5	54.8	93.0	68.8	57.5	26.0	34.5	57.0	70.7	115.5	33.1	44.7	126.3	67.4	42.1	25.7	24.0	22.3	27.2	35.6	39.3	41.9

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* There is no report titled *Annual Energy Outlook 1988* due to a change in the naming convention of the *AEO*s.

Sources: Forecasts: *Annual Energy Outlook*, Mid-Price or Reference Case Projections, Various Editions, "Imported Crude Oil Price" (which is average imported refiners' acquisition cost for crude oil -- "IRAC").

Historical Data: Energy Information Administration, Annual Energy Review 2007, DOE/EIA-0384(2007) (Washington, DC, June 23, 2008), Table 5.21.

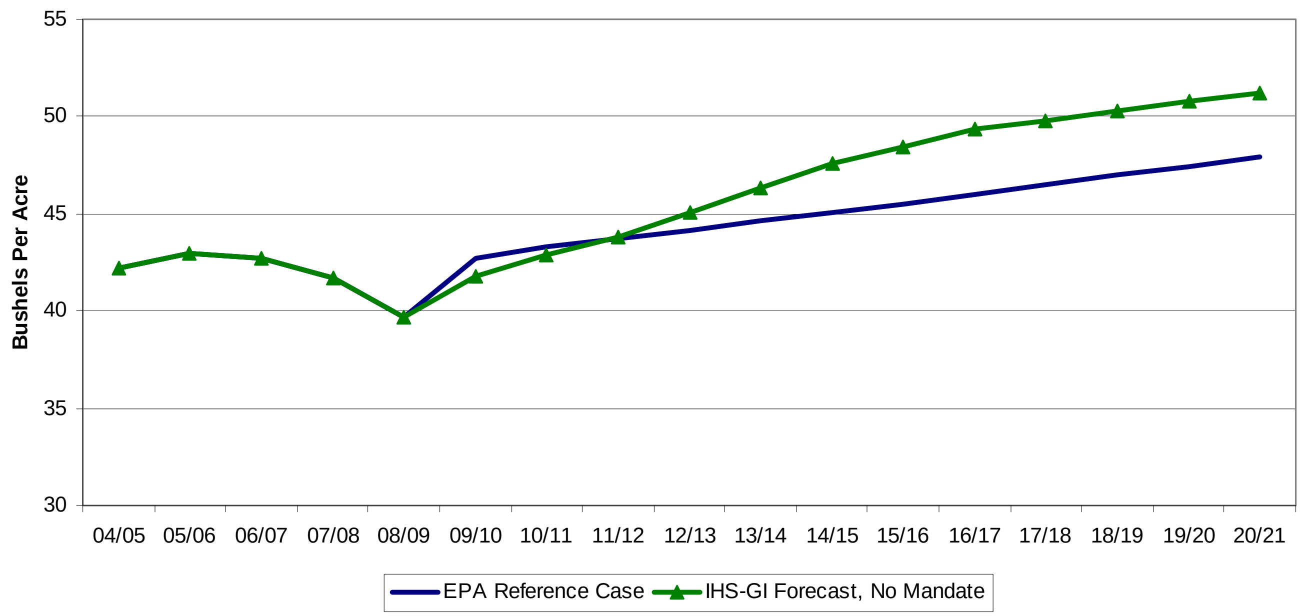
Source: "Annual Energy Outlook Retrospective Review: Evaluation of Projections in Past Editions (1982-2008)" Department of Energy, Energy Information Administration – 06403, September 2008

The CARD-FAPRI Model

The CARD-FAPRI model is a system of global partial equilibrium models that for purposes of this analysis included the major trading countries for the following commodities: corn, sorghum, barley, oats, rye, soybeans, sunflower, rapeseed/canola, palm, peanuts, wheat, rice, cotton, sugar, biodiesel, ethanol, beef, pork, poultry, and dairy. Notably the U.S. biodiesel and ethanol sub-model was shut off and the macroeconomic energy price assumptions were not lined up to the AOE 2008 energy forecasts as suggested by EPA. In addition, the EPA's volumetric results from analysis of the mandates were imposed directly in the biofuels' supply and demand equations.

In evaluating any model, a good place to begin is the assumptions made in the analysis. The first assumption of concern is the crude oil prices projected from the NEMS model. Significant revisions in the AOE 2009 crude oil price projections suggest a dramatic improvement in the competitiveness of biodiesel with petroleum-based diesel. The second assumption is the non-renewal of the blenders' tax credit when it expires at the end of 2009. It is unclear why this assumption was made when the Volumetric Ethanol Excise Tax Credit (VEETC) was extended for ethanol. The third assumption of concern is the commodity-yield growth assumption. The major seed-technology companies (Monsanto, DuPont, and others) have indicated that significant increases in both corn and soybean yields are already built into the seed technologies that will begin to be significantly released in 2010. For corn, these technologies include 8-way trait stacking and other improvements that are expected to result in a 7.5% step-up in yields above the current trend yield growth. For soybean, agronomists are describing the new Roundup Ready 2™ technology from Monsanto as the most significant yield step in years. With demonstrated yield improvement across numerous strip trials, soybean yields are expected to experience a 10% step-up above the current trend yield growth. These technologies are being developed in the United States, but will be available in South America as well. Incorporating these technological changes significantly improves future yields and reduces the quantity of land needed for

Figure 4. U.S. Soybean Yields



crop production. The yields used in the CARD-FAPRI model are much more conservative than what the seed industry indicates is already

in the system from a yield technology perspective. Note that other improvements such as drought tolerance, better utilization of nitrogen, etc., are not factored into these yield growths, but are coming within the next five years. US soybean yields in the EPA reference case compared with the yields used in the IHS GI forecast are 3.3 bushel per acre lower by 2020.

The second area of model evaluation is their ability to simulate the past. EPA offers no documentation of the error ranges within the CARD-FAPRI models, nor does it provide any data on historical simulation performance. The CARD-FAPRI model results suggest that the most significant indirect land use changes occur in Brazil, India, Nigeria, and Paraguay, which suggests these equations are good place to start. Ideally, one would like to use a measure of model performance such as the root mean square errors associated with dynamic simulation. This is one of the most rigorous model tests across time because it uses the model's own predictions in equations that include lagged dependent variables. However, this would require reconstructing the CARD-FAPRI model to perform this type of analysis.

A less rigorous test is to analyze the errors for each of the individual equations. One can calculate a root mean square error based on the errors associated with each year in the equation. The root mean square error is found by summing the squares of each error, dividing by the number of years, and taking the square root of the resulting number. By dividing that average error by the average of the actual acreage, one can calculate the percent root mean square error. This provides an easily interpreted measure of the percent error the equation exhibits. Table 2 presents the percent root mean square errors for each of the crop planted area equations. The table also includes a column called the intercept adjusted percent root mean square error, which adjusts the intercept in the model so that the actual errors in the equation sum to zero. Since we are only interested in how the acreage equations respond to changes in prices and the actual level of acreage predicted, this removes any intercept bias from the model that leads to higher percent root mean square errors. In the case of Brazilian soybeans, the average area was 23.9 million hectares over the 1991-2007 period, and the intercept adjusted root mean square error is 11%. Comparing the Brazilian soybean indirect land use impact generated by the CARD-FAPRI model (0.32%) with the root mean square error of 11% for this equation illustrates that the impact is very small relative to the potential error in the model. One could construct a prediction interval for the CARD-FAPRI estimates, but it is sufficient to look at the standard deviation of the error terms to see that the CARD-FAPRI impacts are very small relative to the inherent error in the model. Statistically, this suggests that these impacts are not different from zero.

Table 2. CARD-FAPRI Area Equation Errors Compared With Scenario Impacts

	Error Evaluation Period	Period Average (1000 Hectares)	Percent Root Mean Square Error Based On Errors Reported in the Equations	Intercept Adjusted Percent Root Mean Square Error	Intercept Adjusted Standard Deviation of Equation Errors (1000 Hectares)	CARD-FAPRI Biodiesel Impacts in 2022 (1000 Hectares)	2022 Percent Impact from CARD-FAPRI
Brazil Area							
Soybeans	1991-2007	23,936	11.3%	11.0%	2,339	99	0.32%
Sugar Cane	1982-2006	4,533	49.6%	17.2%	895	(6)	-0.06%
Corn	1990-2007	12,980	7.5%	6.9%	1,102	(25)	-0.17%
Wheat	1991-2007	1,790	46.0%	21.8%	485	(2)	-0.09%
Other Crops						(6)	
Total Crop Area		43,239				62	0.10%
India Area							
Corn	1994-2007	6,880	10.8%	10.8%	1,138	3	0.04%
Soybeans	1981-91, 95-07	4,236	36.2%	28.1%	1,199	29	0.27%
Wheat	1994-2007	26,226	10.5%	6.2%	2,285	(8)	-0.03%
Sorghum	1994-2007	10,160	15.0%	6.6%	952	(2)	-0.02%
Sugar Cane	1980-2006	3,687	29.2%	6.3%	263	(0)	0.00%
Rapeseed	1981-91, 95-07	5,462	15.9%	15.5%	979	9	0.13%
Peanuts	1981-91, 95-07	7,525	14.1%	13.8%	1,415	(5)	-0.07%
Other Crops						19	
Total Crop Area						45	0.03%
Nigeria Area							
Sorghum	1986-2007	6,149	28.2%	18.8%	1,247	22	0.26%
Paraguay Area							
Soybeans	1989-2007	1,440	148.9%	51.8%	839	75	1.57%

In evaluating the model, we also considered whether we could replicate the model parameter estimates based on the data used in the CARD-FAPRI model. It is not clear that the CARD-FAPRI models were statistically estimated. In some equations, it appears that elasticities were used from other undocumented sources to create the equations. The period over which these elasticities were estimated is especially important in considering their relevance for current market dynamics. For example, consider the Brazilian soybean harvest equation. In the CARD-FAPRI model the equation is reported to be:

Soybean Acreage Harvested =
-4200
+ 17.26694542*(Last Year's Soybean Price)
-1.959369714*(Last Year's Wheat Price)
-6.688266882*(Last Year's Corn Price)
-7312.025208*(Last Year's Sugar Cane Price)
+0.45*Last Year's Soybean Area Harvested
+294*(YEAR-1964)

Based on the errors associated with the equation, it appears to be calibrated to the 1991-2004 period. Using the same specification over the 1991-2004 and ordinary least squares to estimate the parameters, the following result is obtained:

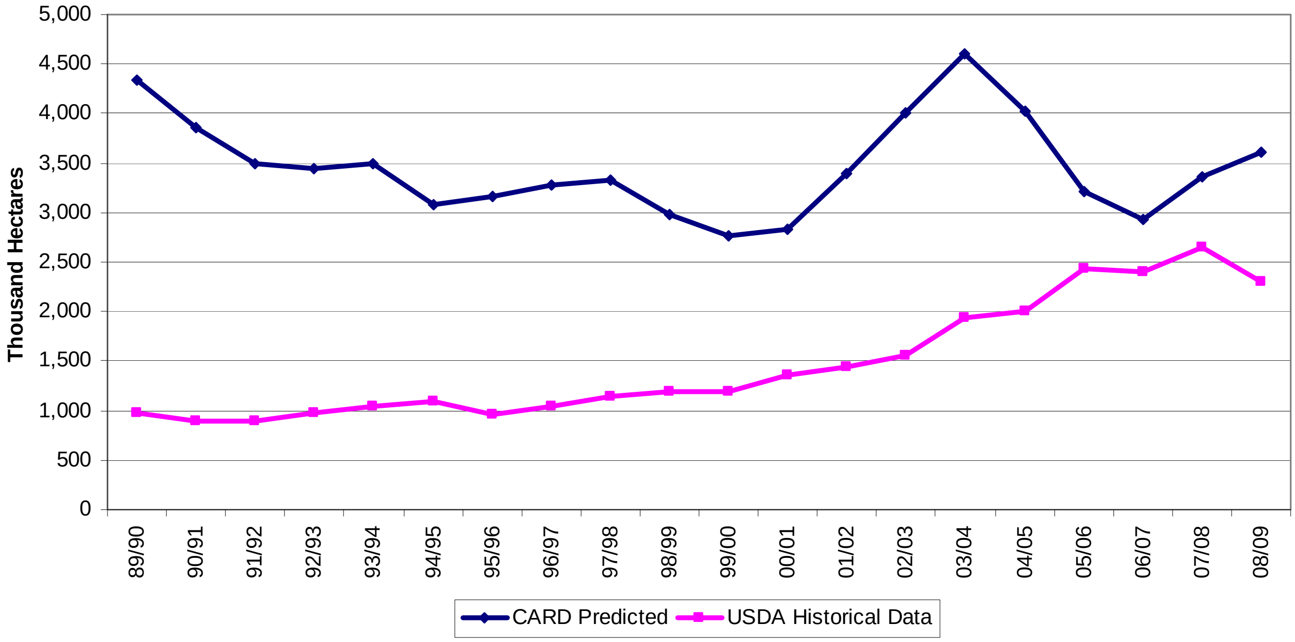
Soybean Acreage Harvested =
-4079.466
+ 4.566847*(Last Year's Soybean Price)
+28.44774*(Last Year's Wheat Price)
-34.93544*(Last Year's Corn Price)
-7153.732*(Last Year's Sugar Cane Price)
+0.28*Last Year's Soybean Area Harvested
+163.214*(YEAR-1964)

While the equations may appear similar, there are some important differences. First, in the estimated equation the parameter estimates on last year's soybean price and last year's sugar cane price are not statistically different from zero. Second, the sign of the parameter estimate on last year's wheat price is positive, which is incorrect (or at least unexpected). Multicollinearity among the crop prices could also contribute to the problem with the unexpected signs on the parameter estimates. The size of the parameter estimates for last year's soybean-area harvested, and the trend variable, are also significantly different. In the CARD-FAPRI equation, soybean-acreage harvested is driven more by trend and last year's harvested area versus the estimated equation. This leads to larger long-run acreage elasticities, amplifying the acreage response to a model shock.

Perhaps most importantly, the size of the parameter on last year's soybean price is also four times larger than the estimated equation, making the soybean area more responsive to changes in soybean prices versus the estimated equation. The point is not that the estimated equation is better, but rather that equations used by the CARD-FAPRI cannot be replicated by using ordinary least squares estimation. If elasticities have been drawn from other studies, then reference for those studies should be provided. If the elasticities are based on analyst judgement, then sensitivity analysis to the choice of these elasticities should be provided to insure that the acreage changes they imply are not arbitrary. For example, in the CARD-FAPRI model, the equation for Paraguay soybean area appears to be oversensitive to soybean prices. Notice the variance in predicted values relative to the actual area planted. This suggests that Paraguay soybean equation is too responsive to soybean prices, which would lead to overstatement of land use change for Paraguay.

Throughout the literature, econometric models are often estimated with data that does not include the last few years in order to allow out-of-sample simulation or to avoid potential data revisions in the last few years. Many of the econometric models in existence today were estimated over periods of relatively low prices with little variability. Extrapolating these models into today's period of high commodity prices with increased price variability is risky because this extends the models into ranges in which they have not been tested. For example, in determining how much acreage to plant, farmers could easily vary their crop mix in response to small price changes. But with huge swings in prices, farmers have resource constraints that do not fully allow them to respond to large price changes with the same degree of responsiveness they would use for small acreage changes. With lagged dependent variables in the acreage equations, the potential short run over responsiveness of the models to large price changes gets carried forward into the long-term acreage levels.

Figure 5. Paraguay Soybean Area Harvested



The Forest and Agriculture Sector Optimization Model (FASOM)

FASOM is a large quadratic programming model that is comprised of thousands of equations (with over 2,000 production possibilities) that require numerous data inputs. For the FASOM scenarios used in the EPA analysis, the raw data was not provided, so it was not possible to determine the exact model specifications, elasticities, and data that were used. Many of the comments are based on a 2005 documentation of FASOM referred to by EPA at the following link: http://agecon2.tamu.edu/people/faculty/mccarl-bruce/papers/1212FASOMGHG_doc.pdf

Model Structure

1. Most of the demand and supply curves in FASOM are assumed to be functions of the cost elasticity. In fact, in the agricultural sector, costs are not the only driver. Other factors such as income, prices of other commodities (complements or substitutes), etc. should be included in the specifications. Ignoring these other factors could distort the model results.

2. FASOM assumes that producers and consumers have *perfect foresight* regarding future demand, yields, technologies, and prices. These assumptions are not realistic and do not allow the flexibility of market adjustment. In addition, the model solves for multiple interlinked market equilibria in five-year increments. This may be appropriate for the forestry sector, but it is a relatively long response period for annual crops to adjust.

3. In the FASOM model-solving algorithm, historical data is used to constrain extreme specialization, particularly on crop and livestock mixes. For example, if the model finds an extreme solution specializing in one crop, the historical data of crop mix of that region will be used as a constraint. Therefore, in such cases, crop mixes will be distributed proportionally. This may be necessary to prevent such problems. However, it may not reflect real adjustment. Such extreme specialization solution may reflect model misspecification or the tendency for quadratic programming models to find corner solutions.

4. The models contain a single submodel representative farm, e.g., all corn-soybean farms in Iowa. They are highly aggregated representations of the operations, which include land, labor, and water without considering a variety of farm factors such as crop rotation. The model does not consider producer's risk behavior, financial reserves, capital constraints, yield, and price expectations, etc.

5. In EPA's FASOM analysis, the forestry module was not activated, which did not allow substitution of land between the forestry and cropland sectors. Potentially, this could limit U.S.

crop production, result in smaller U.S. exports, and increase land use change impacts in the rest of the world. This artificially forces land use change to occur outside of the United States, where EPA has predicted GHG emissions to be much higher than crop expansions in the United States.

EPA FASOM Model Scenarios

In the Reference Case, the EPA projects biofuel volumes for corn ethanol, cellulosic ethanol, and biodiesel at 12.3, 0.3, and 0.4 billion gallons per year in 2022, respectively. In the Control Case, the biofuel volumes for corn ethanol, cellulosic ethanol, and biodiesel are projected (by FASOM and other models) to reach 15, 10.2, and 1 billion gallons per year in 2022, respectively. FASOM is used to model the full potential impacts on the domestic agricultural sector given higher renewable fuel volumes due to RFS2. It was selected in part because it provides detailed greenhouse gas information resulting from these changes. FASOM also chooses the production pathway to meet the mandate. For example, to satisfy the *cellulosic ethanol* mandate, the FASOM model was able to choose how much cellulosic ethanol was produced through the different production pathways based on net return of each feedstock.

Some of the feedstock sources of biofuels are not modeled in FASOM model, e.g., biodiesel from corn oil fractionation and municipal solid waste. Further, the U.S. forestry sector in FASOM was not activated; thus, biofuel derived from forest sector is not included in the model. These parameters, however, have been estimated outside the model.

Domestic Impacts

Commodity Prices

The FASOM model predicts an increase in prices for the primary feedstocks of biofuels, due to an increase in volume for biofuel due to EISA. Corn price in 2022 is predicted to increase $0.15 per bushel (4.6%) above the Reference Case price of $3.19 per bushel. Similarly, by 2022, the increase in demand for biodiesel production leads to an increase of U.S. soybean prices by $0.29 per bushel

(2.9%) above the Reference Case price of $9.97 per bushel. The price of sugarcane in 2022 would increase $13.34/ton (41%) above the Reference Case price of $32.49 per ton.

There are also indirect effects from the RFS2 proposal reflected in commodity prices. For instance, corn is a major component in animal feed in the United States, and as corn prices rise in 2022, beef prices would increase $0.93 per hundred pounds (1.4%) relative to the Reference Case price of $67.72 per hundred pounds. Higher U.S. corn prices would have a direct impact on the value of U.S. agricultural land. As demand for corn and other farm products increases, the price of U.S. farm land would also increase. Land prices would increase by approximately 21% by 2022, relative to the Reference Case.

The FAPRI models also provide some domestic agriculture impacts in the U.S. In 2022, FAPRI predicts that U.S. corn prices would increase $0.22 per bushel (8.2%) above the Reference Case to $2.91 per bushel. Soybean prices would increase $0.42 per bushel (5.7%) above the Reference Case to $7.86 per bushel in 2022.

Commodity Use Changes

Table 3. Reductions in U.S. Exports from the Reference Case in 2022
Units: Exports in bushels, value of exports in constant 2006 dollars

FASOM Model		
Exports	**Change**	**% Change**
Corn	263 million	-9.9
Soybeans	96.6 million	-9.3
Total Value of Exports	**Change**	**% Change**
Corn	-$487 million	-5.7
Soybeans	-$691 million	-6.7
FAPRI Model		
Exports	**Change**	**% Change**
Corn	288 million	-7.6
Soybeans	96.6 million	-5.1
Total Value of Exports	**Change**	**% Change**
Corn	$0	0
Soybeans	$19.4 million	0.3

Source: Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program, the USEPA May 2009

Crop Land Use Changes

FASOM and FAPRI estimations of U.S. land use change are shown in the following table.

Table 4. Change in Crop Acres Relative to the Reference Case in 2022
Units: million acres

Crop	**Change**	**% Change**
Corn	3.2	3.9
Hay	-0.6	-1.1
Rice	-0.2	-3.8
Soybeans	-0.4	-0.5
Sugarcane	0.7	55
Switchgrass	2.8	N/A
Wheat	0.7	-1.5

Source: Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program, the USEPA May 2009

Alternative Scenarios

IHS Global Insight also maintains a global partial equilibrium agricultural modeling system that can be used to simulate the impact of the biodiesel mandate in the RFS 2. In the IHS Global Insight analysis, the EIA 2008 reference case projections for energy prices were used as the EPA assumptions instead of the assumptions detailed in the U.S. crops version of the CARD-FAPRI model. Four alternative scenarios were considered that address the underlying sensitivity to the assumptions laid out by EPA in the CARD-FAPRI analysis.

- Scenario 1: Utilizes the oil price assumptions proposed by EPA, the yields used by EPA, removes the RFS 2, and removes the blenders' credit. Essentially the only difference from the EPA reference case is the updated historical data through the 2007/08 marketing year and the use of the IHS Global Insight model.
- Scenario 2: Utilizes the oil price assumptions proposed by EPA, the yields used by EPA, removes the RFS 2, but maintains the blenders' credit.
- Scenario 3: Utilizes the oil price assumption proposed by EPA, the yields from IHS Global Insight, removes the RFS 2, but maintains the blenders' credit.
- Scenario 4: Utilizes the oil price projections from IHS-Global Insight, the yields from IHS Global Insight, removes the RFS 2, but maintains the blenders' credit.

These scenarios illustrate the sensitivity of the analysis to the assumptions made regarding the extension of the blenders' credit, technology, and oil price projections. The results indicate that generation 1 biodiesel plants are most sensitive to crude oil prices, followed by the extension of the blender's credit, and technology. Certainly feedstock prices would also impact the competitiveness of biodiesel plants, but assumptions driving international demand such as income and population growth were not adjusted in this analysis.

Since the four scenarios were simulated using global partial equilibrium models maintained by IHS Global Insight, voluminous results were generated including supply and demand estimates for every major country and/or region including the commodities (and their derivatives) of corn, sorghum, barley, wheat, rice, cotton, soybeans, sunflowers, rapeseed, and palm. In the interest of brevity, a small subset of those results focusing on the U.S. biodiesel industry and land use changes are included here.

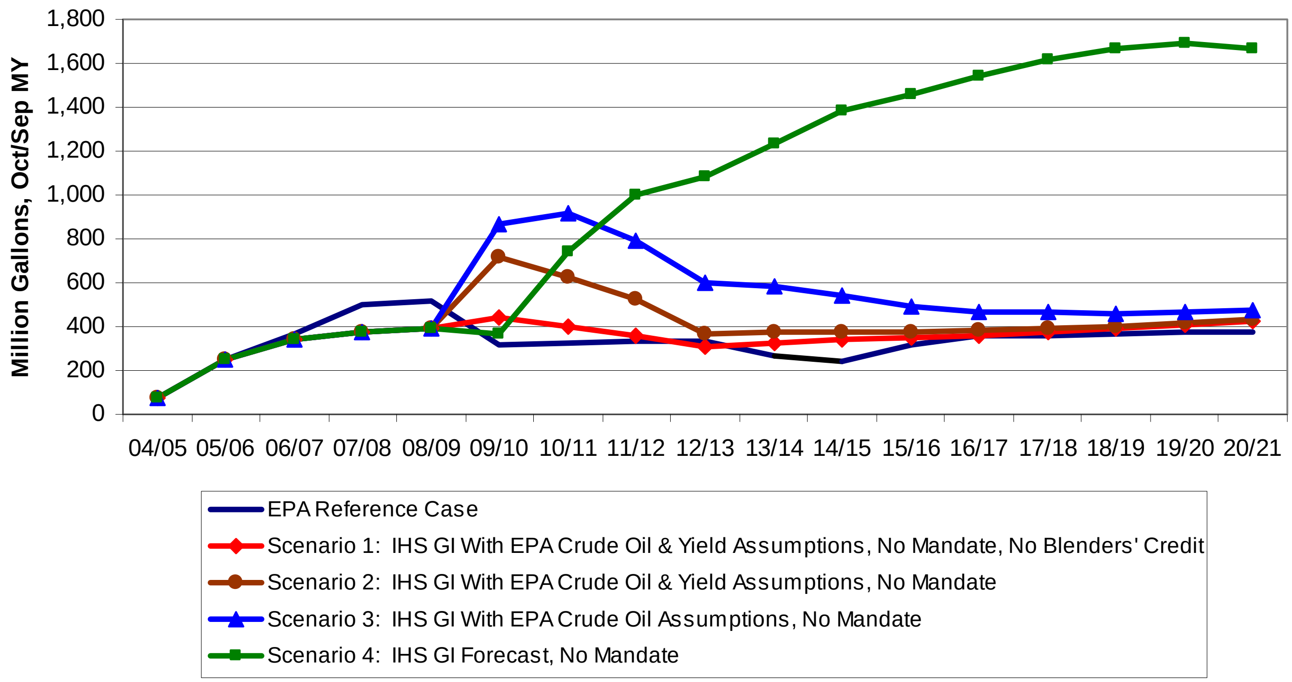
Scenario 1

Scenario 1 was designed to essentially replicate the EPA reference scenario assumptions. As Utilizing the EPA assumptions of no RFS 2, no blenders' credit, flat crude oil prices, and weaker yield growth, yields a U.S. biodiesel domestic demand path very similar to the EPA reference scenario. By 2020, U.S. biodiesel domestic demand is 46 million gallons higher than the EPA reference case. Without the blender's credit and no mandate from RFS 2, biodiesel producers using only virgin vegetable oils cannot compete. Plants that can use cheaper feedstocks, such as corn oil from distillers' grains or palm fatty acid distillate, account for virtually all of the biodiesel produced.

Scenario 2

Scenario 2 represents the first assumption change from the EPA reference scenario in that the blenders' credit is extended across the forecast horizon. Over the 2009 through 2011 period when crude oil prices are in the $70 per barrel range, extension of the blenders' credit allows an average of 223 million gallons of biodiesel to be consumed domestically. Beyond 2011, crude oil prices were projected by EIA to fall into the $59 to $67 per barrel range just as vegetable oil price edge higher from growth in international food demand. The resulting squeeze in margins makes biodiesel plants using only virgin vegetable oils uncompetitive with petroleum-based diesel even with the blenders' credit.

Figure 6. U.S. Biodiesel Domestic Demand



Scenario 3

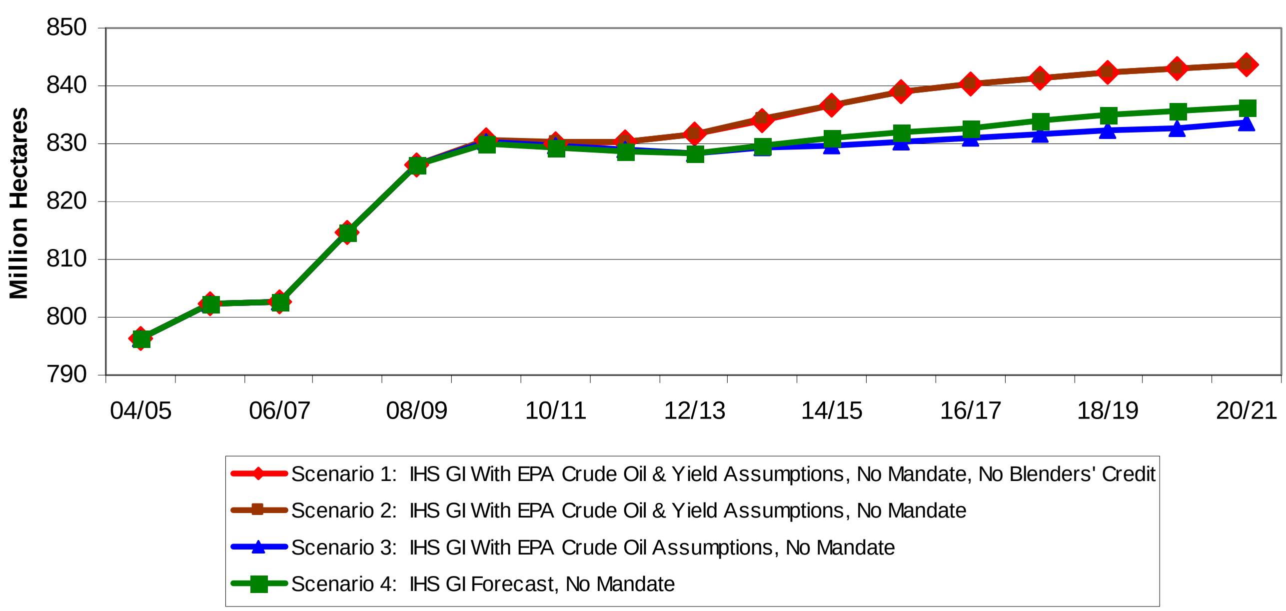
Scenario 3 builds on scenario 2 by replacing EPA's yield assumptions with the IHS Global Insight yield assumptions for corn and soybeans. The most important yield differences from EPA assumptions are in the United States and South America. Over the the 2009–11 period when EPA's crude oil price assumptions are higher, the U.S. domestic demand for biodiesel averages 233 million gallons higher than scenario 1, and 456 million gallons higher than the EPA reference scenario. In marketing year 2010/11, biodiesel production reaches 920 million gallons, well above the mandated level of 763 million gallons.

Scenario 3 also illustrates the impact of the yield assumptions on total world acreage needed to meet total world demand for all uses. In scenario 2, world crop area grows by 13.1 million hectares over the 11-year period from 2010 to 2020. In scenario 3, with the IHS Global Insight yields, world crop area grows by 3.4 million hectares.

Scenario 4

In Scenario 4, the July crude oil price and other macroeconomic projections from IHS Global Insight are used replacing the EIA 2008 reference case assumptions used by EPA. The IHS Global Insight projections for crude oil prices in July 2009 are still considerably more conservative than the April 2009 EIA reference case. The impact of this change in crude oil prices on biodiesel demand is very significant. Biodiesel demand reaches 1.6 billion gallons by 2020, well above the legislated 1 billion gallon mandate. The 2009/10 marketing year is the only time the U.S. biodiesel demand is below the 613 million gallon mandate (crop year adjusted mandate) due to weak crude oil prices. (The biodiesel industry has argued that part of the purpose of the mandate is to protect the industry in periods of low crude oil prices allowing the industry to survive these periods.) Higher crude oil prices in this scenario add 1.2 billion gallons to U.S. biodiesel demand in 2020, compared to scenarios 1 through 3. Since EPA's charge is to evaluate indirect land use change associated with the biodiesel mandate, scenario 4 illustrates a situation with virtually no possibility for indirect land use change since biodiesel

Figure 7. World Crop Area



demand is well above mandated levels in all but the 2009/10 marketing year.

Summary and Conclusions

The results of EPA's analysis of the biodiesel mandate are heavily dependent on the assumptions made regarding the crude oil price, the extension of the blenders' credit, and technology. The IHS Global Insight global agricultural modeling system reveals this sensitivity under simulation of alternative assumptions. IHS Global Insight's July projections for crude oil prices have crude oil prices growing from $47 to $107 per barrel over the 2009 to 2020 period. The DOE/EIA Reference Case from April 2009 has even higher prices with crude oil prices reaching $145 per barrel. With the more conservative IHS Global Insight projections, biodiesel production in excess of mandated levels occurs every year with the exception of 2009/10, in which crude oil prices are low due to the global recession. When biodiesel production exceeds mandated levels, there is no indirect land use impact resulting from the mandate. This is in stark contrast with EPA's baseline projection of biodiesel demand that is just under 400 million gallons, well below mandated levels. The EPA projection, however, is based on very low crude oil prices that range between $59 and $72 per barrel over the 2009 through 2022 period. With crude oil prices ranging from $35 to $145 per barrel in the last year, a different projection regarding oil prices can make a large difference in the competitiveness of the biodiesel sector.

The EPA's assumption that the biodiesel blenders' credit will not be extended, while at the same time assuming the ethanol tax credit will be extended is inconsistent. Both expire under current legislation. It would seem more consistent to extend the biodiesel blenders' credit as well the ethanol tax credit. This assumption has significant implications for the biodiesel sector in the scenario without a mandate in periods with oil prices exceeding $70 per barrel. With oil prices below $70 per barrel and no mandate, much of biodiesel production reverts to generation 2 plants that utilize cheap by-product feed stocks such as corn oil or palm fatty acid distillate while leaving plants relying solely on generation 1 feed stocks idle.

Technology assumptions also impact the magnitude of EPA's results. By omitting the impacts of new technology on crop yields, the EPA overstates the magnitude of indirect land use change. Seed technologies in the pipeline that will become increasingly available over the next two or three years are expected to result in significant increases in crop yields, particularly for corn and soybeans. This yield growth will offset much of the need for bringing additional crop land acreage into production. Scenarios 2 and 3 illustrate the impact of yield assumptions on world crop area needed. In scenario 2, world crop area grows by 13.1 million hectares over the 11-year period from 2010 to 2020. In scenario 3, with the IHS Global Insight yields, world crop area grows by 3.4 million hectares. In 1998, combined world harvested area for corn, sorghum, barley, wheat, rice, soybeans, sunflowers, rapeseed, palm, and cotton was 778.2 million hectares. In 2009, combined world harvested area for these same crops is expected to be 830.0 million hectares, an increase of 51.7 million hectares over the last 11 years. In the next 11 years, with faster yield growth, world harvested area for these same crops is expected to grow by 6.4 million hectares and that includes 1.6 billion gallons of biodiesel demand. Using EPA's reference case yield assumptions in the IHS Global Insight model, world area grows 13.1 million hectares, more than twice as much. Therefore, any indirect land use impacts are overstated by at least 50% given the yield assumptions used.

Finally, the CARD-FAPRI model used by EPA to measure international indirect land use did not generate impacts that were statistically different from zero given the prediction errors associated with the model equations. Further analysis of the acreage equations errors suggests that the equations were not statistically estimated using actual data from a recent time period, but instead are constructed based on elasticities that are not documented by EPA. It is not clear if the elasticities were taken from other studies or reflect analyst judgment; what is clear is the relatively poor historical performance of the equations in simulating historical responsiveness of acreage to changes in commodity prices. If these elasticities cannot simulate the historical movement in acreage in response to prices, one questions how accurate they can be in simulating indirect land use changes resulting from changes in biofuels policies, particularly for the small level of acreage impacts found by their models for biodiesel. This issue is further complicated by the fact that many of the econometric models in existence today were estimated over periods of relatively low prices with little variability. Extrapolating these models into today's period of high commodity prices with increased price variability is risky because this extends the models into ranges in which they have not been tested.

Appendix

Table A.1 US Biodiesel Supply and Utilization, Scenario 1

Marketing Year Beginning October 1	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Specific Assumptions															
Crude Oil Prices (Dollars Per Barrel)															
Petroleum, Refiners Acquisition	59.40	99.61	80.03	71.47	69.75	68.09	66.24	64.34	62.42	60.42	60.60	62.39	64.60	66.84	68.96
Petroleum, West Texas Intermediate	63.28	105.66	85.07	76.24	74.45	72.72	70.79	68.80	66.79	64.70	64.90	66.77	69.08	71.41	73.63
Diesel Fuel Prices (Dollars Per Gallon)															
#2 Diesel Wholesale	2.01	3.13	1.81	2.28	2.22	2.17	2.11	2.05	1.99	1.93	1.94	2.00	2.07	2.14	2.21
#2 Diesel Retail	2.70	3.88	2.60	2.94	2.89	2.83	2.77	2.70	2.64	2.57	2.59	2.65	2.72	2.80	2.87
Biodiesel Mandate (Million Gallons)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blenders' Credits (Dollars Per Gallon)															
Virgin Oil Tax Credit	1.00	1.00	1.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Feedstocks Tax Credit	0.50	0.50	1.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
US Soybean Yield (Bushels Per Acre)	42.7	41.7	39.6	42.7	43.2	43.7	44.1	44.5	45.0	45.4	45.9	46.3	46.8	47.3	47.8
Supply, Demand, and Price Projections															
Biodiesel Supply (Million Gallons)															
Total Production	429	735	564	443	402	360	308	322	338	349	361	376	391	406	424
Domestic Disappearance	346	374	394	443	402	360	308	322	338	349	361	376	391	406	424
Net Exports	84	360	174	0	0	0	0	0	0	0	0	0	0	0	0
Total Disappearance	429	735	568	443	402	360	308	322	338	349	361	376	391	406	424
Biodiesel Plant Price (Dollars Per Gallon)	3.30	4.50	3.00	2.73	2.68	2.64	2.59	2.53	2.46	2.39	2.41	2.47	2.54	2.62	2.69

Soybean yields were assumed to be CARD-FAPRI levels

Table A.2 US Biodiesel Supply and Utilization, Scenario 2

Marketing Year Beginning October 1	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Specific Assumptions															
Crude Oil Prices (Dollars Per Barrel)															
Petroleum, Refiners Acquisition	59.40	99.61	80.03	71.47	69.75	68.09	66.24	64.34	62.42	60.42	60.60	62.39	64.60	66.84	68.96
Petroleum, West Texas Intermediate	63.28	105.66	85.07	76.24	74.45	72.72	70.79	68.80	66.79	64.70	64.90	66.77	69.08	71.41	73.63
Diesel Fuel Prices (Dollars Per Gallon)															
#2 Diesel Wholesale	2.01	3.13	1.81	2.28	2.22	2.17	2.11	2.05	1.99	1.93	1.94	2.00	2.07	2.14	2.21
#2 Diesel Retail	2.70	3.88	2.60	2.94	2.89	2.83	2.77	2.70	2.64	2.57	2.59	2.65	2.72	2.80	2.87
Biodiesel Mandate (Million Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blenders' Credits (Dollars Per Gallon)															
Virgin Oil Tax Credit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other Feedstocks Tax Credit	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
US Soybean Yield (Bushels Per Acre)	42.7	41.7	39.6	42.7	43.2	43.7	44.1	44.5	45.0	45.4	45.9	46.3	46.8	47.3	47.8
Change in Supply, Demand, & Prices from Scenario 1															
Biodiesel Supply (Million Gallons)															
Total Production	0	0	0	277	224	169	57	52	40	27	19	16	12	12	12
Domestic Disappearance	0	0	0	277	224	169	57	52	40	27	19	16	12	12	12
Net Exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Disappearance	0	0	0	277	224	169	57	52	40	27	19	16	12	12	12
Biodiesel Plant Price (Dollars Per Gallon)	0.00	0.00	0.00	0.49	0.48	0.47	0.48	0.45	0.43	0.41	0.38	0.34	0.29	0.23	0.18

Soybean yields were assumed to be CARD-FAPRI levels

Table A.3 US Biodiesel Supply and Utilization, Scenario 3

Marketing Year Beginning October 1	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Specific Assumptions															
Crude Oil Prices (Dollars Per Barrel)															
Petroleum, Refiners Acquisition	59.40	99.61	80.03	71.47	69.75	68.09	66.24	64.34	62.42	60.42	60.60	62.39	64.60	66.84	68.96
Petroleum, West Texas Intermediate	63.28	105.66	85.07	76.24	74.45	72.72	70.79	68.80	66.79	64.70	64.90	66.77	69.08	71.41	73.63
Diesel Fuel Prices (Dollars Per Gallon)															
#2 Diesel Wholesale	2.01	3.13	1.81	2.28	2.22	2.17	2.11	2.05	1.99	1.93	1.94	2.00	2.07	2.14	2.21
#2 Diesel Retail	2.70	3.88	2.60	2.94	2.89	2.83	2.77	2.70	2.64	2.57	2.59	2.65	2.72	2.80	2.87
Biodiesel Mandate (Million Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blenders' Credits (Dollars Per Gallon)															
Virgin Oil Tax Credit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other Feedstocks Tax Credit	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
US Soybean Yield (Bushels Per Acre)	42.7	41.7	39.6	41.8	42.9	43.8	45.0	46.3	47.6	48.4	49.4	49.9	50.3	50.8	51.3
Change in Supply, Demand, & Prices from Scenario 1															
Biodiesel Supply (Million Gallons)															
Total Production	0	0	0	423	517	426	293	258	197	138	103	88	65	56	45
Domestic Disappearance	0	0	0	424	518	428	295	261	201	143	108	94	71	62	52
Net Exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Disappearance	0	0	0	424	518	428	295	261	201	143	108	94	71	62	52
Biodiesel Plant Price (Dollars Per Gallon)	0.00	0.00	0.00	0.44	0.39	0.39	0.41	0.39	0.39	0.38	0.36	0.32	0.27	0.22	0.17

IHS GI yield growth assumptions were used.

Table A.4 US Biodiesel Supply and Utilization, Scenario 4

Marketing Year Beginning October 1	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20	20/21
Specific Assumptions															
Crude Oil Prices (Dollars Per Barrel)															
Petroleum, Refiners Acquisition	59.40	99.61	62.83	50.01	57.12	68.08	77.56	82.97	87.01	91.02	95.05	99.16	102.76	106.17	109.68
Petroleum, West Texas Intermediate	63.28	105.66	67.11	53.95	61.56	73.22	83.29	89.03	93.30	97.54	101.82	106.18	109.99	113.60	117.32
Diesel Fuel Prices (Dollars Per Gallon)															
#2 Diesel Wholesale	2.01	3.13	1.81	1.68	1.94	2.27	2.60	2.78	2.91	3.05	3.18	3.32	3.43	3.48	3.42
#2 Diesel Retail	2.70	3.88	2.60	2.42	2.63	2.95	3.28	3.47	3.61	3.74	3.88	4.02	4.15	4.20	4.14
Biodiesel Mandate (Million Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blenders' Credits (Dollars Per Gallon)															
Virgin Oil Tax Credit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other Feedstocks Tax Credit	0.50	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
US Soybean Yield (Bushels Per Acre)	42.7	41.7	39.6	41.8	42.9	43.8	45.0	46.3	47.6	48.4	49.3	49.8	50.3	50.8	51.2
Change in Supply, Demand, & Prices from Scenario 1															
Biodiesel Supply (Million Gallons)															
Total Production	0	0	0	-20	341	642	774	908	1,045	1,104	1,177	1,236	1,267	1,282	1,237
Domestic Disappearance	0	0	0	-74	342	643	776	911	1,049	1,108	1,182	1,242	1,274	1,289	1,244
Net Exports	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0
Total Disappearance	0	0	0	-19	342	643	776	911	1,049	1,108	1,182	1,242	1,274	1,289	1,244
Biodiesel Plant Price (Dollars Per Gallon)	0.00	0.00	0.00	0.13	0.35	0.65	1.00	1.19	1.33	1.50	1.58	1.62	1.65	1.61	1.50

IHS GI yield growth assumptions were used.

Table A.5 World Crop Area in 2020 Under Alternative Scenarios

		Change from Scenario 1		
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1000 hectares				
Feed Grains				
Corn	162,223	-15	-4,699	-3,437
Sorghum	42,207	-2	-277	-105
Barley	54,226	-2	-729	-551
Feed Grains Total	258,655	-18	-5,704	-4,092
Food Grains				
Wheat	219,055	0	-2,885	-3,062
Rice	153,918	1	-178	-134
Food Grains Total	372,972	1	-3,062	-3,196
Oilseeds				
Soybeans	108,734	26	-1,392	-692
Sunflowers	23,548	7	62	524
Rapeseed/Canola	34,389	5	-50	114
Palm	15,316	3	-55	18
Oilseeds Total	181,986	42	-1,435	-36
Fiber Crops				
Cotton	30,037	0	308	90
Total World Crop Area (Listed Crops)	843,651	24	-9,893	-7,234

Scenario 1: IHS-GI With EPA Crude Oil & Yield Assumptions, No Mandate, No Blenders' Credit
Scenario 2: IHS-GI With EPA Crude Oil & Yield Assumptions, No Mandate
Scenario 3: IHS-GI With EPA Crude Oil Assumptions, No Mandate
Scenario 4: IHS-GI Forecast, No Mandate