ATTACHMENTS 1-20

COMMENTS OF THE NATIONAL BIODIESEL BOARD ON REGULATION OF FUELS AND FUEL ADDITIVES: CHANGES TO RENEWABLE FUEL STANDARD PROGRAM; NOTICE OF PROPOSED RULEMAKING, 74 FED. REG. 24,904 (MAY 26, 2009), and NOTICE OF AVAILABILITY OF EXPERT PEER REVIEW RECORD, 74 FED. REG. 41,359 (AUG. 17, 2009)

ATTACHMENT 1

LECG

ECONOMIC CONTRIBUTION OF THE BIODIESEL INDUSTRY

Prepared for the National Biodiesel Board
With Funding Support from the United Soybean Board[1]

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Biodiesel is a non-toxic, biodegradable diesel fuel made from soybean and other vegetable oils, animal fats, and used or recycled oils and fats. The biodiesel industry is in its infancy but is poised for significant growth. An estimated 690 million gallons of biodiesel will be produced and used in the U.S. in 2008, up from 450 million gallons last year and about 500 thousand gallons in 1999. According to the National Biodiesel Board the there are 176 manufacturing capable of producing biodiesel in the U.S. These plants have an annual capacity of 2.61 billion gallons.

The biodiesel industry makes a substantial contribution to the American economy and the economy of the communities where biodiesel production is located. The demand for soybean oil and other fats and oils used to produce biodiesel increases crush demand for soybeans, supports soybean prices, and keeps land in soybean production. Consequently biodiesel production helps increase the value of agricultural production and farm income from marketing and stimulates the demand for goods and services produced by other sectors of the economy and delivered to agriculture.

The impact of biodiesel production on the economy is provided by the direct effects of annual expenditures for soybean oil, other fats and oils used as feedstocks, and inputs such as natural gas, other utilities, and labor to produce biodiesel. Additionally the biodiesel industry invested in infrastructure aimed at increasing the supply of biodiesel to final customers and on scientific R&D largely directed at new feedstocks such as algae. Spending for these goods and services represents the purchase of output of the supplying industries. For example, soybean oil is the output of the fats

[1] The USB is made up of farmer-directors who oversee the investments of the soybean check-off on behalf of all U.S. soybean farmers. Check-off funds are invested in the areas of animal utilization, human utilization, industrial utilization, industry relations, market access and supply.

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and oils refining and blending industry. This spending circulates throughout the entire economy several fold stimulating aggregate demand, supporting the creation of new jobs, generating household income, and providing tax revenue for government at all levels.

The biodiesel industry will spend nearly $2.9 billion on raw materials, goods and services to produce 690 million gallons of biodiesel this year. Feedstock costs (soybean oil and other feedstocks) are the largest component of operating costs, accounting for about 87 percent of production costs. As indicated above the biodiesel industry invested an estimated $90 million on infrastructure and $197 million on scientific research and development for feedstock development. The total impact of the biodiesel industry includes the impacts of ongoing annualized operations and the direct value added by the production of biodiesel and co-products (glycerin). The price of B100 (FOB Plant, Iowa) has averaged $4.63 per gallon for 2008. Consequently the 690 million gallons of biodiesel produced this year is valued at $3.2 billion. The biodiesel industry also produces glycerin as a byproduct. Given large supplies on the market, raw glycerin prices are averaging about 16.4 cents per pound. The 530 million pounds of raw glycerin produced by the biodiesel industry are valued at about $87 million. The detailed impact of this spending is illustrated in Table 1.

Table 1

Economic Contribution of Biodiesel by Industry: 2008

Industry	Spending (Mil 2008 $)	GDP (Mil 2008 $)	Impact Earnings (Mil 2008 $)	Employment (Jobs)
Infrastructure construction	$90.0	$160.6	$95.7	2,400
Feedstocks (soybean oil and other fats)	$2,270.8	$3,319.6	$1,643.4	41,081
Industrial chemicals	$195.1	$273.9	$140.0	2,738
Electric, natural gas, water	$59.6	$85.3	$39.2	723
Maintenance and repair	$10.6	$18.5	$10.0	264
Business Services	$8.6	$14.6	$7.8	196
Research & Development	$197.0	$359.6	$212.9	4,078
Earnings paid to households	$33.1	$31.3	$15.6	412
Subtotal	$2,864.8	$4,263.4	$2,164.6	51,893
Plus Value of biodiesel output		$3,194.7	$23.5	
Plus Value of co-product glycerin		$87.3		
Total Impact		**$7,545.4**	**$2,188.1**	**51,893**

As shown in Table 1, when the value of biodiesel and glycerin is added to the indirect impacts generated by the spending to create this output, the biodiesel industry will add $7.6 billion to GDP this year, increase household income by nearly $2.2 billion, and support 51,893 jobs in all sectors of the economy.

- Operation of the biodiesel industry generates additional tax revenues for government at all levels from personal and corporate income taxes that increase in line with higher output levels, larger GDP, and additional household income. The biodiesel industry is expected to generate $1.5 billion of additional tax revenue for federal, state, and local government this year.

- The biodiesel industry more than pays for itself. The additional tax revenues generated by the biodiesel industry are significantly larger than the value of the major Federal tax incentive for biodiesel. With the biodiesel tax credit of $1.00 per gallon for agri-biodiesel and $0.50 per gallon for biodiesel from other sources, this program will cost approximately $621 million this year.[2] However, as indicated above the industry will generate $915 million of new revenue for the Federal Treasury for a positive net balance of $294 million.

- The biodiesel industry contributes to improving America's energy security. The 690 million gallons of biodiesel produced in 2008 will displace 38.1 million barrels of crude oil.[3] Since the U.S. is a net importer of oil, this means that less oil will need to be imported. At the 2008 average crude oil price of $104 per barrel this means that nearly $4 billion remained in the American economy instead of being sent abroad to finance oil imports.

The impact of the biodiesel industry on the economy was estimated by applying the current appropriate final demand multipliers for value added, earnings, and employment for the relevant supplying industry calculated by the U.S. Bureau of Economic Analysis (BEA) to estimates of

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[2] Using Census data as a base we estimate that soybean oil accounted for 60% of methyl ester production and animal fats (lard and inedible and edible tallow) accounted for 20%. Other fats and oils made up the final 20%.

[3] Distillate is produced along with gasoline. The 38 .1 million barrels of crude oil reflect the amount of oil that would be required to produce the combination of gasoline consistent with 690 million gallons of distillate at 2008 year-to-date refinery yields.

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expenditures for annual operations described above.[4] The final demand multipliers for GDP (value added), earnings, and employment for the sectors that supply the biodiesel industry are shown in Table 2.

Table 2
U.S. Final Demand Multipliers

	Final Demand	Household Earnings	Employment
Construction	1.7842	1.0629	26.7
Fats and oils refining and blending	1.4974	0.7685	20.5
Rendering and meat byproduct proc	1.3847	0.6266	15.7
Power generation and Supply	1.4367	0.6004	11.6
Natural gas distribution	1.4180	0.6565	12.5
Water, sewer and other systems	1.5420	0.7141	16.0
Other basic organic chemical mfg	1.4038	0.7174	14.7
Office administrative services	1.7943	1.0112	22.9
Monetary Authorities	1.4644	0.5982	13.7
Business support services	1.6307	0.8179	24.9
Facilities support services	1.7491	0.9519	26.2
Scientific R&D	1.8256	1.0808	21.7
Households	1.3340	0.6645	18.4

The estimates summarized above result from a static analysis of the impact of increasing biodiesel fuels demand and production on the American economy. That is, they reflect the combination of a series of snapshots of the economy rather than a dynamic flow analysis.

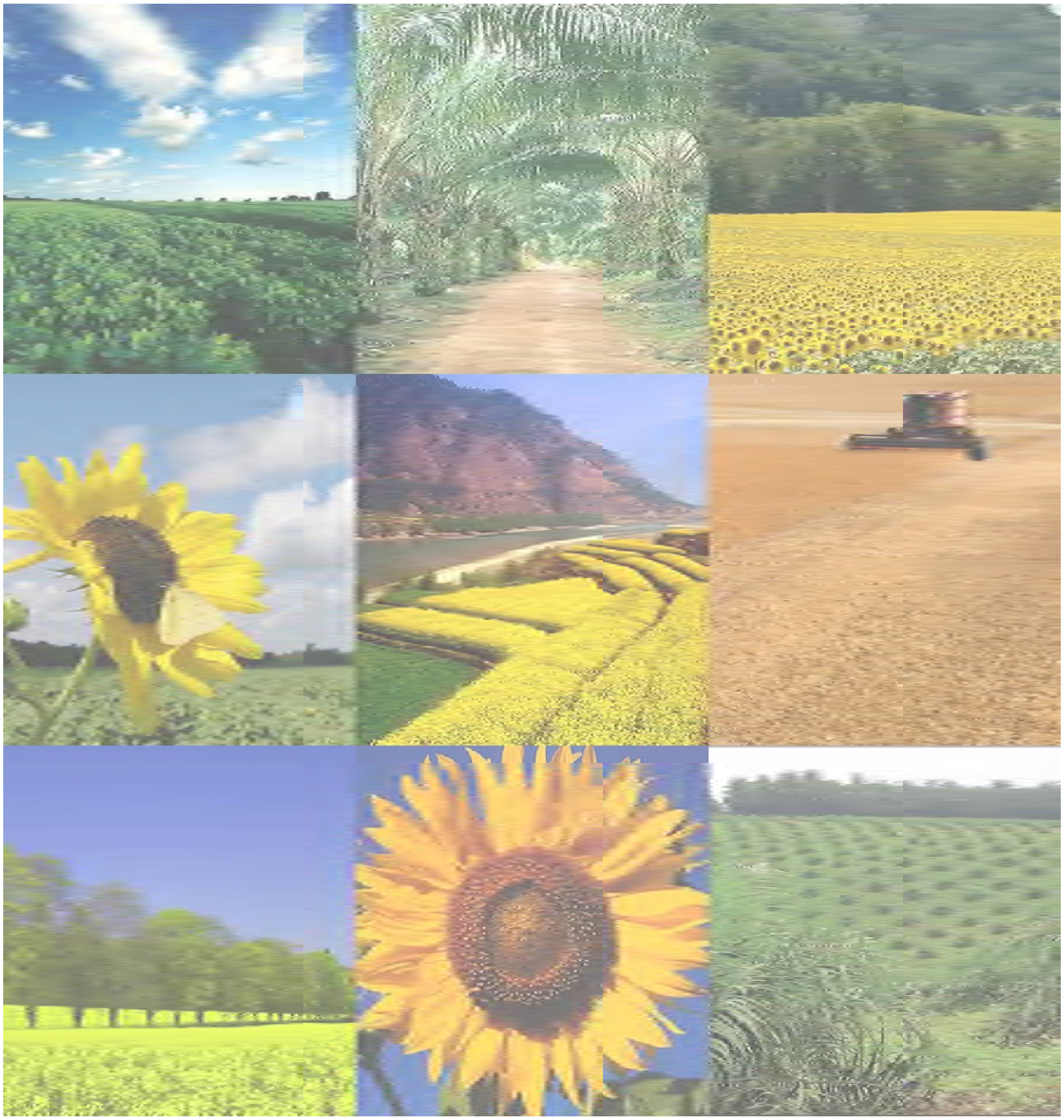
The annual expenditures for biodiesel were estimated by multiplying the average cost per gallon for each major expenditure category by the number of gallons produced. The estimated costs to produce biodiesel are based on a process model for a new 10 million gallon biodiesel plant developed by USDA/ARS.[5] The prices for soybean oil, biodiesel, natural gas, and electricity reflect averages for

[4] The multipliers used in this analysis are the detailed industry RIMS II multipliers for the U.S. prepared by the Regional Economic Analysis Division, Bureau of Economic Analysis, U.S. Department of Commerce. These multipliers are based on 2006 regional data and 1997 national benchmark input-output data
[5] Haas, Michael J., Andrew J. McAloon, Winnie C. Yee, and Thomas A. Foglia. "A process model to estimate biodiesel production costs". *Bioresource Technology*. 2005.

January through early December 2008. Prices for other inputs and labor reflect current market conditions.

ATTACHMENT 2

Feedstock Supplies for U. S. Biodiesel Production



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January, 2009

Summary

President George W. Bush signed into law the Energy Independence and Security Act of 2007 (EISA) on December 19, 2007. The legislation was designed to reduce U.S. dependence on foreign oil by increasing the supply of alternative fuels. EISA requires increased biofuel production from various sources, including biodiesel. In addition to the federal renewable fuels standard, some U.S. states – most notably, California – have adopted, or are in the process of adopting, policies that could expand utilization of biodiesel as a result of its greenhouse gas reduction benefits. The purpose of this paper is to analyze the availability of domestic feedstock that could be used to meet these potential new demands without affecting existing uses (e.g. the animal feed industry).

The biodiesel industry has experienced significant growth in production over the past five years. In 2007, approximately 500 million gallons of biodiesel were produced in the United States. It is estimated that nearly 700 million gallons of biodiesel were produced in 2008. During this time period, biodiesel producers have made use of a variety of fats and oils sources, including soybean oil, inedible tallow and greases, yellow grease, canola oil, imported palm oil, and corn oil generated from ethanol facilities.

Although many opportunities exist for new feedstocks for biodiesel production, it is relatively clear where near term supplies will be generated. Approximately ¾ of a billion gallons of soybean oil should be available for biodiesel production in 2012, and higher oil content oilseeds such as camelina and canola can add more than 200 million gallons of feedstock supplies. Although lacking a supply response, animal fats and yellow grease can have a significant impact on biodiesel production; potentially adding more than 400 million gallons of production by 2012. Including 400 million gallons of feedstock from U.S. ethanol plants, more than 1.8 billion gallons of feedstock from domestic sources would be available for biodiesel production by 2012.

More difficult to quantify are opportunities such as decreased exports, expanded U.S. processing capacity, and greater use of brown grease that may add even greater amounts of feedstock by 2012. These sources will be highly dependent upon commodity economics, market forces, and global policy. Should conditions prove favorable, more than 4.3 billion gallons of feedstock from domestic sources may be available for biodiesel production. Other new feedstock sources could prove to be equally important to future biodiesel growth. The current feedstock supply situation has sent numerous price signals to the market to invest in new technologies and methods to increase raw material supplies. Investment in new, non-edible raw materials sources such as algae, jatropha, mustard, pennycress, and halophytes continues at an aggressive rate.

In addition to questions related to feedstock supplies, policy requiring specific quantities of biodiesel also brings industry plant capacity to the forefront. There are presently 176 companies, with an annual plant capacity of 2.6 billion gallons, which have invested millions of dollars into the development of biodiesel manufacturing plants.

In summary, neither equity investment in plant capacity nor feedstock supplies represent a constraint in the marketplace for production of sufficient quantities of biodiesel to meet the RFS2 requirements for one billion gallons of biomass derived diesel by 2012 or state policies requiring similar amounts of fuel such as the California low carbon fuel standard.

Background

Government policies are being enacted to utilize higher volumes of alternative fuels, such as biodiesel, for a number of stated benefits including energy independence, economic security, and an improved human health and natural environment.

President George W. Bush signed into law the Energy Independence and Security Act of 2007 (EISA) on December 19, 2007. The legislation was designed to reduce U.S. dependence on foreign oil by increasing the supply of alternative fuels. EISA requires increased biofuel production, 36 billion by 2022, and must be met, in part, from biodiesel.

EISA differentiates between "conventional biofuel" (corn-based ethanol) and "advanced biofuel." Advanced biofuel is renewable fuel, other than corn-based ethanol, with lifecycle greenhouse gas emissions that are at least 50 percent less than greenhouse gas emissions produced by gasoline or diesel. EISA also requires the use of one billion gallons of biomass based diesel fuel by 2012.

In addition to the federal renewable fuels standard, states are beginning to enact comprehensive greenhouse gas reduction policies that rely on low carbon fuels such as biodiesel for compliance. The most prominent such policy is California's low carbon fuel standard which some estimate could account for more than one billion gallons of biodiesel utilization by 2020.

Near Term Soybean Supplies

The biodiesel industry has experienced significant growth in production over the past five years. In 2007, approximately 500 million gallons of biodiesel were produced in the United States. It is estimated that nearly 700 million gallons of biodiesel were produced in 2008.[1]

During this time period, biodiesel producers have made use of a variety of fats and oils sources, including soybean oil, inedible tallow and greases, yellow grease, canola oil, imported palm oil, and corn oil generated from ethanol facilities. The U.S. Census Bureau documents production, consumption, and stocks of fats and oils through the "M311K - Fats and Oils: Production, Consumption, and Stocks" survey. In 2007, soybean oil was the feedstock used to generate approximately 80 percent of production (roughly 400 million gallons), while in 2008 soybean oil represents roughly 60 percent of production through November.

Two relevant statistics can be derived from this census information. First, the use of soybean oil for biodiesel production represented only 14 percent of domestic soybean oil consumption in 2007. Although overall biodiesel production grew in 2008, the amount of soybean oil used for the production of biodiesel will remain similar to 2007 figures. Second, the use of animal fats, yellow grease, and other non-edible vegetable oils are largely responsible for the increase of biodiesel production in 2008.

The November 10, 2008 World Agricultural Supply and Demand Estimates released by USDA projected the 2008 soybean crop would be 2.92 billion bushels based upon harvested acreage of 74.4 million acres and an average national yield of 39.3 bushels/acre. U.S. soybean

[1] Production statistics derived from U.S. Census statistics collected on M311K survey.

processors are projected to process 1.745 billion bushels of soybeans with another 1.02 billion bushels exported.

USDA projected 3.1 billion pounds of soybean oil (an estimated 413 million gallons of potential biodiesel) to be utilized in the production of biodiesel. In addition, soybean oil exports were projected to be 2.3 billion pounds (an estimated 307 million gallons of biodiesel).

<u>Soybean Virtual Acres—new technology will add significantly to the U.S. raw material supply</u>—As indicated previously, soybean oil has been the most utilized feedstock to date in the U.S. Based upon historical yield trends, domestic production of soybeans will continue to increase. However, a major research focus of companies such as Pioneer and Monsanto has been to create "virtual acres" through stepwise enhancements in yield technology and/or oil content. Monsanto plans to introduce new technology that can increase soybean yields 9 to 11 percent. Pioneer, a DuPont Company, is commercializing soybean varieties that increase yields by as much as 12 percent. After years of research investments by the life science companies, these technologies have reached commercialization and are set to have a meaningful impact on soybean yields in 2010. More than 90 percent of U.S. farmers currently utilize herbicide-resistant soybean varieties, demonstrating farmers' willingness and desire to adopt technology that can enable improved profits through increased yields or decreased costs. If this same 90 percent of U.S. soybean acres adopted the new yield technology, more than 60 million acres could see a 10 percent increase in yield. This equates to more than 250 million additional bushels of soybeans (the equivalent of 380 million gallons of biodiesel) without increasing acreage in the U.S. Although technology will enable increased production per acre, realization of additional vegetable oil supplies will be dependent upon an expansion of oilseed processing capacity. Stated a different way, protein demand will need to increase to create an economic incentive to expand processing capacity to process additional bushels.

The same benefit can be achieved by increasing soybean oil content. Current industry genetic programs suggest 10 percent oil increases are achievable within the next few years, and increasing soybean oil content by that percentage would generate approximately 120 million gallons of additional oil if adopted on 50 percent of soybean acreage. New approaches for achieving even higher oil levels in plants are being actively researched. Previous efforts focused on increasing the flow of carbon into the oil biosynthesis pathway. However, downstream bottlenecks appear to reduce the value of this approach. The National Biodiesel Board (NBB) has partnered with The Donald Danforth Plant Science Center to identify novel approaches to enhance oil production in soybeans and other oilseeds. This work centers on the hypothesis that the ability to utilize available carbon limits oil production. Therefore, the Danforth Center's work will focus on engineering carbon sinks that will pull metabolites through the oil production process in plants. This is a three-year program that was initiated in 2008.

The soybean industry will continue to play a key role in providing feedstock for the biodiesel industry for years to come. Based upon current technology available to soybean producers, if processing capacity expands it is reasonable to project the production of at least 780 million gallons of biodiesel with existing soybean oil supplies in 2012. This estimate does not take into consideration soybean oil exports, amounting to more than 300 million gallons of soybean oil in 2008, which could be diverted into domestic biodiesel production. Nor does it take into account an estimated one billion bushels of soybeans that are exported and could be a source of biodiesel feedstock if the domestic crushing industry further expanded capacity.

Near Term Yellow Grease Supplies

As reported in, *Statewide Feasibility Study for a Potential New York State Biodiesel Industry, May 5 2004*, recycled cooking and restaurant greases are collected and processed primarily by the independent rendering sector since it is generally not a practice for packer or processing facilities to process yellow grease. Although the supply and availability of waste grease is difficult to quantify, approximately 300 million gallons of biodiesel could be produced from yellow grease generated in the United States[2].

It is estimated that a very high percentage of used cooking/restaurant grease is capable of being collected from restaurant and food operations. According to the U.S. Census, 1,484,711,376 pounds of yellow grease (estimated 185.6 million gallons) were generated in 2007. Accordingly, 62 percent of the potential recycled cooking oils in the U.S. were collected and processed into yellow grease.

Realistically, all waste oils are not collected and other uses for yellow grease exist. The primary markets have been the use of yellow grease as a feed ingredient for livestock, poultry, companion animals, and aquaculture. Recent policy changes that allow yellow grease-based biodiesel to receive the $1 biodiesel blenders tax credit are expected to encourage substantially more collection of used cooking oils and restaurant grease and also shift the economics of yellow grease toward biodiesel production versus other markets.

In 2007, 47 percent of the inedible grease produced (which includes yellow grease) in the U.S. was exported.[3] If 50 percent of potential yellow grease supplies were converted to biodiesel, approximately 150 million gallons of biodiesel could be produced from that feedstock. The National Renderers Association estimates yellow grease supplies will grow by 4 percent between 2008 and 2012,[4] thus an additional 156 million gallons of biodiesel could be produced in 2012.

Near Term Animal Fats Supplies

Animal fats are derived from the rendering process using animal tissues as the raw material. The raw material is a byproduct of the processing of meat animals and poultry. The amount of fat produced is directly related to the species of animal processed and the degree of further processing that is associated with the marketing/distribution of the meat product. Derived from U.S. Census Bureau statistics, approximately 964 million gallons of biodiesel could have been produced from animal fats generated by the rendering industry in 2007.

Similar to yellow grease, current markets of rendered fats include use as feed ingredients for livestock, poultry, companion animals and aquaculture. In addition, products such as edible tallow are used for soap and fatty acid production. Industry analysts anticipate that roughly 25 percent of the rendered animal fat supplies could be diverted to biodiesel production given current uses. Thus, approximately 240 million gallons of biodiesel could be produced nationally from rendered animal fats. The National Rendering Association forecasts rendered fat supplies

[2] Based upon the assumption that 9.4 lbs of recycled oils are generated per capita, 85% conversion rate to yellow grease, and a U.S. population of 300 million.
[3] U.S. Census Bureau, Oils, Production, Consumption, and Stocks – 2007, Issued June, 2008
[4] Personal communication with National Renderers Association, November 2008.

to grow approximately 6 percent by 2012,[5] thus an estimated 254 million gallons of biodiesel could be produced from rendered fats in 2012.

Fat Production (metric tons) in 2007 U.S. Census Bureau Source	mmt	Estimated Biodiesel gallons
Inedible Tallow	1,272,500	350,573,750
Edible Tallow	811,400	223,540,700
Lard	211,200	58,185,600
Poultry Fat	624,800	172,132,400
Other Grease	579,000	159,514,500
		963,946,950

Increased Raw Material Availability—Crops and Technology Contributing to Expansion of Raw Material Supplies

Raw material supplies for biodiesel production will also include:

- Other oilseeds with high-oil content (camelina, canola, etc.);
- Expansion of vegetable oil supplies from ethanol production;
- Expanded domestic oilseed crushing capacity.

<u>Camelina</u>

Just as biodiesel producers are fond of saying that biodiesel can be used in any application that diesel fuel is used, camelina is said to be adapted to any region where wheat can be grown. Researchers and producers indicate the crop can be grown in arid conditions, prefers lower humidity levels, does not require significant levels of inputs such as fertilizer, and the oil will produce a high quality biodiesel. Typical varieties of camelina contain approximately 38 to 40 percent oil. Camelina performs well under drought stress and can yield up to 2,200 pounds per acre (1,200 to 1,500 lbs/acre can be typical) in areas with less than 16 inches of annual rain. Camelina is thought to be ideal for cool regions where canola production is challenging.

At least two firms are offering contracts in 2009 to producers with stated goals of achieving two million acres of production in the near future. The extent to which camelina acreage increases in the near term will be dependent upon numerous factors including:

- Success of breeding programs to increase yield and oil content;
- Expansion of crush locations;
- Addition of risk management options for growers (e.g. crop insurance);
- The extent to which camelina is competitive with other crops (e.g. wheat).

[5] Personal communication with National Renderers Association, November 2008.

The six-year average of wheat acreage between 2002 and 2007 in Colorado, Idaho, Montana, Nebraska, North Dakota, Oregon, Washington, and Wyoming was 21.86 million acres. If 2 million acres of camelina were grown (less than 10 percent of the wheat acreage) and processed utilizing mechanical extraction, approximately 116 million gallons of oil could be added to the market.[6]

Canola

Canola is a type of rapeseed that was first developed in the 1970s. Canadian plant breeders developed canola explicitly for its health advantages compared to industrial rapeseed. Original rapeseed's nutritional content has always been questioned due to its high levels of elcosenoic and erucic fatty acids, the latter having been shown to be linked to heart disease. In the 1960s, Canada began researching rapeseeds by isolating specific lines that were low in erucic acid to

produce an oilseed that could be considered safe for human consumption. The result of these efforts was "Canola," defined as oil that contains less than 2 percent erucic acid.

Canola is a popular crop throughout the world because of its variety of uses and its health value compared to competing oilseeds. Canola can be produced in some countries where similar crops are not able to grow because of short growing seasons. In the U.S., North Dakota is the leading producer of canola. Both spring and winter (fall planted) canola have been found to be a good rotation crop with wheat in several states, helping break up plant diseases that occur in fields where wheat is grown every year. Canola oil has been increasing its market share in the United States because of its nutritional advantages compared to other competitive vegetable

[6] Assumes 35% oil content and average yields of 1,500 lbs/acre.

oils. Although canola oil would primarily move into edible markets, increased U.S. acreage will have positive impacts on the overall vegetable oil supply.

The U.S. Canola Association has established goals and programs to expand canola acreage to two million acres by 2010.[7] Canola in the U.S. is almost exclusively grown as a spring crop. However, a significant portion of the goal would be achieved by expanding winter canola acres in the Pacific Northwest, Great Plains, and mid-South. Similar to camelina, the extent to which winter canola is successful will be dependent upon the economic returns offered to farmers versus other rotation crops (e.g. wheat). Vegetable oil from increased canola acreage would most likely be utilized in edible products rather than biodiesel due to the premium value of canola oil. However, expanding canola acreage still benefits the biodiesel industry by creating a larger supply of vegetable oils, allowing more soybean (and palm) oil to be used for biodiesel without affecting edible oil supplies. The projected increase in U.S. canola acreage by 2010 has the potential to add more than 100 million gallons of oil to the overall vegetable oil supply.

<u>Corn Oil</u>

The changing biofuels landscape creates the opportunity to benefit from increased ethanol usage. Ethanol producers may offer the biodiesel industry its nearest term opportunity for significant additive plant oil supplies. Historically, corn oil has not been a viable biodiesel feedstock due to its relative high cost and high value as edible oil. In current dry grind processes, the corn oil essentially passes through the process and remains in the resulting distillers dry grains with solubles (DDGS). Ethanol firms are investigating fractionation technology to remove corn germ (the portion of the corn kernel that contains oil) prior to the ethanol process. Furthermore, some ethanol plants have either began construction or announced their intent to employ technology to remove the remaining vegetable oil from dried distillers grains, a co-product of the ethanol process. In addition to the various extraction technologies, the quantity of corn oil could also be increased in the long term by producing more high-oil corn varieties.

All of these technologies could add to the biodiesel raw material supply in a meaningful way. Corn oil could help to meet feedstock market demand in two ways. First, edible corn oil could displace other edible oils that could then be diverted to biodiesel production. Second, non-edible corn oil could be used directly for biodiesel production. For example, reaching the federal renewable fuel standard goal of 15 billion gallons of ethanol production in 2015 could generate nearly 400 million gallons of vegetable oil if only one-half pound (less than one third of the potential oil) was extracted from each bushel of corn.

Several ethanol plants have invested in de-oiling technology, and the U.S. Census Bureau initiated coverage of corn oil in their m311k surveys in June, 2008.

[7] http://www.uscanola.com/index.asp?Type=B_BASIC&SEC={7719E6F7-D189-4CD4-870A-2A866A0D3A7F}

Expanded Domestic Soybean Processing

Although highly dependent upon processing economics and domestic demand, vegetable oil supplies could be significantly increased through expansion of the U.S. soybean processing industry. Slightly more than 1 billion bushels of soybeans were projected by USDA to be exported in the 2008 marketing year. If processing capacity were expanded from market signals, more vegetable oil would be available in the U.S. market. Processing an additional one billion bushels of soybeans is the equivalent of 1.5 billion gallons of biodiesel.

Brown Grease Supplies

As reported in, *Statewide Feasibility Study for a Potential New York State Biodiesel Industry, May 5 2004*, brown grease is collected from grease traps installed in commercial, industrial, or municipal sewage facilities to separate grease and oil from wastewater. This 2004 study utilized estimates by Wiltsee that annual production of trap grease averages an estimated 13.37 pounds per person. In the Wiltsee study, he indicates, “Data collected on grease trap wastes are subject to inherent inaccuracies because this material can include a significant amount of water and other materials mixed with the grease…. In all cases, a best effort has been made in this report to adjust grease trap resource data to include only the grease, and to exclude water and other materials that may be present.” Assuming that 95 percent of the material collected was lipid, more than 475 million gallons of biodiesel could be produced from brown grease generated in the United States.

Photo by: Joel Rose

Summary of Near-term Feedstock Supplies

Although many opportunities exist for new feedstocks for biodiesel production, it is relatively clear where near term supplies will be generated. Approximately ¾ of a billion gallons of soybean oil should be available for biodiesel production in 2012, and higher oil content oilseeds such as camelina and canola can add more than 200 million gallons of feedstock supplies (refer to table 1). Although lacking a supply response, animal fats and yellow grease can have a significant impact on biodiesel production; potentially adding more than 400 million gallons of production by 2012. If 400 million gallons of feedstock are realized from U.S. ethanol plants, more than 1.8 billion gallons of feedstock would be available for biodiesel production by 2012.

More difficult to quantify are opportunities that may add even greater amounts of feedstock by 2012. These sources will be highly dependent upon commodity economics, market forces, and global policy. Questions that will have to be answered include:

- What percent of vegetable oil exports may be diverted to biodiesel production?
- Will economics dictate expansion of the U.S. crushing industry and divert exports of raw seed to biodiesel production?
- Will processing economics promote expansion of higher oil content soybeans?
- What impact will imported feedstocks such as oilseed palm, South American soybean oil imports, and new imports such as jatropha have on U.S. biodiesel production?

- Will acres in the Conservation Reserve Program be re-enrolled or will acreage be released and available for commodity production?

Table 1. Estimated Feedstock Supplies for the Production of Biodiesel in 2012

Feedstock Source	*million gallons*
Soybean Oil	780
Animal Fats & Yellow Grease	410
Expansion of Camelina Acreage	116
Expansion of Canola Acreage	100
Corn Oil from Ethanol Plants	400
Total near-term sources	**1,806**
Additional near-term feedstock opportunities:	
Diversion of soybean oil exports (maximum potential)	300^
Expanded U.S. oilseed crush (maximum potential)	1,500^
Increased oil content in soybeans	240^
Imports of vegetable oils (palm, jatropha, SBO)	*
Brown grease (maximum potential)	475
Additional potential near-term sources	**2,515**

** Variable - dependent upon market forces and global policy*
^ The extent to which these sources contribute to feedstock supplies will be dependent upon processing economics.

Should conditions prove favorable, more than 4.3 billion gallons of feedstock may be available for biodiesel production. In addition to these highlighted opportunities, several new feedstock sources that will be discussed in the next section could prove to be equally important for future biodiesel growth.

Future Contributions by New Feedstock Sources

The current feedstock supply situation has sent numerous signals to the market to invest in new technologies and methods to increase raw material supplies. Investment in new, non-edible raw materials sources such as algae, jatropha, mustard, pennycress, and halophytes continues at an aggressive rate. Significant volumes of feedstock may also be realized from sources such as high oil corn or oilseed production on acres expiring from the conservation reserve program. Summary information on some of these sources is provided in the following pages.

<u>Algae</u>

Lipid (fat) production from algae holds much promise for the biodiesel industry. Microalgae are microscopic aquatic plants that carry out the same process and mechanism of photosynthesis as higher plants in converting sunlight, water and carbon dioxide into biomass, lipids and oxygen. However, algae production does not require fresh water or arable land used for cultivation of food crops.

Large-scale production of these algal lipids is still a few years away, but many companies and universities are working to unlock the potential of these single-celled plants, which can contain up to 50 percent oil by weight and double their numbers in a single day. Once realized, oil yield per acre is expected to be the highest of any triglyceride source currently available. Yield projections in the medium term are estimated to range from 2,000-5,000 gallons per acre.

There are multiple algae production paths that are being pursued: open ponds, photo bioreactors, and heterotrophic growth. The open pond method involves growing the algae in open ponds of water, much like it grows in nature. Open ponds are generally less capital intensive than the other production methods but require a reliable supply of water to replenish fluid lost due to evaporation. The lack of temperature, weather, and algae species control can decrease yields from their theoretical potential.

Closed loop, or bioreactor, systems grow algae in a controlled environment using a wide variety of production processes like plastic bags, tubes, or fermentation reactions. Closed loop systems provide the advantage of additional control over seasonal temperature changes, evaporation losses and contamination by undesired algae strains. However, the capital costs of bioreactors tend to be higher than for open pond systems.

Locating algae processing plants strategically can add to their efficiency. For example, locating algae facilities next to carbon producing power plants or manufacturing plants could allow for sequestration of CO_2 for use in growing the algae, which needs the CO_2 for photosynthesis.

Ultimately, algae production represents an enormous opportunity for biodiesel producers. However, obstacles remain and commercial production is assumed to be at least five years away.

<u>Halophytes</u>

Many land areas are presently not arable because freshwater is lacking, the soils are naturally saline, or the soils are salty as the result of previous agricultural practices. Many of these areas have abundant saline water available either as surface or ground water. Halophytes are plants that can either survive or thrive in a salt or brackish water environment. Examples include salicornia, an annual salt-marsh plant with an oil content of 15 to 35 percent, and seashore mallow, a perennial which grows on coastal marshlands or inland brackish lakes and has an oil content of 18 percent. The oil from salicornia is similar to safflower oil and seashore mallow to that of cottonseed oil. Halophytes represent a non-edible feedstock source that would be grown on acres not currently being utilized for edible production.

Salicornia is reported to be tolerant of salt levels up to twice that of seawater, has more than six years of field trials in Mexico, and could generate more than 80 gallons of oil per acre for biodiesel production.

Seashore mallow is a novel salt-tolerant perennial crop derived from a salt marsh plant. With an oil content of approximately 18 percent and residual meal that contains 30 percent protein, this crop can be grown on saline land and produce vegetable oil on underutilized or non-arable land. As reported by researchers at the University of Delaware, seashore mallow has a productive life of about a decade and the oil is very similar to cottonseed oil in fatty acid composition. There are few reported insects or diseases that impact the crop. Due to limited breeding efforts, yields of seashore mallow are low compared to other oilseeds. Researchers envision at least four ways that seashore mallow may fit into agronomic scenarios:

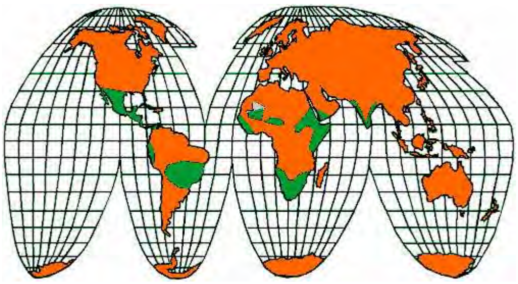
- Grown on salinized farmland;
- Grown on dry farmland with brackish water wells;
- Grown on sandy coastal deserts; or
- Grown on farmland or aquatic ecosystems in transition.

Seashore mallow has been evaluated in more than four years of field trials in the Delaware Coastal Plain and could generate more than 30 gallons per acre of oil for biodiesel production.

Jatropha

Jatropha is a small but versatile bush/tree from the Euphorbiaceae family. The tree flowers and produces clusters of about 10-15 fruits with a seed containing high concentrations of oil. *Jatropha Curcas L*. is gaining a lot of attention as a potential feedstock for biodiesel production due to its high oil content and ability to grow in less than ideal conditions. However, harvesting and logistical challenges have kept the plant from being grown in large scale production in places where there is not an abundance of low cost labor.

Historically, most of the Jatropha has been grown in tropical areas including Africa and Asia, especially India. More recently, it has been grown on most continents around the world. The green shading on the map below indicates the primary areas where Jatropha is grown. These areas are mainly inside the tropics and are not known to have land of good quality.



This low maintenance plant has generally proven to be resistant to local pests under common cultivation practices and can produce seeds containing up to 40 percent oil. While Jatropha is touted as being able to survive in poor soils with very little fertilizer and water, the fruit (and thus oil) yields increase significantly with increased soil fertility and water. For example, adding small amounts of magnesium, sulfur, and calcium have a significant impact on improving yields. Jatropha can survive in areas with annual rainfall of 8-12 inches. In extreme conditions, plants will survive drought by dropping its leaves to reduce transpiration loss. In fact, this resilient plant can survive three full years of drought before it would die. However, fruit production is very low during these drought years. While Jatropha is most commonly grown in low altitude regions that are relatively warm, it can grow at higher altitudes but can only handle a slight frost.

Since Jatropha can grow in arid areas that are not suitable for traditional grain crops, there could be a potential market for growing Jatropha in portions of the United States. Such areas could include much of the dry southern states including Arizona, Texas, and New Mexico, and other arid grounds. Literature has also suggested that Jatropha could grow very well in Florida, California, Alabama, Mississippi, and Louisiana. In order to be economically viable in these states, Jatropha would need to be grown in a manner that does not compete with existing crops or alternative competition such as urban sprawl.

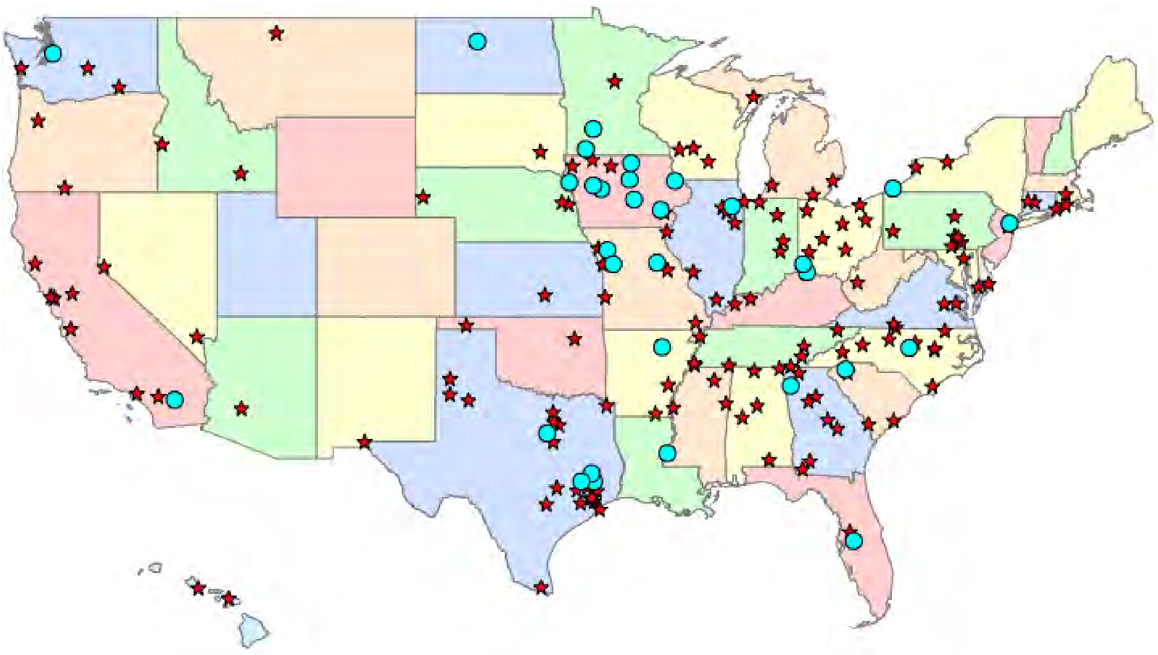
High Oil Corn

In the early 1990s the production of high oil corn was on the rise for its enhanced feed value. However, production has since declined due to yield drag, pollination challenges, segregation costs, and handling issues while offering only moderate added value. If the technologies described above prove to be economically viable, then growing high oil corn may make sense economically. This could drive demand such that seed companies would re-focus efforts on high oil varieties to address production challenges. Traditional corn has oil content of about 3.5 percent. High oil varieties have oil yields of about 6.8 percent.

Biodiesel Industry Capacity

In addition to questions related to feedstock supplies, policy requiring specific quantities of biodiesel also brings industry plant capacity to the forefront. There are presently 176 companies that have invested millions of dollars into the development of biodiesel manufacturing plants and are actively marketing biodiesel. The annual production capacity from these plants is 2.61 billion gallons per year. It is important to note that production capacity differs from the actual number of gallons sold. Between 25 and 50 million gallons of production capacity currently exists in California, and approximately 125 million gallons of capacity exists in Washington and Oregon.

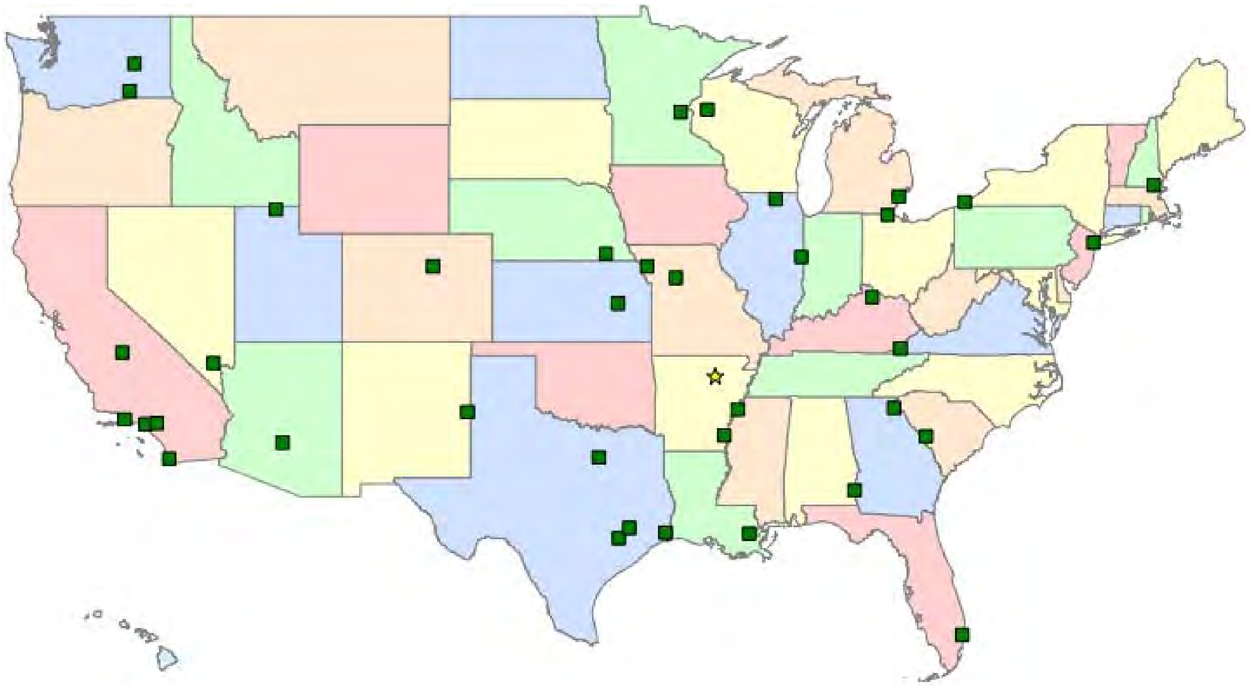
Figure 1. Biodiesel Production Locations, September 2008[8].



Thirty-nine companies have reported that their plants are currently under construction and are scheduled to be completed within the next 12-18 months. One plant is expanding their existing operation. Their combined capacity, if realized, would result in another 849.9 million gallons per year of biodiesel production.

[8] www.biodiesel.org

Figure 2. Biodiesel Plants Under Construction & Expansion, September 2008[9].



Neither equity investment in plant capacity nor feedstock supplies represent a constraint in the marketplace for production of sufficient quantities of biodiesel to meet the RFS2 requirements for biomass derived diesel.

Conclusion

The biodiesel industry has experienced rapid growth in production capacity in the last five years. This rapid expansion has lead to competition for feedstock among biodiesel producers and the need for biodiesel plants to develop the capability to process a wide variety of feedstock to remain economically competitive. Consequently, efforts are underway to increase the supply of traditional plant oils and animal fats and to develop nontraditional sources. These efforts are also seeking to increase feedstock supplies while being environmental responsible.

Demand for biodiesel is expected to continue to grow. However, the anticipated expansion of existing feedstock supplies in the short term has the potential to produce at least 1.8 billion gallons of biodiesel by 2012. If the development of longer-term feedstock prospects is realized, the potential supply of biodiesel feedstock will keep pace with future demand for biodiesel.

[9] www.biodiesel.org

ATTACHMENT 3

Review of EPA's Proposed RFS2 Program for Biodiesel:

Implications of Land Use Restrictions & EPA's Production Estimates

Prepared by:

MARC-IV Consulting

August, 2009

Implications of EPA's Biodiesel Baseline and Production Estimates

Background

In Section V of the notice of proposed rulemaking, EPA provides an "Assessment of Renewable Fuel Production Capacity and Use." A reference and control case for biofuels production are presented. EPA relies upon the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2007 projections for their reference case. The AEO 2007 presents long-term projections of energy supply, demand, and prices through 2030 based on results from EIA's National Energy Modeling System (NEMS). AEO 2007 projections generally are based on Federal, State, and local laws and regulations in effect on or before October 31, 2006. The potential impacts of pending or proposed legislation, regulations, and standards are not reflected in the projections according to EPA.

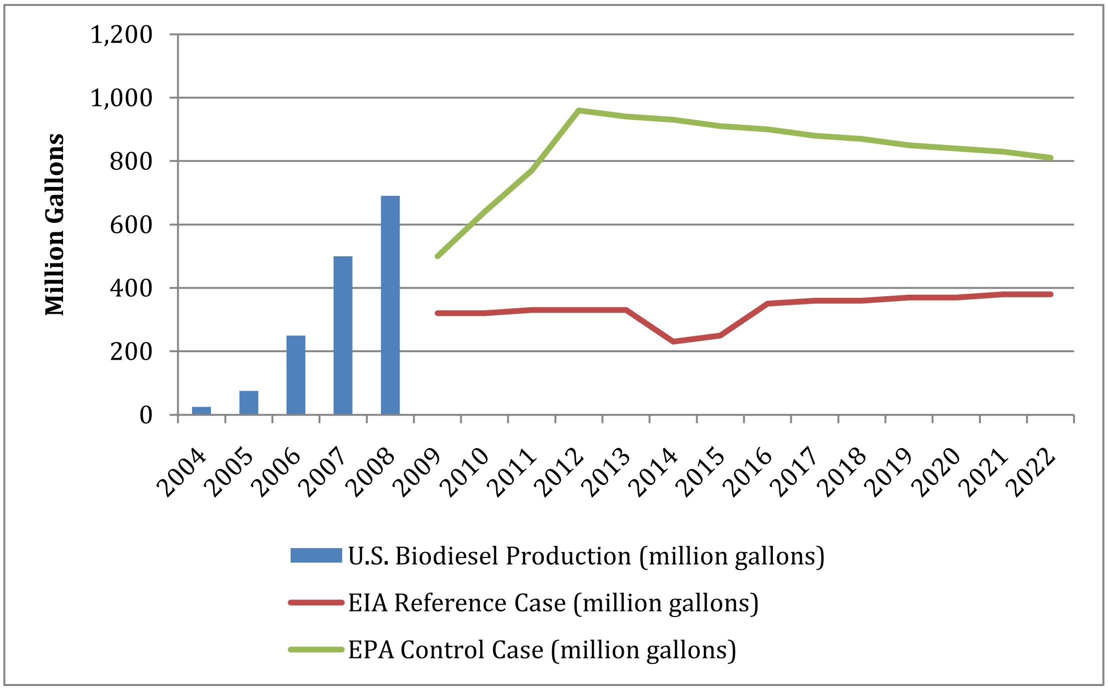
In the control case developed by EPA, biodiesel production is assumed to increase to 960 million gallons per year (mgpy) in 2012 and then gradually decreases to 810 mgpy in 2022. The EPA analysis assumes that virgin plant oils would be preferentially processed by biodiesel plants, while the majority of fats and greases would be routed to renewable diesel production. Utilizing commodity econometric models, domestic soybean oil production is assumed to represent 550 million gallons of the stated production. EPA also estimates vegetable oil from ethanol plants would represent approximately 150 million gallons per year, up to 30% of rendered fats and waste grease could be converted into fuel, and lipid sources such as algae and jatropha will not make contributions to the biodiesel feedstock supply.

The reference case utilized by EPA does not accurately reflect the biodiesel marketplace and underestimates potential biodiesel production volumes.

Review of the EPA reference case, which was used to calculate the increased levels of biofuels needed to meet RFS2, reveals the fact that EPA has penalized the biodiesel industry when calculating potential global land use change by establishing an artificially low production baseline. EPA utilizes a 2007 Energy Information Administration analysis that assumes 320 million gallons of biodiesel will be produced in 2009, increasing to 330 mgpy in 2013. Then dropping to 230 mgpy in 2013 before rising again to 380 mgpy in 2022. Several inconsistencies exist relative to the biodiesel industry:

- AEO2007 does not treat the ethanol and biodiesel reference cases consistently. AEO2007 assumes that the ethanol tax credit, as modified under JOBS 2004, will be extended when it expires in 2010 and will remain in force indefinitely. EIA assumes its continuation due to the legislative history of the ethanol incentive. For the biodiesel industry, however the tax credit is assumed to expire due to a lack of legislative history for extensions. This inconsistency should favor ethanol economics relative to biodiesel and will undercount potential biodiesel production.
- The NEMS model utilized in AEO2007 is not transparent. Details of the biodiesel component of the NEMS model are not readily available, and it is not apparent how biodiesel demand has been derived. How econometrically rigorous is the NEMS model for a lipid-based fuel such as biodiesel?
- The U.S. biodiesel industry has already achieved and surpassed the assumed levels of production in the EPA reference case. The U.S. biodiesel industry produced approximately 690 million gallons of biodiesel in 2008, significantly greater than the assumed level of 320 million gallons by EIA. Thus, the "penalty" assessed to biodiesel for global land use change is overstated.
- In addition, there are several state policies and fleet requirements that will come into affect between 2008 and 2022. Counting only the mandates for Louisiana, Massachusetts, Minnesota, New Mexico, Oregon, Pennsylvania, and Washington that go into effect between 2009 and 2012 adds an additional 221 to 230 mgpy to biodiesel use. These requirements will add to the baseline volume of biodiesel that will be used irrespective of the RFS-2 program.

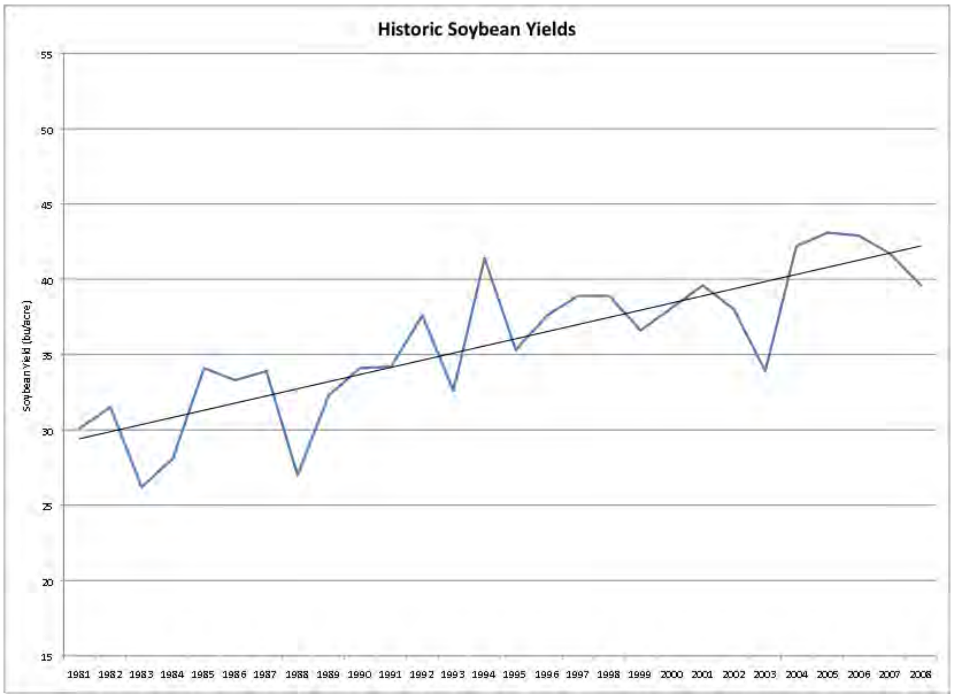
As depicted graphically in the chart below, underestimating biodiesel volumes in the reference case has the effect of penalizing biodiesel when indirect land use changes are calculated. In fact, prior to supporting legislative language now engrossed in RFS2, the biodiesel industry conducted multiple economic analyses to estimate the levels of biodiesel that could be produced domestically without significantly impacting the fats & oils markets.



<u>EPA has not fully considered new fats & oils technology that can increase the contribution biodiesel will make to the Biomass Based Diesel category in RFS2.</u>
The EPA analysis also penalizes the biodiesel industry by not fully considering new fats & oils technology that can increase the contribution biodiesel will make to the biomass-based diesel category in RFS2. The proposed rule only considers soybean oil, vegetable oil from ethanol plants, and rendered fats and waste greases in their analysis. Lipid sources such as camelina, winter canola, and algae production are not factored into the feedstock supply. In addition, higher yielding oilseed technology has not been fully incorporated. Unless otherwise prohibited by rulemaking, vegetable oils will not only play a key role in the renewable fuels standard, but can generate significantly greater volumes of biodiesel than assumed by EPA in their control case.

New yield technology will add significantly to the U.S. vegetable oil supplywithout *impacting acreage domestically or abroad*. Based upon historical yield trends, domestic production of soybeans will continue to increase. In 2008, the average U.S. soybean yield was 39.6 bushels/acre. Given historic trends, yields can be expected to increase to almost 49 bushels/acre by 2022. U.S. producers planted 77.5 million acres of soybean in 2009. More than 725 million additional bushels of soybeans (an estimated <u>*1 billion gallons of additional*</u> feedstock) would be produced in 2022 on the same 77.5 million acres.

Furthermore, a major research focus of companies such as Pioneer Hi-Bred International, Inc. and Monsanto has been to create "virtual acres" through stepwise enhancements in yield technology and/or oil content. Monsanto plans to introduce new technology that can increase soybean yields 9 to 11 percent. Pioneer Hi-Bred International, Inc., is commercializing soybean varieties that increase yields by as much as 12 percent. After years of research investments by the life science companies, these technologies have reached commercialization and are set to have a meaningful impact on soybean yields in 2010. More than 90 percent of U.S. farmers currently utilize herbicide-resistant soybean varieties, demonstrating farmers' willingness and desire to adopt technology that can enable improved profits through increased yields or decreased costs. If this same 90 percent of U.S. soybean acres adopted the new yield technology, farmers would see a 10 percent increase in current yields on 70 million acres. This equates to approximately 280 million additional bushels of soybeans (the equivalent of 420 million gallons of biodiesel) without increasing acreage in the U.S. Although technology will enable increased production per acre, realization of additional vegetable oil supplies will be dependent upon an expansion of oilseed processing capacity. Stated a different way, protein demand drives the soybean market and will need to increase to create an economic incentive to expand capacity to process additional bushels of soybeans and other oilseeds.



Some argue that yield enhancements will be made regardless of whether or not vegetable oils are allowed under RFS2. However, it is a straight-forward concept that technology companies prefer to invest in growth markets. Implementation of a workable RFS2 Program will continue to support investment in new technology. Thus, EPA has severely overestimated potential indirect land use change associated with vegetable oil-based biodiesel.

The EPA analysis also does not consider the contribution that camelina can make to the biodiesel fuel supply. Just as biodiesel producers are fond of saying that biodiesel can be used in any application that diesel fuel is used, camelina is said to be adapted to any region where wheat can be grown. Researchers and producers indicate the crop can be grown in arid conditions, prefers lower humidity levels, does not require significant levels of inputs such as fertilizer, and the oil will produce a high quality biodiesel. Typical varieties of camelina contain approximately 38 to 40 percent oil. Camelina performs well under drought stress and can yield up to 2,200 pounds per acre (1,200 to 1,500 lbs/acre are typical) in areas with less than 16 inches of annual rain.

At least two firms are offering contracts to producers in 2009 with stated goals of achieving two million acres of production in the near future. The six-year average of wheat acreage between 2002 and 2007 in Colorado, Idaho, Montana, Nebraska, North Dakota, Oregon, Washington, and Wyoming was 21.86 million acres. If 2 million acres of camelina were grown (less than 10 percent of the wheat acreage) and processed utilizing mechanical extraction, approximately 116 million gallons of oil could be added to the market.[1]

Jatropha also represents an oilseed that is primarily planted in regions outside of the U.S., but can have an impact on the U.S. biofuels market. *Jatropha curcas L*. is gaining considerable attention as a feedstock for biodiesel production due to its high oil content and ability to grow in less than ideal conditions. However, harvesting and logistical challenges have kept the plant from being grown for large - production in places where there is not an abundance of low-cost labor.

Since jatropha can grow in arid climates not suitable for traditional grain crops, there could be a potential market for growing jatropha in portions of the United States, including Arizona, Texas, and New Mexico. Literature has also suggested that jatropha could grow in parts of Florida, California, Alabama, Mississippi, and Louisiana.

The author concurs with EPA that issues such as frost tolerance and lack of mechanical harvesting will constrain domestic production. However, significant acreage has been planted with the intent of shipping crude or refined oil globally. A May, 2008 report prepared by GEXSI titled, "Global Market Study on Jatropha" estimated 900,000 hectares (2.22 million acres) of jatropha have been planted. The authors of the GEXSI study estimate 5 million hectares (12.25 million acres) will be in production by 2010 and 13 million hectares (32 million acres) by 2015.

Finally, the author concurs that significant research issues remain to commercialize algae for biodiesel production. However, algae can play a role in the RFS during the timeframe outlined in the control case. Lipid (fat) production from algae holds much promise for the biodiesel industry. Microalgae are microscopic aquatic plants that carry out the same process and mechanism of photosynthesis as higher plants in converting sunlight, water and carbon dioxide into biomass, lipids and oxygen. However, algae production does not require fresh water or arable land.

Large-scale production of these algal lipids is still a few years away, but many companies and universities are working to unlock the potential of these single-celled plants, which can double their numbers in a single day and contain up to 50 percent oil by weight. Once realized, oil yield per acre is expected to be the highest of any triglyceride source currently available. Yield projections in the medium term are estimated to range from 2,000-5,000 gallons per acre. Ultimately, algae production represents an enormous opportunity for biodiesel producers. However, obstacles remain and initial commercial production is assumed to be at least five years away.

[1] Assumes 35% oil content and average yields of 1,500 lbs/acre.

Implications of EPA's Proposed Land Restrictions for Renewable Biomass

<u>Background</u>
The Energy Independence Security Act of 2007 (EISA) limits not only the types of feedstocks that can be used to make renewable fuel, but also the land from which feedstocks are produced. Specifically, EISA's definition of renewable biomass incorporates land restrictions for planted crops and crop residue, planted trees and tree residue, slash and pre-commercial thinnings, and biomass from wildfire areas. Planted crops and crop residue are to be harvested from agricultural land cleared or cultivated at any time prior to December 19, 2007, that is either actively managed or fallow, and nonforested.

In Section III of the notice of proposed rulemaking, EPA states they believe the most important criteria is whether agricultural land is actively managed or fallow, and nonforested, per the statutory language. EPA proposes to interpret the phrase "that is actively managed or fallow, and nonforested" as meaning that land must have been actively managed or fallow, and nonforested, on December 19, 2007, and continuously thereafter in order to qualify for renewable biomass production.

EPA proposes that "actively managed" would mean managed for a predetermined outcome as evidenced by any of the following: sales records for planted crops, crop residue, or livestock; purchasing records for land treatments such as fertilizer, weed control, or reseeding; a written management plan for agricultural purposes; documentation of participation in an agricultural program sponsored by a federal, state or local government agency; or documentation of land management in accordance with an agricultural certification program.

Embedded in EPA's proposal is the requirement that renewable fuel producers will need to have information about the origin of the feedstock they procure in order to determine if the feedstock was produced on land that meets the above requirements and can be used to generate RINs. EPA outlined multiple proposed approaches.

<u>EPA's Proposed Enforcement Mechanisms Costly to Renewable Fuel Producers and Consumers</u>
EPA's first proposal for ensuring that producers generate RINs properly would be for EPA to require that renewable fuel producers obtain documentation about their feedstocks from their feedstock supplier(s) and take the measures necessary to ensure that they know the source of their feedstocks and can demonstrate to EPA that they have complied with the EISA definition of renewable biomass. EPA would require renewable fuel producers to maintain sufficient records to support these claims. Specifically, renewable fuel producers would be required to have copies of their feedstock producers' written records that serve as evidence of land being actively managed.

EPA's proposed approach would require identity preservation of crops (feedstock). The U.S. grain production and handling systems are similar to petroleum distribution in the fact that commodity grains are fungible. Soybeans produced in Kansas enter the handling/distribution channel typically at a local elevator. From the local elevator, commodity grain may move to a processor or to terminal elevators. From terminal elevators, grain will typically move to processors or to export facilities. At all points along the chain, commodity grain is commingled with grain of similar quality from multiple production points in the U.S.

As reported by Bender (2003), two primary distribution systems have traditionally existed for corn and soybeans - one distribution system has focused on commodity crops, and the other distribution system has focused on very high-value traits. The distribution system for commodity crops is focused on homogeneity. A smaller percentage of trade in corn and soybeans has been in high value crops, such as certified organic corn and soybeans. An identity preserved supply chain used for these high value crops typically consists of a specialty grain firm contracting variety specific grain production, with particular production and/or management requirements. The goals are to minimize the number of handlings so as to reduce quality deterioration and to minimize the potential for commingling with non-differentiated corn or soybeans.

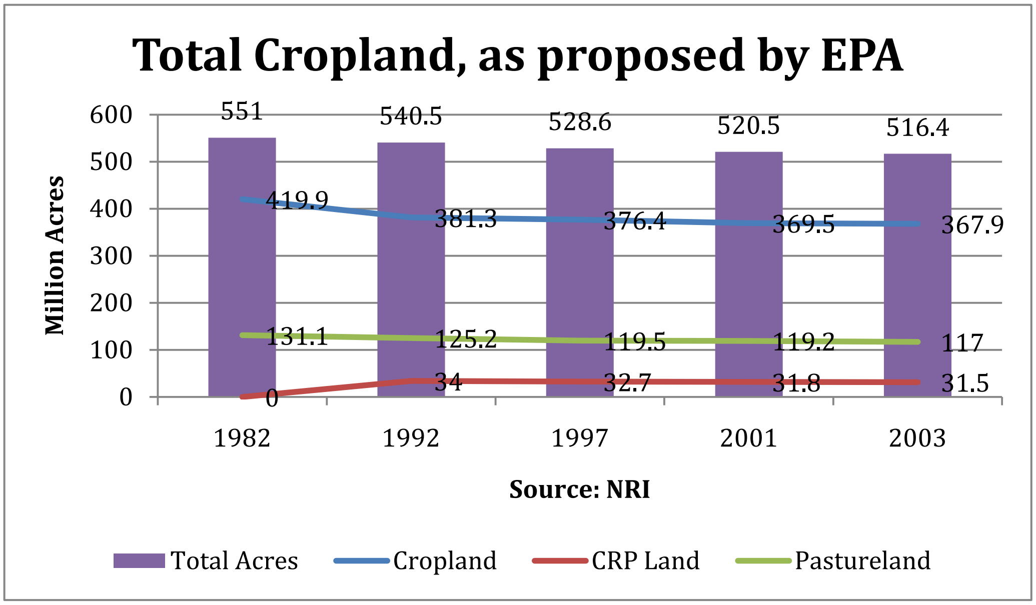
The EPA proposed rule will require renewable fuel producers to know the specific parcel of land from which a quantity of feedstock is produced. This identity preservation will have significant cost impacts on the feedstock and thus to consumers. Bender (2003) cites producer survey results conducted in Illinois during the 2000-01 marketing year regarding additional costs incurred in the production, handling and marketing of value added crops relative to costs incurred for traditional commodity markets. Total added costs to the producer ranged from $0.17/bu for non-genetically modified (GM) soybeans to $3.02/bu for tofu soybeans. For Illinois elevators, the total additional costs of handling value-added crops ranged from a low of $0.06/bushel for tofu soybeans to $0.15/bushel for white food grade corn.

A separate USDA Economic Research Service article and analysis, published in 2000 by Lin, Chambers, and Harwood, indicated that segregation could add about $0.22/bushel. The analysis noted that segregation of nonbiotech soybeans at elevators could add $0.54/bushel, on average, excluding the nonbiotech producer premiums. Those estimates reflected costs at elevators and not necessarily the costs incurred beyond that point by any one elevator or other elevators in general. Those costs also did not take into account any additional costs that could be associated with segregation at the farm level and shipment expenses beyond export elevators to international markets.

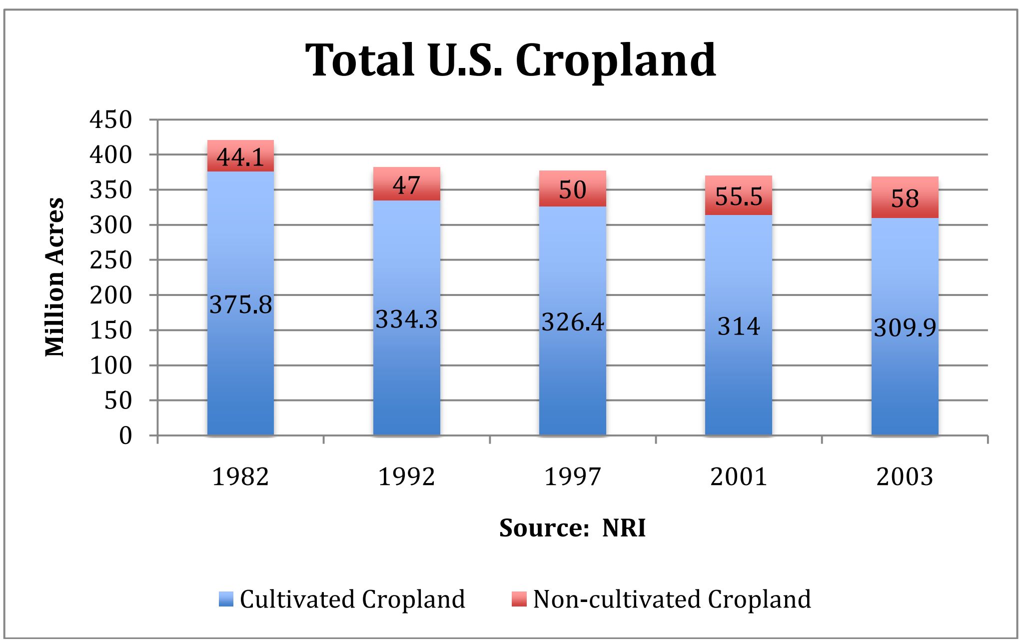
The size of the U.S. soybean crop is approximately 3 billion bushels. Requiring the segregation of all soybean feedstock supplies to ensure that renewable fuel producers legally comply with the RFS2 would add $660 million to the cost of feedstocks (assuming an estimate of adding 22¢ per bushel for identify preservation). These costs will ultimately be bourn by consumers.

<u>Establishing Baseline Production of Eligible Land Most Efficient for Industry and Consumers</u>
Other approaches proposed by EPA are different in detail, but equally as cumbersome for the renewable fuels industry, and ultimately these costs will be paid by U.S. consumers. The only approach practical for industry is to establish a baseline level of production of biomass feedstocks such that reporting and recordkeeping requirements are triggered only when the baseline production levels of feedstocks used for biofuels are exceeded.

EPA has proposed to utilize National Resources Inventory (NRI) land classifications. According to NRI data, total cropland (defined in the proposed rule as cropland, CRP, and pastureland) has decreased during the time period of 1982 to 2003. Data from 2007 NRI should be utilized as the baseline, and if the total cropland acres are not eclipsed, no reporting requirements would be needed.



It is important to note that not all U.S. cropland is being cultivated, although it would still meet the definition of cropland as it would be actively managed. In addition, many crops are interchangeable on existing cropland acres that are actively managed. Therefore it is not appropriate to establish thresholds based on individual crop acreage reporting.



SOURCES:

"Biotechnology: U.S. Grain Handlers Look Ahead", Special Article in Agricultural Outlook, 2000.

"Product Differentiation and Identity Preservation: Implications for Market Developments in U.S. Corn and Soybeans", Karen Bender, University of Illinois – Urbana Champaign, Paper presented at the USDA-ERS and Farm Foundation Symposium, January 27-28, 2003.

National Resources Inventory, 2003 Annual NRI, February 2007.

ATTACHMENT 4

Association of Public and Land-Grant Universities
Advancing Research, Learning and Engagement

September 8, 2009

COPY

The Honorable Colin C. Peterson
Chairman
Committee on Agriculture
U. S. House of Representatives
Washington, DC 20515

The Honorable Frank D. Lucas
Ranking Member
Committee on Agriculture
U. S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman and Ranking Member Lucas:

The U. S. House of Representatives has proposed a revision to the Energy Independence and Security Act (EISA) to conduct a federal study on the indirect land use issue within five years.

We welcome the opportunity for the federal government to fund a study that puts science behind the theory on indirect land use changes.

The EISA's Renewable Fuels Standard (RFS2) initially had a provision on taking indirect land use into account in meeting greenhouse gas reduction goals. The theory was that indirect land use changes result when corn grown in the U. S. is used for biofuels instead of the traditional feed, food or fiber. The theory anticipates that farmers in other parts of the world would plant a food crop on land previously not under crop production, thus increasing the release of greenhouse gases.

The issue has ignited debate among scientists and economists about the science, assumptions and parameters used to determine land use change. The logic behind the theory is valid — if biofuels increase commodity prices, total world production of agricultural commodities will increase, which will increase land used for agriculture. What's in question is our ability to measure the increase and to determine whether emissions from increased land use overwhelm the emission reduction from using a renewable feedstock. The measurement issues have raised questions on the effectiveness of policy based on indirect land use changes in actually reducing greenhouse gas emissions.

If the indirect land use effects are not assessed accurately, the risk is that biofuels would be declared to have a negative climate impact before the science and technology to bring them to their full potential could be pursued. The possible consequences of not exploring the full potential of biofuels could be a failure to reduce dependence on foreign oil supplies and a failure to substantially reduce greenhouse gas emissions.

We believe scientific data aren't currently available on a global basis to be able to accurately determine the extent to which biofuel production causes land use changes in remote locations or the greenhouse gas emissions that might exist. While current research has provided important insights into the issue, there is no simple answer to the biofuels induced land use change and GHG impact question. Some of the most challenging questions where better data are needed include:

- Which countries will respond with higher production to higher prices caused by diversion of feed grains and vegetable oils from food to fuel? The answer depends in part on whether farmers in a particular country "see" the change in price or whether they are shielded from price changes by import tariffs, export taxes or government stabilization policies. Improvements are needed in the way that economic models capture individual countries' policies.
- Do we have access to data on how a country expands production in response to higher prices? Do yields increase because now farmers can afford more fertilizer? Or does acreage increase?
- If crop acreage increases, is there idle land (for example, abandoned farms in Africa) that will be brought into production? Will crop acreage displace land used for grazing livestock? If so, what will happen to the livestock? This knowledge is needed on a country-by-country basis.
- Will expanded crop production in other countries come at the expense of acreage planted to other crops or will yields increase? If acreage increases, improvements are needed in estimating where the acreage increase takes place and which type of land is converted. If it is forest land, what happens to the biomass? Is it used for fuel? Is it harvested? Is it burned?
- How is the land managed after it is brought into agricultural production? These data are needed to determine whether soil carbon increases or decreases.

We appreciate that the government and others look to research universities for answers to these concerns. We need science to better quantify the indirect effects of how decisions about management of agricultural land in one country impact land use in other countries.

We do need additional research funding to better assess biofuels production and its impact on land use. We support Congress' efforts to make that happen. We are hopeful that the upcoming federal study will clearly outline data that are available and data that are needed. Indirect land use change is a complex issue, but U. S. policy on the future of the nation's energy sources deserves the best science.

Greenhouse gas emissions impact on climate change is real and must be addressed by the United States and the world. Leaders in agriculture understand that climate change has the potential to dramatically impact all aspects of crop and livestock production. Farmers know that how they manage their land may help reduce climate change. But additional research is needed to develop advanced strategies to reduce greenhouse emissions from agricultural land.

If the federal study determines that indirect land use can be reliably estimated, then Congress should consider holding all fuels, no matter how they are produced, accountable to the same standard.

We urge Congress to continue to raise questions about the current state of the science regarding indirect land use change and to continue to support research to address the questions.

Sincerely,

Jay Akridge
Glenn W. Sample Dean of Agriculture
Purdue University

Jeffrey D. Armstrong
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ATTACHMENT 5

March 2, 2009

The Honorable Arnold Schwarzenegger
Office of the Governor
State Capitol
Sacramento, CA 95814

RE: Opposed to Selective Enforcement of Indirect Effects in CA LCFS

Dear Governor Schwarzenegger,

We are writing regarding the California Air Resources Board's (ARB) ongoing development of the Low Carbon Fuel Standard (LCFS). With the rulemaking nearing its final stage, we would like to offer comments on the critical issue of how to address the issue of indirect, market-mediated effects.

As you are aware, ARB staff continues to push a regulation that includes an indirect land use change (iLUC) penalty for biofuels. To be clear, this effect is not the direct land conversion from growing crops for fuel. It is the alleged indirect, price-induced land conversion effect that could occur in the world economy as a result of any increase in demand for agricultural production. The ability to predict this alleged effect depends on using an economic model to predict worldwide carbon effects, and the outcomes are unusually sensitive to the assumptions made by the researchers conducting the model runs. In addition, this field of science is in its nascent stage, is controversial in much of the scientific community, and is only being enforced against biofuels in the proposed LCFS.

The push to include iLUC in the carbon score for biofuel is driven at least partially by concerns about global deforestation. There is no question that global deforestation is a problem, and that indirect effects must be looked at very carefully to ensure that future fuels dramatically reduce GHG emissions without unintended consequences. The scientific community is actively seeking ways to mitigate deforestation, enhance efficient land use, feed the poor and malnourished and reduce global warming. Because of the complex and important issues involved, it is critical that we rely on science-based decision-making to properly determine and evaluate the indirect effects of all fuels, as well as any predicted changes in agricultural and forestry practices. In a general sense, it is worth noting that most primary forest deforestation is currently occurring in places like Brazil, Indonesia and Russia as a direct result of logging, cattle ranching and subsistence farming. Adding an iLUC penalty to biofuels will hold the sector accountable to decision-making far outside of its control (i.e. for decisions related to the supply chains of other products), and is unlikely to have any effect on protecting forests or mitigating GHG emissions as a result of land management practices. But because indirect effects are not enforced against any other fuel in the proposed LCFS, an iLUC penalty will chill investment in both conventional and advanced biofuel production, including advanced biofuels made from dedicated energy feedstocks such as switchgrass and miscanthus, which have the potential to make the agricultural sector far less resource-intensive and could provide a significant carbon negative source of transportation fuel.

More than 20 scientists wrote to the ARB in June 2008 suggesting that more time and analysis is required to truly understand the iLUC effect of biofuels. In addition to iLUC, we know very little about the indirect effects of other fuels, and therefore cannot establish a proper relative value for indirect effects among the various compliance fuels and petroleum under the LCFS. In consideration of this and other rulemaking activities and research conducted since June 2008, we, the undersigned 111 scientists, continue to believe that the enforcement of any indirect effect, including iLUC, is highly premature at this time, based on the following two principles:

1) <u>The Science Is Far Too Limited and Uncertain For Regulatory Enforcement</u>

ARB staff is proposing to enforce a penalty on all biofuels for indirect land use change as determined by a computable general equilibrium (CGE) model called GTAP. This model is set to a static world economic condition (e.g. 2006), then shocked with a volume of biofuel to create the perceived land conversion result. The modeling outcome is applicable to the set of assumptions used for that particular run, but is not particularly relevant when there is a shift in policy, weather, world economic conditions or other economic, social or political variables. For example, by definition, these models assume zero innovation, which means they could not have predicted the 500% increase in corn yields since 1940, the tripling of wheat yields since 1960, or the 700% increase in yield that can occur if farmers in developing countries adopt higher yield seed varieties and more efficient farming practices. This inability to predict innovation is not limited to agriculture; similar attempts to use economic equilibrium models in other emerging markets like telephony or computing would have been equally unsuccessful. As discussed, the model runs are unusually sensitive to the assumptions made by the modelers, which is why the iLUC modeling results published thus far differ by a factor of at least four, and under some scenarios, are actually zero for today's biofuels. Even at this late stage in the LCFS process, the GTAP model runs still do not reflect basic on-the-ground realities, such as the use of marginal and idle lands. They do not reflect recent articles about the potential for energy crops to absorb carbon at higher rates than previously thought. A partial solution to this problem is to conduct a series of model runs with different assumptions and adjustments. Unfortunately, this has not occurred at ARB (researchers have run limited sensitivity analysis within the current set of primary assumptions). We are only in the very early stages of assessing and understanding the indirect, market-mediated effects of different fuels. Indirect effects have never been enforced against any product in the world. California should not be setting a wide-reaching carbon regulation based on one set of assumptions with clear omissions relevant to the real world.

2) <u>Indirect Effects Are Often Misunderstood And Should Not Be Enforced Selectively</u>

In basic terms, there is only one type of carbon impact from a commercial fuel: its direct effect. Direct carbon effects are those directly attributable to the production of the fuel, which in the case of biofuel includes the land converted to produce the biofuel feedstock. Indirect effects, on the other hand, are those that allegedly happen in the marketplace as a result of shifting behaviors. As such, penalizing a biofuel gallon for direct *and* indirect land use change is the equivalent of ascribing the carbon impact of land converted to produce biofuel feedstock as well as the land needed to produce another, allegedly displaced supply chain (e.g. soy production for food). Leaving aside the issue of whether these effects can be predicted with precision or accuracy, or whether such a penalty is appropriate for the LCFS, it is clear that indirect effects should not be enforced against only one fuel pathway. Petroleum, for example, has a price-induced effect on commodities, the agricultural sector and other markets. Electric cars will increase pressure on the grid, potentially increasing the demand for marginal electricity production from coal, natural gas or residual oil. Yet, to date, ARB is proposing to enforce indirect effects against biofuel production only. This proposal creates an asymmetry or bias in a regulation designed to create a level playing field. It violates the fundamental presumption that all fuels in a performance-based standard should be judged the same way (i.e. identical LCA boundaries). Enforcing different compliance metrics against different fuels is the equivalent of picking winners and losers, which is in direct conflict with the ambition of the LCFS.

Proponents of iLUC inclusion claim that all regulations are uncertain. This is true. However, the level of uncertainty implicated here far outweighs that found in other regulatory fields. For example, the European Parliament declared in December that the iLUC of biofuel "is not currently expressed in a form that is immediately usable by economic operators."[1] They decided not to incorporate iLUC penalties in their biofuel programs and initiated further analysis of the issue. It is also not enough to suggest that iLUC is a significant indirect effect, while other indirect effects are likely smaller. The magnitude of the alleged iLUC effect ranges from zero to very large, depending on the assumptions utilized. This is also likely true for other fuels, especially with regard to the marginal gallons of petroleum that are coming into the marketplace, such as heavy oil, enhanced oil recovery, and tar sands. Either way, even small effects are significant under the LCFS. Just a few g/MJ separate corn ethanol from petroleum in the proposed regulation, and advanced biofuel is very close to CNG and hydrogen under certain scenarios. We agree with the sentiment expressed by many experts that while indirect effects are important to understand, enforcing them prematurely and selectively on only certain fuels in a performance-based standard could have major negative consequences, even for GHG mitigation. Put another way, no level of certainty justifies asymmetrical enforcement of indirect effects.

Given the limited time, a reasonable solution to the challenges discussed above is to submit an LCFS regulation based on direct carbon effects (including direct land use impacts) and support a rigorous 24-month analysis of the indirect, market-mediated effects of petroleum and the entire spectrum of alternative fuels, regardless of source. The analysis could be conducted in collaboration with other institutions and governments implementing carbon-based fuel standards, and should include a consideration of the best way to prevent carbon effects outside the primary system boundary, including promoting sound land use practice with more direct policy solutions. This approach is consistent with the principle that all fuels should be judged through the same lens in a performance-based standard, as well as the approach taken by the European Parliament. It is worth noting that an LCFS

[1] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2008 0613+0+DOC+XML+V0//EN&language=EN#BKMD-27

policy based on direct effects already favors non-land intensive, advanced biofuel production over conventional biofuel production.

The LCFS provides an incredible opportunity to reduce the carbon intensity of transportation fuel and promote a more sustainable transportation fuel marketplace. We commend your leadership and the ARB staff for their ability to process a challenging set of scientific data resources into a workable regulation. However, it is critical that the LCFS stay on course with regard to its primary mission of establishing a level, carbon-based playing field for all fuels.

We are writing this letter as researchers in the field of biomass to bioenergy conversion, but the signatories do not represent the official views of the home institutions, universities, companies, the Department of Energy, the United States Department of Agriculture, or any of the National Laboratories. We look forward to working with ARB to ensure that the regulation reflects the best science available, and takes a policy approach that is balanced across all fuel pathways.

Sincerely,

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A.G. Kawamura, Secretary, California Department of Food & Agriculture
Mike Scheible, Deputy Director, Air Resources Board
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The Honorable Stephen L. Johnson
Administrator
United States Environmental Protection Agency
1200 Pennsylvania Ave, N.W.
Washington, D.C. 20460

Dear Administrator Johnson:

We are writing concerning the EPA's imminent rulemaking in response to the Renewable Fuel Standard passed in the Energy Independence and Security Act of 2007. In that legislation, the EPA was called on to determine the GHG lifecycle emissions reductions due to production of various biofuels. The EPA was directed to account for "significant indirect emissions such as significant emissions from land use changes" (ILUC) in their assessment.

We strongly believe that a requirement to account for ILUC in the legislation was premature, as there are no generally accepted methods for determining indirect land use change, or for that matter, any indirect (market-driven) change, and there is no way to apply even current methods in any meaningful way to the choices a farmer makes. We are not aware of a single published paper in the lifecycle literature using indirect effects, and the International Standards Organization (ISO) has published no standards for analyzing indirect (market-driven) effects. In short, what the legislation requires is currently impossible.

We believe that the GHG lifecycle benefits of 2nd generation biofuels, in particular, are very positive. However, if flawed assumptions and methods are used to determine GHG lifecycle emissions reduction, then the GHG emissions benefits of biofuels produced from perennial grasses, such as switchgrass and Miscanthus, may be underestimated substantially.

Of particular concern is that the EPA appears to be relying heavily on the February 2008 paper concerning potential land use change impacts authored by Searchinger et al. (Science, 319, 1238-40, 2008). We believe this would be a grave error. The Searchinger paper started an important policy discussion, but it is certainly not the last word on the issue. This paper presented a "gedanken" experiment about potential ILUC impacts under a narrowly cast set of assumptions. The authors started with an assumption that any acre taken out of food production in the U.S. would lead to an increase in global agricultural acreage, leading to conversion of native acres to food production acres. In the model Searchinger et al. used, there is little elasticity in food demand, land productivity, land availability, etc.

For example, the authors claim that "[t]he diversion [of land from food to biofuel production] triggers higher crop prices, and farmers around the world respond by clearing more forest and grassland to replace crops for feed and food." While there can be pressure to free up previously "native" lands, a large number of underutilized acres are available globally, and whose conversion to either food or biofuel production would not necessarily lead to any conversion of "native" lands. 200 million cattle are grazing on 500 million acres of pasture land in Brazil; experts project that 150 million acres could be made available for biofuels, with increased intensification of meat production on the remaining 350 million acres, without affecting food supply or "native" land conversion.

Furthermore, the Searchinger paper took the rates of land use change occurring worldwide in the 1990s as a basis for land use change a decade from now, around 2015. There is no basis for such an assumption. These authors also assumed that all of the historical land use change was driven by agricultural expansion. This is a naïve and uninformed assumption. Of 152 cases of land use change studied worldwide, only 4% could be associated with agricultural expansion alone. The cluster of factors that drive land use change is much more complex than the single factor agricultural expansion driver assumed by Searchinger et al.

Additional research is being done on ILUC utilizing different assumptions than the Searchinger paper and very different results are emerging. For example, the Searchinger paper assumed that the worst (most prone to release soil carbon) tillage practices were used on converted land. However, if current average tillage practices, or the emerging best practices, are used instead, much shorter "payback" periods result. In summary, the science and appropriate methodologies for ILUC analysis are just beginning to be done. EPA should delay rulemaking until the science is ready.

In the Renewable Fuel Standard, Congress called for increasingly large amounts of biomass for biofuels to come from low-carbon biomass sources, such as switchgrass and Miscanthus, from 2015 onward, to meet the combined targets on energy security and climate change mitigation. Switchgrass and Miscanthus are perennial crops, with low nutrient requirements, and they also sequester carbon into soil through their extensive root development. Since these products can also be produced on lands with soil types that are not suitable for high-yield production of annual food crops, their production on alternative lands are likely to contribute strongly to both energy security and mitigation of climate change. It would be very unfortunate if a rush to judgment by the EPA would cast unwarranted doubt on the value of these low-carbon, 2nd generation biofuels.

For these reasons, the undersigned urge you to delay this aspect of the rulemaking that is currently planned for October 31st, and to utilize new general models for agricultural land, economics and trade that will give a more realistic assessment of potential adverse effects of indirect land use change.

Thank you for considering this recommendation.

Sincerely,

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June 24, 2008

Dear Chairwoman Nichols,

We are writing regarding the California Air Resources Board's (ARB) ongoing development of the Low Carbon Fuel Standard (LCFS). As you are well aware, the Governor issued Executive Order S-1-07 on January 18, 2007, which calls for a reduction of at least 10 percent in the carbon intensity of California's transportation fuels by 2020.

As researchers and scientists in the field of biomass to biofuel conversion, we are convinced that there simply is not enough hard empirical data to base any sound policy regulation in regards to the indirect impacts of renewable biofuels production. The field is relatively new, especially when compared to the vast knowledgebase present in fossil fuel production, and the limited analyses are driven by assumptions that sometimes lack robust empirical validation.

As an example of the confusion that this lack of reliable data produces, there has been significant attention to a recent article by Searchinger and coworkers in Science Express ("Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land Use Change," February 7, 2008). This article attempted to address the issues of fuel ethanol's effects on greenhouse gas (GHG) emissions by including GHG emissions from potential land use changes arising from ethanol production. It has prompted a large response from the scientific community, pointing out apparent errors and/or gaps in the analysis presented.

For example, Searchinger et al. estimated that U.S. corn ethanol production (between 15 billion and 30 billion gallons) would result in a requirement for an additional 10.8 million hectares of crop land worldwide; 2.8 million hectares in Brazil, 2.3 million hectares in China and India, and 2.2 million hectares in the United States, with the remaining hectares in other countries. Searchinger et al. maintain that the United States has already experienced a 62% reduction in corn exports. In reality, U.S. corn exports have remained relatively constant at around 2-billion-bushels-per-year since 1980. In 2007, when U.S. corn ethanol production increased dramatically to approximately 6 billion gallons, corn exports increased to 2.45 billion bushels -- a 14% increase from the 2006 level (excerpt taken from Wang's response to Searchinger, 2008). Searchinger also ignored the fact that the protein in corn still goes on for use as cattle feed as it cannot be converted to ethanol, with the result that there is no reduction in protein available for feeding animals, the major (about 60%) market for corn.

The traditional tools used by researchers, including Searchinger et al., to determine the direct and indirect impacts of renewable biofuel production are life cycle analysis (LCA) coupled with land-use change (LUC) projections. The results produced by the majority of the LCA models are highly sensitive to LUC assumptions, as well as baseline projections and test cases that have very limited scope. These sensitivities highlight how common LCA models can be applied to the same problem but produce significantly different, and often contradictory, results. There remain great uncertainties and challenges in combining LUC and LCA models that make their use highly problematic, particularly if the outputs of these models are used as a basis for policy decisions, or for comparing indirect impacts between fuel types. Some of the problems include the lack of large-scale, reliable data sets from field and process trials of growing, harvesting, and converting dedicated energy crops into biofuels. These data are needed as "training sets" for the LCA models.

Moreover, without validation of the results produced by the LCA models, they should not be considered as based in fact, but rather based on statistical correlations. Thus it is extremely difficult to make a comparison of the direct and indirect impacts between fossil fuels and renewable biofuels.

Significant research is still required to develop reliable data training sets and validated LCA tools that can accurately guide policies such as the LCFS. Renewable biofuels remain a relatively new field of study with significant gaps in our current understanding that will only be filled with research over an extended period of time. Given that our only options for sustainably powering transportation with a significant reduction in transportation related greenhouse gas emissions are biofuels, batteries, and hydrogen, a presumptive policy implementation based on the current understanding of indirect impacts will have a significant chance to hurt real progress on reducing carbon emissions and decreasing our reliance on fossil fuels. We propose that a sound policy approach would be to base the initial LCFS on existing data sets that possess scientific consensus. These include the direct impacts of renewable biofuels production. The scientific and economic communities can then take advantage of the necessary time over the next five years to fully understand, gather, and validate the indirect impacts of biofuels production with empirical evidence that will enable the implementation of a sound policy that can address any indirect impacts.

It is clear that building a LCFS is a significant undertaking. Many states and countries will look to this regulation as a template for reducing the impact of transportation fuels in other parts of this country and overseas. It is therefore critical that we keep the underlying need for innovation in mind, and base the LCFS upon data obtained from robust and mature tools and empirical validation.

We are writing this letter as researchers in the field of biomass to biofuel conversion, but do not represent the official views of the Department of Energy, the United States Department of Agriculture, or the National Laboratories.

Thank you in advance for your consideration of this important issue.

Sincerely,

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Indirect Land Use Thoughts: Bruce Dale   March 3, 2008

Dear Colleagues:
I have spent a lot of time the last couple of weeks, including most of a recent 12 hour Tokyo-Detroit flight, trying to think through the indirect land use change (ILUC) issue. I have divided my current point of view into two questions that I am asking myself: 1) are we in fact currently able to estimate these changes with any degree of confidence?, and 2) if we could estimate such changes, would it be a good idea to base policy on those estimates? My current answer to both questions is "no". Please don't be put off by my answers—I ask you to consider my reasons. Here they are.

1) Are we able to estimate such changes? These changes are estimated by linking demand for corn with land use decisions and the land use decisions with release of greenhouse gases. Three models must be linked: the economic model for supply and demand, the supply and demand model with the land use decision model and the land use model with the release of greenhouse gases. We actually know a fair amount about the effect of land use changes on release of greenhouse gases. My lab has been working with DAYCENT (an agroecosystem model) for the past seven years to better understand the environmental impacts of agricultural operations, including land use change.

I think it is beyond argument that this agroecosystem model, based on thousands of actual field experiments, actual plant and microbial physiology and actual soil-water physical relationships, is by far the most "scientific" piece of the whole "cause and effect" structure outlined above. If you accept that statement, here is a major conclusion of our DAYCENT work to date. It is not possible to draw broad conclusions across a large geographic region about the effects of a particular land use change on the resulting greenhouse gas emissions. Very different greenhouse gas emissions are caused by differences in local soil types (organic matter content, sand, etc.), local climate (temperature, rainfall, etc.), and especially by different tillage and fertilization practices.

For example, we have studied the effects of a change from continuous corn production to a corn-soybean rotation on resulting greenhouse gas emissions in different parts of the Corn Belt. The resulting emissions vary by more than 10 fold in our studies using DAYCENT. Furthermore, it is possible to change these emission patterns greatly by how the system is managed. So how can I possibly believe a model that says that if an area as vast as the Brazilian *cerrado* is converted to corn, that a specific greenhouse gas emission level will occur? I simply don't believe it. The reality is a lot more complicated, and much more important, a lot more subject to human intervention and management.

If the most "scientific" part of the overall linkage described in the Fargione and Searchinger papers is in fact highly uncertain and imprecise, how can the results of linking three uncertain models together be anything other than speculation? The time may come when a reasonable degree of certainty can be applied to such analyses, but I can tell you that that time is not now based on the uncertainty surrounding the most scientific part of the overall system, the agroecosystem model. Believe the Searchinger and Fargione results if you wish, but they are not science, they are speculation.

<u>2) If we could predict the effects of such changes, should we base policy decisions on them?</u> I have arranged my reasons from the most specific to the most general.

- The legislation regarding ILUC is couched in life cycle terms. Whether Congress intended to or not, LCA has some formal rules. For example, LCA strives to analyze based on <u>specific</u> knowledge of the environmental impacts of inputs and outputs. For example, if electricity is an input for a product, we strive to be specific about where the product is manufactured, because different areas of the country are served by different electrical grids, and each grid has its own greenhouse gas footprint.
- A farmer who produces corn in one county in Iowa under specific practices will have a particular environmental impact, and a farmer in an adjacent county using different practices will have a different impact. If a responsible corn ethanol producer wants to improve his environmental impact, he will source corn from the environmentally superior corn grower. I believe we should encourage, not discourage, such good behavior. The perversity of the ILUC concept is that both the environmentally conscious corn producer and the irresponsible one are equally linked to environmental changes thousands of miles away over which they have <u>no control</u>.
- One of the tenets of the environmental movement has been "think globally, act locally". But the ILUC idea stands that tenet on its head. If I act to produce a crop with the very best local knowledge, I am still guilty by a very tenuous and speculative association for the actions of others thousands of miles away over whom I have no control. I believe we are much more likely to make environmental progress by holding people responsible for <u>their</u> behavior, and not that of others. The ILUC idea takes the focus off things an individual can control and shifts them toward things he cannot control. That is the wrong direction.
- The policy dilemmas are obvious. If a corn farmer in the U.S., trying to meet national fuel security objectives and also produce corn in an environmentally responsible way, is deemed to contribute to bad behavior in Brazil, just exactly what is the appropriate U. S. policy response? Abandon or limit corn ethanol, tell the Brazilians to clean up their act (good luck on that one), or something else? We may decide to limit biofuel production to certain classes of land, as Searchinger and Fargione recommend, but as far as I am concerned they have not proven their case…not by a long shot.
- My last reason, which I think is the strongest, may also be the most difficult to explain well. I will try. The Searchinger and Fargione argument at its root is this: corn (and perhaps cellulosic) ethanol is not sustainable because it will divert land use for <u>animal feed</u> (over 70% of corn is fed to animals) to new lands that will release large amounts of greenhouse gases as they are cultivated. But if corn for animal feed production were to be expanded, I am confident that they would come to the same conclusion: that would be an unsustainable practice because of the greenhouse gases that would be released as new lands were opened up for corn cultivation. So they are saying that ethanol production from corn or cellulosics is unsustainable by linking it to a practice <u>which by itself is not sustainable</u>. In other words, any attempt to use current corn land to make any fuel is unsustainable because <u>we must have that land to continue another unsustainable practice</u>. They are not really making a comparison between gasoline and ethanol, as they think. In reality, they are making a comparison between ethanol and steak (or milk and cheese), and the analysis is forced to choose

steak. How logical is that? I think most folks are missing this enormous contradiction at the root of ILUC analysis. The only way out is to "reimagine agriculture" as Lee and some of the rest of us have suggested.

A couple of sincere and I hope conciliatory parting remarks to my friends. I am doing what I can to ensure that biofuels live up to their potential for environmental improvements. But please recall that there are three fundamental drivers for biofuels, three reasons why we finally have the political coalition necessary to promote biofuels: 1) national security improvements, 2) environmental benefits and 3) rural economic development. Please recall that we are discussing features of the Energy *Independence* and *Security* Act of 2007 (emphasis added). In our current focus on environmental issues, please let us not lose sight of the other biofuel drivers. Whatever corn ethanol's environmental performance (I believe it is pretty good and, most important, that it can be improved), without a doubt corn ethanol displaces lots of petroleum (about 22 to 1 on an energy basis) and contributes very significantly to rural development. I score corn ethanol 2.5 on a scale of 0 to 3.0. Without corn ethanol to clear the way, cellulosic ethanol would have a much more difficult task. In our zeal for the "perfect", let us not destroy the "pretty darn good". I realize that many of you have a strong distaste (double *entendre* intended) for corn ethanol.

I am not in favor of shielding corn ethanol or any other biofuel from legitimate, well-founded analysis. I just don't think the ILUC issue is legitimate and well-founded, and certainly not in its current state of development. When we allow poor analysis to get a pass because the result reinforces our beliefs, I think we set ourselves up to have poor analysis used as a weapon against us. We need to be very clear on this, extremely powerful forces would like to bury biofuels, and they will use any weapon that is handy. Whatever the motivations of the authors, the papers by Searchinger and Fargione are being used as weapons against all biofuels, regardless of the actual merits of the fuels.

I strongly believe that our society <u>will have fuels.</u> The alternative to biofuels is not some perfect fuel, most likely it is coal to liquids, or tar sands oil, or oil shale. I continue to be struck at how much biofuel commentary and analysis fails to make any sort of reasonable comparisons with the alternatives. If David Pimentel had been forced to compare ethanol's "net energy" with that of gasoline, perhaps that specious net energy issue would never have gotten the hold it has on people's thinking. So, my friends, what are the <u>direct and indirect</u> effects of making fuels from coal, or oil shale, or the tar sands? Now, that is the question I will be asking loudly, but hopefully with my usual courtesy and decorum. ☺ I invite you to join me in asking that question, while we continue honest and rigorous analysis of biofuels.

I hope you feel somewhat rewarded for reading this far. I appreciate it.

Your contrary friend,
Bruce

ATTACHMENT 6

Review of US Environmental Protection Agency RFS-2 Rule

Several **major** problems exist relating to the US Environmental Protection Agency (US EPA) Draft RFS-2 rule. As a general overview of the entire process, it is felt that while emissions from changes in international land use may be an area of importance, it is plainly obvious that the technical and scientific arguments used by the US EPA, as well as their process of review and comment, are terribly flawed.

Background

Two major points can be made concerning the US EPA's rulemaking with respect to international land use and biofuels: 1) their reliance on a very small set of scientific data, and 2) no attempt to adequately acknowledge the myriad of global political, agricultural, economic, and human interactions that take place on a daily basis and are so intertwined that it absolutely begs for more research and time to even begin to make large-scale decisions such as they are trying make. Reliance upon a single study such as the one by Timothy Searchinger and the inclusion of other studies in his analysis that are flawed in respect to crop yields and land use change satellite data that has errors of over 50% is certainly not good science and should definitely not be used to make such broad changes in the US and possibly global biofuels industries. More importantly, it appears that the US EPA has not really made any real attempt to verify if the claims/data made in the Searchinger article have any 'real-world' validity. Other prominent researchers have 'de-bunked' some of the data and claims made in the Searchinger article and these have not been acknowledged by the US EPA.

In addition, the following are of concern with respect to the US EPA's decision-making process:

1) <u>The US EPA Peer Review Process</u>

   The Office of Management and Budget (OMB) has strict rules concerning a peer review process, especially that they include provisions for scientific and process integrity. The actions of the US EPA in this regard do not seem to follow the OMB guidance. The US EPA was to provide the peer reviewer's access to comments, etc. provided by the general public and did not (at least of this date 9/17/09). The public it appears has been excluded from the peer review process and that the peer review panels will not even have a chance to review comments, data, etc. provided by the public. Also of interest, is US EPA's ability to provide documents associated with the peer review process and as of late last week, these documents have not been made available. Without all parties that have an interest in this process and debate having access to all information, this not only makes the review extremely difficult, but also provides a backdrop that something is being hidden or withheld on purpose.

2) <u>Peer Reviewer Selection</u>

   Any peer review process ought, at a minimum, contain at least the appearance of being unbiased as to have as much of all sides of the debate represented. The US

EPA's peer review process selection seems to be terribly flawed, especially in that they (US EPA) does not actually provide the names of those that provided recommendations for serving as a peer reviewer. Also, it seems that there was no large, general request for recommendations or to even serve as a potential reviewer.

3) Peer Review Reports

In considering the peer review reports provided in the docket, there are many areas of disagreement among the peer reviewers and disagreement with the EPA's methods. No one thought EPA's choice of models was very good. Michael Wang from Argonne National Labs thought consequential lifecycle analysis was not ready for regulatory application. Timothy Searchinger thought EPA should use FAPRI but not FASOM and definitely not GTAP. Searchinger says that mingling these models gives the potential for "inconsistent results" This is a very revealing statement. If the models don't give consistent results, why should we believe either one? John Sheehan from the University of Minnesota supports using a dynamic model like STELLA rather than FASOM or FAPRI. Sheehan says, "Even with the detail that EPA has provided on its analysis using these models, it is impossible to judge with confidence what is going on in these models, what limitations in the models may be biasing the results, or what fundamental data underlying the models may be influencing the outcomes." It is impossible to judge with confidence what is going on in these models and what limitations in them may be biasing the results.

Reviewers mostly kept away from the numbers and focused on the methodology, so they didn't find the significant errors in data and assumptions, overlap between the models, double-counting or misalignment where models intercept. This is interesting because the feedback given by EPA in their public hearing and workshop was that they were more interested in correcting any numbers they had wrong than in discussing the methodology. EPA seemed to be quite close-minded in accepting principle flaws in their overall assumptions and methodology, but admitted they did not have the resources to ensure all data points were correct.

The peer reviewers did include discussion of EPA's error concerning N_2O emissions for soy, but failed to mention the lack of credit for glycerin as a co-product of biodiesel production.

The EPA was descriptive in asking for specific input. However, there were many additional things of which they could have and should have requested analysis, but didn't. Regardless of the questions posed, it is unrealistic to expect that the peer reviewers could delve into the details to adequately assess such a convoluted set of models and assumptions with the time and resources allotted. Doing so has also been a challenge for independent and industry experts. EPA should consider closely the technical recommendations provided by industry experts who have completed the due diligence that EPA has been unable to complete on their own or through the brief peer review period.

Not surprisingly, the panel looking at time horizons and discount rates seem to have the most disagreement. The assumption for time horizon and arbitrary application of a discount rate have no direct correlation to the fuel lifecycle, yet have huge impacts on EPA's overall scoring of all Biofuels. Because these factors cannot be supported by sound physical science, but instead offer themselves to political manipulation, EPA should modify their methodology to eliminate the inclusion of these factors. It is wholly inappropriate to discount physical emission as one would discount economic considerations. If anything, emission will be more costly in the future, so EPA's discount rate should be applied in reverse to properly value the future carbon offset of Biofuels.

An alternative to inclusion of a time horizon would be to compare the annual sequestration of cropland with the lost sequestration of the alternative land use, such as a forest. EPA includes this comparison, which is independent of a time horizon. However, EPA also penalizes biofuels for carbon emissions of clearing mature forests. This is double counting, because mature forest reach equilibrium in carbon sequestration and do not sequester as much carbon as a young, growing forest. By comparing only the lost sequestration potential, a more robust method of accounting results. This method eliminates the uncertainty of choosing a time horizon. It eliminates the uncertainty of whether forests are cleared by burning or by harvesting the wood products. EPA lacks any forward-looking data to show the method of future land conversion. Applied fairly, economic models would surely predict land owners would harvest valuable timer rather than waste it by burning. Harvesting forest products could generate credits for sequestering carbon. However, that credit would be due to the forestry industry, not livestock or row crop agriculture, which EPA claims drives land conversion. This also raises the question, if timber harvest causes removal of forest material, does burning of the remaining biomass get attributed to the timber industry or the land use that follows the initial land conversion activity? The alternative accounting suggested here, removes this difficult to answer questions from the equation. Failing evolution of the approach suggested here, EPA should consider a very long time horizon. Since, Biofuels derive their biggest carbon benefit by displacing petroleum, and it took millions of years to sequester that carbon into fossil fuels, even a 100-year time horizon severely undervalues the benefits of renewable fuel.

Unfortunately, EPA provided no big picture review of their modeling. We know that there are imperfections in all of the models and the data, but what impact do all of those problems and assumptions have on the final number? There is no discussion about the basic concept that more demand means more land, for example. One thing the review did highlight is the fact that the experts have very different opinions about how the various parts of this should be done. It adds weight, in my view, that more time and a lot more data is required before anyone could possibly think that they have the right number.

4) <u>Limitations of Emissions Imposed by the RFS-2 Rule by Congress</u>

The original legislation put forth by the US Congress contains no evidence that it ever intended to address *international land use issues* associated with biofuel production, yet the US EPA seems to significantly bend this rule. International land use and any emissions that result from its use for energy, environmental, and economic purposes is highly complex and has not been adequately researched or debated to make such broad and far-reaching conclusions that have significant effects to the US biofuels industry.

5) Omission of N_2O in the Emissions Life-Cycle

It appears that the US EPA failed to even follow the IPCC (International Panel on Climate Change) protocols with respect to N_2O emissions, did not appear to realize soybeans actually 'fix, nitrogen in the soil, and appeared to impose a penalty on soybeans for N_2O emissions.

In addition, as a larger issue, the US EPA does not appear to have a real grasp of US agriculture concerning crops, yields, cropping rotations, and the physical and chemical characteristics of soil all of which affect production, yield and eventual effect on air, soil, and water quality all of which have a "roll through" effect on land use emissions.

6) Omission of a Co-product Credit with respect to the Production of Glycerin

The US EPA also does not give credit to the biodiesel production co-product of glycerin through their use of the FASOM model. The GREET model does give credit and that credit has always been accepted by the scientific community.

7) Other Concerns

US EPA relies upon several models to gain insight on agricultural, economic, and trade issues. The interaction of these models has definitely not been thoroughly vetted to see even if the data sources upon which they rely even match up. In addition, it also appears that the general scientific community really has no idea how these models really work or what the actual calculations are that influence the outcomes. This is a major flaw with respect to the US EPA's overall approach and significantly damages their credibility and approach.

Conclusions

In conclusion, there are significant problems with the approach, data, review, and just general handling of US EPA's rulemaking concerning greenhouse gas emissions associated with biofuels production. These problems are so vast and far-reaching that the engineering, economic, environmental, and policy recommendations put forth by the US EPA can not be taken seriously and need to be opened up to the general public for a more transparent review and definitely need much more scientific analysis in the areas of agriculture/agronomy, economics, environment, sociological, and trade performed before this is allowed to proceed.

As a start, given the global warming potential of N_2O and its dramatic effect on greenhouse gas life-cycle emissions as well as the obvious omission of a co-product credit for glycerin, these two areas need to be re-analyzed immediately by a number of credible engineering and science-based professionals and researchers. These two areas, if adequately corrected, could have a tremendous effect on the life-cycle greenhouse gas outcome and will have a large and direct effect on the US EPA's approach to estimating international land use emissions.

Submitted September 17, 2009
Dr. Richard Nelson
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ATTACHMENT 7

LECG

REVIEW OF MODELS USED BY EPA TO ESTIMATE INDIRECT LAND USE CHANGES TO RENEWABLE FUEL STANDARD

John M. Urbanchuk
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Revised September 7, 2009

The United States Environmental Protection Agency (EPA) has undertaken a lifecycle assessment (LCA) of greenhouse gas (GHG) emissions associated with increased renewable fuels production as part of the proposed revisions to the National Renewable Fuel Standard program (RFS2). The Energy Independence and Security Act of 2007 (EISA 2007) established mandatory lifecycle GHG reduction thresholds for renewable fuels. EISA 2007 further specified that EPA's analysis must take into account GHG emissions resulting from all stages of fuel and feedstock production distribution, and use and requires EPA to determine which renewable fuel production pathways reduce GHG emissions by required threshold amounts relative to a 2005 petroleum baseline.

The lifecycle analysis proscribed by EISA 2007 requires an assessment of both direct and indirect emissions associated with the entire renewable fuel lifecycle. Direct emissions are those that are emitted from each stage of the renewable fuel lifecycle. Examples of direct emissions from a renewable fuel are those caused by growing and harvesting a feedstock (e.g corn for ethanol or soybeans used to produce soybean oil), transporting the feedstock to the ethanol or biodiesel producer, production of the renewable fuel, distribution of the finished fuel to the consumer, and use of the fuel. Indirect emissions are those that occur as a consequence of the production and use of the renewable fuel. These include emissions resulting from changes livestock and poultry numbers due to changes in profitability resulting from grain, oilseed and forage prices, or shifts in acreage between different crops resulting from increased demand for renewable fuels. The definition of indirect emissions specifically includes "land-use changes" such as shifts of existing agricultural land between different crops and uses including forest and pasture, or the reallocation of land from nonagricultural uses to the production of renewable feedstocks

Overview of Models Used By EPA

EPA used two primary models to estimate the indirect land use changes and implications for domestic and international commodity prices for their RFS 2 analysis: the FASOM and CARD/FAPRI models.

The Forest and Agricultural Sector Optimization Model (FASOM) is a dynamic, nonlinear programming model of the forest and agricultural sectors in the U.S. The FASOM model initially was developed to evaluate welfare and market impacts of alternative policies for sequestering carbon in trees. FASOM also has been applied to evaluate policy scenarios for a wider range of forest and agricultural commodities.

FASOM is a partial equilibrium agricultural sector model that focuses on *domestic* land competition (e.g. forest vs. pasture converted to crop production) and models major crop commodity prices. The model was used by EPA in combination with the FAPRI model to establish consistent set of domestic assumptions and forecast agricultural/forestry implications of GHG reduction targets.

FASOM includes a price-endogenous agricultural sector model that simulates production of 36 primary crop and livestock commodities and 39 secondary, or processed, commodities. Crops compete regionally for land, labor, and irrigation water. The cost of these and other inputs are included in the budgets for regional production variables modeled in FASOM. There are more than 200 production possibilities (budgets) representing agricultural production. Several major categories of agricultural land use are modeled in FASOM:

- Cropland
- CRP land (constrained at 32 million acres)

- Pastureland (land suitable for livestock pasture calculated based on livestock budgets by region and livestock type).
- Grazing land (rangeland available for livestock grazing divided into public and private grazing by region).
- Forestland (timberland available for timber production)

FASOM adjusts crop yields based on historical growth. Assumed yield increases for corn and soybeans in the EPA study were modified to line up with the most recent USDA long-term projections (through 2017) and then extrapolated through 2022. FASOM <u>does not</u> directly incorporate yield responses to changes in price.

A unique feature of the agricultural sector model in FASOM is the method it uses to prevent unrealistic combinations of crops from entering the optimal solution, a common problem in mathematical programming models. Although the agricultural sector in FASOM is divided into 63 homogenous production regions and 11 market regions, each having available many production possibilities, it often happens that the optimal, unconstrained solution in some regions is represented by one crop budget—complete specialization. In reality, risks associated with weather and the effects of other exogenous and sometimes transient variables on agricultural prices lead to diversification in crop mixes, and such a representation cannot capture the full factor-product substitution possibilities in each area. This is avoided by requiring the crops in a region to fall within the mix of crops observed in historical cropping records, as reported in the agricultural statistics series. The model is constrained so that for each area, the crop mix falls within one of the mixes observed in the past 20 years.[1]

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[1] Adams, Darius M.; Alig, Ralph J.; Callaway, J.M.; McCarl, Bruce A.; Winnett, Steven M. "The forest and agricultural sector optimization model (FASOM): model structure and policy applications". Res. Pap. PNW-RP-495. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 1996.

FASOM assumes that existing ethanol and biodiesel production are mature technologies and have essentially reached technical limits on feedstock conversion. Consequently, FASOM holds ethanol and biodiesel yields constant over time.

The CARD/FAPRI model is a joint effort of Iowa State University's Center for Agricultural and Rural Development (CARD) and the University of Missouri-Columbia. Both the Missouri and ISU teams utilize (and frequently change) the models for policy analysis and to prepare outlooks at the request of Congress and other largely public sector groups. The model used for the EPA analysis is the version maintained at and run by the forecast group at CARD under the direction of Dr. Bruce Babcock.

FAPRI utilizes a set of interrelated supply and demand models to estimate the impacts of changes in policy and economic parameters on prices and production levels of important agricultural commodities in major importing and exporting countries. FAPRI analyses of the impacts of U.S. policy changes on the U.S. agricultural sector are conducted using stochastic models.[2]

The CARD/FAPRI model is a non-spatial partial equilibrium agricultural sector model that includes not only domestic land competition but determines net acreage change by country. The model assumes that a decrease in U.S. exports results in increased crop production in foreign markets. Although not all export losses are made up with production in the model, shifts in crops and decrease in demand also occur. The CARD/FAPRI model solves for representative world prices by equating excess supply and demand across countries. Domestic prices for each country are determined through the use of price transmission equations that incorporate exchange rates and other price policy variables such as tariffs, export taxes and domestic support prices.

[2] Simla Tokgoz, Amani Elobeid, Jacinto Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Hsiang (Edward) Yu, Fengxia Dong, Chad E. Hart, and John C. Beghin. " Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets". *FAPRI Staff Report 07-SR 101.* May 2007

The CARD/FAPRI U.S. model is divided into nine production regions and includes behavioral equations for principal by-products of renewable fuel production (HFCS, ethanol, corn oil, biodiesel)

Changes in area planted to crops in the CARD/FAPRI model are based on yields in different countries but the model does not include price induced yield changes from intensification of agricultural practices. The model also makes no differentiation in yields on marginal land brought into production and land already in production. CARD claims that these two assumptions cancel each other out. The CARD/FAPRI model assumes that the net increase in all crop acres results in land being converted into agriculture with associated land use change GHG impacts.

The CARD/FAPRI model assumes that existing domestic and foreign agricultural and trade policy variables remain unchanged in the projection period. Finally, the model was designed to produce a 10-year projection and was "forced" to produce a projection through 2022.

Model Strengths and weaknesses

Strengths

- Both FASOM and CARD/FAPRI are long-term structural partial equilibrium models. Partial equilibrium models consider a few markets at a time while a general equilibrium model (such as the GTAP model at Purdue University) models all markets simultaneously, allowing markets to interact with each other. Partial equilibrium models typically have smaller data requirements, models, are easier to work with, and are more transparent (the modeling process is more straightforward and easy to explain).

- FASOM includes the ability to calculate greenhouse gas emissions resulting from changes in agricultural sector performance.

- Both models have wide agricultural commodity coverage; specifically FASOM includes a forestry sector.

- Good geographic coverage of domestic production regions in FASOM and major producing countries in CARD/FAPRI.

- The CARD/FAPRI model is well regarded and is used for policy analysis at Congressional request.

- Both models are carefully maintained and contain good supporting databases.

- Both FASOM and CARD/FAPRI have a staff of solid experienced analysts.

Weaknesses

- While partial equilibrium models have advantages they also have some disadvantages. Specifically since they are partial models they model only a predetermined number of variables. A modeler may miss important feedbacks between sectors. The use of a partial equilibrium model forces the modeler to carefully evaluate the potential full range of impacts. Also, partial equilibrium models can be very sensitive to a few elasticities.

  - FASOM models only agricultural and forest systems in the U.S. and does not model land use and agricultural sector changes outside of the U.S.

  - CARD/FAPRI models only agricultural commodities, does not incorporate forest area, and ignores products/services outside the agricultural sector.

  - Both models essentially ignore broader economic implications and other economic effects outside of agriculture.

  - The CARD/FAPRI models contain very specific elasticities that determine land use allocation in foreign markets.

- It is interesting to note that while FASOM contains a forestry component, EPA states that the model does not model biofuels from MSW or forestry sector feedstocks.

- The CARD/FAPRI model was provided in spreadsheet format with limited documentation. It was very difficult to replicate the results of the CARD/FAPRI model runs with information provided. The FASOM model was usable only with the subscription to a separate modeling software program. This limited the usefulness of the model for validation purposes.

- No account is made for technological progress in biofuel yields that would reduce the amount of feedstock required.

- CARD/FAPRI does not model cellulosic feedstocks. This omission potentially affects land allocation amongst conventional grain and oilseed crops (e.g. corn and soybeans) both domestically and internationally.

- The CARD/FAPRI model accounts for renewable fuel co-products from ethanol (notably distillers grains) but do not account for glycerin from biodiesel production. This is an issue for FASOM since the model estimates GHG emissions.

- Neither FASOM nor CARD/FAPRI model potential alternative biofuel feedstocks such as corn oil nor other oilseeds used for biodiesel, algae, or MSW. It is unclear how these models incorporate white and yellow grease as a biodiesel feedstock.

Modeling Methodology

- EPA uses the projections provided in the Energy Information Administration 2007 Annual Energy Outlook (AEO 2007) as the base for comparison. It is unclear what the control case projection is for either FASOM or CARD.

- EPA used FASOM for domestic agricultural impacts and land use changes and CARD/FAPRI for international impacts. EPA admits that using two separate models provides inherent challenges in reconciling results.

- For example each model produces different commodity price impacts with CARD/FAPRI producing larger impacts. To the extent that these price changes determine world prices and that relative prices affect the allocation of land among commodities in foreign producing countries, this could lead to inconsistent land use changes. The bias would likely be on greater area shifts outside of the U.S.

- EPA provided no information about how the two model teams coordinated with each other and EPA staff. Forecasting is as much an art as a science. The model is a tool and the results reflect the experience and expertise of the modeler. Major questions include:

  - What adjustments were made to the models and what forecast procedure was utilized?

  - What changes were required to force a projection beyond the normal 10-year horizon? Who provided the macroeconomic assumptions and how were they determined?

  - Who at EPA consolidated the output of the two models and made decisions regarding conflicts? What basis was used for this?

- It is unclear how EPA estimated the macroeconomic impacts of changes in agricultural sector performance. Specifically who did the analysis and what model was used. At one point EPA mentioned that ORNL was tasked with this and that the EPA NEMS (National Energy Modeling System) was used to analyze the impacts on petroleum imports.

- EPA indicated that a thorough macroeconomic impact assessment of RFS2 rules will be done before the final rulemaking.

  - Who will do this?

  - What model will be used?

- How will the commodity and agricultural price, output, and trade impacts from FASOM and CARD factor into this analysis and how will the macroeconomic impacts factor into the agricultural analysis?

- Will there be an opportunity to review and comment on these results before the final rule is published?

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ATTACHMENT 8

COMMENTS ON EPA RFS2
PREAMBLE AND
DRAFT REGULATORY IMPACT ANALYSIS
DIRECT EMISSIONS

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Date: September 21, 2009

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). The proposed rule intends to address changes to the Renewable Fuel Standard program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new greenhouse gas emission (GHG) thresholds for renewable fuels.

As part of proposed revisions to the National Renewable Fuel Standard program (commonly known as the RFS program), EPA analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. The Energy Independence and Security Act of 2007 (EISA) establishes new renewable fuel categories and eligibility requirements. EISA sets the first U.S. mandatory lifecycle GHG reduction thresholds for renewable fuel categories, as compared to those of average petroleum fuels used in 2005. The regulatory purpose of the lifecycle greenhouse gas emissions analysis is to determine whether renewable fuels meet the GHG thresholds for the different categories of renewable fuel.

Lifecycle GHG emissions are the aggregate quantity of GHGs related to the full fuel cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation and extraction through distribution and delivery and use of the finished fuel. The lifecycle GHG emissions of the renewable fuel are compared to the lifecycle GHG emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005.

EISA defines lifecycle GHG emissions as follows:

> *The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.*

This work reviews, comments and provides alternative data on the petroleum lifecycle analysis and the direct emissions for the soybean biodiesel analysis that is provided in the Preamble, the Rule and the Draft Regulatory Impact Analysis (DRIA) that has been released by the EPA.

The concept of life-cycle assessment emerged in the late 1980's from competition among manufacturers attempting to persuade users about the superiority of one product choice over another. As more comparative studies were released with conflicting claims, it became evident that different approaches were being taken related to the key elements in the LCA analysis:

- boundary conditions (the "reach" or "extent" of the product system);
- data sources (actual vs. modeled); and
- definition of the functional unit.

In order to address these issues and to standardize LCA methodologies and streamline the international marketplace, the International Standards Organization (ISO) has developed a series of international LCA standards and technical reports under its ISO 14000 Environmental Management series.

The approach taken by the EPA in their analysis of the GHG emissions of biofuels broadly follows the guidance of the ISO standards but there are several deviations that do create some concern.

The first is that many of the models employed by the EPA are complex economic models which compromises the scientific approach to undertaking LCA work. Since ISO established their standards, there has been a growing body of work that has incorporated economic approaches to help understand some of the more complex issues such as valuing co-products and trying to predict what future systems may look like. There are advantages and disadvantages to this type of analysis. These economic models tend to have less transparency (another fundamental ISO principle), the economic models usually cannot be validated since they are estimates of future scenarios, and there is a far greater likelihood that two models will produce vastly different outputs. All of these points are true with the EPA body of work.

The reporting of the EPA on their methodology and findings also lacks transparency. This has hampered the analysis of the work since many of the important details have not been included in the Draft Regulatory Impact statement or the Preamble to the Rule Making.

There are issues with the relative approach employed by the EPA. They are comparing the GHG emissions of petroleum fuels, nominally in the year 2005, to the difference between two future scenarios in 2022. Not only are the time periods of comparison different, but also the system boundaries are very different. This is a fundamental breach of the ISO principles.

Unlike many systems, agricultural is constantly changing with new varieties of seeds being developed, yields changing year over year, fertilizer requirements dropping, new management practices being developed and deployed, and market demands can also change as eating habits change and different rates of population growth being experienced in different regions of the world.

The EPA has tried to accommodate some of these changes into their modelling but other changes have essentially been ignored, either deliberately or de facto, because of the models used. In the case of soybean production, it has been assumed that yields in some countries, including the United States increase from about 42 bu/acre in 2005 to 50 bu/acre in 2022. The reference case assumes 71.5 million acres of soybeans in 2022, about the same as in 2005. The disposition of the extra 570 million bushels of soybeans is not explicitly detailed in the EPA documentation. There is enough oil in this increased production to produce 830 million gallons of biodiesel, almost three times the increased scenario that is modelled in 2022, but this increased productivity is not factored into the analysis. The modelling assumes that this material is either used domestically or exported. Given that domestic demand has been flat or falling for several years, the most likely scenario that is modelled is one of increased exports. It is against this increased export scenario that the land use impacts of increased soybean biodiesel are measured against, not the current land use in the United States or internationally.

Two major quantifiable issues have been identified that have a large impact on the results. Numerous other issues have been identified that are difficult to quantify but nevertheless introduce errors and biases in the results presented by the EPA. These errors and issues are summarized below.

The Reference Case

The EPA is estimating the GHG emissions from the production and use of biofuels in the year 2022. The land use emissions in 2022 are estimated based on the difference in a business as usual scenario and an expanded biofuels scenario. These emissions are then compared to petroleum GHG emissions purportedly for the year 2005. The data used for estimating the petroleum emissions is actually older than 2005. No estimate of land use emissions, direct or indirect, is included for the petroleum emissions.

The comparison in GHG emissions is therefore based on a different time period and uses different system boundaries. The models used to calculate the petroleum emissions and biofuel emissions are different in both structure and concept. These factors all introduce great uncertainty into the analysis and make meaningful comparisons almost impossible.

The methodology employed by the EPA almost totally negates any impact of agricultural productivity and ignores fundamental shifts in product demand from conventional markets. The probability of the 2022 scenarios realistically representing actual conditions in 2022 is extremely low.

Petroleum Baseline

The petroleum baseline emissions rely on the GREET model developed for the DOE by Argonne National Laboratory. While GREET has many positive features it is poorly documented and much of the data is old and in need of an update. As a result, the model will tend to underestimate emissions from processes that are in decline, such as crude oil production, and overestimate emissions from technologies that are still developing such as biofuels.

This review has estimated that GREET underestimates the emissions for the production and use of diesel fuel by about 3%. Furthermore the data presented shows that these emissions are increasing and can be expected to be significantly higher in the year 2022.

The petroleum baseline emissions do not include any emissions associated with land use change. This source of emissions has not been seriously researched and some estimates developed here suggest that for some regions of the world they may not be as low as many have suggested.

The EPA also has baseline information developed by NETL. Some aspects of this baseline are better than the GREET data, however, the NETL information has deficiencies as well. A combination of the data and data sources from NETL and the use of the GREET model would provide the best baseline data (although this would still not include land use emissions).

Domestic Agriculture Emissions

There is a large and serious error in the estimate of the domestic agricultural emissions for the production of soybeans. The FASOM model is calculating N_2O emissions from the production of nitrogen fixing crops in addition to N_2O emissions from the application of nitrogen fertilizer and the decomposition of crop residues. It is now widely accepted by most soil scientists and the IPCC that these emissions do not exist. The EPA has not calculated these emissions for soybeans grown internationally and they should not be calculated for domestic soybean production. These emissions account for about 20,000 g CO_2 eq/mm BTU, more than 20% of the lifecycle emissions of diesel fuel.

The domestic agricultural emissions are also based on very high energy consumption rates, 50% higher than those used in the GREET model and 300% higher than a recent survey of Iowa soybean producers. Because of the structure of the FASOM model it is difficult to quantify the impact of high energy consumption on the soybean biodiesel scenario. It appears that the impact will be relatively small, perhaps under 2,000 g CO_2 eq/mm BTU.

International Agricultural Emissions

The data used to estimate international agricultural emissions is very weak. Fertilizer use looks to be similar to that in the United States, after adjustment for yield, but the use of herbicides and pesticides is very low. This indicates an obvious potential to increase agricultural productivity internationally without bringing new land into production. These opportunities are not addressed in the EPA work.

The estimates of energy used for crop production internationally are also extremely weak. Even though the US data shows different energy requirements for different crops the assumptions used for international production are that within a given country all cropland requires the same amount of energy. This approach will clearly overestimate emissions attributable to soybean production.

Domestic land Use Change

The FASOM model is projecting a small reduction in GHG emissions for domestic land use from changing management practices. This is consistent with data that the EPA reports to the UN climate change program annually.

Biodiesel Production

There is another methodology error in the biodiesel production emission calculations and the process data used for the biodiesel production is higher than current industry performance and thus far above the expected performance in the year 2022.

There is no mention of the glycerine co-product and allocation of any of the emissions to that product. The use of the economic models FASOM and FAPRI, in theory, should eliminate the need for allocation of the emissions between the feed products and the biofuels. The models do not appear to have the capacity to do the same for the glycerine co-product. Using the displacement approach to allocating emissions (the same approach used by FASOM and FAPRI), there should be an emissions credit for the glycerine. On the basis that the crude glycerine from biodiesel displaces the emissions embedded in the feedstock for synthetic glycerine these emissions amount to 16,957 g CO_2 eq/mm BTU.

Transportation Emissions

The transportation emissions for feedstock and fuel are calculated from the GREET model using the model defaults. The concern here is that the feedstock transportation emissions may also be included in the FASOM emission estimates because this energy is included in farm energy. These emissions would amount to 2,615 g CO_2 eq/mm BTU and could be double counted.

Summary

The EPA projected that soybean biodiesel would have a 22% reduction in GHG emissions using a 100 year time frame and a 2% discount rate. The impacts of the two largest issues with the EPA analysis are shown in the following table using the same format as Table VI.C.1-10 in the Preamble.

Table ES- 1 Biodiesel GHG Emissions – 100 Year Time Frame 2% Discount Rate

Lifecycle Stage	Petroleum Diesel	EPA Reported Soy Biodiesel	Soy Biodiesel w/o domestic N_2O emissions	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit and revised production energy
	g CO_2eq/mm BTU				
Net Domestic Agriculture (w/o land use change)		-423,206	-1,295,306	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980	-8,980
International Land Use Change		2,474,074	2,474,074	2,474,074	2,474,074
Fuel Production	749,132	838,490	838,490	107,677	43,177
Fuel and Feedstock Transport		149,258	149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169	30,169
Net Total Emissions:	4,173,768	3,255,109	2,383,009	1,652,196	1,587,696
% Change		-22.0	-42.9	-60.4	-62.0

Correcting these issues will increase the GHG emission reduction for biodiesel to over 60% even without making any changes to the indirect land use emission calculations or the time period or discount rate. The impacts of the three largest quantifiable issues are summarized in the following table.

Table ES- 2 Summary of the Impact of the Three Largest Direct Emissions Issues

Scenario	Emissions[1], g CO_2/mm BTU	% Reduction from Diesel	Percentage Change
Petroleum Baseline	4,173,768		-
Soy Biodiesel EPA	3,255,109	22.0	-
Less nitrogen fixing crops	2,383,009	42.9	20.9
Glycerine co-product	1,652,196	60.4	17.5
Biodiesel Energy	1,587,696	62.0	1.6

The time frame and the discount rate chosen by the EPA have a significant impact on the results as shown in the following table. These results assume that the errors with respect to N_2O emissions, the glycerine co-product and the biodiesel processing energy have been corrected.

Table ES- 3 Impact of Time Frame and Discount Rate

Time Frame	Discount rate	% Reduction in GHG emissions
30	0%	36.5
100	2%	62.0
100	0%	87.7

This report has also identified issues with the petroleum baseline that if addressed, would increase those emissions. There are other issues raised with energy use in the soybean production cycle domestically and internationally that could increase the GHG emission reduction potential of soy biodiesel but cannot be quantifies with the information that is available.

[1] 100 Year Time Frame, 2% discount rate.

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1. INTRODUCTION

The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). The proposed rule intends to address changes to the Renewable Fuel Standard program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new greenhouse gas emission (GHG) thresholds for renewable fuels. The regulatory requirements for RFS will apply to domestic and foreign producers and importers of renewable fuel.

EISA established new renewable fuel categories and eligibility requirements, including setting the first ever mandatory GHG reduction thresholds for the various categories of fuels. For each renewable fuel pathway, GHG emissions are evaluated over the full lifecycle, including production and transport of the feedstock; land use change; production, distribution, and blending of the renewable fuel; and end use of the renewable fuel. The GHG emissions are then compared to the lifecycle emissions of 2005 petroleum baseline fuels (base year established as 2005 by EISA) displaced by the renewable fuel, such as gasoline or diesel.

As part of proposed revisions to the National Renewable Fuel Standard program (commonly known as the RFS program), EPA analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. The Energy Independence and Security Act of 2007 (EISA) establishes new renewable fuel categories and eligibility requirements. EISA sets the first U.S. mandatory lifecycle GHG reduction thresholds for renewable fuel categories, as compared to those of average petroleum fuels used in 2005. The regulatory purpose of the lifecycle greenhouse gas emissions analysis is to determine whether renewable fuels meet the GHG thresholds for the different categories of renewable fuel.

Lifecycle GHG emissions are the aggregate quantity of GHGs related to the full fuel cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation and extraction through distribution and delivery and use of the finished fuel. The lifecycle GHG emissions of the renewable fuel are compared to the lifecycle GHG emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005.

EISA defines lifecycle GHG emissions as follows:

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1.1 SCOPE OF WORK

This work reviews, comments and provides alternative data on the petroleum lifecycle analysis and the soybean biodiesel analysis that is provided in the Preamble, the Rule and the Draft Regulatory Impact Analysis (DRIA) that has been released by the EPA.

1.2 LIFECYCLE ANALYSIS

The concept of life-cycle assessment emerged in the late 1980's from competition among manufacturers attempting to persuade users about the superiority of one product choice over another. As more comparative studies were released with conflicting claims, it became evident that different approaches were being taken related to the key elements in the LCA analysis:

- boundary conditions (the "reach" or "extent" of the product system);
- data sources (actual vs. modeled); and
- definition of the functional unit.

In order to address these issues and to standardize LCA methodologies and streamline the international marketplace, the International Standards Organization (ISO) has developed a series of international LCA standards and technical reports under its ISO 14000 Environmental Management series. In 1997-2000, ISO developed a set of four standards that established the principles and framework for LCA (ISO 14040:1997) and the requirements for the different phases of LCA (ISO 14041-14043).

By 2006, these LCA standards were consolidated and replaced by two current standards: one for LCA principles (ISO 14040:2006); and one for LCA requirements and guidelines (ISO 14044:2006).

The ISO 14040:2006 standard describes the principles and framework for life cycle assessment including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA. The intended application of LCA or LCI results is considered during definition of the goal and scope, but the application itself is outside the scope of this International Standard.

It is useful to consider seven basic principles in the design and development of life cycle assessments as a measure of environmental performance. The seven principles outlined below are the basis of ISO Standard 14040:2006:

- Life Cycle Perspective (the entire stages of a product or service);
- Environmental Focus (addresses environmental aspects);
- Relative Approach and Functional Unit (analysis is relative to a functional unit);
- Iterative Approach (phased approach with continuous improvement)
- Transparency (clarity is key to properly interpret results)
- Comprehensiveness (considers all attributes and aspects)
- Priority of Scientific Approach (preference for scientific-based decisions)

1.2.1 Life Cycle Perspective

LCA considers the entire life cycle stages of a product or service, including: extraction and acquisition of all relevant raw materials, energy inputs and outputs, material production and manufacturing, use or delivery, end-of-life treatment, and disposal or recovery. This systematic overview of the product "system" provides perspective on the potential differences in environmental burden between life cycle stages or individual processes.

1.2.2 Environmental Focus

The primary focus of a LCA is on the environmental aspects and impacts of a product system. Environmental aspects are elements of an activity, product, or service that cause or can cause an environmental impact through interaction with the environment. Some examples of environmental aspects are: air emissions, water consumption, releases to water, land contamination, and use of natural resources. Economic and social aspects are typically outside the scope of an LCA, although it is possible to model some of these elements. Other tools may be combined with LCA for more extensive analysis.

1.2.3 Relative Approach and Functional Unit

LCA is a relative analytical approach, which is structured on the basis of a functional unit of product or service. The functional unit defines what is being studied and the life cycle inventory (LCI) is developed relative to one functional unit. An example of a functional unit is a light-duty gasoline vehicle driving an average distance (with other details of time, geography, trip characteristics, and potential fuels added). All subsequent analyses are then developed relative to that functional unit since all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit.

An LCA does not attempt to develop an absolute inventory of environmental aspects (e.g. air emissions inventory) integrated over an organizational unit, such as a nation, region, sector, or technology group.

1.2.4 Iterative Approach

LCA is an iterative analytical approach. The individual phases of an LCA (Goal and Scope Definition; Inventory Analysis; Impact Assessment; and Interpretation) are all influenced by, and use the results from, the other phases. The iterative approach within and between phases contributes to a more comprehensive analysis and higher quality results.

1.2.5 Transparency

The value of an LCA depends on the degree of transparency provided in the analysis (for example: the system description, data sources, assumptions and key decisions). The principle of transparency allows users to understand the inherent uncertainty is the analysis and properly interpret the results.

1.2.6 Comprehensiveness

A well-designed LCA considers all stages of the product system (the “reach”) and all attributes or aspects of the natural environment, human health, and resources. Tradeoffs between alternative product system stages and between environmental aspects in different media can be identified and assessed.

1.2.7 Priority of Scientific Approach

It is preferable to make decisions from an LCA analysis based on technical or science reasoning, rather than from social or economic sciences. Where scientific approaches cannot be established, consensual international agreement (e.g. international conventions) can be used. The power of the technical or scientific approach lies in the proper attribution of facts to sources and the potential reproducibility of these facts under scientific conditions.

While the scientific approach is typically more objective than economic or social values, it does not preclude the use economic or social values for informing LCA decisions.

1.3 The EPA Approach

The approach taken by the EPA in their analysis of the GHG emissions of biofuels broadly follows the guidance of the ISO standards but there are several deviations that do create some concern.

The first is that many of the models employed by the EPA are complex economic models which compromises the scientific approach to undertaking LCA work. Since ISO established their standards, there has been a growing body of work that has incorporated economic approaches to help understand some of the more complex issues such as valuing co-products and trying to predict what future systems may look like. There are advantages and disadvantages to this type of analysis. These economic models tend to have less transparency (another fundamental ISO principle), the economic models usually cannot be validated since they are estimates of future scenarios, and there is a far greater likelihood that two models will produce vastly different outputs. All of these points are true with the EPA body of work.

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Unlike many systems, agricultural is constantly changing with new varieties of seeds being developed, yields changing year over year, fertilizer requirements dropping, new management practices being developed and deployed, and market demands can also change as eating habits change and different rates of population growth being experienced in different regions of the world.

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Each of the chapters in the report reviews a different aspect of the EPA GHG emission analysis. The next chapter considers the petroleum baseline fuels.

2. THE PETROLEUM BASELINE

Since the objective of the rulemaking is to identify the reductions in GHG emissions it is necessary to compare the emissions of biofuels to a reference fuel. The reference fuel that the EPA is using is the 2005 average life cycle emissions of diesel fuel used in the United States. The EPA is using the GREET model to determine these emissions. Furthermore they are relying mostly on the defaults values within version 1.8b of the GREET model. An alternative analysis of the gasoline and diesel fuel emissions has been developed by the National Energy Technology Laboratory and the EPA is inviting comments on this alternative approach.

This section provides comments on the GREET default values, the changes that the EPA has made to GREET for this analysis and the NETL approach.

2.1 GREET DEFAULTS

GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) is a full life-cycle model developed by Argonne National Laboratory with sponsorship from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). It allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis. While GREET is an excellent lifecycle assessment tool, like all models, the results are dependent on the model inputs and with thousands of input variables that typically are found in a single pathway it is important that these be reviewed to ensure that they accurately portray the existing industry.

The critical inputs for estimating the GHG emissions for gasoline and diesel fuel are the emissions associated with crude oil production, crude oil transport, refining, and fuel transportation.

2.2 CRUDE OIL PRODUCTION

The default value in GREET assumes that the energy efficiency of crude oil production is 98%. It would appear that the EPA has used this value for 72% of the oil used in the model. They have assumed that 5% of the crude oil is bitumen derived product from Canada and these emissions are calculated in GREET and are discussed below. The remainder of the crude oil is composed of 1% very heavy crude oil mostly from Venezuela and the remaining 23% is heavy oil. The energy requirements for the heavy oil are scaled with heavy oil using 1.07 times the energy of conventional oil and the Venezuela extra heavy oil using 2.4 times the energy of conventional oil. This suggests that the average scaling factor is 1.042 for the non oil sands material, or an energy efficiency of 97.91% of the energy in the crude oil. Using this value in GREET produces a result close to that reported in Table 2.4-10 of the DRIA.

There is very little supporting data in the GREET documentation for the 98% default value. The California Air Resources Board, in their use and modification of the GREET model have used a value of 93.0% based on the weighted average of the 98% value for crude oil produced outside of the State of California and their calculated value for California heavy crude oil.

The International Association of Oil and Gas Producers (OGP) has for several years been publishing the direct energy requirements and emission data from their members. The data for the year 2005 is available (OGP, 2006). That data is probably the most complete set of information on the upstream oil and gas industry worldwide but it does only cover about 34% of the global population of hydrocarbon production. They report an average energy requirement of 1.40 GJ/tonne of hydrocarbons produced. This varied by region as shown in the following table.

Table 2-1 Energy Requirements for Hydrocarbon Production

	% Coverage	GJ/tonne
Africa	66	0.84
Asia/Australasia	46	1.48
Europe	98	1.02
FSU	4	1.16
Middle east	16	1.29
North America	29	2.28
South America	53	1.74
Overall	34	1.40

This value of 1.4 GJ/tonne is equivalent to 96.7% efficiency. The members of the OGP are among the worlds largest oil companies and include Shell, BP, ExxonMobil and others. The 2005 data is aggregated from 28 companies working in 55 countries. Given the size of the companies involved the data set probably under represents the total energy requirements for all oil production because these large companies would not typically operate smaller, older oil fields, which usually are less efficient. Nevertheless, this is the best number available, it is documented and it should be used in place of the 97.9% value in the EPA version of GREET. OGP is the original source of data for the NETL calculations (although they used data from 2002).

GREET also has a default assumption that 16,800 BTU of natural gas are flared for each million BTU of crude oil produced. Again the source of the information is difficult to determine. The World Bank has sponsored work on the quantification of emissions from gas flaring and venting. A quantification of the emissions has been undertaken by NOAA using satellite imagery. They reported that in 2005, 160 billion cubic metres of gas were flared. The world oil production in 2005 was 30.87 billion barrels (EIA). This would suggest that on average, 4.11 cubic metres of natural gas are flared for each barrel of oil produced or 26,227 BTU/million BTU.

The combustion of this gas is not completed and the emission factor (CO_2eq/cubic metre of gas) is typically about 1.4 times higher than gas combustion in a furnace. In GREET the emission factor used for natural gas flared is not significantly different and thus GREET underestimates the GHG emissions from the flaring of associated gas by underestimating the quantity of gas flared and underestimating the unburned methane component of that gas. Cell H12 on sheet EF should be increased to 1,140 g methane/million BTU from 49 g/million BTU to properly account for these emissions.

GREET also assumes methane emissions from oil production of 13.15 g/million BTU. Segmented data is presented by OGP for 2005 which indicates that the methane emissions from sources other than flaring totals 0.745 kg methane per tonne of production or 18.43 g/million BTU, 40% higher than the GREET value.

Combining these three factors produces the values summarized in the following table.

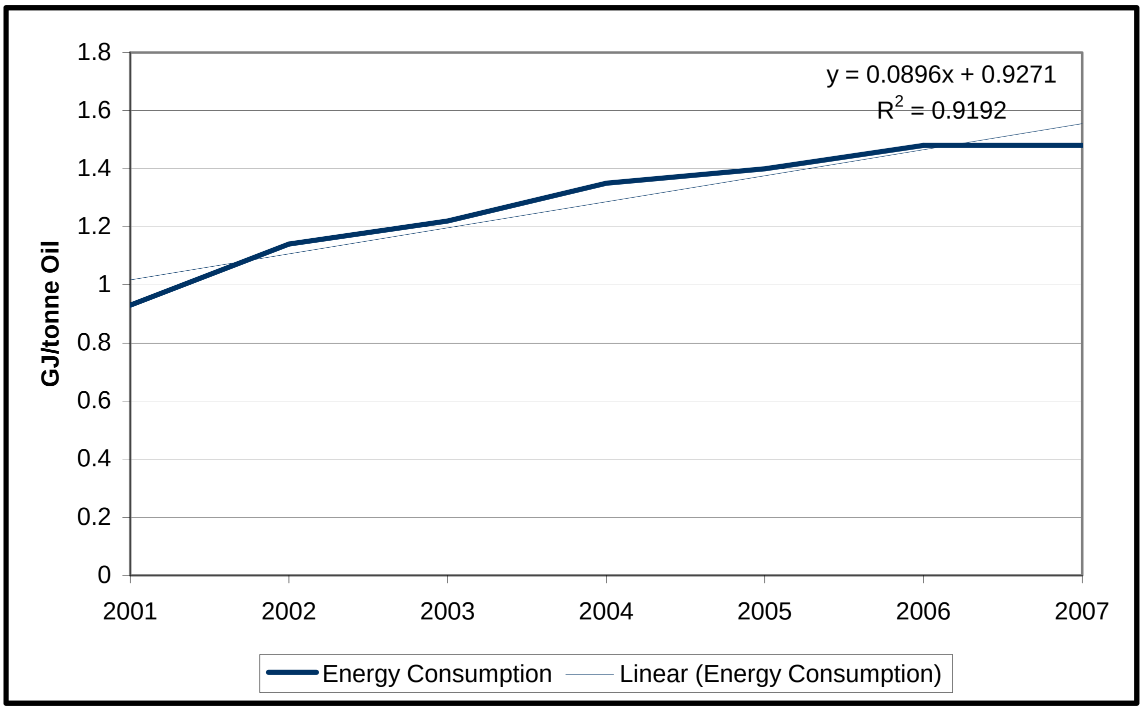
Table 2-2 Adjusted Default Values for Diesel Fuel

	Table 2.4-10	Base GREET 1.8b	Revised GREET conventional oil
	g/MM BTU		
Methane	106	103	141
Nitrous Oxide	0.25	0.24	0.27
CO_2	15,074	14,881	16,581
CO_2 eq	17,381	17,123	19,621

These emissions are 12.9% higher than proposed in the DRIA and while this doesn't include the refinery or end use emissions this increase will flow through to the lifecycle emissions result and increase these emissions by about 2.5%.

What is more concerning, however, is that the OGP data indicates a very significant trend in the energy used for crude oil production. The energy used in oil production is a function of the depth of the reservoirs, their internal pressure, the amount of co-produced water and other factors. It is known that as reservoirs age the energy required to produce the oil increases. Data from OGP is available for the years 2001 to 2007 and the average energy requirements are shown in the following figure. This figure could be influenced by different participation rates and different companies participating but other than the Americas, the participation rates have been steady through the time period.

Figure 2-1 Change in Energy Consumption



Extrapolating the trend through to 2022 would indicate that the energy requirements could increase from the 1.40 GJ/tonne in 2005 to 2.70 in 2022. This would increase the baseline emissions by approximately a further 2,500 g/mm BTU.

2.3 OIL SANDS

The EPA has modelled 5% of US oil supply coming from the oil sands of Alberta. GREET does have two pathways for modelling in-situ production and mined production and upgrading to synthetic oil. The portions of the 5% that are produced in-situ versus mined production are not specified in the documents. We have used the GREET defaults of 68% mined and 32% produced in-situ. The default GREET upgrades the mined bitumen but does not upgrade the product produced in situ. We have made the same assumption.

2.3.1 Mining and Extraction

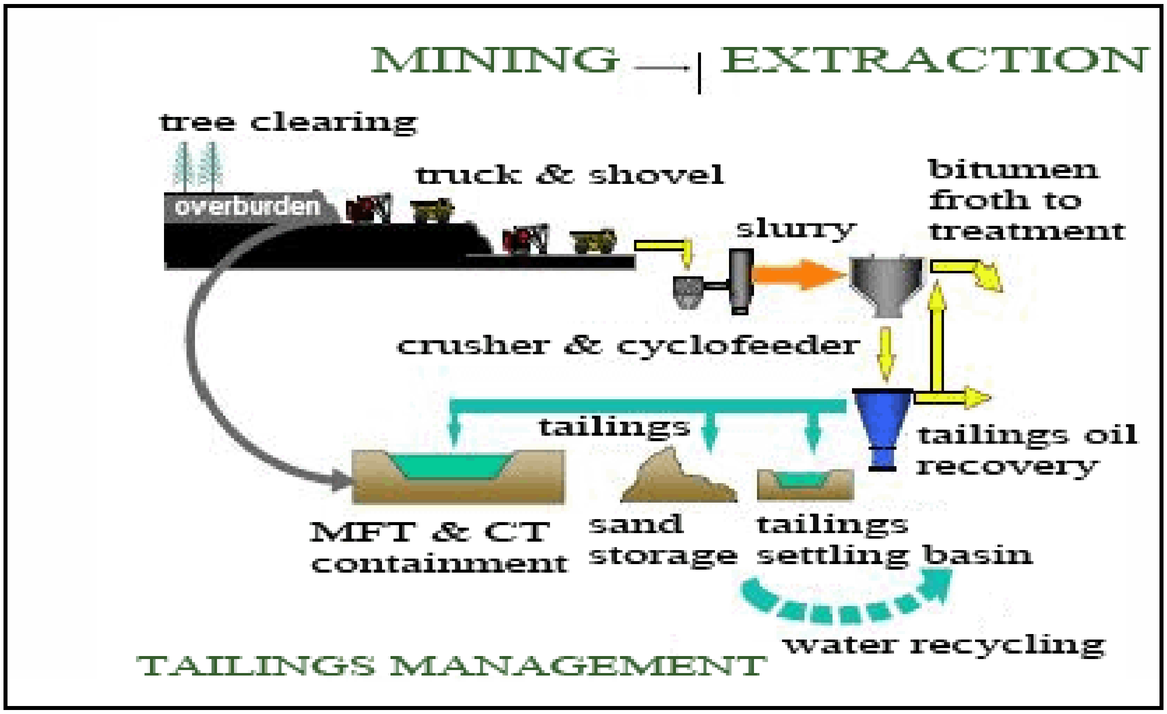
The GREET default energy efficiency for mining oil sands is 94.8% or 2.2 MM BTU/tonne of oil.

When the oil sand is not deeply buried, surface mining is the most viable method of recovery. In this process;

- Layers of muskeg and earth are removed first. Suitable soil materials are used in ongoing reclamation.
- Beneath the muskeg is a layer of overburden, which is removed to expose the thick deposit of oil sand.
- Today, trucks and shovels remove the overburden and mine the oil sand.
- The oil sand is trucked to crushers, where large chunks are broken down for transport via hydro-transport or conveyor to bitumen extraction facilities.

The process is shown in the following figure.

Figure 2-2 Bitumen Mining Schematic



Since mined bitumen production is a relatively new standalone process, information on the energy requirements are not widely available. Flint (2005) estimates that GHG emissions are about 250 kg CO_2 eq/cubic metre of bitumen produced. The Pembina Institute (2008) reported on the GHG emissions for a number of mining and extraction operations and the results are summarized in the following table. These emissions are reported to cover the mine fleet, mine face, fugitive emissions, processing plants, electricity production (on or offsite), tailings ponds, and facility heating.

Table 2-3 Reported GHG Emissions for Mining and Extraction Operations

Operation	GHG Emissions	
	Kg CO_2 eq/bbl	Kg CO_2 eq/m^3
Albian Sands - Muskeg Existing	24.44	153.7
Albian Sands - Muskeg Expansion	44.44	279.5
Canadian Natural - Horizon	23.34	146.8
Imperial Oil - Kearl	40.39	254.0
Petro Canada - Fort Hills	40.50	254.7
Shell - Jackpine Phase 1	36.14	227.3
Syneco - Northern Lights	41.56	261.4
Average	35.38	225.3

For GREET we need the energy requirements and the most detailed information on mining and extraction emissions was found in the Environmental Impact Assessments for the Shell Jackpine expansion (including the Pierre River deposits) and the Total Joslyn mine.

The Shell information contains GHG emissions for mining and extraction by emission source for two different mining operations. From that information the following energy consumption rates have been calculated. The Shell data also has some options for reduced natural gas but increased asphaltene use. The energy use for the Total operation has similar natural gas and gasoline consumption, almost twice the rate of diesel fuel use, and power consumption more than an order of magnitude higher. Each individual mine will have unique situations that dictate energy use.

Table 2-4 Estimated Energy Use at Shell Mining and Extraction Operations

		Jackpine Phase 1	Jackpine Expansion	Pierre River	Average	%
Natural gas	BTU/mm BTU	69,700	69,700	65,800	68,400	79.2%
Gasoline	BTU/mm BTU	184	184	138	169	0.2%
Diesel Fuel	BTU/mm BTU	18,320	18,320	15,504	17,381	20.1%
Power	BTU/mm BTU	253	253	757	421	0.5%
Total	BTU/mm BTU	88,400	88,400	82,200	86,400	100.0%

Based on this data the values used in GREET should be 91.35% efficiency and with less power purchased and more diesel fuel consumed.

2.3.2 In Situ Production

There are two primary in-situ approaches being employed today, Cyclic Steam Stimulation (CSS), and Steam Assisted Gravity Drainage (SAGD). Other approaches are being developed that utilize solvents to supplement or replace steam (VAPEX), and controlled underground combustion to heat the reservoir (THAI).

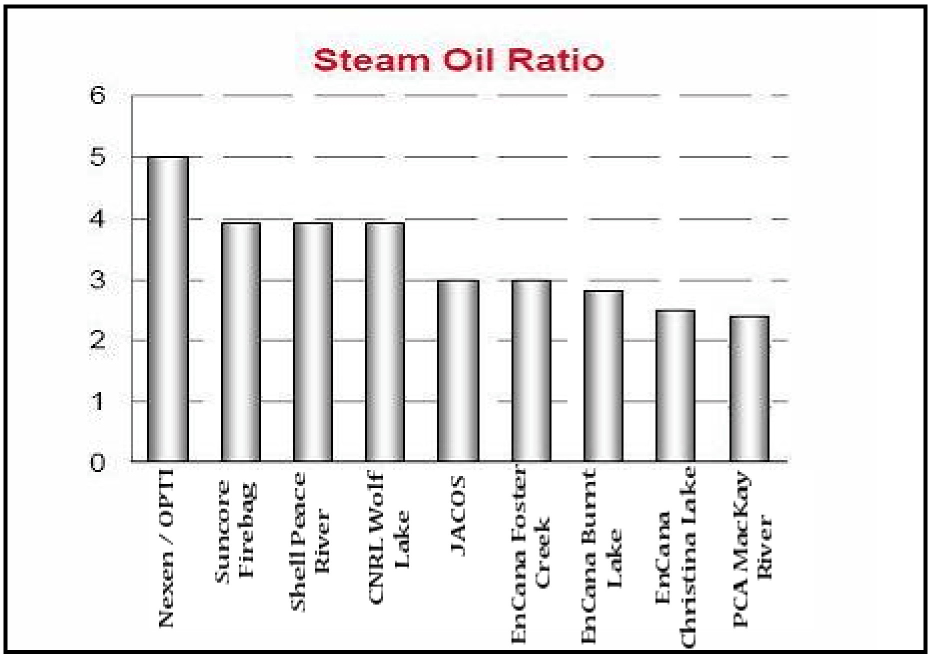
Only a small portion of the oil sands can be recovered through surface mining, and other in situ extraction techniques are required for the majority of the resource. The development of steam assisted gravity drainage (SAGD) dramatically increases the economical viability of oil sands reserves.

Whereas cyclic steam stimulation works best in formations like those near Cold Lake with good horizontal permeability, SAGD works better in deposits with good vertical permeability, like the Athabasca deposits near Fort McMurray.

Both CSS and SAGD use significant amounts of natural gas to make the steam necessary to extract the bitumen.

A critical component of determining the energy efficiency of bitumen production is the SOR. The SOR will vary from project to project depending on the characteristics of the oil sands. Petro Canada (2006) reported that their MacKay River project had one of the lower SOR in the industry as shown in the following figure. As can be seen in the figure the SOR can range from 2.5 to 5.0, although other references show values as low as 2.0 and as high as 10.0 for some demonstration projects.

Figure 2-3 Reported SOR for SAGD Projects

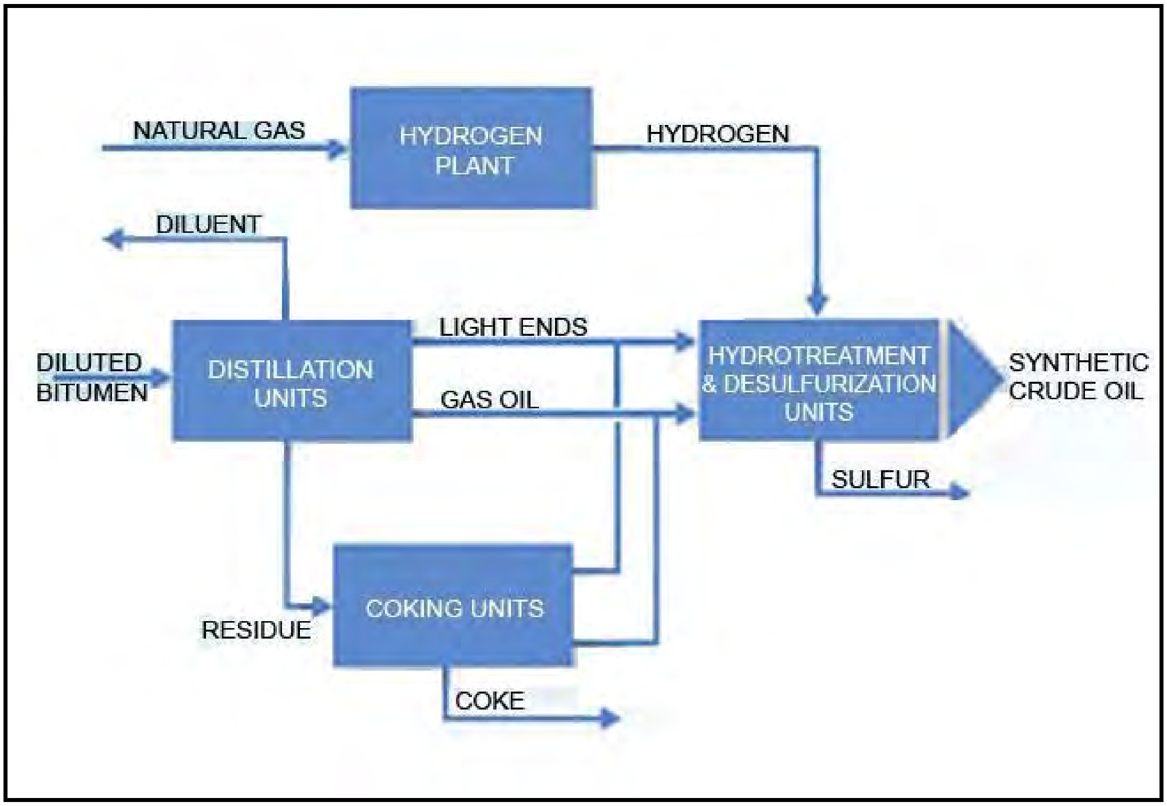


The typical value is a SOR of 3.2 produces a natural gas consumption rate of 9.0 million BTU/tonne of oil produced (225,000 BTU/million BTU). The electric power consumption will be 205,000 BTU/tonne of oil produced (5,125 BTU/million BTU). The electric power in GREET is approximately correct but the natural gas rate is low by about 10%. This variance is not that large given the uncertainty of the actual values for the various projects.

2.3.3 Bitumen Upgrading

Bitumen can be blended with a diluent to allow it to be transported through the pipeline system and then refined or it can be upgraded to a lighter crude oil. There are two fundamental approaches used for upgrading, either carbon can be removed from the bitumen to reduce the density and viscosity, or hydrogen can be added to the product. Most upgraders are employing the first approach with a delayed coker system but Shell is using the later approach (hydrocracking) at its upgrader near Edmonton. A delayed coker schematic is shown in the following figure.

Figure 2-4 Delayed Coker Schematic



Several variations of this basic process can be developed including systems that utilize the gasification of the coke to produce hydrogen rather than using natural gas, the utilization of produced fuel gas hydrogen production, the inclusion of cogeneration systems to produce power as well as thermal energy and other systems.

The Petro Canada (2006), Northwest Upgrading (2006), and Shell (2007) EIA statements have been reviewed to determine the proposed mass and energy balances of the two approaches to upgrading. The information is summarized in the following table.

Table 2-5 Reported GHG Emission Intensity for Upgraders

Project	Comments	Direct Emissions Intensity	Indirect Emission Intensity	Total Emission Intensity
		kg/bbl	kg/bbl	kg/bbl
Scotford Upgrader	Hydrocracking	33.6	5.8	39.4
Scotford Upgrader after expansion	Hydrocracking	32.9	10.5	43.4
Scotford Upgrader 2	Hydrocracking	60.9	19.1	80.3
Northwest Upgrader	Delayed coking	92.8	Not available	
Northern Lights Upgrader	Delayed coking/gasification	141.4	Not available	
PC Sturgeon Phase 1	Delayed coking	40.7	Not available	
PC Sturgeon Phase 2	Delayed coking	62.6	Not available	
Opti/Nexen	Integrated/gasification	180-200	Not available	
BA Energy	New technology	14.0	Not available	
Husky Lloydminster	Delayed coking	65.6	Not available	
Suncor	Integrated	108.7	Not available	
Syncrude	Integrated	106.0	Not available	

It is apparent from the table that there is a wide range of reported emissions for upgraders. None of these emissions are lifecycle emissions in that the emissions associated with the production of purchased fuel is not included in the totals. Even within a complex the emissions can vary with stage. The fuel used can also vary with some operations using natural gas and others choosing to gasify coke or asphaltenes.

For the default values for GREET we have chosen inputs that produce lifecycle emissions of 70 kg/bbl (~11,000 g/mm BTU). These values are not from any specific project but were determined from considering the range of fuels and inputs from a number of projects. The input values were then adjusted to provide the emission target. These are summarized in the following table.

Table 2-6 Proposed Upgrader Input Values

	Energy Consumed, BTU/mm BTU
Natural gas	50,000
Electric power	13,750
Fuel gas	87,500
Petroleum coke	27,500
Total	178,750

This energy is about double that which is included in GREET when the hydrogen requirements are included. This is a significant variation. The energy efficiency is 82.2% rather than the 98.6% but the higher value doesn't include the extra hydrogen requirements. In the following table the upstream emissions when the oil sands emission factors are adjusted are compared to the previous changes and the original value.

Table 2-7 Adjusted Default Values for Diesel Fuel

	Table 2.4-10	Base GREET 1.8b	Revised GREET conventional oil	Revised GREET conventional oil and oil sands
	g/MM BTU			
Methane	106	103	141	142
Nitrous Oxide	0.25	0.24	0.27	0.28
CO_2	15,074	14,881	16,581	17,031
CO_2 eq	17,381	17,123	19,621	20,102

Even though the oil sands material only contributes 5% of the crude oil supply utilizing input values that are closer to actual operating conditions does increase the average upstream emissions by a further 2.5%. The combined impact of more realistic input values will add 2,700 g/mm BTU (2.9%) to the lifecycle emissions for diesel fuel.

In the future, oil sands material is expected to be a larger share of the US refining mix and thus this is a second reason why the 2005 base line will underestimate the emissions from gasoline and diesel fuel in the future.

2.4 Crude Oil Transportation

There is little information in GREET to support the default transportation distances. It is noted that the sources of crude oil modelled do not correlate with the actual source of oil in 2005 according to EIA data, as shown in the following table.

Table 2-8 GREET Defaults vs. Actual

	GREET	EIA
	%	%
Domestic Alaska	7	6
48 States	35	28
Imported (total)	58	66
Total	100	100

In addition to underestimating the quantity of imported oil the transportation distance would also appear to be low. An analysis of the weighted average distances for imported crude oil by ship produced a distance of 6,600 miles rather than 5,500 miles. Increasing the fraction and distance of crude shipped would increase the lifecycle emissions of diesel fuel by a further 104 g/mm BTU.

It is not clear that GREET makes any allowance for crude oil transportation in the country of origin prior to being shipped to the United States. Most oil producing countries have extensive pipeline systems to gather the oil and move it to port.

2.5 Refining

The refining emissions in GREET have been updated recently and there are no comments.

2.6 FUEL TRANSPORTATION

The fuel transportation emissions are not as critical as the crude oil transportation emissions since the biofuels will also need to be transported along with the petroleum products.

2.7 NETL BASELINE

There are advantages and disadvantages of using the NETL approach to determining the baseline emissions for gasoline and diesel fuel. The primary advantage is that the approach used by NETL is very well documented compared to the data values that are used in GREET. However, there are a few assumptions with respect to the data that have been made by NETL that are probably not appropriate. The primary disadvantages are that the energy system is so interconnected and the GREET values have been used for so many other emissions estimates in the calculations for biofuels that consistency is lost and it would not be appropriate to use one model for petroleum emissions and a second model for biofuels. The NETL report, while well documented, is not particularly transparent and there do appear to be some issues with some of the emission factors chosen by NETL.

The baseline value calculated by the EPA using GREET for diesel fuel is 79,461 g CO_2 eq/mm BTU for the vehicle and 17,382 g CO_2 eq/mm BTU for the upstream emissions for a total diesel fuel lifecycle emissions of 96,843 g CO_2 eq/mm BTU. It has been shown in this section that the upstream emissions should be higher, at least 20,227 for a total lifecycle emissions of 99,688 g CO_2 eq/mm BTU.

The NETL report suggests that the diesel fuel baseline for the year 2005 should be 95,000 g CO_2 eq/mm BTU for diesel fuel. Of this 18,400 are the upstream emissions and 76,600 g CO_2 eq/mm BTU are the vehicle emissions. The vehicle emissions are a function of the carbon content of the fuel and the exhaust emissions of methane and N_2O. NETL are using the more recent IPCC GWPs of 1, 25, and 298, which accounts for 0.9 kg/mm BTU for the upstream emissions and little effect on the vehicle emissions, but the largest contributor to the difference is probably the assumption about the carbon content of the diesel fuel.

The comparison of the values from each approach is shown in the following table based on the stages that have been chosen by NETL.

Table 2-9 Comparison of NETL and GREET Baseline Emissions

	GREET	NETL	Difference
	kg/mm BTU		
Crude Oil Production	4.2	6.6	-2.4
Crude Oil Transport	2.3	1.3	1.0
Refining	10.3	9.5	0.8
Fuel Transportation	0.5	0.9	-0.4
Sub Total	17.3	18.4	-1.1
Fuel Use	79.5	76.6	2.9
Total	96.8	95.0	1.8

The NETL upstream emissions are higher because they have estimated these on a regional basis using a purchased GaBi database. The GaBi data is in turn derived from the OGP data for the year 2002. While NETL states that the 2002 data should be applicable to 2005, it has been shown here that the energy requirements for crude oil production were actually 23% higher in 2005 than they were in 2002. NETL also uses more up to date data for estimating the venting and flaring emissions than the default values in GREET. In summary, the NETL data on emissions from crude oil production is more reflective of actual emissions than the data in GREET, it still underestimates emissions by using data from 2002 and not 2005 and as noted earlier the OGP data probably underestimates the total emissions by only having data from some of the worlds largest producing companies.

Crude oil transportation emissions in NETL are lower than they are in GREET even though NETL included the emissions associated with crude oil transportation within the country of origin, a source of emissions that is not included in GREET. The energy intensity for ocean transport used by NETL is 5.5 BTU/barrel nautical mile (43 BTU/ton-mile) versus the 42 value used in GREET. The transportation distance calculated in NETL averages 6,500 miles versus 5,500 miles in GREET. There appear to be two reasons for the lower emissions in NETL, they do not include methane emissions during loading and shipping and they use an emission factor for residual oil that only includes the combustion and not the production related emissions. This should be corrected.

The NETL calculations for the refining energy are lower for diesel fuel than the GREET values. The methodologies are similar but there are differences in allocation between the products.

The NETL emissions are higher for product transportation. This is in spite of using emission factors that do not include the emissions for fuel production. The higher emissions appear to be a function of better data on the distances and modes of transportation that are in GREET.

The NETL emissions from fuel use are derived from MOVES, the same source used by EPA. It is not clear why the emissions are not the same but different assumptions regarding the carbon content of the diesel fuel would appear to be the primary factor.

In summary, neither the EPA nor NETL determined baseline emissions for diesel fuel are ideal. There are shortcomings in both sets of information. Some of the NETL data does verify the comments made in the earlier sections with respect to the baseline emissions currently underestimating actual practices. It would appear that much of the information developed by NETL could be used in GREET to provide a better estimate of the baseline emissions of diesel fuel. To do this the crude oil emission energy consumption should be updated to 2005 data.

2.8 Other Emissions

There are no land use emissions calculated for crude oil production in the EPA proposal or the NETL baseline report. There is significant land that is disrupted during exploration, drilling, production and transport. We are not aware of any global accounting of these emissions but some estimates have been made in individual countries.

Some preliminary work on land use impacts of crude oil production has been carried out for California crude oil and some Alberta oil sands projects (Yeh et al, 2009). Their preliminary analysis suggest that the GHG emissions associated with land use conversion are in the range of 25 to 1,400 gCO_2e/mm BTU for conventional oil production, 1,500–3,100 gCO_2e/mm BTU for oil sands surface mining and up to 4,000 gCO_2e/mm BTU for in situ productions of oil sands. The conventional oil calculations were performed in a region with low carbon intensity vegetation and very old oil fields, so some of the initial impacts of seismic activity and road building would no longer be visible.

Some estimates of surface disturbances have been made for conventional oil production in the forested areas of Alberta, Canada. During oil exploration seismic activities must be carried out. In forested areas the vegetation must be removed to place the charges and the data collection sensors. In Canada, an average of 57,750 kilometres of seismic lines were deployed between 1979 and 1995 in forested areas (Alberta Centre for Boreal Studies). Each line is 6-8 metres in width resulting in 40,000 hectares per year being deforested with hardly any recovery of wood for lumber or pulp. Regeneration in these areas is very slow and studies have found that after 20 years almost 90% is still not regenerating. With an average of 50 tonnes/ha of carbon in the standing forest and the assumption that oil discoveries equal oil production (~1.5 million barrels/day in Canada) which is a reasonable assumption, then the CO_2 emissions per barrel of oil would amount to 13,400 g/bbl or about 2,600 g CO_2/mm BTU. Using the methodology employed for the land use calculations for biofuels the lost sequestration capacity of this land would also have to be calculated.

Each oil well also requires some land surrounding it to be cleared of vegetation. This results in a one time loss and the lost ongoing sequestration capacity. The Alberta Centre for Boreal Studies has estimated that 1 ha is required for each well and that in 2000, almost 12,000 new wells were drilled. Using the same approach as above this would result in a further 800 g/mm BTU of CO_2 emissions.

Each well will have a road leading in to it and a pipeline right of way away from it. Each of these is likely to have a cleared right of way of 40 to 50 metres and so even if each well only needed 5 km of new road and pipeline right of way, this would result in 240,000 ha of land clearing annually or 15,600 g of CO_2 eq/mm BTU. Total direct land use change emissions could approach 20,000 g CO_2 eq/mm BTU for some oil production systems. This is 20% of the other direct GHG emissions that are calculated for petroleum fuels.

Not all oil is produced on land and not all land based oil production is undertaken in forested areas but the land emissions from oil production would not appear to be as trivial as some have suggested and further investigation is definitely warranted.

2.9 Summary Petroleum Baseline

The petroleum products baseline results for 2005 underestimate the actual emissions associated with gasoline and diesel fuel in the United States. This statement applies to both the EPA and NETL proposed baselines. The underestimation is primarily due to the difficulty of accessing data on production practices in foreign countries. The NETL baseline is better documented than the GREET baseline but it uses data from a subset of oil producers in 2002. A combination of updated NETL data being used in the GREET model would produce a baseline emissions value that is about 3% higher than is suggested in the DRIA. This would increase slightly more if the latest IPCC GWPs were used rather than the values from 1995.

Furthermore the available data suggests that the emissions for the petroleum fuels are increasing annually and can be expected to be significantly higher in 2022 than they were in 2005.

In addition to underestimating the emissions from various stages of the lifecycle, the direct land use emissions related to crude oil production, which are not accounted for in either the EPA or the NETL baseline estimates, may not be as low as some have suggested. These emissions could add a further 2 to 5% to the lifecycle emissions of gasoline and diesel fuel.

While 3-8% may not appear to be a significant variation for a baseline value it factors into both the numerator and denominator of the percent reduction in GHG emissions, a 20% reduction in GHG emissions becomes a 24% reduction when the baseline increases by 5%.

3. AGRICULTURAL EMISSIONS

Unlike the petroleum fuel base line analysis, the EPA has not used the traditional attributional LCA approach in developing the lifecycle GHG emissions for biofuels. Instead they have employed economic models to determine the changes in economy wide agricultural practices and then applied a combination of model results and emission factors to determine the changes in the total agricultural GHG emissions caused by the change in demand for the agricultural products.

This approach complicates the analyses of the emission results, as the results for soybean biodiesel are a function not only of the production of soybeans but also the crops that are displaced by the soybeans and the estimated relative efficiency of the international producers compared to domestic producers for each crop. For example, if the inputs for producing soybeans are correct but some corn acres are displaced and the inputs for corn were underestimated then the emissions attributed to soybeans would be overestimated.

In the EPA analysis of the increased soybean biodiesel production scenario, there is a decrease in corn, wheat, hay, rice, oats, and sorghum acres and an increase in soybean and cotton acres. The increase in soybean acres (for the biodiesel only case) is not as large as the decrease in soybean acres resulting from the increased corn ethanol demand. Thus soybean acres are reduced from the 2022 baseline case and it is assumed that the changes in the non-fuel market demand and the international acres would adjust to compensate for the lost domestic acres.

In the documents, the emissions associated with feedstock production are calculated separately for domestic and international programs. Comments on the data used for each is presented below.

3.1 DOMESTIC SOYBEAN PRODUCTION

The scenario modelled by the EPA forecasts an increase production of soybean oil in the US to meet the demand for an additional 300 million gallons of biodiesel, but a decrease in the quantity of soybeans produced in the United States. This would mean a reduction in exports. There is some confusion about the exact scenario because the 300 million gallons is mentioned in Tables 2.1-1 and 2.3-1 but Table 2.6-1 implies that 400 million gallons of soybean biodiesel is modelled. The world demand for soybeans (or soybean oil) is met with increased production from other countries. The domestic land use change for the control scenario is summarized in the following table.

Table 3-1 Changes in Domestic Land Use

	Million Acres	Percent 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%

The FASOM model predicts that domestic soyoil production and consumption would increase by 0.4 million tons and exports would fall by 1.3 million tons as a result of the biodiesel scenario modelled. One million, seven hundred thousand tons of soyoil should produce 460 million gallons of biodiesel, this is clearly inconsistent with the scenarios being modelled. The FAPRI model results are projecting a drop in exports of 2.9 billion pounds; this would produce 400 million gallons of soy biodiesel. This inconsistency between models and the increased demand is concerning because it directly impacts how much new land is needed.

Nowhere in the DRIA is the actual change in domestic land use presented for the biodiesel only case except in Figure 2.6-1, which has insufficient detail to check any of the calculations. All of the tables indicate that domestic agricultural GHG emissions decrease for the biodiesel only case.

The emissions associated with soybean production are a function of fertilizer production and application, field energy expenditures and land use changes. These are discussed below.

3.1.1 Yield

The soybean yield in 2022 is projected to be 50 bu/acre. This is a reasonable projection based on historical trends. Some of the seed companies have suggested that the soybean yield could increase faster in the future as a result of their breeding programs.

3.1.2 Fertilizer

The only information on the fertilizer inputs is for the nitrogen use. This is stated to be less than 10 lbs/acre in 2022. According to USDA data the average nitrogen applied per acre has been below 5 pounds/acre since 1962. The actual number used in the modelling work is not provided but Figure 2.6.3 would indicate that about 6 pounds/acre has been used. The trend line would suggest that nitrogen use in 2022 could be 5.3 pounds/acre.

The fertilizer application rates for potassium and phosphorus are not provided in the documentation so it is not possible to comment on those values. The emissions from fertilizer manufacture account for almost 20% of the emissions of growing soybeans so it is important not to over estimate the application rates. The application of P and K fertilizers have also been dropping on a per bushel produced basis and this should be factored into the 2022 cases.

3.1.3 Energy Requirements

The energy requirements for soybean production in the DRIA are presented in a series of figures. The estimated values are summarized in the following table.

Table 3-2 Soybean Production Energy Requirements

	Gallons/acre	BTU/acre
Diesel	9.7	1,246,000
Gasoline	3.4	395,000
Electricity	7.4 kWh/acre	25,271
Total		1,666,271

Assuming 50 bushels/acre then the energy requirements per bushel of soybeans are 33,325 BTU/bu. This is 50% higher than the value in GREET of 22,087 BTU/bushel. The GREET inputs are based on a 2007 USDA survey (ANL, 2008).

The determination of crop energy use has always been a challenging exercise and questions remain about the accuracy of the various estimates and measurements. The Iowa Soybean Board worked with 51 individual members to determine their energy crop budgets (Iowa Soybean Board, 2009). These members used a total of 116 different crop scenarios (combination of land and management practices). While this is not a very large sample, and the results from the individual scenarios varied widely, the average filed energy use was only 11,160 BTU/bushel. This includes production, harvesting and transport energy to the farm. The highest value reported was 18,250 BTU/bushel, which is still less than the GREET or FASOM values. Furthermore. As production energy is more a function of area than yield, this energy value would be expected to be lower in 2022 than it was in 2006 and 2007.

3.1.4 Domestic GHG Emissions

As noted earlier, the biodiesel only scenario (an attempt to isolate the biodiesel related impacts) shows a reduction in domestic agricultural emissions. The changes in the inputs are summarized in the following table along with the emission factors that are found in GREET to arrive at the estimated total emission change.

Table 3-3 Domestic GHG Emissions – Production Inputs

Input	Unit	Change	GHG Emission Factor	GHG Emissions, tons
Total N use	Tons	-97,581	2.724 tons/ton	-265,810
Total P_2O_5 use	Tons	-4,454	0.935 tons/ton	-4,165
Total K_2O use	Tons	-17,678	0.626	-11,066
Total Lime Use	Tons	-39	0.572	-22
Herbicide Use	Tons	-328	19.46	-6,383
Pesticide Use	Tons	-383	22.50	-8,617
Total Diesel Fuel use	gal	379,967	0.0124 tons/gal	4,711
Total Gasoline use	gal	605,625	0.0114 tons/gal	6,904
Total Electricity Use	kWh	129,994	.000685 tons/kWh	89
Total Natural Gas Use	10^6Btu	-3.5E+6	0.0687 tons/10^6 BTU	-240,450
Total				-524,809

In Table 2.6-12 of the DRIA the domestic emission reduction excluding N_2O emissions is estimated to be –555,978 tonnes for on farm combustion, fuel production upstream, and fertilizer production. This is reasonably close to that estimated here but the increase in emissions due to fossil fuel use could be a function of the very high energy demand that is apparently in the FASOM model. It could be that FASOM models the total farm energy (energy to move the product to market, energy related to household activities, etc.) and not just the energy required to produce the crop. If so, this is inconsistent with the system boundaries used in the petroleum baseline emission estimates, and the emissions calculated elsewhere in the fuel production system.

The increased production of soybeans and cotton and the reduced production of corn, wheat, rice, sorghum, oats and hay result in lower GHG emissions associated with crop inputs.

3.1.5 N_2O Emissions

The application of nitrogen fertilizer and the growth of nitrogen fixing crops results in increased N_2O emissions. The soybean production only uses a small quantity of nitrogen so most of the N_2O emissions result from nitrogen fixation and the decomposition of crop residues. Figure 2.6-12 indicates that a total of about 750 kg CO_2 eq/acre of N_2O are released during soybean production. Five hundred kg CO_2 eq/acre are due to nitrogen fixing.

There has been some debate in the scientific community in the last decade about the generation of N_2O from nitrogen fixing crops. This was resolved several years ago when the IPCC released their 2006 Guidelines for National Greenhouse Gas Inventories. In Volume 4, Section 11.2 it is stated that:

> *Biological nitrogen fixation has been removed as a direct source of N_2O because of the lack of evidence of significant emissions arising from the fixation process itself (Rochette and Janzen, 2005). These authors concluded that the N_2O emissions induced by the growth of legume crops/forages may be estimated solely as a function of the above-ground and below-ground nitrogen inputs from crop/forage residue (the nitrogen residue from forages is only accounted for during pasture renewal). Conversely, the release of N by mineralisation of soil organic matter as a result of change of land use or management is now included as an additional source. These are significant adjustments to the methodology previously described in the 1996 IPCC Guidelines.*

It appears that FASOM has not been updated with this latest guidance. Thus the DRIA grossly overstates the N_2O emissions by a factor of three compared to that which would be calculated by the IPCC guidelines (which are stated as the methodology being followed). The domestic net N_2O emissions reported for the biodiesel only case of 654,000 tons should actually be -245,000 tons, a difference of 899,000 tons per year.

3.1.6 Other Domestic Agriculture GHG Emissions

There are estimates made of GHG emissions related to grain drying, domestic rice production, domestic residue burning, and domestic livestock production. It is difficult to provide meaningful comments on the soybean scenario case given the lack of detail provided for the scenarios.

3.1.7 Summary Domestic Agriculture GHG Emissions

The domestic GHG emissions reported in Table 2.6-13 are overstated because of the incorrect treatment of nitrogen fixing crops. The emissions from the on farm combustion of fossil fuels may also be overstated due to the very high energy consumption factors used for soybean production in FASOM. In the following table the original table for the soybean biodiesel case is compared to what it should be.

Table 3-4 Domestic Agriculture Emissions

	Soybean Biodiesel Case			
	DRIA Values		Corrected N Fixation	
Emission Source	Tonnes CO_2-eq.	g/MMBtu CO_2-eq.	Tonnes CO_2-eq.	g/MMBtu CO_2-eq.
On-Farm Combustion	-228,655	-5,147	-228,655[2]	-5,147[1]
Fuel Production Upstream	-31,032	-698	-31,032	-698
Farm Chemical Production / Transport Upstream	-296,291	-6,669	-296,291	-6,669
Livestock Change	-181,679	-4,089	-181,679	-4,089
Rice Production Changes	-354,897	-7,988	-354,897	-7,988
Fertilizer Application / Soil N_2O Emissions	654,440	14,730	-244,560	-5,504
Residue Burning	1,851	42	1,851	42
Total	-436,263	-9,819	-1,335,263	-30,053

The draft RIA overstates GHG emissions due soybean cultivation by 20,234 g/MMBtu CO_2-eq. This is a very significant error as it represents more than 21% of the reported diesel fuel lifecycle GHG emissions.

3.2 INTERNATIONAL AGRICULTURAL EMISSIONS

The FAPRI model does not provide as much information about the agricultural sector as the FASOM model does and thus there is a lot more "manual" calculations that must be done to calculate the change in GHG emissions internationally. The EPA has relied on data from the UN FAO, the IEA, emission factors from GREET, their own calculations in order to produce an estimate of GHG emissions from International agriculture. The data used and resulting GHG emission estimates are even less precise than they are for domestic agriculture.

The majority of the international land use change for the biodiesel only case appears to be an increase on soybean production (675,000 acres out of a total change of 880,000 acres). There are smaller increases in rapeseed, cotton, sunflower, corn, sorghum, rice, sugar beets and palm area and decreases in wheat, barley, peanuts and sugar cane. This is somewhat surprising since it means that there is an increase in the availability of protein meal that results from the increase in demand for vegetable oils. One would have thought that an increase in demand for vegetable oils (and a decrease in livestock production from the higher prices) would have shifted production to crops that produced more oil and less protein such as rapeseed and palm. The fact that this doesn't happen may indicate a serious limitation in the modelling.

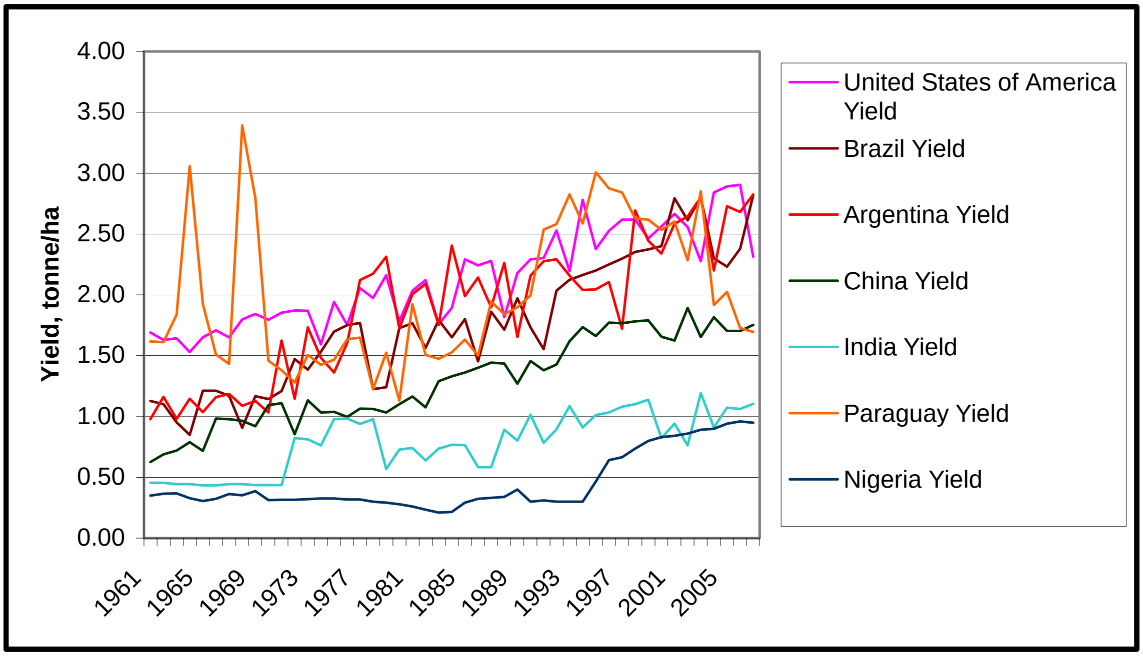
The increase in acres is largest in Paraguay, Brazil, India, Nigeria, and China.

3.2.1 Yield

The only information on yield that is presented in the DRIA is for Argentina and Brazil and the expected soybean yield in 2022 is 48 to 50 bu/acre. There is little information on the yields in the other countries that are expected to see area changes. The FAO data on soybean yields in the major countries identified by the EPA are shown in the following figure.

[2] Probably too high as well, but there is insufficient detail to determine proper value.

Figure 3-1 International Soybean Yields



It can be seen that yields in Nigeria, India, and China are well below the yields in the other countries and this will increase the quantity of land that must be converted to produce the required crop. There can be a number of reasons for the low yields but nutrient application, varieties planted and management practices can be addressed in short periods of time. India and China, for example do not use genetically modified soybean seeds and that has a detrimental impact on yield, China imports GM soybeans and India produces GM cotton so it is not unreasonable to consider that they could decide to produce GM soybeans before 2022 and thus have a significant impact on the world supply and demand and the estimated indirect land use change which is being attributed to soybean biodiesel.

3.2.2 Fertilizer

The fertilizer requirements for the soybean only case are presented for the total of all of the crops that are changed. The methodology followed is reported to have taken fertilizer use by crop data from the FAO. Given the lack of information provided it is difficult to comment on the application rates. In the following table the application rates per acre are compared to those in the GREET model for soybeans assuming that the yield is 50 bushels/acre.

Table 3-5 Comparison of Fertilizer Inputs

	EPA		GREET
	Tons	g/bushel	g/bu
Nitrogen	3,627	75	61.2
Phosphorus	9,495	196	186.1
Potash	8,640	179	325.5
Herbicide	57	1.2	47.8
Pesticide	58	1.2	0.48

The fertilizer application rates are reasonable if the yield is 50 bushels/acre but if the yield is lower, then the fertilizer application rates may be too high. The interesting metric is the low application of herbicides, which is consistent with low yields caused by a loss of productivity due to competing weeds. This also points out the gains that can be made in agricultural productivity through the use of modern crop production practices without bringing new land into production.

3.2.3 Energy Requirements

There is very little data available on energy use by crop internationally. The methodology used total agricultural energy use reported by the IEA divided by the total agricultural land in each country. No data is presented with respect to the results, just the total change for each biofuel scenario modelled. The same energy consumption per acre is applied to each crop. This approach is inconsistent with the domestic energy use data, which does vary with crop. The domestic data showed that soybeans use less energy per acre than corn and most of the other crops do. The use of a single factor for all crops therefore overestimates the GHG emissions for soybeans.

3.2.4 Fertilizer and N_2O Emissions

Unlike the emissions estimated by the FASOM model the international N_2O emissions have been calculated manually using the IPCC guidelines and Tier 1 default values. In this case there are no emissions calculated for nitrogen fixing crops, other than those related to fertilizer application and crop residues. This is further evidence of the error in the FASOM estimates for soybean production.

3.2.5 Total International Direct GHG Emissions

The international direct GHG emissions for agriculture are a relatively small portion of the emissions burden calculated by the EPA. Farm energy use is the largest portion and this may be overstated. Changes in livestock and rice emissions essentially offset each other. The remainder of the direct international emissions are related to fertilizer production and N_2O emissions from fertilizer and crop residues.

The concern with respect to the international direct emissions is whether the basic scenario is correct. The DRIA states that FAPRI predicts a reduction in soybean oil exports of 2.9 billion pounds. This is enough oil to produce 390 million gallons of biodiesel, not the 300 million gallons that is supposed to be required. Furthermore the increased net land requirements are estimated at 900,000 acres. With a biodiesel yield of 75 gallons per acre, this land would only produce 67 million gallons of biodiesel. Higher yields are possible with palm oil production and this would offset the extra soymeal that would otherwise be available but the figures in the report show very little land being converted in Southeast Asia. These discrepancies are concerning, as they could indicate that direct foreign GHG emissions should be higher.

It may also be that the protein meal offsets account for the difference in land, if the oil is 20% of the seed then the effective soybean yield would be 375 gallons/acre and the net land would be sufficient. The lack of transparency in the documentation makes it difficult to determine the actual scenario modelled in any detail.

Note that the combination of domestic and international agricultural emissions are negative for the biodiesel case modelled by the EPA.

4. BIODIESEL PRODUCTION

The GHG emissions from biodiesel production reported in the DRIA are 19,455 g CO_2eq/mm BTU. They are larger than the total of the non land use change emissions. In spite of the significance, the description of the emissions amounts to one page in the DRIA. There is no discussion of the glycerine co-product that is produced during the biodiesel production process.

4.1 SOYBEAN CRUSHING

The DRIA indicates that EPA relied on information from USDA Aspen modelling for the energy and material inputs into the process.

4.1.1 Energy

The assumptions made for soybean crushing include an oil yield of 11.2 lbs/bushel (18.7%) and energy use of 14,532 BTU/gal of biodiesel for natural gas and an electrical consumption of 2,740 BTU/gal of biodiesel. All of this energy is attributed to the biodiesel in the analysis since it is assumed that FASOM has accounted for a reduction in protein meal and oil demand in other sectors. The DRIA does not state if FAPRI makes the same allowances.

In the following table this information is compared to the industry performance data recently obtained from NOPA. The EPA has assumed that one gallon of vegetable oil produces one gallon of biodiesel.

Table 4-1 Comparison of Soybean Crushing Data

	EPA	NOPA
Year	2022	2008
Oil Yield	18.7%	19.1%
Natural gas	14,532 BTU/gal Biodiesel	20,057 BTU/gal soy oil
Electricity	2,740 BTU/gal Biodiesel	3,320 BTU/gal soy oil
GHG emissions	1,593 g CO_2eq/gal Biodiesel	2,100 g CO_2eq/gal Biodiesel
GHG emissions	13,490g CO_2eq/mm BTU	17,645 g CO_2eq/mm BTU

Other than a low oil yield, the EPA is forecasting continuing improvement in the energy efficiency of soybean crushing facilities. It could also be that the energy requirements used are representative of newer plants. This continuing improvement is what one would expect and there are indications that the energy requirements for soybean crushing operations were reduced by 50% between 1980 and 2008 based on the energy requirements found in GREET and the date of the original source of that data. The EPA estimates are a reasonable forecast for the year 2022.

4.1.2 Materials

There is a small amount of hexane that is consumed in the oil extraction process but there is no indication in the DRIA of what has been assumed for modelling.

4.2 BIODIESEL PRODUCTION

The biodiesel production energy requirements are also for the total process and have been estimated by the USDA. There is no mention of the co-product glycerine and unlike soybean meal, glycerine is not included in FASOM. There should be a glycerine co-product credit that is calculated by the displacement method to be consistent with the approach used in FASOM and FAPRI.

4.2.1 Energy

The energy requirements used by EPA are compared to the results of a recent survey undertaken by the NBB. It can be seen that the industry is using considerably less energy than the EPA has allowed for in 2022. The GHG emissions have been calculated using the emission factors found in GREET.

Table 4-2 Comparison of Biodiesel Processing Energy

	EPA	NBB
Year	2022	2008
Natural gas	5,559 BTU/gal Biodiesel	2,700 BTU/gal Biodiesel
Electricity	340 BTU/gal Biodiesel	410 BTU/gal Biodiesel
GHG emissions	458 g CO_2eq/gal Biodiesel	275 g CO_2eq/gal Biodiesel
GHG emissions	3,850 g CO_2eq/mm BTU	2,310 g CO_2eq/mm BTU

At the very least the EPA analysis should be adjusted for the actual energy consumption in 2008 rather than using an estimate for 2022 that is higher than current use.

4.2.2 Materials

The DRIA provides the GHG emissions intensity for methanol, sodium hydroxide, sodium methoxide, and hydrochloric acid, but does not specify the consumption rate of these chemicals. If we assume the consumption rates that are included in GREET, and the EPA emission intensity figures, then the GHG emissions related to the use of chemicals can be calculated. This is shown in the following table. The GHG emissions imbedded in the materials are 1,985 g CO_2eq/mm BTU.

Table 4-3 GHG Emissions From Biodiesel Chemicals

	Consumption	GHG Emission Intensity	GHG Emissions
	G/gal Biodiesel	g CO_2eq/g	g CO_2eq/gal Biodiesel
Methanol	336	0.465	156
Sodium Hydroxide	17	1.01	17
Sodium Methoxide	42	0.923	39
Hydrochloric acid	24	1.011	24
Total			236

4.2.3 Glycerine

There is no mention of the glycerine co-product in the DRIA. While the approach used by the EPA with the FASOM and FAPRI models should deal with the agricultural co-products as part of the new equilibrium, the models are not capable of automatically compensating for non-agricultural co-products and these would have to be dealt with outside of the models.

The biodiesel process produces one pound of glycerine for every ten pounds of biodiesel produced. This means that 0.74 pounds are produced for every gallon of biodiesel or 6.2 pounds per mm BTU of biodiesel.

GREET calculates the GHG emissions associated with the materials that are embedded in the glycerine. These emissions are 2,735 g CO_2 eq/pound of glycerine. This amounts to 16,957 g CO_2 eq/mm BTU of biodiesel.

There is more energy required to produce glycerine than the energy embedded in the raw materials. Agarwal (1990) reported that the processing energy required was 17,400 BTU/pound in addition to the energy embedded in the raw materials. He also reported that glycerol produced from crude glycerine from the soap making process required 13,000 BTU/pound of glycerine. The conservative approach would be to assume that the crude glycerine from a biodiesel plant has the same values as the ingredients used to make synthetic glycerine, this approach still results in a significant emission credit for biodiesel that is not accounted for in the EPA analysis.

4.3 Results

The results presented in the Proposed Rule and the DRIA are compared with those calculated here and shown in the following table. The emissions calculated from the DRIA data correspond well with the value in the proposed Rule. The values calculated here from industry data are for the year 2008 and have not been reduced to an expected value in 2022. A case could be made for even lower emissions in 2022.

Table 4-4 Biodiesel Production GHG Emissions

	Proposed Rule	Calculated from DRIA	Calculated Here
	g CO_2 eq/mm BTU		
Soybean Crushing		13,490	17,645
Biodiesel Energy		3,850	2,310
Biodiesel Materials		1,985	1,985
Glycerine		0	-16,960
Total	19,455	19,325	4,980

The difference between the value proposed by the EPA and that calculated here is 14,475 g CO_2eq/mm BTU of biodiesel, primarily resulting from the inclusion of the glycerine co-product credit. The difference could be even larger if the energy requirements for the crushing and biodiesel processing were extrapolated to the year 2022.

The 14,475 g CO_2eq/mm BTU is equivalent to 434,250 g CO_2eq/mm BTU in the 30 year undiscounted case and 622,000 g CO_2eq/mm BTU in the 100 year discounted case. This is a significant quantity of emission benefit that is not currently included in the EPA calculations.

The combination of the farming N_2O emissions and the glycerine co-product credit are sufficient to move the GHG emission reductions past the 50% threshold outlined in EISA.

There could be some push back from the EPA on this issue due to a view that synthetic glycerine is not being displaced or that not all biodiesel producers are selling their glycerine for upgrading. Alternative glycerine utilization approaches could involve use as an energy source for animal feed or as a fuel for combustion.

On the animal feed issue if the glycerine displaced soy oil as an energy source then in the EPA modelling that should reduce the international land use change quantity. The reduction should be on the order of 10% of the reported emissions (5,000 to 8,000 g CO_2eq/mm BTU).

If the glycerine is combusted then the emission benefit will arise from producing the fuel. Most of the carbon is the glycerine is deemed to be fossil carbon (from the methanol) and this there is not a large GHG emission benefit from its use. This credit will be on the order of 1,500 to 2,000 BTU/mm BTU of biodiesel.

In practice, the actual credit will probably be some combination of all different applications. Note that a conservative estimate has been used for the glycerine credit in the estimations made of the corrected GHG emissions for soybean biodiesel made here and the crushing energy that is used is the current value, not the forecast value in 2022. The emission reductions that are forecast here are therefore quite conservative.

5. FEEDSTOCK AND FUEL TRANSPORTATION

The feedstock and fuel transportation emissions are reported as a separate category in the Proposed Rule Making. These emissions account for 3,463 g CO_2eq/mm BTU. In the discounted 100 year case they represent 4.6% of the lifecycle emissions. In the 30 year undiscounted case they represent 3.4% of the lifecycle emissions. The emissions are calculated using the default values in GREET although the EPA is suggesting that they are undertaking their own analysis of the transportation distances involved and may include those in the Final Rule.

5.1 FEEDSTOCK

The feedstock emissions are calculated based on the assumption that the soybeans move 10 miles by truck from the filed to stacks and the 40 miles from the stack to the biodiesel plant. These GREET default values are combined with the GREET emission factors to arrive at the GHG emissions. Unlike in GREET, there is no allocation of these emissions between the oil and the meal as the FASOM and FAPRI models are assumed to take care of this. As a result the feedstock emissions total 2,615 g CO_2eq/mm BTU, or 75% of the transportation emissions.

While these emissions are real it is not clear that they have not already been included in the FASOM calculations as on farm combustion emissions. It was noted that the reported energy consumption for soybeans used in FASOM was significantly higher than reported by other sources. While both the FASOM data and the other data can be traced back to the USDA, it is not clear what the system boundaries are for both data sets. One explanation of the high energy values in FASOM is that they include the energy used to move the crop from the farm to the processor or elevator. If this is the case, then these emissions are double counted in the EPA calculations.

5.2 BIODIESEL TRANSPORTATION

The biodiesel transportation assumptions in GREET are that 8% of the product is moved 520 miles by barge, 29% is moved 800 miles by rail and the remaining 63% is moved 50 miles by truck all to a distribution terminal. All product is then moved a further 30 miles by truck to the retail outlet. The emissions account for 701 g CO_2eq/mm BTU or 25% of the feedstock and fuel transportation emissions.

The EPA has stated that they are reviewing these assumptions and they may change in the Final Rule.

6. OTHER ISSUES

The EPA has chosen to use the 1995 IPCC global warming potentials for methane and nitrous oxides. The IPCC has updated these values twice since these values were produced. The new values put a greater weighting on methane and a lower weighting on nitrous oxide. In the comparison of biofuels to petroleum fuels we see that the importance of each gas is different. Methane is a more important gas for the petroleum fuels and nitrous oxide is more important to the biofuel pathways.

The choice of the 2007 IPCC GWPs could be expected to increase the emissions related to gasoline and diesel fuel and reduce the emissions associated with biofuels. In the interest of using the best science available these GWPs should be used instead of the older 1995 values.

7. DISCUSSION AND SUMMARY

It has been a difficult task to evaluate the EPA work on GHG emissions of soy biodiesel as the documentation in the DRIA and the Preamble is not fully transparent and in some cases it is contradictory.

Nevertheless two major, and a third smaller, quantifiable issues have been identified that have a large impact on the results. Numerous other issues have been identified that are difficult to quantify but nevertheless introduce errors and biases in the results presented by the EPA. These errors and issues are summarized below.

7.1 THE REFERENCE CASE

The EPA is estimating the GHG emissions from the production and use of biofuels in the year 2022. The land use emissions in 2022 are estimated based on the difference in a business as usual scenario and an expanded biofuels scenario. These emissions are then compared to petroleum GHG emissions purportedly for the year 2005. The data used for estimating the petroleum emissions is actually older than 2005. No estimate of land use emissions is included for the petroleum emissions.

The comparison in GHG emissions is therefore based on a different time period and uses different system boundaries. The models used to calculate the petroleum emissions and biofuel emissions are different in both structure and concept. These factors all introduce great uncertainty into the analysis and make meaningful comparisons almost impossible.

The methodology employed by the EPA almost totally negates any impact of agricultural productivity and ignores fundamental shifts in product demand from conventional markets. The probability of the 2022 scenarios realistically representing actual conditions in 2022 is extremely low.

7.2 PETROLEUM BASELINE

The petroleum baseline emissions rely on the GREET model developed for the DOE by Argonne National Laboratory. While GREET has many positive features it is poorly documented and much of the data is old and in need of an update. As a result, the model will tend to underestimate emissions from processes that are in decline, such as crude oil production, and overestimate emissions from technologies that are still developing such as biofuels.

The review has estimated that GREET underestimates the emissions for the production and use of diesel fuel by about 3%. Furthermore the data presented shows that these emissions are increasing and can be expected to be significantly higher in the year 2022.

The petroleum baseline emissions do not include any emissions associated with land use change. This source of emissions has not been seriously researched and some estimates developed here suggest that for some regions of the world they may not be as low as many have suggested.

The EPA also has baseline information developed by NETL. Some aspects of this baseline are better than the GREET data, however the NETL information has deficiencies as well. A combination of the data and data sources from NETL and the use of the GREET model would provide the best baseline data (this would still not include direct or indirect land use emissions).

7.3 Domestic Agriculture Emissions

There is a large and serious error in the estimate of the domestic agricultural emissions for the production of soybeans. The FASOM model is calculating N_2O emissions from the production of nitrogen fixing crops in addition to N_2O emissions from the application of nitrogen fertilizer and the decomposition of crop residues. It is now widely accepted by most soil scientists and the IPCC that these emissions do not exist. The EPA has not calculated these emissions for soybeans grown internationally and they should not be calculated for domestic soybean production. These emissions account for about 20,000 g CO_2 eq/mm BTU, more than 20% of the lifecycle emissions of diesel fuel.

The domestic agricultural emissions are also based on very high energy consumption rates, 50% higher than those used in the GREET model and 300% higher than a recent survey of Iowa soybean producers. Because of the structure of the FASOM model it is difficult to quantify the impact of high energy consumption on the soybean biodiesel scenario. It appears that the impact will be relatively small, perhaps under 2,000 g CO_2 eq/mm BTU.

7.4 International Agricultural Emissions

The data used to estimate international agricultural emissions is very weak. Fertilizer use looks to be similar to that in the United States, after adjustment for yield, but the use of herbicides and pesticides is very low. This indicates an obvious potential to increase agricultural productivity internationally without bringing new land into production. These opportunities are not addressed in the EPA work.

The estimates of energy used for crop production internationally are extremely also weak. Even though the US data shows different energy requirements for different crops the assumptions used for international production are that within a given country all crop land requires the same amount of energy. This approach will clearly overestimate emissions attributable to soybean production.

7.5 Domestic land Use Change

The FASOM model is projecting a small reduction in GHG emissions for domestic land use from changing management practices. This is consistent with data that the EPA reports to the UN climate change program annually.

7.6 Biodiesel Production

There is another methodology error in the biodiesel production emission calculations and the process data used for the biodiesel production is higher than current industry performance and thus far above the expected performance in the year 2022.

There is no mention of the glycerine co-product and allocation of any of the emissions to that product. The use of the economic models FASOM and FAPRI, in theory, should eliminate the need for allocation of the emissions between the feed products and the biofuels. The models do not appear to have the capacity to do the same for the glycerine co-product. Using the displacement approach to allocating emissions (the same approach used by FASOM and FAPRI), there should be an emissions credit for the glycerine. On the basis that the crude glycerine from biodiesel displaces the emissions embedded in the feedstock for synthetic glycerine these emissions amount to 16,957 g CO_2 eq/mm BTU.

7.7 Transportation Emissions

The transportation emissions for feedstock and fuel are calculated from the GREET model using the model defaults. The concern here is that the feedstock transportation emissions may also be included in the FASOM emission estimates because this energy is included in farm energy. These emissions would amount to 2,615 g CO_2 eq/mm BTU and could be double counted.

7.8 Summary

The EPA projected that soybean biodiesel would have a 22% reduction in GHG emissions using a 100 year time frame and a 2% discount rate. The impacts of the two largest issues with the EPA analysis are shown in the following table using the same format as Table VI.C.1-10 in the Preamble.

Table 7-1 Biodiesel GHG Emissions – 100 Year Time Frame 2% Discount Rate

Lifecycle Stage	Petroleum Diesel	EPA Reported Soy Biodiesel	Soy Biodiesel w/o domestic N_2O emissions	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit and revised production energy
	g CO_2eq/mm BTU				
Net Domestic Agriculture (w/o land use change)		-423,206	-1,295,306	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980	-8,980
International Land Use Change		2,474,074	2,474,074	2,474,074	2,474,074
Fuel Production	749,132	838,490	838,490	107,677	43,177
Fuel and Feedstock Transport		149,258	149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169	30,169
Net Total Emissions:	4,173,768	3,255,109	2,383,009	1,652,196	1,587,696
% Change		-22.0	-42.9	-60.4	-62.0

Correcting these issues will increase the GHG emission reduction for biodiesel to over 60% even without making any changes to the indirect land use emission calculations. The impacts of the three largest quantifiable issues are summarized in the following table.

Table 7-2 Summary of the Impact of the Three Largest Direct Emissions Issues

Scenario	Emissions[3], g CO_2/mm BTU	% Reduction	Percentage Change
Petroleum Baseline	4,173,768		-
Soy Biodiesel EPA	3,255,109	22.0	-
Less nitrogen fixing crops	2,383,009	42.9	20.9
Glycerine co-product	1,652,196	60.4	17.5
Biodiesel Energy	1,587,696	62.0	1.6

The time frame and the discount rate chosen by the EPA have a significant impact on the results as shown in the following table. These results assume that the errors with respect to N_2O emissions, the glycerine co-product and the biodiesel processing energy have been corrected.

Table 7-3 Impact of Time Frame and Discount Rate

Time Frame	Discount rate	% Reduction in GHG emissions
30	0%	36.5
100	2%	62.0
100	0%	87.7

This report has also identified issues with the petroleum baseline that if addressed would increase those emissions. There are other issues raised with energy use in the soybean production cycle domestically and internationally that could increase the GHG emission reduction potential of soy biodiesel.

[3] 100 Year Time Frame, 2% discount rate.

8. REFERENCES

Agarwal. G.P. 1990. Advances in Biochemical Engineering/Biotechnology. Microbial Bioproducts. ISSN 0724-6145 (Print) 1616-8542 (Online). Volume 41/1990. DOI 10.1007/BFb0010229. http://www.springerlink.com/content/m6614tn40874x196/

Alberta Centre for Boreal Studies. The Oil and Gas Industry in Alberta: Drilling and Production. http://www.borealcentre.ca/facts/drilling.pdf

Alberta Centre for Boreal Studies. The Oil and Gas Industry in Alberta: Seismic Exploration. http://www.borealcentre.ca/facts/seismic.pdf

Argonne National Laboratory. Life-Cycle Assessment of Energy and Greenhouse Gas Effects of Soybean-Derived Biodiesel and Renewable Fuels. ANL/ESD/08-2. http://www.transportation.anl.gov/pdfs/AF/467.pdf

FAO. 2005. Forest Resources Assessment 2005. www.fao.org

Flint, L. 2005. Bitumen Recovery Technology. A Review of Long Term R&D Opportunities. http://www.ptac.org/links/dl/BitumenRecoveryTechnology.pdf

International Association of Oil & Gas Producers. 2006. Environmental performance of the E&P Industry – 2005 Data. http://www.ogp.org.uk/pubs/383.pdf

Iowa Soybean Association. 2009. CEMSA Energy Planning and Assessment Project. Soy Scenarios. Data Extraction, Analysis and Report. Prepared bu Environmental Intelligence Inc. March 2009.

IPCC. 2007. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

Northwest Upgrader. 2006. North West Upgrading Integrated Application for Approval. http://www.northwestupgrading.com/upload/media_element/40/01/north_west_upgrading_integrated_application_for_approval.pdf

Pembina Institute. 2008. Undermining the Environment: The Oil Sands Report Card. http://pubs.pembina.org/reports/OS-Undermining-data-tables.pdf

Petro Canada. 2006. Sturgeon Upgrader Application Documentation Volume 1 - Project Description. http://www.petro-canada.ca/en/about/589.aspx#Sturgeon

Reijnders, L. 2009. Are forestation, bio-char and landfilled biomass adequate offsets for the climate effects of burning fossil fuels? Energy Policy. Volume 37, Issue 8, August 2009, Pages 2839-2841. http://dx.doi.org/10.1016/j.enpol.2009.03.047

Rolf Derpsch. 2008. Area under No- tillage in different countries. http://www.rolf-derpsch.com/

Shell. 2007. Application For Approval Of The Jackpine Mine Expansion Project. http://www.shell.com/static//ca-en/downloads/about_shell/what_we_do/oil_sands/aosp/shell_web_pdfs/jpm/eia_vol3_sec3a.pdf

Shell. 2007. Scotford Upgrader 2 Project - Supplemental Information. http://www.shell.ca/home/content/ca-en/about_shell/what_we_do/oil_sands/aosp/expansion/aosp_expansion_news.html

Total E&P Canada. 2006. Greenhouse Gas Management Plan Deer Creek Energy Limited – Joslyn North Mine Project. http://www.total-ep-canada.com/joslyn/documents/application/appmenu.pdf

US Census Bureau. 2009. M311K - Fats and Oils: Production, Consumption, and Stocks. http://www.census.gov/cir/www/311/m311k.html

Yeh, S., Jordaan, S., Brandt, A., Spatari, S. 2009. Land Use Greenhouse Gas Emissions for Conventional and Unconventional Oil Production. UCD-ITS-RR-09-04. http://steps.ucdavis.edu/People/slyeh/syeh-resources/uc-lcfs/Fossil%20fuel%20land%20use%20GHG%20Extended%20Abstract.pdf

ATTACHMENT 9

LIFE CYCLE ANALYSIS DEFICIENCIES IN EPA DRAFT REPORT

Several important deficiencies in the EPA Draft Report in terms of technical life cycle analysis are observed. These include sensitivity analysis, allocation and model testing. These will be discussed in turn.

Sensitivity Analysis

It is beyond argument that the system analyzed in the EPA Draft Report is extremely complex and depends on many variables. EPA has examined some variables, but not others. These are some of the important variables that apparently have not been explored:

1. <u>Use of Standing Carbon Stock</u>

EPA is not clear on its assumptions regarding the fate of the existing carbon stock (forest or grassland) in the analysis of indirect effects. Since any productive use of the existing carbon stock (eg, pulp and paper, furniture, etc) would displace products for which GHG emissions would otherwise be generated, this is an important omission. EPA should conduct a sensitivity analysis to determine the effect on calculated indirect emissions if the existing carbon stock on the land presumably cleared because of biofuels is put to productive use. If these effects are significant, a more in depth analysis is required to determine how to account for this effect in the final report.

Also, since the different types of land converted give such different results (grassland vs. forest), EPA needs to conduct a sensitivity analysis with regard to the effects of converting forest vs. grassland on the final result. For example, if the mix of land converted is, say, 40% forest and 60% grassland, versus 60% forest and 40% grassland, how does that change the results of GHG calculations? What is the confidence level that EPA has in the actual mix of land types supposedly converted?

It is also unclear what fraction of land supposedly converted as a result of biofuel production is predicted by EPA to occur in the United States. EPA needs to be explicit about this fraction and bring it forward in their analysis. There are two reasons for this: 1) since we maintain good information on land use and land use changes, for this fraction of the predicted land use change arising from the models, we can actually test the models quite well. EPA should do this. 2) highlighting this fraction will also serve as useful data for policy makers to see how much of our indirect land use change regulation falls within our borders and is somewhat susceptible to our influence, and how much lies outside our borders and is therefore not very susceptible to US governmental influence.

2. <u>Management of Land</u>

EPA has assumed full tillage (although less than half of US corn is grown this way) and medium levels of inputs. However, it is known that different land management strategies will cause different amounts of carbon to be stored in the soil. EPA should conduct a sensitivity analysis to determine the effects of different management strategies on overall GHG emissions. No till, reduced till and conventional tillage practices, plus cover crops, should all be explored as well as the effects of climate and fertilization practices. If the effects are significant, a more in depth analysis is required to determine how to properly account for this effect in the final report.

3. Probability distribution for variables

EPA states correctly that the values chosen for important variables in the analysis of indirect effects are uncertain and subject to some distribution function. Then EPA says that since the probability distribution function is unknown, it would be more scientific not to assume a distribution function. Apparently EPA relies on point estimates for the different variables.

But this is not an adequate response and contradicts LCA principles. It also contradicts EPA's own statements in the draft report. For example, on Page 286 EPA states:

"Although there are uncertainties associated with these estimates, it would be far less scientifically credible to ignore the effects of land use changes altogether than it is to use the best approach available to assess these known emissions sources."

If this is correct, then EPA does not seem to be justified when is states on pg. 304

"While this may be the most intellectually pleasing approach in theory, there are several significant barriers to this approach. Most significantly, it is difficult to determine scientifically-defensible probability distribution functions for all (or even the most significant) input variables. Applying functions that are not well understood may serve to misstate uncertainty."

We do not understand why it is scientifically credible to use the best approach available to estimate GHG emissions (given the uncertainties in the modeling approach) on page 286 and then on page 304 to ignore the uncertainties in input variables.

It seems that a better approach, more scientific and more in keeping with LCA principles, would be to assume various distribution functions and determine the effects of these functions on the estimated GHG emissions. For example, EPA could assume Poisson distribution and normal distribution and compare the results. But it is unacceptable scientifically not to deal with the fact of uncertainty and determine its potential effects on the conclusions of the EPA study. This is especially true since the calculated indirect effect GHG emission is by far the largest factor in assessing the GHG burden of biofuels. Thus the confidence interval around this number is critical and deserves to be estimated.

4. Effect of Abandoned Land

It is well known that nearly a billion acres of abandoned land, formerly in agricultural production, exists around the world. Surely some of this land will be brought into production as a result of the mechanisms explored by EPA in their draft report and will thereby reduce the amount of virgin land supposedly cleared as a result of biofuel production. It is not clear if EPA has considered this abandoned land in their analysis. If so, it should be considered as the allocation issue becomes critical here. Any GHG release from these lands was incurred long ago for other purposes and cannot reasonably be attributed to biofuel production today.

5. Sensitivity to Allocation

A key LCA issue is how to allocate environmental burdens between different products in a multiproduct system. Both corn ethanol and soy biodiesel are multiproduct systems. EPA is not clear on how it handles the allocation between biofuels and coproducts in these systems. A separate sensitivity analysis should be done to show the effects of different allocation methods on the results. In the event these are important, EPA should solicit external input as to the most valid ways of allocating GHG emissions.

Allocation Issues

It is obvious that we use land for many purposes and that most human use of land is actually to provide feed for our livestock. EPA has interpreted EISA as requiring that all incremental land demand supposedly caused by biofuel production be assessed against biofuels. Another way of interpreting EISA is that biofuels should be assessed their fractional total of all human use of land. This would allow policy makers to weigh other human uses of land and to decide how and if to allocate GHG releases due to these other land uses. Or this analysis could also be done quite easily as a sensitivity analysis wherein the different uses of land were each assessed their appropriate weighted fractions of GHG release. For example, we could as a society decide to curtail use of some animal products so as to have more land available for biofuels. Unless these policy choices are illuminated by the appropriate analysis, however, we cannot make the choices.

Specifically regarding the modeling of the animal feeding system, it is not clear how EPA has done the carbon mass balance around the cow. It is true that cows emit methane, but that methane is supposedly from plant derived carbon. Or is it? The details of the GHG accounting and allocation for the ruminant animal system are not clear and they need to be. Likewise, the allocation of GHG burdens between soy meal and soy oil for the soy biodiesel system are not clear. Allocation is a critical issue and clarity about assumptions is needed if these are to be properly evaluated.

Baseline Comparisons

On Page 332 EPA states.

"In addition to direct N2O emissions from croplands, there are several additional sources of indirect emissions, including emissions from volatilization, leaching, crop residues, and residue burning. Some of the N applied to agricultural soils as fertilizer volatilizes, entering the atmosphere as ammonia and other oxides of nitrogen. The volatilized N subsequently returns to soils through N deposition and then contributes to N2O emissions. After fertilizer application or heavy rain, large amounts of N may leach from the soil into drainage ditches, streams, rivers and eventually estuaries. Some of this N is emitted as nitrous oxide when the leached nitrogen fertilizer undergoes the process of nitrification or denitrification. There are also N2O emissions from crop residues that are incorporated into agricultural soils. Following IPCC guidance, N2O emissions are calculated as 1% of the N from crop residues that is incorporated into the soil. FASOM

also assumes that a certain fraction of fields are burned each year, which results in N2O (and methane) emissions. These emissions are calculated using the IPCC default value, which assumes that on average 0.7% of N contained in the burned residue is emitted as N2O. In addition, methane emissions are calculated based on the average methane emissions per acre, but these emissions are typically quite small relative to the other emissions tracked in FASOM. All FASOM calculations of N2O emissions are based on IPCC guidance (See DRIA Chapter 5 for more details). "

This is a reasonable approach given EPA's mandate to consider indirect effects. But if this approach is valid for biofuels, then it is also valid for gasoline and diesel. What are the indirect GHG effects of gasoline and diesel production? It is not scientifically justified to consider indirect effects in one analysis and to ignore them in another.

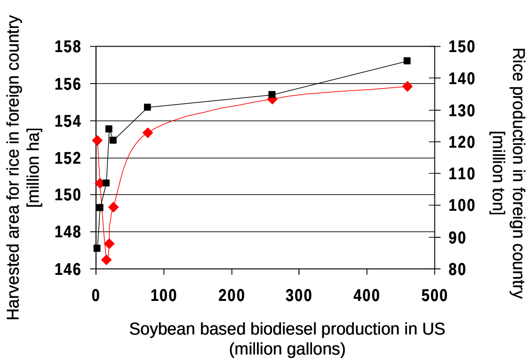
Tests of Modeling System

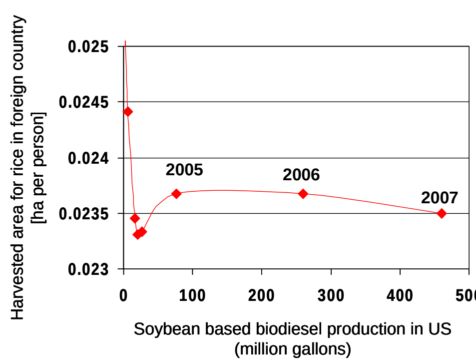
As EPA is well aware, the modeling system they have constructed is the "first of a kind". In order to have confidence in the results, especially given the critical nature of the analysis to the future of biofuels, it is important to test the model. It seems that EPA could test its modeling construct by determining if it predicts the changes actually observed in land clearing and world agriculture during the first phase of the expansion of the corn ethanol industry, for example between 2001 and 2005. If the model is able to backcast with acceptable accuracy, then we can have some confidence in its ability to forecast. If not, then the whole scientific basis for the regulation is undermined.

For example, here is one way that we have tested the model. Apparently, at least in this instance, the model is unable to backcast.

Page 282

"… the FASOM model projects that increasing the production of soy-based biodiesel will reduce domestic livestock and rice production, which reduces methane emissions from those sectors. To compensate for this decrease in domestic rice and livestock production, the FAPRI models project that foreign countries will expand their rice and livestock production."





This prediction has not actually occurred according to the figures above. Soy biodiesel production has expanded by 5 fold between 2005 and 2007, while harvested rice area per person has actually declined (in other words, factoring out increased human food demand from the overall picture).

Submitted May 26, 2009
Bruce E. Dale

ATTACHMENT 10

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

18 September 2009

PREPARED BY
IHS Global Insight

A special report by IHS Global Insight's Agriculture Group

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

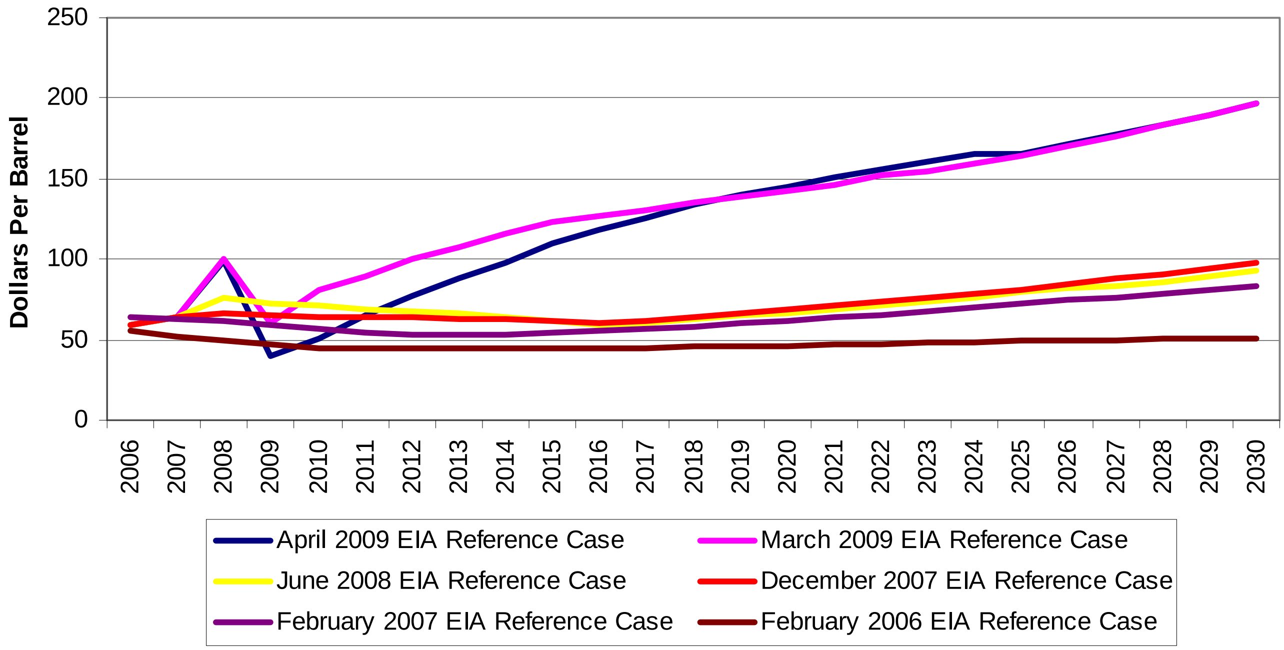


Figure 2. Crude Oil Refiners' Acquisition Price

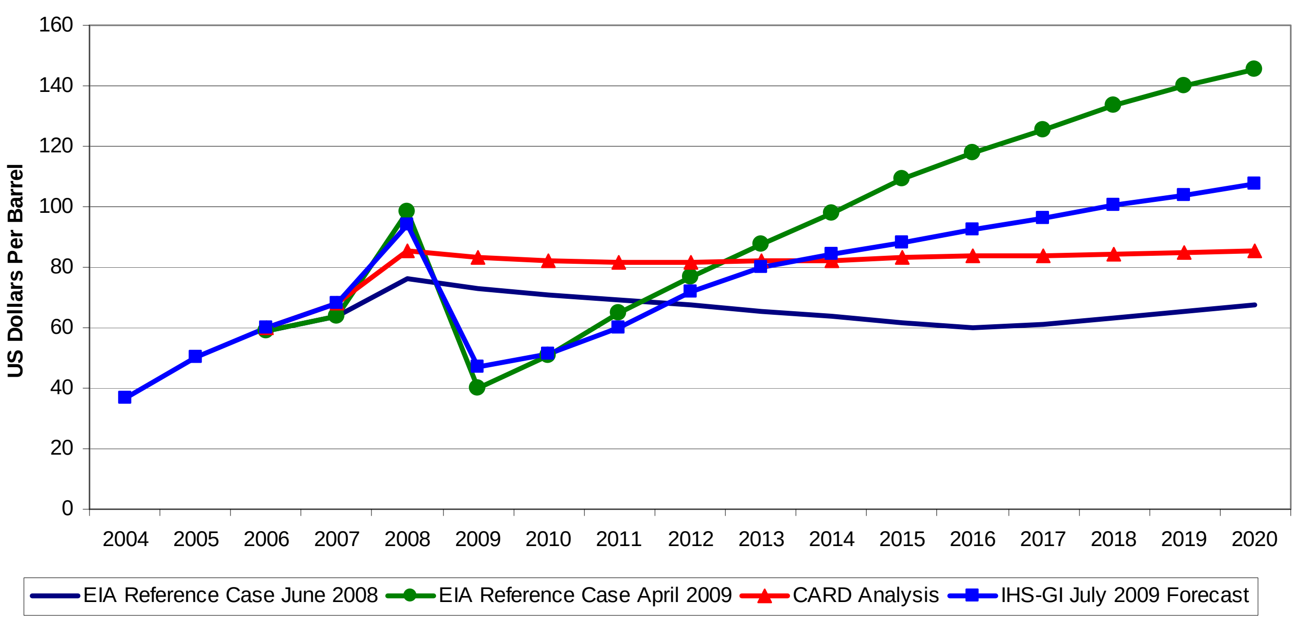


Figure 3. Daily West Texas Crude Oil Prices

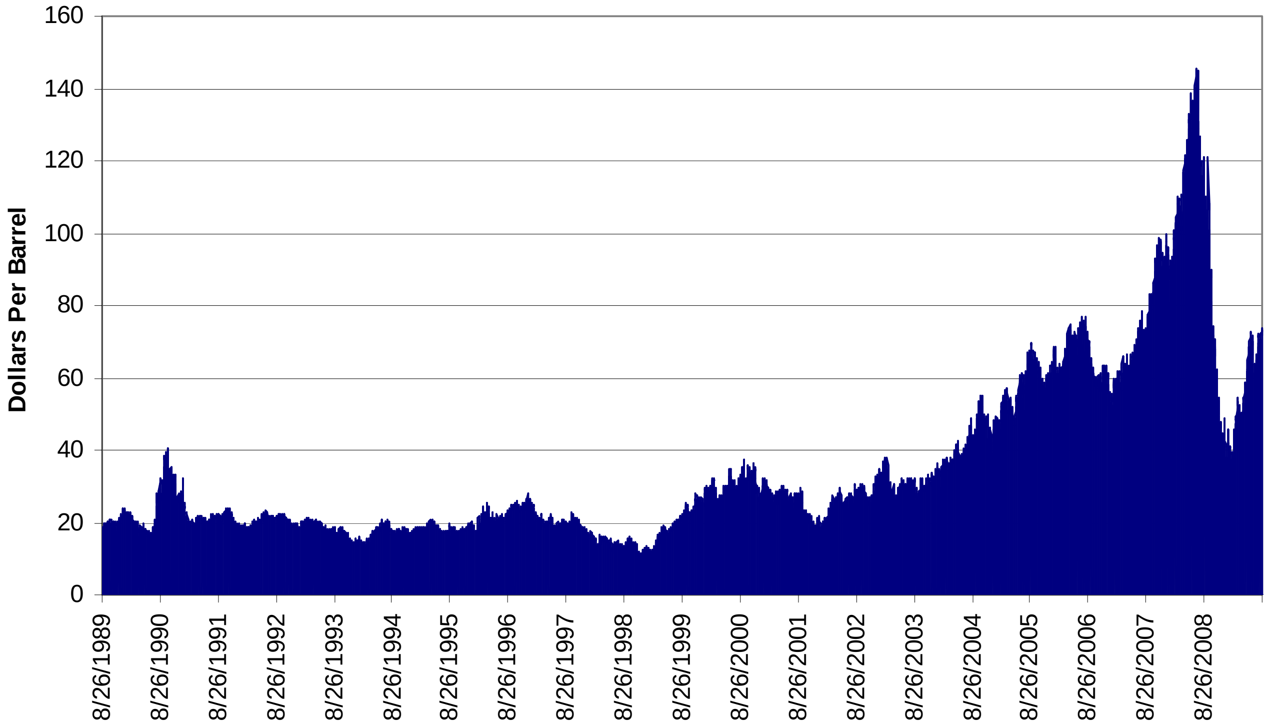


Table 1. World Oil Prices, Projected vs. Actual
(percent difference)

	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.

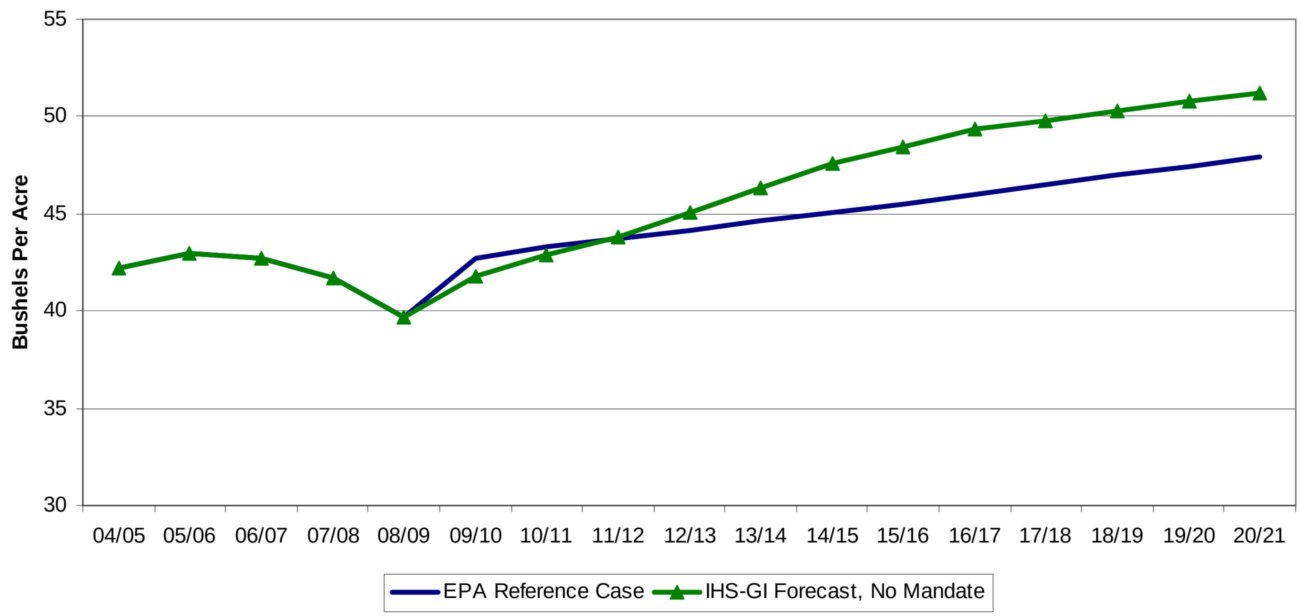
Source: "Annual Energy Outlook Retrospective Review: Evaluation of Projections in Past Editions (1982-2008)" Department of Energy, Energy Information Administration – 06403, September 2008

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:

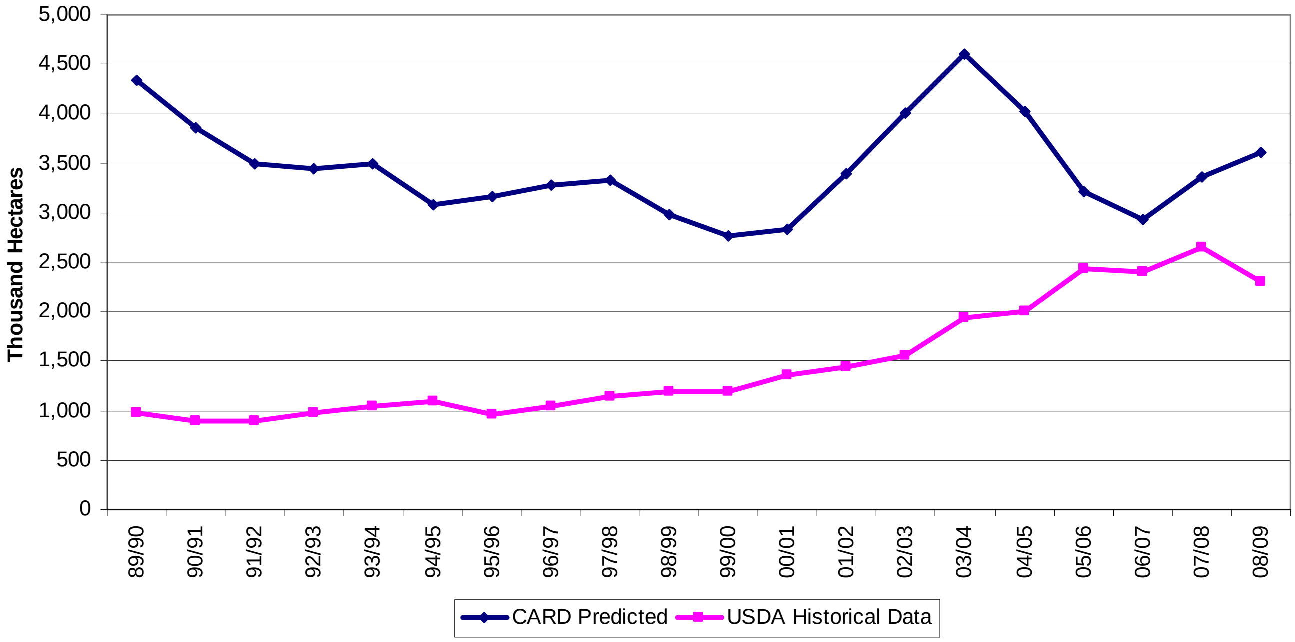
Soybean Acreage Harvested =
-4079.466
+ 4.566847*(Last Year's Soybean Price)
+28.44774*(Last Year's Wheat Price)
-34.93544*(Last Year's Corn Price)
-7153.732*(Last Year's Sugar Cane Price)
+0.28*Last Year's Soybean Area Harvested
+163.214*(YEAR-1964)

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.

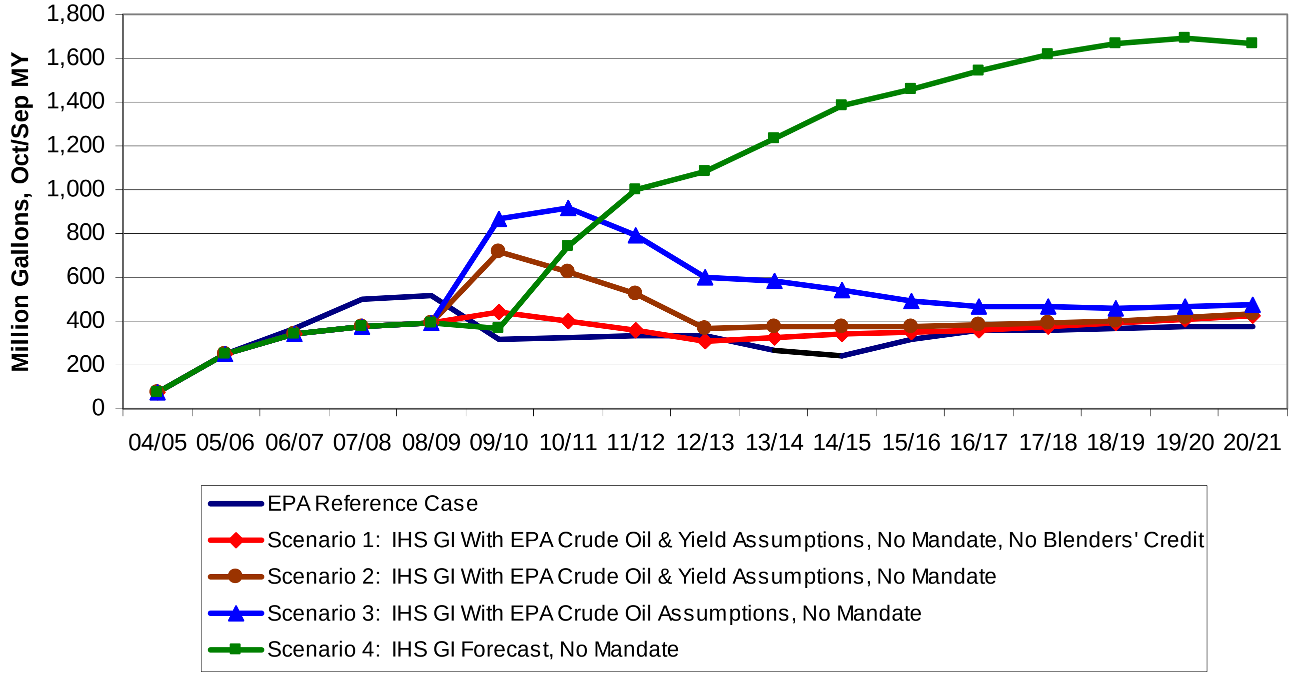
Scenario 1

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

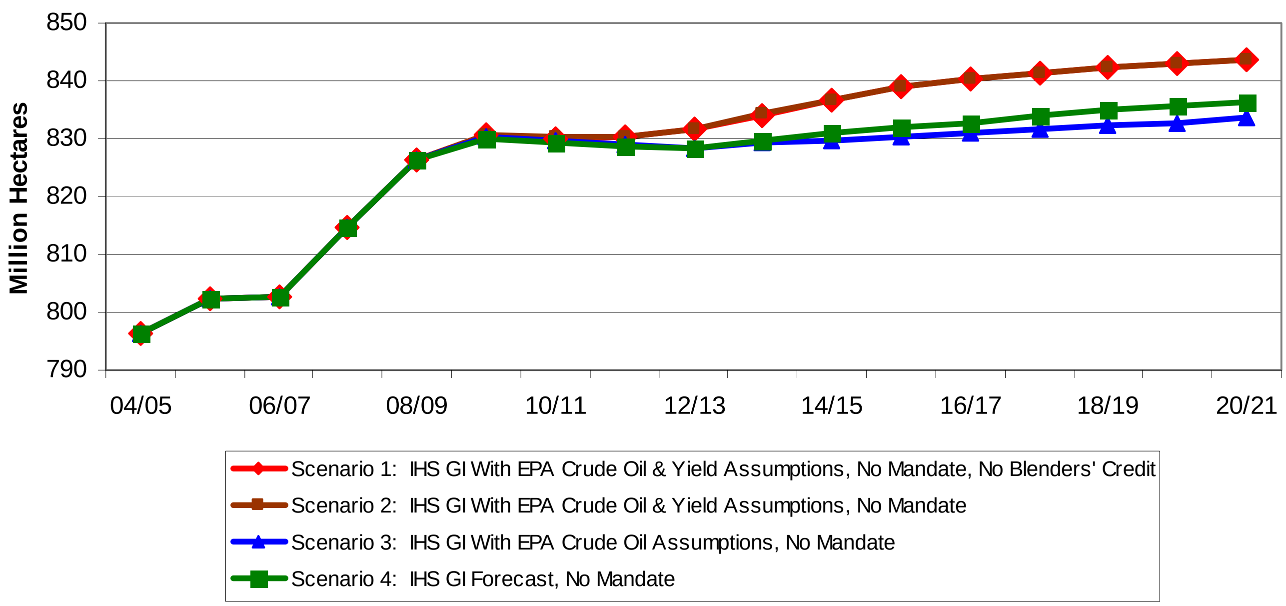
Scenario 3 builds on scenario 2 by replacing EPA's yield assumptions with the IHS Global Insight yield assumptions for corn and soybeans. The most important yield differences from EPA assumptions are in the United States and South America. Over the the 2009–11 period when EPA's crude oil price assumptions 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

ATTACHMENT 11

COMMENTS ON EPA RFS2 INDIRECT LAND USE CHANGE CALCULATIONS

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Date: September 21, 2009

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). The proposed rule intends to address changes to the Renewable Fuel Standard program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new greenhouse gas emission (GHG) thresholds for renewable fuels.

As part of proposed revisions to the National Renewable Fuel Standard program (commonly known as the RFS program), EPA analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. The Energy Independence and Security Act of 2007 (EISA) establishes new renewable fuel categories and eligibility requirements. EISA sets the first U.S. mandatory lifecycle GHG reduction thresholds for renewable fuel categories, as compared to those of average petroleum fuels used in 2005. The regulatory purpose of the lifecycle greenhouse gas emissions analysis is to determine whether renewable fuels meet the GHG thresholds for the different categories of renewable fuel.

Lifecycle GHG emissions are the aggregate quantity of GHGs related to the full fuel cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation and extraction through distribution and delivery and use of the finished fuel. The lifecycle GHG emissions of the renewable fuel are compared to the lifecycle GHG emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005.

EISA defines lifecycle GHG emissions as follows:

> *The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential.*

This work reviews, comments and provides alternative data on the indirect land use analysis of the soybean biodiesel pathway. In addition to the information that is provided in the Preamble, the Rule and the Draft Regulatory Impact Analysis (DRIA) it relies on the supplemental information that is included in the EPA docket.

The concept of life-cycle assessment emerged in the late 1980's from competition among manufacturers attempting to persuade users about the superiority of one product choice over another. As more comparative studies were released with conflicting claims, it became evident that different approaches were being taken related to the key elements in the LCA analysis:

- boundary conditions (the "reach" or "extent" of the product system);
- data sources (actual vs. modeled); and
- definition of the functional unit.

In order to address these issues and to standardize LCA methodologies and streamline the international marketplace, the International Standards Organization (ISO) has developed a series of international LCA standards and technical reports under its ISO 14000 Environmental Management series.

The approach taken by the EPA in their analysis of the GHG emissions of biofuels broadly follows the guidance of the ISO standards but there are several deviations that do create some concern.

The first is that many of the models employed by the EPA are complex economic models which compromises the scientific approach to undertaking LCA work. Since ISO established their standards, there has been a growing body of work that has incorporated economic approaches to help understand some of the more complex issues such as valuing co-products and trying to predict what future systems may look like. There are advantages and disadvantages to this type of analysis. These economic models tend to have less transparency (another fundamental ISO principle), the economic models usually cannot be validated since they are estimates of future scenarios, and there is a far greater likelihood that two models will produce vastly different outputs. All of these points are true with the EPA body of work.

The very nature of indirect emissions, the impact of a possible future change, means that they cannot be measured, only estimated for an assumed scenario; since the future cannot be predicted with any certainty.

All models have some basic underlying assumptions that allow them to undertake their calculations. Looking at the US EPA estimates for indirect land use emissions it is important to understand the modelling framework and the assumptions that have been made to arrive at the estimates. The EPA basically use a two step process, first estimate the quantity of new land required to meet an increase in feedstock demand (FASOM and FAPRI models), and then determine the changes in carbon resulting from this land use change (Winrock estimates). However, there are at least three fundamental assumptions, although these have not been explicitly stated, that have been made prior to the actual modeling exercise, that are important to understand. These are:

1. All agricultural systems throughout the world are operating at maximum capacity.
2. The supply and demand for all agricultural products is in balance.
3. Any future increases in supply will equal the increase in demand from existing product users.

The first assumption means that all essentially new production must require new land. The second assumption is required because the models that are being used are econometric models that require systems to be in equilibrium in order to function. The third assumption is required because the models do not have a time dimension to them, they are incapable of considering how the systems change in one year or ten years.

Of course models that predict what might happen in the future are based on what has happened in the past and so that these kinds of models must also assume that these complex systems will behave exactly the same way in the future as they have in the past.

The modelling framework employed by the EPA is conceptually correct but the individual models that have been employed to generate the indirect emissions have serious deficiencies.

1. The implied assumption that new demand can only be met with increased land is not a credible assumption given divergence in agricultural productivity that is seen throughout the world.

2. The FAPRI model results indicate that a 0.052% increase in land is required to meet the biodiesel scenario. This is over a period of about 15 years and one needs to question whether the model capabilities, algorithms, and input data are capable of making such long term projections this accurately.
3. The land cover data that is used to estimate the types of land that would be converted to agricultural land has too low an accuracy to be used for the purpose that EPA has used it for. The implied assumption that there is no "supply curve" for new agricultural land is not credible. No other complex system behaves in the simplistic way that EPA suggests international land use change occurs. The assumption that the EPA has made regarding the need to replace grassland converted to crops is not based on any information that suggests that pasture systems throughout the world are operating at capacity.
4. The assumption on the wood products harvest intensity rate used by the EPA is far too low. The available data suggests that the rate should be at least 4 to 5 times higher when sustainable forest management practices are used and even higher when the land is clear cut, as it would be to prepare for crop production. The impact of the HWP becomes much more significant when reasonable harvest rate are use.
5. The EPA has not considered the fact that living forest sometimes die prematurely from natural disturbances and natural mortality within a stand. The carbon losses that have been charged to land use conversion statistically would have happened eventually. The only impact of the carbon losses is therefore when it happens. The IPCC recommends including carbon losses from disturbances in their guidance documents and there is some information on global disturbances available from the FAO. Including an allowance for this future carbon loss offsets the lost sequestration and a significant portion of the original carbon loss, depending on the time horizon considered.
6. There are enough issues identified with the calculations of the indirect emissions from land use change that significantly more effort is required by the EPA to produce a sound, science based estimate of any indirect impacts from an increase in demand for soybeans.

In the following table the impact of some of the assumptions that EPA have made in their analysis is evaluated using alternative reasonable assumptions. The lack of consideration of the permanence of the living forests in the EPA calculations is a significant factor in determining the indirect emissions of biofuels.

Table ES- 1 Impact of Assumptions on Biodiesel Lifecycle Emissions

Lifecycle Stage	Petroleum Diesel	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit and biodiesel processing energy	Soy Biodiesel w/o savanna and grassland replacement	Soy Biodiesel w/o savanna and grassland replacement with HWP	Soy Biodiesel w/o savanna and grassland replacement and including natural disturbances
	g CO_2eq/mm BTU				
Net Domestic Agriculture (w/o land use change)		-1,295,306	-1,295,306	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980	-8,980
International Land Use Change		2,474,074	1,887,397	1,736,405	919,118
Fuel Production	749,132	43,177	43,177	43,177	43,177
Fuel and Feedstock Transport		149,258	149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169	30,169
Net Total Emissions:	4,173,768	1,587,696	1,001,019	850,027	32,740
% Change		-62.0	-76.0	-79.6	-99.2

In the following table the impact of all of the changes that are recommended for the direct and indirect emissions for soybean biodiesel are shown.

Table ES- 2 Summary of the Impact of the Impact of the Largest Issues

Scenarios (Cumulative)	Emissions[1], g CO_2/mm BTU	% Reduction from Diesel	Percentage Change
Petroleum Baseline	4,173,768		-
Soy Biodiesel EPA	3,255,109	22.0	-
Less nitrogen fixing crops	2,383,009	42.9	20.9
Glycerine co-product	1,652,196	60.4	17.5
Biodiesel Energy	1,587,696	62.0	1.6
No Pasture Replacement	1,001,019	76.0	14.0
HWP rate	850,027	79.6	3.6
Natural Disturbances	32,740	99.2	19.6

It can be seen that there are as many issues with the EPA indirect analysis as there are for the direct analysis. Significantly more effort is required by the EPA to produce a sound, science based estimate of any indirect impacts from an increase in demand for soybeans.

[1] 100 Year Time Frame, 2% discount rate.

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1. INTRODUCTION

The U.S. Environmental Protection Agency is proposing revisions to the National Renewable Fuel Standard program (commonly known as the RFS program). The proposed rule intends to address changes to the Renewable Fuel Standard program as required by the Energy Independence and Security Act of 2007 (EISA). The revised statutory requirements establish new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year. The revised statutory requirements also include new definitions and criteria for both renewable fuels and the feedstocks used to produce them, including new greenhouse gas emission (GHG) thresholds for renewable fuels. The regulatory requirements for RFS will apply to domestic and foreign producers and importers of renewable fuel.

EISA established new renewable fuel categories and eligibility requirements, including setting the first ever mandatory GHG reduction thresholds for the various categories of fuels. For each renewable fuel pathway, GHG emissions are evaluated over the full lifecycle, including production and transport of the feedstock; land use change; production, distribution, and blending of the renewable fuel; and end use of the renewable fuel. The GHG emissions are then compared to the lifecycle emissions of 2005 petroleum baseline fuels (base year established as 2005 by EISA) displaced by the renewable fuel, such as gasoline or diesel.

As part of proposed revisions to the National Renewable Fuel Standard program (commonly known as the RFS program), EPA analyzed lifecycle greenhouse gas (GHG) emissions from increased renewable fuels use. The Energy Independence and Security Act of 2007 (EISA) establishes new renewable fuel categories and eligibility requirements. EISA sets the first U.S. mandatory lifecycle GHG reduction thresholds for renewable fuel categories, as compared to those of average petroleum fuels used in 2005. The regulatory purpose of the lifecycle greenhouse gas emissions analysis is to determine whether renewable fuels meet the GHG thresholds for the different categories of renewable fuel.

Lifecycle GHG emissions are the aggregate quantity of GHGs related to the full fuel cycle, including all stages of fuel and feedstock production and distribution, from feedstock generation and extraction through distribution and delivery and use of the finished fuel. The lifecycle GHG emissions of the renewable fuel are compared to the lifecycle GHG emissions for gasoline or diesel (whichever is being replaced by the renewable fuel) sold or distributed as transportation fuel in 2005.

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1.1 SCOPE OF WORK

This work reviews, comments and provides alternative data on the indirect land use analysis of the soybean biodiesel pathway. In addition to the information that is provided in the

Preamble, the Rule and the Draft Regulatory Impact Analysis (DRIA) it relies on the supplemental information that is included in the EPA docket.

1.2 Lifecycle Analysis

The concept of life-cycle assessment emerged in the late 1980's from competition among manufacturers attempting to persuade users about the superiority of one product choice over another. As more comparative studies were released with conflicting claims, it became evident that different approaches were being taken related to the key elements in the LCA analysis:

- boundary conditions (the "reach" or "extent" of the product system);
- data sources (actual vs. modeled); and
- definition of the functional unit.

In order to address these issues and to standardize LCA methodologies and streamline the international marketplace, the International Standards Organization (ISO) has developed a series of international LCA standards and technical reports under its ISO 14000 Environmental Management series. In 1997-2000, ISO developed a set of four standards that established the principles and framework for LCA (ISO 14040:1997) and the requirements for the different phases of LCA (ISO 14041-14043).

By 2006, these LCA standards were consolidated and replaced by two current standards: one for LCA principles (ISO 14040:2006); and one for LCA requirements and guidelines (ISO 14044:2006).

The ISO 14040:2006 standard describes the principles and framework for life cycle assessment including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA. The intended application of LCA or LCI results is considered during definition of the goal and scope, but the application itself is outside the scope of this International Standard.

It is useful to consider seven basic principles in the design and development of life cycle assessments as a measure of environmental performance. The seven principles outlined below are the basis of ISO Standard 14040:2006:

- Life Cycle Perspective (the entire stages of a product or service);
- Environmental Focus (addresses environmental aspects);
- Relative Approach and Functional Unit (analysis is relative to a functional unit);
- Iterative Approach (phased approach with continuous improvement)
- Transparency (clarity is key to properly interpret results)
- Comprehensiveness (considers all attributes and aspects)
- Priority of Scientific Approach (preference for scientific-based decisions)

1.2.1 Life Cycle Perspective

LCA considers the entire life cycle stages of a product or service, including: extraction and acquisition of all relevant raw materials, energy inputs and outputs, material production and manufacturing, use or delivery, end-of-life treatment, and disposal or recovery. This systematic overview of the product “system” provides perspective on the potential differences in environmental burden between life cycle stages or individual processes.

1.2.2 Environmental Focus

The primary focus of a LCA is on the environmental aspects and impacts of a product system. Environmental aspects are elements of an activity, product, or service that cause or can cause an environmental impact through interaction with the environment. Some examples of environmental aspects are: air emissions, water consumption, releases to water, land contamination, and use of natural resources. Economic and social aspects are typically outside the scope of an LCA, although it is possible to model some of these elements. Other tools may be combined with LCA for more extensive analysis.

1.2.3 Relative Approach and Functional Unit

LCA is a relative analytical approach, which is structured on the basis of a functional unit of product or service. The functional unit defines what is being studied and the life cycle inventory (LCI) is developed relative to one functional unit. An example of a functional unit is a light-duty gasoline vehicle driving an average distance (with other details of time, geography, trip characteristics, and potential fuels added). All subsequent analyses are then developed relative to that functional unit since all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit.

An LCA does not attempt to develop an absolute inventory of environmental aspects (e.g. air emissions inventory) integrated over an organizational unit, such as a nation, region, sector, or technology group.

1.2.4 Iterative Approach

LCA is an iterative analytical approach. The individual phases of an LCA (Goal and Scope Definition; Inventory Analysis; Impact Assessment; and Interpretation) are all influenced by, and use the results from, the other phases. The iterative approach within and between phases contributes to a more comprehensive analysis and higher quality results.

1.2.5 Transparency

The value of an LCA depends on the degree of transparency provided in the analysis (for example: the system description, data sources, assumptions and key decisions). The principle of transparency allows users to understand the inherent uncertainty is the analysis and properly interpret the results.

1.2.6 Comprehensiveness

A well-designed LCA considers all stages of the product system (the “reach”) and all attributes or aspects of the natural environment, human health, and resources. Tradeoffs between alternative product system stages and between environmental aspects in different media can be identified and assessed.

1.2.7 Priority of Scientific Approach

It is preferable to make decisions from an LCA analysis based on technical or science reasoning, rather than from social or economic sciences. Where scientific approaches cannot be established, consensual international agreement (e.g. international conventions) can be used. The power of the technical or scientific approach lies in the proper attribution of facts to sources and the potential reproducibility of these facts under scientific conditions. While the scientific approach is typically more objective than economic or social values, it does not preclude the use economic or social values for informing LCA decisions.

1.3 THE EPA APPROACH

The approach taken by the EPA in their analysis of the GHG emissions of biofuels broadly follows the guidance of the ISO standards but there are several deviations that do create some concern.

The first is that many of the models employed by the EPA, particularly those that are the foundation of the indirect land use estimates, are complex economic models which compromises the scientific approach to undertaking LCA work. Since ISO established their standards, there has been a growing body of work that has incorporated economic approaches to help understand some of the more complex issues such as valuing co-products and trying to predict what future systems may look like. There are advantages and disadvantages to this type of analysis. These economic models tend to have less transparency (another fundamental ISO principle), the economic models usually cannot be validated since they are estimates of future scenarios, and there is a far greater likelihood that two models will produce vastly different outputs. All of these points are true with the EPA body of work.

The reporting of the EPA on their methodology and findings also lacks full transparency. Some of the models used by the EPA cannot be run by independent groups wishing to verify the results but the EPA has provided a considerable amount of detail on the output from these models.

There are issues with the relative approach employed by the EPA. They are comparing the GHG emissions of petroleum fuels, nominally in the year 2005, to the difference between two future scenarios in 2022. Not only are the time periods of comparison different, but also the system boundaries are very different. This is a fundamental breach of the ISO principles.

2. INDIRECT LAND USE

The indirect land use emissions for soybean biodiesel represent 76 to 82% of the lifecycle GHG emissions according to the EPA, depending on the time horizon chosen and the discounting applied to future emission benefits. However, the EPA has acknowledged that there are issues with the direct emission calculations for soybean biodiesel; the N_2O emissions from soybean production are overstated, and that no consideration has been given to the emissions avoided by the production of the glycerine co-product. If these two factors are corrected, and other data issues resolved then the emissions for soybean biodiesel are summarized and compared in the following table using a 100 year time frame and a 2% discount rate.

Table 2-1 Summary of Original and Corrected Soybean Biodiesel GHG Emissions

Lifecycle Stage	Petroleum Diesel	EPA Reported Soy Biodiesel	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit and revised processing energy
	g CO_2eq/mm BTU		
Net Domestic Agriculture (w/o land use change)		-423,206	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304
Domestic Land Use Change		-8,980	-8,980
International Land Use Change		2,474,074	2,474,074
Fuel Production	749,132	838,490	43,177
Fuel and Feedstock Transport		149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169
Net Total Emissions:	4,173,768	3,255,109	1,587,696
% Change		-22.0	-62.0

When the EPA errors are corrected, soybean biodiesel GHG emissions without the indirect land use emissions are negative and the indirect land use emissions account for over 100% of the total emissions. In this case, the FASOM model, used for the domestic agricultural emissions, has allocated all of the emissions to soybean meal, the model essentially recognizes that soybeans are primarily grown for their protein content and that the soybean oil is effectively a co-product.

In this section the calculations that are made to arrive at the indirect land use calculations are examined in detail.

2.1 THE UNDERLYING ASSUMPTIONS

The very nature of indirect emissions, the impact of a possible future change, means that they cannot be measured, only estimated for an assumed scenario; since the future cannot be predicted with any certainty.

All models have some basic underlying assumptions that allow them to undertake their calculations. Looking at the US EPA estimates for indirect land use emissions it is important to understand the modelling framework and the assumptions that have been made to arrive at the estimates. The EPA basically use a two step process, first estimate the quantity of new land required to meet an increase in feedstock demand (FASOM and FAPRI models), and then determine the changes in carbon resulting from this land use change (Winrock estimates). However, there are at least three fundamental assumptions, although these have not been explicitly stated, that have been made prior to the actual modeling exercise, that are important to understand. These are:

1. All agricultural systems throughout the world are operating at maximum capacity.
2. The supply and demand for all agricultural products is in balance.
3. Any future increases in supply will equal the increase in demand from existing product users.

The first assumption means that all essentially new production must require new land. The second assumption is required because the models that are being used are econometric models that require systems to be in equilibrium in order to function. The third assumption is required because the models do not have a time dimension to them, they are incapable of considering how the systems change in one year or ten years.

Of course models that predict what might happen in the future are based on what has happened in the past and so that these kinds of models must also assume that these complex systems will behave exactly the same way in the future as they have in the past.

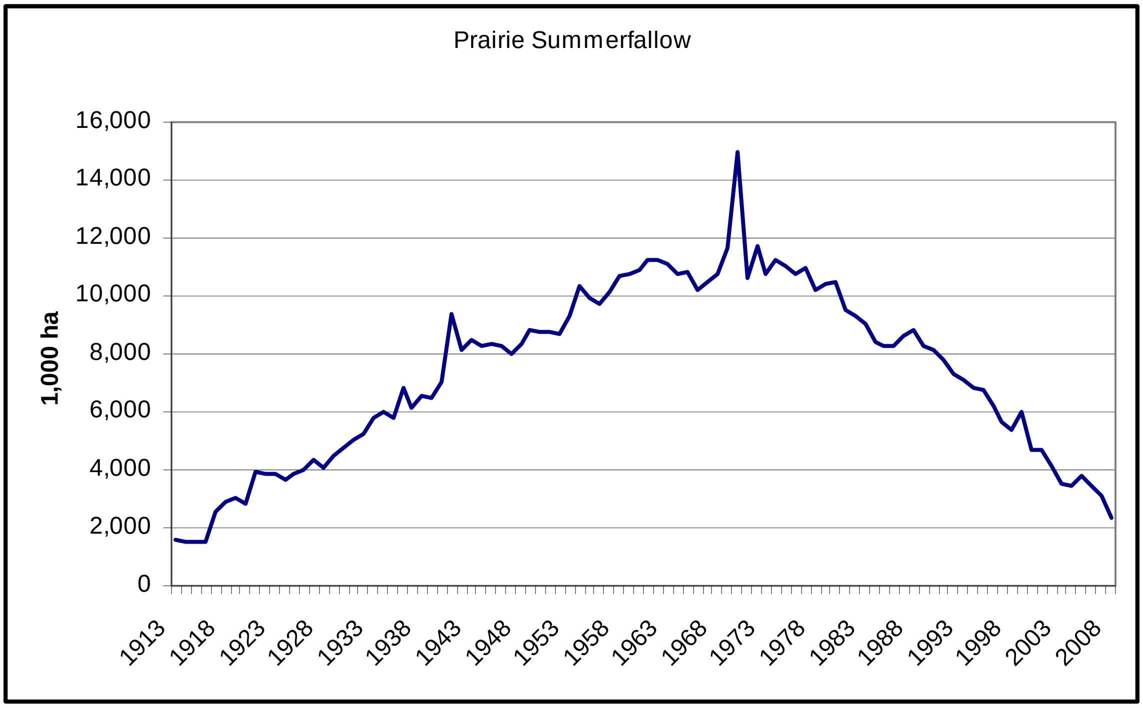
In reality, none of these three fundamental assumptions are valid. Each of the three fundamental assumptions is considered below.

2.1.1 World Agricultural System Productivity

World agricultural productivity is not maximized, significant amounts of agricultural land throughout the world are in summerfallow, land that is deliberately taken out of production for a year. Summerfallow has the benefit of conserving soil moisture, controlling weeds, and freeing some available nitrogen (at the expense of GHG emissions) but other management practices such as no till agriculture can provide some of the same benefits and this practice is slowly declining in many countries.

Canada is the closest trading partner to the United States and western Canada still has significant summerfallow area. This are has been dropping but it will be many years before the practice is eliminated as shown in the following figure.

Figure 2-1 Canadian Summerfallow Area



Two million hectares (~5 million acres) of idle agricultural land in Canada is about equal to the land use changes projected by the EPA for the corn only case (4.4 million acres) and the soybean biodiesel case (880,000 foreign acres). Many more countries have significant areas of fallow land as will be shown later in the analysis.

Fallow land statistics are not kept for all countries so it is difficult to get an accurate picture of the quantity of this resource. The FAO statistical database reports fallow land for a number of countries as shown in the following table. Only though countries that reported data for 2005 of more than 500,000 ha are shown in the table. The FAO database shows only a single year of data for the US (2002).

Table 2-2 FAO Fallow Land Statistics

Country	Fallow land, 1,000 ha
India	24,176
Indonesia	11,342
Pakistan	6,680
Turkey	4,876
Iran, Islamic Republic of	4,507
Sudan	4,269
Canada	4,087
Algeria	3,590
Spain	3,500
Ukraine	2,428
Morocco	1,854
Bolivia	1,648
Ethiopia	1,398
France	1,300
Nicaragua	1,196
Cuba	1,106
Poland	1,029
Tunisia	913
Germany	794
Colombia	774
Syrian Arab Republic	690
Romania	517
Other Countries	6,408
Total	89,082

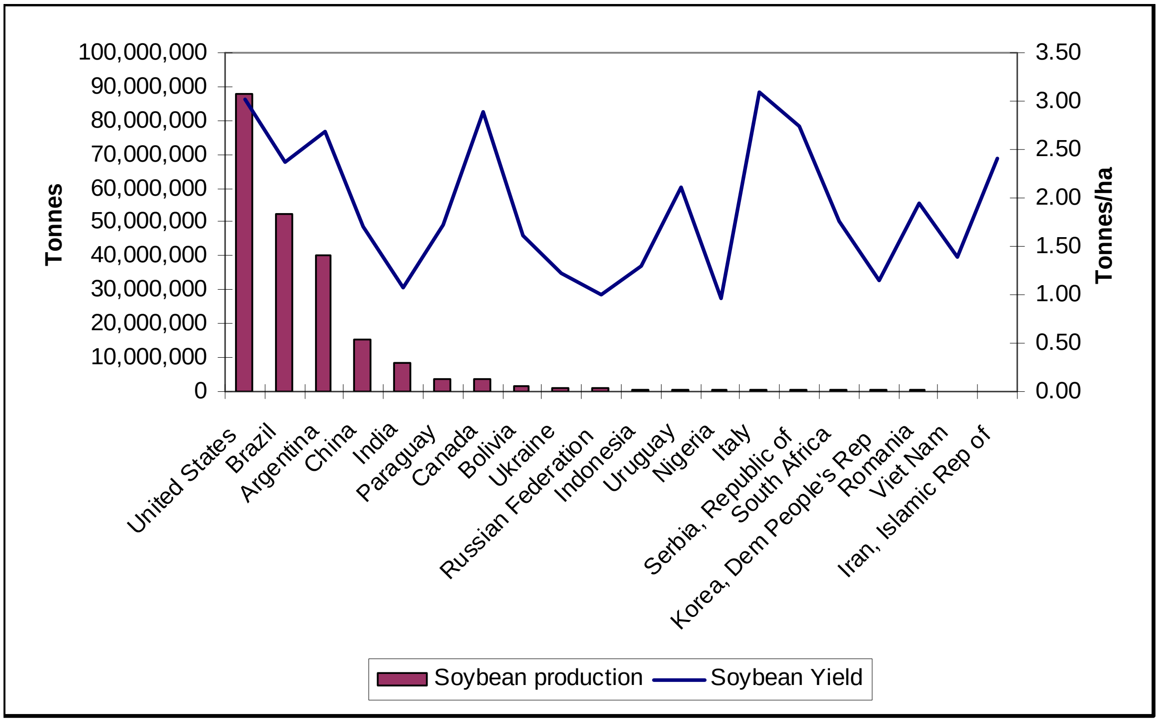
Clearly there is additional agricultural land that can be brought into production without converting forest land or grassland to agriculture.

The second aspect of operating at maximum capacity is that many countries are not as developed as they are in the United States and increased fertilizer, better machinery, or different agronomic practices would increase crop yields without bringing new land into production. Changes in production practices in response to the higher prices (the markets response to increased demand) are at least as plausible a future outcome as increasing the amount of land farmed. In fact, it is probably a more likely scenario as most “systems” look to employing more capital (land, in this case) as a last resource.

The impact of the various components of agricultural productivity have been studied by academics over the past several decades but from a different perspective, looking at the drivers of agricultural productivity in developing countries (Fulginiti, 1998). The Fulginiti paper concluded that changes in land was responsible for about 5% of the change in productivity, with fertilizer and machinery use dominating the impact on productivity.

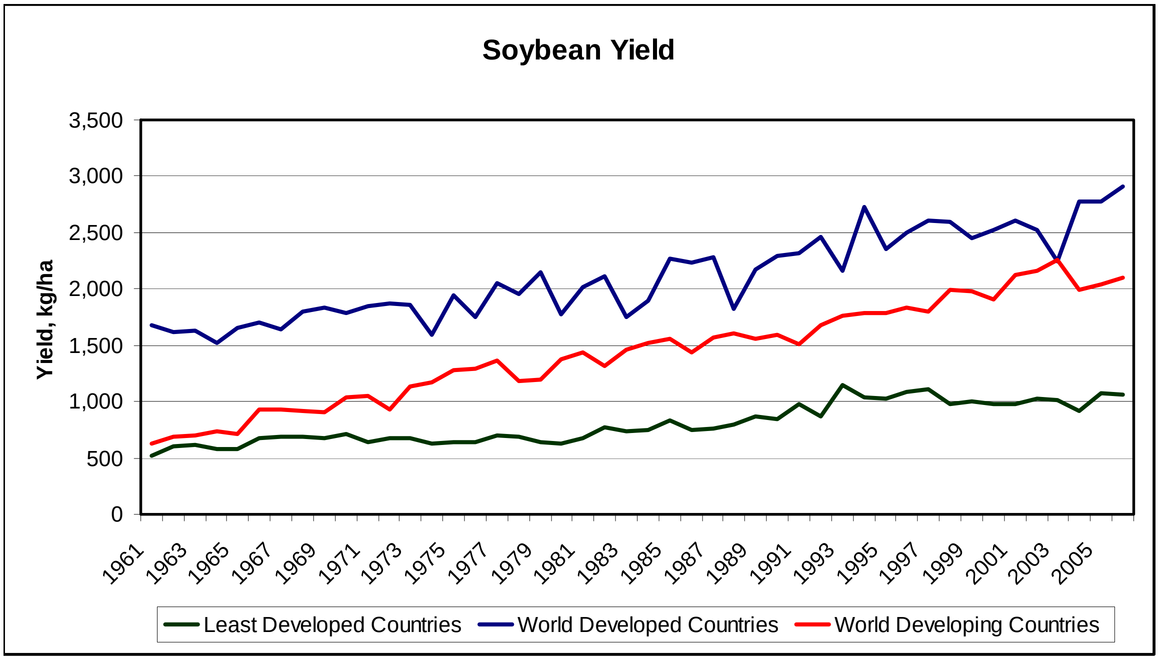
The opportunity for increased yields is shown in the following figure, where the 2006 soybean yields (FAO database) for the top producing countries in the world are shown.

Figure 2-2 World Soybean Production and Yield



This huge variation in the 2006 data is not a function of the weather as the same kind of pattern is apparent when yields over time are considered. In the following figure the yield trends for soybeans for the developed world, the developing world and the least developed countries are shown (FAO database). It is clear that there is significant opportunity to increase crop yields without increasing the land base.

Figure 2-3 Soybean Trends Over Time



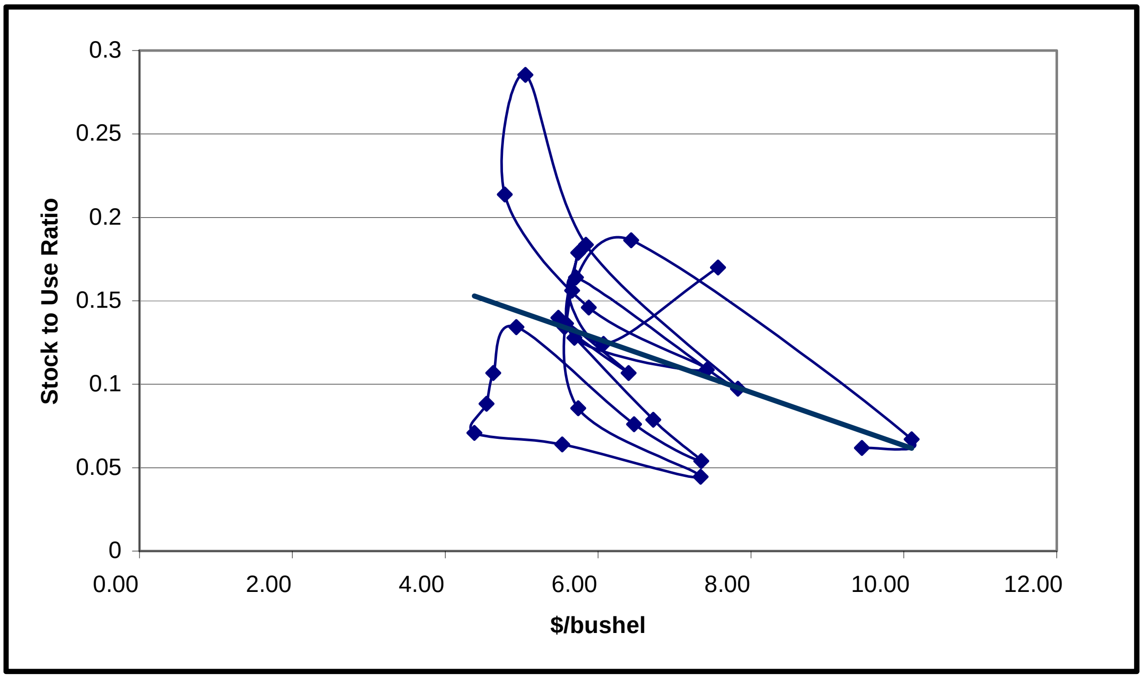
In summary, the available data does not support the assumption that the world agricultural system is operating at capacity and that new demand can only be supplied by production from new land. The GTAP model used by California does have elasticity factors for yield response to increased production, so other models recognize the concept that factors other than land availability play a role. The problem is that there is little data available to provide guidance to what the yield response is to increasing prices.

2.1.2 Supply and Demand Equilibrium

The implications of the assumption that supply and demand in general are in equilibrium is less of a problem over time as it is in a single year, but since the models that are used do not really have a time dimension to them it is troublesome.

The volatility seen in agricultural markets is an indication of the lack of equilibrium in these markets. In the following figure, the relationship between stocks to use ratio at year end to the average price of soybeans are shown. Perfect markets would find that the values all fall on or close to the trend line. The large degree of scatter seen in this diagram is indicative of a very complex market influenced by much more than just the supply and demand fundamentals.

Figure 2-4 Soybean Price vs. Stocks to Use Ratio

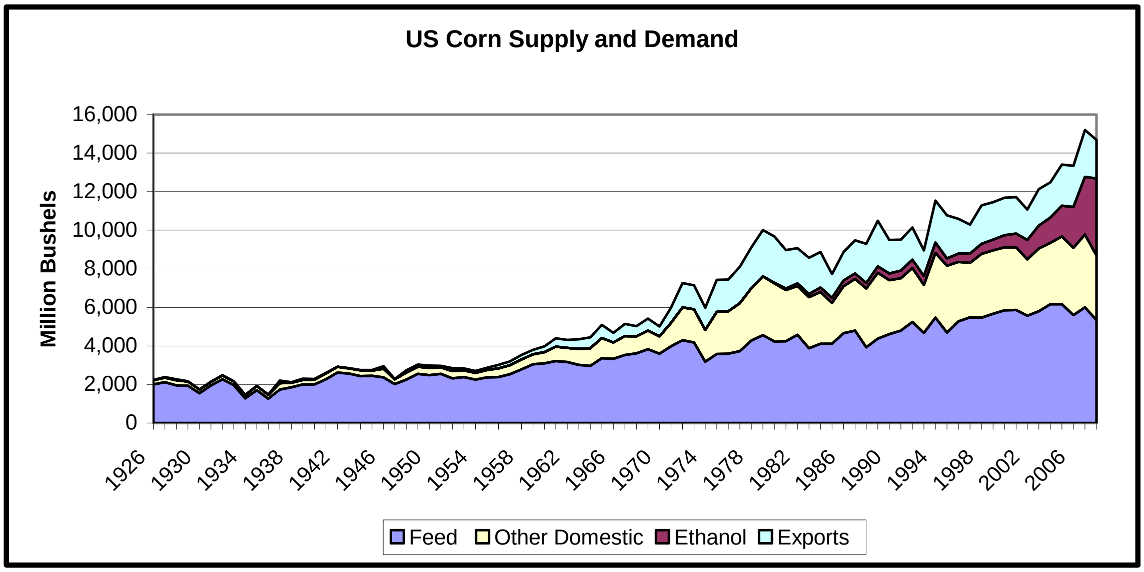


It must also be recognized that agricultural markets are heavily influenced by government policies and financial support systems through the world. For more than 20 years the governments of OECD member states have been providing over $250 billion per year in direct payments to producers. While some progress has been made on reducing these payments on a percentage basis of the crops produced, the increase in production has kept the level of support payments high. These payments distort the international market response to changes in supply and demand and create further issues for models that rely on the operation of a rational market.

2.1.3 Increases in Supply are Absorbed by Traditional Markets

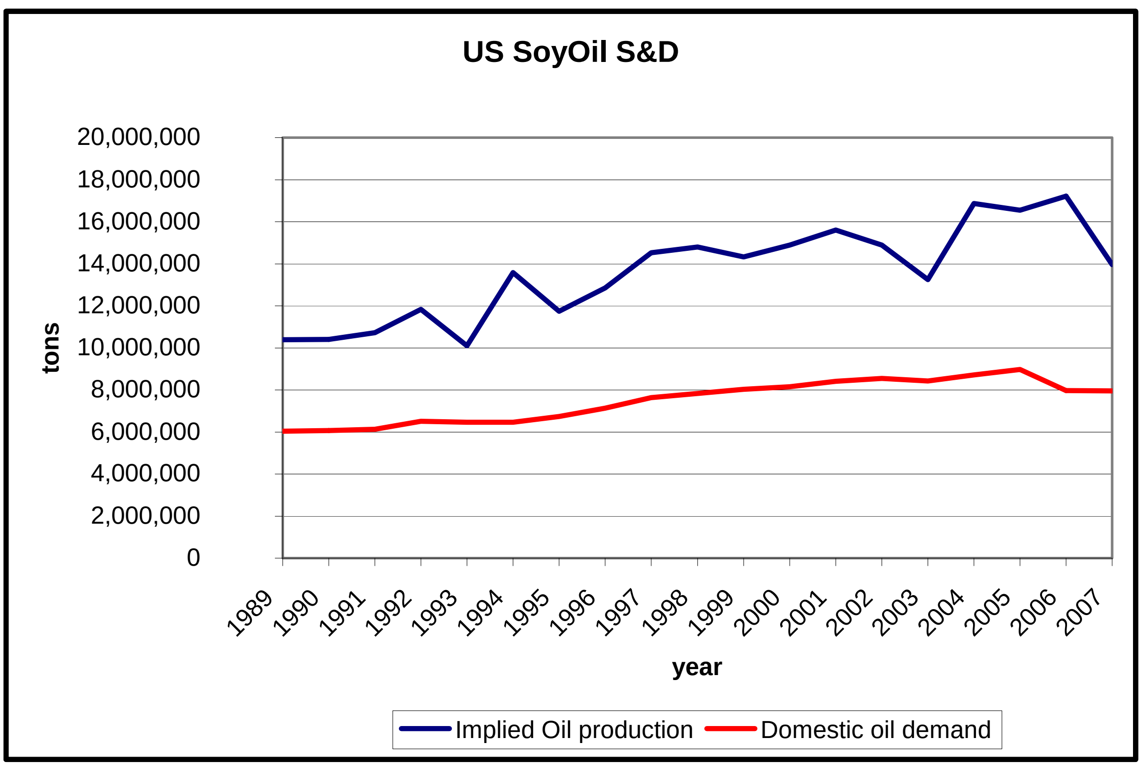
The problem with the third basic assumption, that demand from traditional applications is increasing at the same rate as the supply, is apparent in the following figure of US corn supply and disposition. Demand for feed and food has been flat for many years while the supply continued to increase. The use of corn for ethanol production is the only factor that has stopped the world from being flooded with subsidized US corn. An increase in the US exports of subsidized corn would cause further distress for local agricultural producers in many developing countries.

Figure 2-5 Long Term Corn Supply and Demand



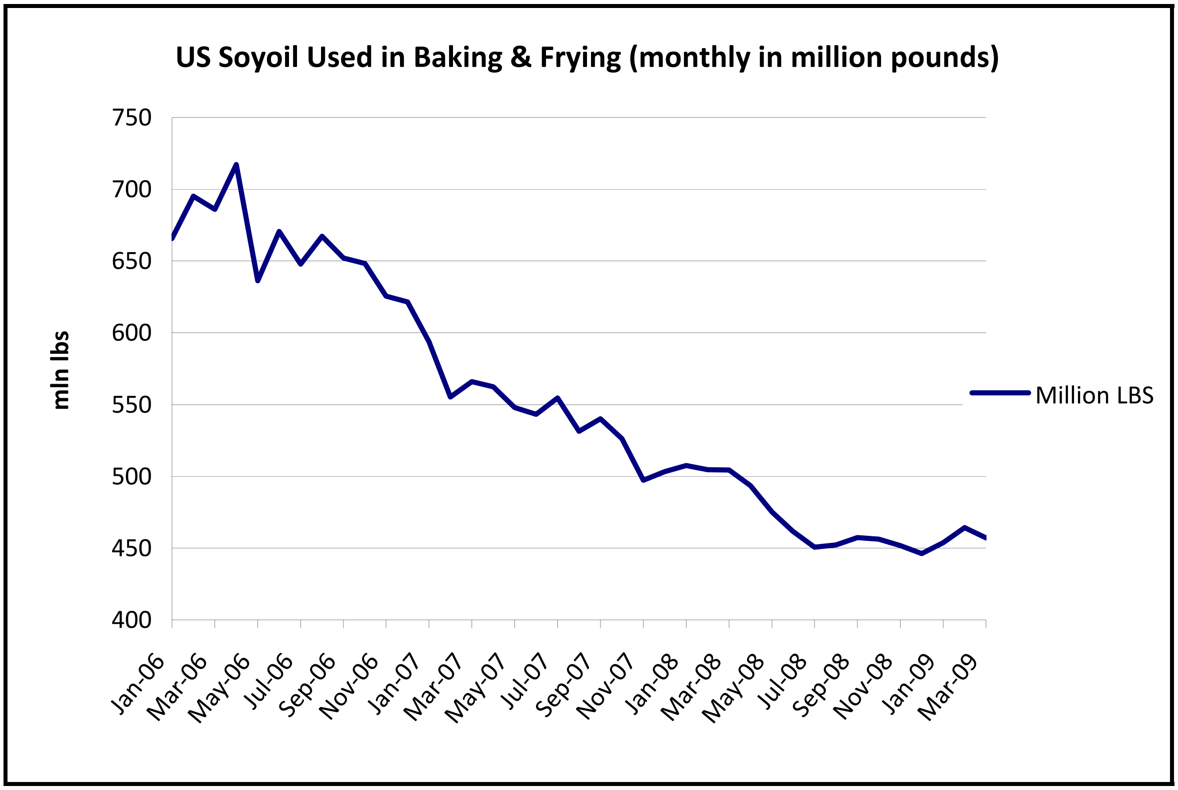
A similar situation exists for soybeans, the domestic demand for soybean oil (and meal) has not been increasing at the same rate as production in the recent past as shown in the following figure. Since 1989 production is up about 50% but domestic oil demand is up only about 30% as shown in the following figure.

Figure 2-6 US Soyoil Production and Demand



The short term trend in soyoil demand for food purposes (US Census Bureau) is shown in the following figure. This more dramatically shows the impact of recent demand changes. This type of non-biofuel demand change cannot be accommodated in the land use modelling done by the EPA and this is a clear shortcoming in the approach.

Figure 2-7 Short Term Soyoil Demand



The implications of this information are that between now and 2022, there may be a growing imbalance between supply and demand. By only looking at a scenario in 2022 with and without demand for biofuels disregards the impact that biofuels can make in addressing the imbalance between now and 2022.

2.2 The Modelling Scenario and ISO LCA Principles

Perhaps the more troubling issue with respect to the reference case is the indirect land use emission baseline. This is established as a 2022 business as usual scenario. So the combined reference system for biofuels is actually the direct emissions for a petroleum diesel fuel baseline with data from the 1990's and a projected 2022 land use scenario for calculating the indirect land use emissions. Improvements in agricultural productivity between 2005 and 2022 are essentially ignored (or credited to exports). The only role that agricultural productivity has in the 2022 land use calculations is the quantity of land required to meet the extra demand in 2022.

The 2022 business as usual baseline produces 19% more soybeans than were produced in 2005. There is no information presented in the documentation that shows what this increased production is used for.

Having shown that the fundamental basis for modelling is flawed and that any results that are produced are unlikely to be an accurate representation of future land use patterns there are also issues with the detailed calculations that the EPA undertake. These issues are discussed below.

3. LAND USE CALCULATIONS

3.1 FAPRI RESULTS

The FAPRI model estimates the changes in international agriculture when the system is shocked with new demand. The projected land use changes for the biodiesel scenario are summarized in the following table. The model projects land use changes in about 50 countries but almost all of the change happens in about 15 countries. In some countries a reduction in land use is expected, presumably because some agricultural products will see a reduction in demand as soybean oil demand and prices increase and the increase in soybean meal will offset the need for other animal feed products.

Table 3-1 FAPRI Results for Biodiesel

Country	Barley	Corn	Cotton	Palm	Peanut	Rapeseed/Canola	Rice	Sorghum	Soybean	Sugarbeet	Sugarcane	Sunflower	Wheat	Grand Total	% change of total acres
	Thousand acres														
US	-1	-210	-45	0	12	46	-9	-6	530	-3	0	81	-88	306	0.132%
Paraguay	0	0	0	0	0	0	0	0	186	0	0	0	0	186	1.573%
Brazil	0	-61	-10	0	0	0	-5	0	245	0	-14	0	-4	152	0.099%
India	0	8	13	0	-13	22	33	-6	72	0	0	0	-19	111	0.034%
Argentina	0	-5	0	0	0	0	0	-1	76	0	0	3	-12	61	0.069%
ROW	0	6	0	4	-13	3	3	14	22	2	5	12	0	58	0.034%
Nigeria	0	0	0	0	0	0	0	55	0	0	0	0	0	55	0.204%
China	0	16	-1	0	-4	18	-35	0	43	0	-1	0	-2	34	0.013%
Indonesia	0	9	0	16	0	0	2	0	0	0	0	0	0	28	0.052%
Malaysia	0	0	0	26	0	0	0	0	0	0	0	0	0	27	0.166%
Other Africa	0	8	10	0	0	0	0	0	0	0	0	0	5	23	0.019%
Other Latin America	0	16	3	0	0	0	0	0	0	0	0	0	2	21	0.118%
Western Africa	0	0	17	0	0	0	0	0	0	0	0	0	0	17	0.375%
Other CIS	0	0	13	0	0	0	0	0	0	0	0	0	3	16	0.028%
CIS	0	0	0	0	0	0	0	0	1	0	0	14	0	15	0.035%
Thailand	0	2	0	0	0	0	13	0	0	0	0	0	0	14	0.047%
Australia	1	0	2	0	0	4	0	1	0	0	0	0	2	11	0.022%
Russia	-4	1	0	0	0	0	0	0	0	0	0	0	12	9	0.010%
Canada	-3	4	0	0	0	14	0	0	9	0	0	0	-15	8	0.015%
Philippines	0	4	0	0	0	0	3	0	0	0	0	0	0	8	0.042%
Pakistan	0	1	0	0	0	0	0	0	0	0	1	0	6	8	0.017%
Iran	0	0	0	0	0	0	0	0	0	0	0	0	6	6	0.032%
South Africa	0	6	0	0	0	0	0	0	0	0	0	0	0	6	0.069%
Uzbekistan	0	0	5	0	0	0	0	0	0	0	0	0	0	5	0.127%
Morocco	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0.066%
Egypt	0	3	1	0	0	0	0	0	0	0	0	0	0	3	0.043%
Japan	0	0	0	0	0	0	1	0	2	0	0	0	0	3	0.064%
Vietnam	0	2	0	0	0	0	1	0	0	0	0	0	0	3	0.013%
Tunisia	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0.115%
Algerian	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0.035%
South Korea	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.051%

Turkey	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.044%
Other Eastern Europe	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.027%
Cuba	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.083%
Other Middle East	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0.002%
Columbia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.038%
Iraq	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.089%
Other Asia	0	1	0	0	0	0	0	0	0	0	0	0	-1	0	0.002%
Ivory Coast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.014%
Guatemala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.034%
Uruguay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020%
Venezuela	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.031%
Peru	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.035%
Taiwan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.005%
Myanmar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000%
Ukraine	-2	2	0	0	0	0	0	0	0	0	0	0	-1	-1	-0.002%
Mexico	1	-7	0	0	0	0	0	4	0	0	0	0	1	-1	-0.003%
Bangladesh	0	0	0	0	0	0	-5	0	0	0	0	0	0	-5	-0.017%
EU	-26	-13	0	0	0	26	0	0	3	0	0	24	-30	-15	-0.010%
Total	-34	-204	10	47	-19	134	3	60	1,189	0	-8	134	-125	1,187	0.052%

There is some uncertainty about the regions and there may be some double counting. There are categories for the CIS, Other CIS and then some of the states individually. The area of land use change in these countries is quite small and probably has little impact on the overall results.

The increase in agricultural demand in any given country is quite small relative to the agricultural land base that is already there. All countries except Paraguay show changes of less than 1% in ag land and most countries shows changes of less than 0.1%. The total change over all 50 countries is 0.05%. This is over a period of about 15 years and one needs to question whether the model capabilities, algorithms, and input data are capable of making such long term projections this accurately.

It is interesting that while there are changes in many crops, some positive and others negative the change in soybean acres is almost exactly equal to the change in total acres. Note that Canada is forecast to have an increase of about 8,000 acres, which is miniscule compared to the quantity of summerfallow land available. The Canadian canola industry is projecting very significant growth in canola production as summerfallow area decreases and they are actively looking for new markets for this increased production.

Since it is not possible to independently run FAPRI, the results must be accepted for what they are but like any model they will be based on the assumption that the system behaves in a similar manner in the future as it has in the past. In a world that is constantly changing this may not be the case. Given the potential for increased yields and production from fallow land due to higher prices shown earlier, the FAPRI model will overestimate the quantity of land required to meet an increase in demand.

3.2 LAND USE CHANGES

FAPRI is not capable of projecting which land, what kind of land, and how much biomass is on the land is used in each country so the EPA has worked with Winrock International to estimate the type of land converted.

Winrock utilize satellite images over a short period of time (2001-2004) to identify changes in land cover. Winrock have developed a database of 13 of the countries (or regions) in the FAPRI model. The EPA used 10 of these data sets in their analysis. Winrock have stated that their analysis has an accuracy of 71.6% globally. This not very high considering how the data is being used in the series of calculations undertaken by the EPA.

There are several problems with the Winrock approach including that it does not, and cannot, provide a causal link between the land cover change and the underlying driver. That is the reason for the initial land cover change cannot be linked to a demand for increased land for crops or grazing. It has been shown that there are up to 16 direct drivers of land use change in the tropics and that these drivers work in conjunction with at least 17 underlying causes associated with demography, economics, technology, local and global government policy and cultural attitudes among others (Lambin et al, 2006, Geist et al, 2002).

The Winrock analysis should also identify areas that have been harvested for forest products. Each of the countries that they studied has a significant forestry industry. The FAO database provides estimates of the quantity of round wood harvested in the countries each year. This information is shown in the following table. It is apparent that there should be significant land cover change identified in the Winrock analysis that has nothing to do with increased agricultural demand. No attempt has been made to isolate forestry induced changes from agricultural changes. Furthermore, the EPA in their determination of system carbon changes has ignored this significant quantity of harvested wood products.

Table 3-2 Forest Harvests

	Annual Roundwood Harvest	Estimated Area, ha/year
	cubic metres	Assumes 50 m^3/ha
Argentina	9,333,000	186,660
Brazil	106,758,315	2,135,166
China	94,668,400	1,893,368
India	22,810,000	456,200
Indonesia	32,496,500	649,930
Malaysia	25,351,000	507,020
Mexico	6,912,000	138,240
Philippines	3,060,000	61,200
Russian Federation	130,600,000	2,612,000
European Union +	341,367,656	6,827,353
Total	777,400,871	15,548,067

Since the Winrock data is for a three year period, the forest areas harvested in each country should be multiplied by three for comparison to the Winrock information. This 45 million ha of land harvested for wood products should be put into perspective against the 880,000 ha of new agricultural land for the soybean biodiesel scenario and the 70% accuracy of the Winrock land use estimates.

When the Winrock information is analyzed it is apparent that they project large changes in land cover in most of the countries in a very short period of time. The data for Brazil is shown in the following table.

Table 3-3 Winrock Land Cover for Brazil

	End Category (2004)					
Start Category (2001)	Cropland	Forest	Grassland	Savanna	Shrub	Grand Total
Cropland	9,477,369	249,901	919,366	8,529,974	116,682	19,293,291
Forest	341,186	379,059,490	1,408,111	15,947,827	1,136,045	397,892,659
Grassland	1,472,851	1,453,441	9,152,627	22,384,406	1,456,720	35,920,044
Savanna	6,004,819	18,614,978	12,295,754	214,505,969	4,698,914	256,120,435
Shrub	304,374	1,281,032	2,190,966	16,752,860	7,296,200	27,825,431
Total	17,600,600	400,658,842	25,966,823	278,121,036	14,704,560	737,051,860

Notice that in Brazil the forest land increased between 2001 and 2004 and the cropland decreased according the Winrock interpretation of the satellite data. This is opposed to FAO data that shows both a larger forest areas and a decrease in forest area between 2000 and 2005, and an increase in agricultural land harvested in that time period. Winrock does attempt to address the discrepancy over forest land, and it is apparent that land cover is not the same as land use and some difference should be apparent, but for the two most important categories for this analysis to move in the opposite direction and have significant net change significantly undermines the credibility of the Winrock information.

Note that in the previous table, the difference in forest land remaining forest land between 2001 and 2004 is 19 million ha, and at least 6 million of this would be accounted for by forest operations harvesting roundwood.

When just the changes in land cover are included the picture is a bit clearer as shown in the following table. There has been a change in land cover of almost 16% of the total land area of Brazil analyzed over a three year period. This is a very large change and, if true, is obviously driven by much more than a demand for more agricultural land. In fact cropland remaining cropland only represents 50% of the land cover change involving cropland. With this huge amount of change in short periods of time caused by so many different factors it is difficult to put any credibility on the values derived by Winrock for land use change driven by a demand for increased agricultural land.

Table 3-4 Winrock Land Cover Changes for Brazil

	End Category (2004)					
Start Category (2001)	Cropland	Forest	Grassland	Savanna	Shrub	Grand Total
Cropland	-	249,901	919,366	8,529,974	116,682	9,815,922
Forest	341,186	-	1,408,111	15,947,827	1,136,045	18,833,169
Grassland	1,472,851	1,453,441	-	22,384,406	1,456,720	26,767,418
Savanna	6,004,819	18,614,978	12,295,754	-	4,698,914	41,614,465
Shrub	304,374	1,281,032	2,190,966	16,752,860	-	20,529,232
Total	8,123,231	21,599,352	16,814,196	63,615,066	7,408,361	117,560,206

This table clearly shows that there are changes in land use cover going both ways, cropland created from forest and forest created from cropland. This holds true for every category of land. If one considers the forest land lifecycle, as this land is harvested for timber then the land would drop down to another category, to grassland if it was fully cleared and to shrub land or savanna if it was partially cleared, but as time passed and the trees re-grew then the land cover would become more dense and the land cover category would move back, grassland to savanna, savanna to shrub land, and shrub land to forest cover. Other disturbances such as forest fires, damage from weather events, diseases or pests could also cause forest land to change land cover including to grassland (and then to cropland) and savanna. The approach used by the EPA is to look at the gross changes in cropland and pasture land including all land use drivers, not just agriculture and since the proportion of each land use type is important in determining the carbon penalty, how can agriculture be isolated from this data?

Furthermore, can Brazil even be included since according to the satellite images there was a net reduction in cropland? How can the data be used to calculate the land use emissions for an increase in cropland when the data shows that the net cropland decreased?

Given that the land cover change possibilities are diverse, and impossible to determine what caused them from satellite photos, the EPA has only counted 6 category changes out of the 20 possible land cover changes in their determination of the carbon implications of land use change for agriculture; the four land cover conversions to cropland, forest land converted to grassland and savanna, and shrub land converted to grassland and savanna. This selective use of the data might be appropriate if there was some causal link between these types of land cover changes and increased agricultural land, but there isn't.

The only approach that might be justified from the data is to consider the impact of all of the land use changes related to the area of land that was changed so that the full impact of all activities is included. This has a very large impact on the calculated carbon changes due to above ground carbon loss. This alternate approach allows for the re-growth of timber areas and other positive land use change and thus doesn't charge activities that impact land cover just to increased cropland or pastureland.

A comparison is made of the difference between the EPA approach of only counting six of the 20 categories of cover change with including all 20. This has been done by using the above ground carbon values in the Excel spreadsheets that EPA has posted to the docket (EPA-HQ-OAR-2005-0161-0949.1 to .12) and calculating the carbon contents for all categories that have changed using the country average carbon intensities included in these spreadsheets. This exercise produces results that are slightly different than EPA calculated because of the weighted average for individual states are not used and EPA reduced the quantity of pasture required based on the amount of managed pasture but this exercise does provide a representative view of how the above ground carbon changed for all land cover changes and what the average change per acre was. These results for several countries are summarized in the following table.

Table 3-5 Comparison of Above Ground Carbon Changes for All Land Cover Changes vs. EPA Calculations

Country	Total Area Change	EPA Area Change	EPA Carbon Change	Total Carbon Change	EPA Intensity	Total Carbon Intensity
	Hectares		Tonnes		Tonnes CO_2 eq/ha	
Argentina	62,496,328	24,372,415	1,863,714,781	368,571,327	81	5.9
Brazil	117,560,206	44,422,994	7,415,618,203	-252,868,199	167	-2.2
China	183,092,612	89,583,622	6,699,531,910	604,069,258	75	3.3

In the case of Brazil, according to Winrock, the above ground biomass would appear to have increased between 2001 and 2004, a fact that is at odds with news stories about deforestation. In all countries the average carbon impact from all land use change is much smaller than is suggested by the EPA calculations that just considered one side of land use change for certain categories of land cover change.

Given the fact that all countries have significant forestry operations that will skew the land cover changes, and that the loss of forest land is a significant driver of the calculated emissions loss, the exclusion of any analysis of this by Winrock will tend to overestimated the indirect emissions attributable to agricultural land changes.

A particularly troubling aspect of the analysis undertaken by the EPA and by California, with their GTAP modelling, is that there is an assumption that the land use impact is scalable. It doesn't matter if 100 ha or 100,000 ha of new land is required, the proportion of that new land that is derived from forest land, shrub land, savanna, and grassland is the same. That is, there is no "supply curve" for land conversion to agriculture, no land that is likely to be converted first because it is more suitable for agricultural production, or is cheaper to convert to agriculture. This is not likely to be an accurate assumption but it is driven by the total inadequacy of the models and approaches being used to project what would happen in the real world. Climatic conditions alone would lead one to think that there will be different costs and benefits from the different types of land.

3.2.1 Pasture and Savanna Replacement

The carbon emissions calculated by the EPA include emissions for new cropland and emissions from land conversion to replace grassland and savanna that is converted to cropland. The basis of the land required to replace grassland and savanna is information on land cover from the GTAP model. There is no back up data on livestock populations, pasture utilization, or other factors to support this requirement.

We do know that livestock population per pasture area is very low in some of these countries and that at the same time there is some trend towards the intensification of livestock. None of these trends appear to be factored into the analysis.

In the case of the biodiesel, 57.9% of the indirect emissions result from the creation of the new cropland, 9.8% of the emissions are from replacing the grassland converted to cropland, and 32.4% of the emissions are for replacing savanna that was converted to cropland. Thus more than 40% of the emissions are related to animal production and not biofuel feedstock and yet no information is presented to support the assumptions made. The EPA does state that they intend to do more research on the issue of pasture replacement but the lack of detail provided in the draft RIA introduced great uncertainty in the final determination of land use emissions.

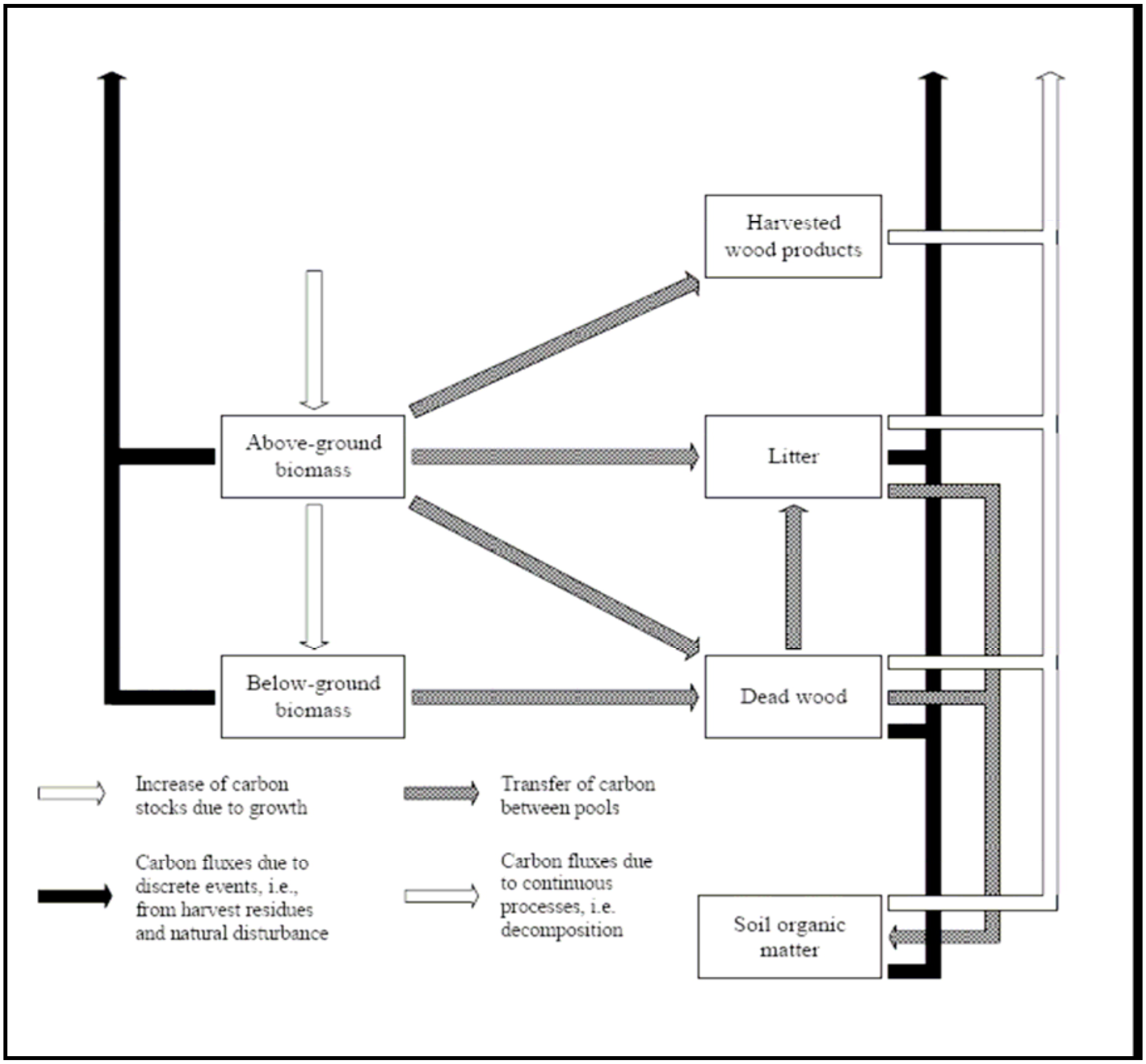
3.3 GHG Emissions from Land Use Changes

The calculation of GHG emissions is based on the change in above ground biomass stocks, an estimate of lost sequestration potential over time, and soil carbon changes (only when cropland is the end use).

3.3.1 Carbon Stocks

As noted earlier, the largest component is driven by the lost forest biomass stocks. A variety of data sources are used to estimate the biomass carbon stocks of the various regions considered. Some IPCC methodologies are followed to determine the changes in carbon stocks over time. The generalized carbon cycle developed by the IPCC is shown in the following figure.

Figure 3-1 IPCC Carbon Cycle



The EPA has not made any allowance for the possibility that some of the wood is converted to wood products (harvested wood products in the previous figure). They conclude that including this would have an immaterial impact on the results. This is based on an assumption that only about 10 m^3 of timber/ha could be harvested.

> *Even if we assumed that forestland cleared from Brazil had 10m^3 of timber/ha, which is likely an upper bound for many of the forests being cleared, this would translate to about 8 tCO_2/ha, or less than 2% of the total emissions from converting forest to cropland*.

It has been shown earlier that each of the countries analyzed by Winrock have significant forestry operations. The FAO reports (FAO, 2002) that an environmentally sustainable harvesting regime in Brazil removes 40 cubic metres/ha in order to prevent excessive opening of the canopy and to minimize damage to residual trees. Another FAO case study found that in Malaysia 45 to 65 cubic metres/ha were removed. The 10 m^3 of timber removed per ha is too low and inconsistent with the carbon stocks that are being assumed to be removed in many of the areas being studied. A value for HWP of at least 40 to 45 m^3 of timber/ha is more appropriate. This would increase the impact of the HWP to about 10%.

In reality this should be even higher because the EPA is assuming that all of the trees (several hundred tonnes of carbon/ha) are being removed in land conversion and the FAO work is assuming that only a portion of the trees are being removed so that the forestry is being undertaken in a sustainable manner. It is not unrealistic to expect that the impact of HWP is as high as 20 or 30% of the forest biomass emissions that are being calculated by the EPA.

3.3.2 Foregone Sequestration

The basic approach taken by the EPA is that carbon stored in the forests is there permanently and unfortunately this is not true. Some of these issues are raised in a recent paper by Reijnders (2009). He argues that forestation is not an ideal means of offsetting carbon emissions. While this is a slightly different perspective than removing a forest, the core issue is essentially the same. Reijnders identifies the issues of permanence in that trees don't live forever and that unforeseen events such as fire, disease, and extreme weather events can further shorten the projected life of carbon storage in forests.

Trees are living organisms and like all living things they have a life cycle and at the end they die. The end of the lifecycle could be caused by natural fires, by disease or pests, or simply by old age. At the end of the lifecycle the carbon in the above ground biomass starts to decompose and is returned to the atmosphere. Thus if the forest land use was changed to produce crops and the carbon stored in the trees is released to the environment, then it may not change the total amount of carbon that is released but ***when*** that carbon is released. In a system that discounts future carbon changes this will have an impact on the net present value of the carbon emissions but in a system that does not discount future changes the premature release of carbon would not impact the overall emissions.

The IPCC recognize this. Equation 2.11 in the 2006 AFOLU guidelines is;

$$\Delta CL = L_{wood - removals} + L_{fuelwood} + L_{disturbance}$$

ΔCL = annual decrease in carbon stocks due to biomass loss in land remaining in the same land-use category, tonnes C yr-1

$L_{wood- removals}$ = annual carbon loss due to wood removals, tonnes C yr-1

$L_{fuelwood}$ = annual biomass carbon loss due to fuelwood removals, tonnes C yr-1

$L_{disturbance}$ = annual biomass carbon losses due to disturbances, tonnes C yr-1

The disturbances can include wildfires, disease and pests, and natural events (wind damage). The IPCC also makes estimates for mortality separate from disturbances and suggests that in actively managed stands mortality may represent 30 to 50% of the lifetime productivity of the stand.

The IPCC reports that the average mortality rate ranges from 1.16% for evergreen and deciduous forests to 1.77% for tropical forests.

Information on disturbances is more difficult to accurately assemble but the FAO 2005 Global Forest Resource Assessment reported that the annual disturbance rates for all regions due to fire was 0.70%, due to insects was 0.93%, due to disease was 0.78% and due to other factors was 0.21%. The total annual forest disturbance rate was thus 2.6%. This would be in addition to the average mortality rate. The total annual disturbance rate could be as high as 4 to 4.5% per year. The report contains information on individual countries so an in-depth analysis for each country could be performed.

By properly accounting for the future losses, as well as the future gains, a proper assessment of carbon changes over time can be performed. The approach in the proposal grossly overestimates the carbon losses over time by assuming that forest carbon is permanent, when it is not. In the 100 year time frame it is likely that none of the carbon that is removed from land use change in the first year would have been standing at the end of the period.

3.3.3 Soil Carbon Loss

To calculate soil carbon losses the IPCC soil carbon tool is used. It has been assumed that the new management practice is full tillage and medium inputs. This typically results in the loss of about 20 to 50% of the soil carbon over a period of 20 years.

There are two issues here; the first is that the IPCC soil carbon toll is not universally accepted and there are many agronomists who believe that it overestimates changes in soil carbon, good and bad, the second is that the assumption of full tillage is not appropriate for many countries. The use of zero tillage management practices could reduce soil carbon losses to half that estimated by the EPA even with the use of minimum inputs. Produces who use no tillage, manure and high inputs can increase soil carbon even on native ecosystem land according to the IPCC soil carbon tool.

No till cultivation is widely practiced throughout the world and many countries including Paraguay, Argentina, and Brazil have a higher utilization of no-till than the United States (Rolf Derpsch). These countries are some of the primary beneficiaries of expanded land use in the biodiesel scenario. Some data on no till management practices by country are shown in the following table.

Table 3-6 No Till Cultivation Practices

Country	Area under No-tillage	Arable land	No Till Portion of Arable Land
	1,000 ha		
USA	25,304	174,244	14.5%
Brazil	23,600	59,000	40.0%
Argentina	18,269	28,500	64.1%
Canada	12,522	45,660	27.4%
Australia	9,000	48,743	18.5%
Paraguay	1,700	4,200	40.5%
Indo-Gangetic-Plains	1,900	159,670	1.2%
Bolivia	550	3,050	18.0%
South Africa	300	14,753	2.0%
Spain	300	13,711	2.2%
Venezuela	300	2,650	11.3%
Uruguay	263	1,370	19.2%
France	150	18,461	0.8%
Chile	120	1,980	6.1%
Colombia	102	2,216	4.6%
China	100	141,664	0.1%
Others (Estimate)	1,000		
Total	95,480		

Based on the data in the table above the soil carbon losses projected by the EPA overestimate the actual loss. The soil carbon loss is probably in the range of 20 to 25% rather than the 30% range that the EPA approach would produce. This difference overestimates emissions by 30 to 50%.

4. DISCUSSION AND SUMMARY

A large number of issues have been discussed in the previous sections of the report and these are summarized here.

4.1 MODELLING FRAMEWORK

The modelling framework undertaken by the EPA contains most of the correct steps that would be required to identify any indirect emission impacts from an increase in demand for biofuel feedstocks. However, in almost every case the actual calculations or mechanics involved in each step has serious issues. The one step that is missing is a determination of the quantity of new demand that will be met by new land and the quantity supplied by a yield response. Due to the modelling limitations, the EPA has assumed that it is met 100% by new land.

The underlying assumptions used by the modelling effort are unrealistic and lead to an overestimation of the quantity of required land and thus overestimate the indirect land use emissions. These assumptions are:

1. All agricultural systems throughout the world are operating at maximum capacity.
2. The supply and demand for all agricultural products is in balance.
3. Any future increases in supply will equal the increase in demand from existing product users.

Evidence was presented that showed that all assumptions not valid. It is the first assumption that is the most important and is the easiest to demonstrate is incorrect. However, it is easier to determine what is wring than it is to suggest a way that the models could be corrected so that the model output were more reasonable. Given that a number of issues with assumptions have been identified and in almost every case it is easier to identify what the values or approach used is problematic than it is to determine the correct value, the EPA could undertake a sensitivity analysis using Monte Carlo simulations to determine a more likely range when all of the uncertainties are combined.

4.2 LAND COVER INFORMATION

The land cover information supplied by Winrock has a low level of accuracy as stated by Winrock. It also would appear to have some biases because it does not account for traditional forestry operations. Land cover changes resulting from forestry operations are likely included in the land cover changes attributed to increased agricultural demand.

The EPA has calculated land cover changes for land converted to cropland as well as land converted to grassland and to savanna. The last two land cover changes account for a total of more than 40% of the initial carbon losses and yet no information on livestock populations, livestock intensity on pasture land is presented to show that this land conversion is required. In addition it is well established that pastures can be better managed to sustainably accommodate greater livestock intensity and no mention of this mitigating action is taken. This is somewhat related to the first underlying assumption that agricultural systems are operating at capacity. Here the EPA has assumed that most of the grassland and savanna that has been converted to cropland must be replaced to support the existing livestock herds.

The impact of this assumption can be evaluated using the spreadsheets developed by the EPA. In the following table the lifecycle emissions for soybean biodiesel are shown after correction for the N_2O issue, the lack of credit for the glycerine production and the lower energy requirement in biodiesel production plants. Only the impact of the initial biomass loss is considered here, the impact of foregone sequestration is not included here so the results are slightly conservative.

Table 4-1 Impact of Assumptions Regarding Grassland Replacement

Lifecycle Stage	Petroleum Diesel	Soy Biodiesel w/o domestic N_2O emissions, glycerine co-product credit and processing energy	Soy Biodiesel w/o savanna replacement	Soy Biodiesel w/o savanna and grassland replacement
	g CO_2eq/mm BTU			
Net Domestic Agriculture (w/o land use change)		-1,295,306	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980
International Land Use Change		2,474,074	2,023,227	1,887,397
Fuel Production	749,132	43,177	43,177	43,177
Fuel and Feedstock Transport		149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169
Net Total Emissions:	4,173,768	1,587,696	1,136,849	1,001,019
% Change		-62.0	-72.8	-76.0

It can be seen from the table that the assumption made by land requirements for livestock has a very significant impact on the results. The difference is large enough that it requires significant justification for the assumptions that the EPA has made. This justification is not included in the DRIA.

4.3 Carbon Stock Calculations

The assumption made by the EPA regarding the level of harvested wood products (HWP) that could be recovered from forests is far too low and thus the impact of harvested wood products is grossly underestimated by the EPA. In sustainably managed forests the harvest intensity is four to five times higher than assumed by the EPA. In addition when the biomass contents of some of the forests are considered the quantity of wood that could be removed as HWP could be two or three times the level of a sustainable harvest.

The EPA suggests that HWP at 10 cubic metres/ha would have an impact of 2% on the lifecycle emissions, in the following table the impact of an 8% reduction is shown.

Table 4-2 Impact of Assumptions Regarding Harvested Wood Products

Lifecycle Stage	Petroleum Diesel	Soy Biodiesel w/o domestic N_2O emissions, glycerine co-product credit and biodiesel processing energy	Soy Biodiesel w/o savanna and grassland replacement	Soy Biodiesel w/o savanna and grassland replacement and HWP
	g CO_2eq/mm BTU			
Net Domestic Agriculture (w/o land use change)		-1,295,306	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980
International Land Use Change		2,474,074	1,887,397	1,736,405
Fuel Production	749,132	43,177	43,177	43,177
Fuel and Feedstock Transport		149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169
Net Total Emissions:	4,173,768	1,587,696	1,001,019	850,027
% Change		-62.0	-76.0	-79.6

The largest issue with the carbon loss calculations is the improper treatment of what might have happened if the tress had not been harvested to facilitate land use change. The EPA has not followed the IPCC guidance with respect to estimating the impact of disturbances and mortality on the initial carbon stocks. The IPCC recognizes that living systems, such as forests, are not permanent and that forest land remaining forest land should be adjusted not only for the annual carbon gains but also the carbon losses. FAO data shows that annual forest disturbances in 2000 were 2.6% of the forested area and that mortality in managed forests could add another 1.2 to 1.8% loss annually.

This is a very significant gap in the EPA analysis. Since trees don't live forever the carbon losses that are being charged to indirect land emissions would have eventually happened. The only difference is when they would happen. In the following table the impact of also including carbon gains, as well as lost carbon losses, is shown for both the 30 undiscounted time frame and the 100 year 2% discounted horizon.

Table 4-3 Impact of Forest Disturbances and Mortality

	Revised base case		Include Disturbance only		Disturbance and Mortality	
Time Frame	30	100	30	100	30	100
Discount Rate	0	2%	0	2%	0	2%
Carbon loss	0%	0%	2.6%	2.6%	4.0%	4.0%
% Reduction in Biodiesel Lifecycle Emissions	36.4	62.0	72.5	98.5	92.0	118.2

This issue has a very large impact on the GHG emissions. It should apparent that in some cases the mortality losses from an older forest could completely offset the foregone sequestration losses, the forest would reach some sort of equilibrium in living biomass content. In the case of disturbances, these are events than we have no control over, they need to be included in any analysis of carbon stock changes over time. These losses can be large and very significant in the determination of the indirect lifecycle emissions.

The soil carbon losses estimated by the EPA assume that full tillage is applied to new agricultural land. However, in many of the countries that are expected to contribute the new land, no till agricultural practices are prevalent. The EPA calculations should be updated to reflect this. This will have a small impact on the lifecycle emissions.

4.4 Individual Examples

In addition to the comments on the methodology and data sources provided previously, it is informative to look at some of the other data that is available for individual countries to determine whether it supports or contradicts the overall approach.

As noted earlier, the soybean biodiesel case results from FAPRI suggest that some 50 countries will see some change in land use and crop patterns. Two of the largest changes are expected to be found in Paraguay and India. These countries are discussed below.

4.4.1 Paraguay

Paraguay is the world’s fifth largest producer of soybeans. Twenty percent of the new land for soybeans projected by the FAPRI model is expected to come from Paraguay, but there is no land use data available for Paraguay from Winrock. The EPA has applied the average carbon losses for the 10 countries that they have data for, to Paraguay. The average for the 10 countries for the biodiesel case is 56.53 tonnes CO_2eq/acre. Paraguay is adjacent to Argentina and a case could be made that the land use emissions for Argentina are more representative than the average of the 10 countries. The land use emissions for Argentina are 26.41 tonnes CO_2eq/acre. If this value were used for Paraguay then the biodiesel indirect land use emissions decline by 11.2%. This is a significant change based on a change in a single assumption used in the modelling.

Further support for the inappropriateness of using the 10 country average emission factor for Paraguay is the fact that the country has an effective deforestation law that is now in effect until 2013. The existing law, in place since 2004, has been credited with an 85% reduction in land lost to deforestation. This has occurred at the same time as soybean production in the country has increased. The government has implemented a policy to cut net carbon emissions from land use change to zero by 2020.

Further investigation into the agricultural economy of Paraguay suggests that the existing agricultural land is not fully utilized and that some 1 million ha of the agricultural area was fallow in 2004 (USAID). Thus a strong case could be made that no new land is required in Paraguay to allow the production of 75,000 additional hectares of soybeans. If this is the case, then the indirect land use emissions for biodiesel drop to a total of 21% less than calculated. This is for one country out of 50 that contribute to the emissions, although it is the largest.

The information that is directly available on practices and policies in Paraguay is significantly different than that which is generated from theoretical models and highlights the issues that arise solely from the reliance on these models.

4.4.2 India

India is expected to contribute 11% of the new land for the soybean biodiesel case. India is the fourth largest soybean producer in the world today. The FAPRI model projects an additional 45,000 hectares of soybeans produced in India.

India has 25 million hectares of fallow land and about 60% of that is current fallow (land that is fallow as part of a rotation). This current fallow land is about 10% of the agricultural land that is under production.

Like Paraguay, it is highly unlikely that new land would be brought into production in India when so much land is available for production with only small changes in management practices.

The total reduction in indirect land use emissions for just India and Paraguay is 28.6% of the value calculated by the EPA. These two changes alone would move the lifecycle emissions of biodiesel by 17 percentage points compared to the petroleum diesel baseline. It is likely that a thorough investigation of the other major countries with new land in the soybean case would uncover other local factors that would further reduce the emissions that are projected by the models.

Paraguay and India are two examples of countries that have agricultural systems that are not operating at capacity. This was one of the underlying assumptions identified earlier that the modelling effort is based on. It is not surprising therefore that when examples are identified that do not comply with the underlying model assumptions, there can be large impacts on the results projected by the model.

4.4.3 China

A recent paper from China (Tian, et al, 2009) considered the potential for additional ethanol and biodiesel feedstocks in China. In the case of biodiesel they identified the potential for increased double cropping that could be done on 5.6 million ha of land (about one third of the potential double cropping area). This would produce as much as 1 billion gallons of additional biodiesel in China.

4.5 SUMMARY

The modelling framework employed by the EPA is conceptually correct but the individual models that have been employed to generate the indirect emissions have serious deficiencies.

1. The implied assumption that new demand can only be met with increased land is not a credible assumption given divergence in agricultural productivity that is seen throughout the world.
2. The FAPRI model results indicate that a 0.052% increase in land is required to meet the biodiesel scenario. This is over a period of about 15 years and one needs to question whether the model capabilities, algorithms, and input data are capable of making such long term projections this accurately.
3. The land cover data that is used to estimate the types of land that would be converted to agricultural land has too low an accuracy to be used for the purpose that EPA has used it for. The implied assumption that there is no "supply curve" for new agricultural land is not credible. No other complex system behaves the way that EPA suggest international land use change occurs. The assumption that the EPA has made regarding the need to replace grassland converted to crops is not based on any information that suggests that pasture systems throughout the world are operating at capacity.
4. The assumption on the wood products harvest intensity rate used by the EPA is far too low. The available data suggests that the rate should be at least 4 to 5 times higher when sustainable forest management practices are used and even higher when the land is clear cut, as it would be to prepare for crop production. The impact of the HWP becomes much more significant when reasonable harvest rate are use.
5. The EPA has not considered the fact that living forest sometimes die prematurely from natural disturbances and natural mortality within a stand. The carbon losses that have been charged to land use conversion statistically would have happened eventually. The only impact of the carbon losses is therefore when it happens. The IPCC recommends including carbon losses from disturbances in their guidance documents and there is some information on global disturbances available from the FAO. Including an allowance for this future carbon loss offset the lost sequestration and a significant portion of the original carbon loss, depending on the time horizon considered.
6. There are enough issues identified with the calculations of the indirect emissions from land use change that significantly more effort is required by the EPA to produce a sound, science based estimate of any indirect impacts from an increase in demand for soybeans.

In the following table the impact of some of the assumptions that EPA have made in their analysis is evaluated using alternative reasonable assumptions. The lack of consideration of the permanence of the living forests in the EPA calculations is a significant factor in determining the indirect emissions of biofuels.

Table 4-4 Impact of Assumptions on Biodiesel Lifecycle Emissions

Lifecycle Stage	Petroleum Diesel	Soy Biodiesel w/o domestic N_2O emissions and glycerine co-product credit and biodiesel processing energy	Soy Biodiesel w/o savanna and grassland replacement	Soy Biodiesel w/o savanna and grassland replacement with HWP	Soy Biodiesel w/o savanna and grassland replacement and including natural disturbances
	g CO_2eq/mm BTU				
Net Domestic Agriculture (w/o land use change)		-1,295,306	-1,295,306	-1,295,306	-1,295,306
Net International Agriculture (w/o land use change)		195,304	195,304	195,304	195,304
Domestic Land Use Change		-8,980	-8,980	-8,980	-8,980
International Land Use Change		2,474,074	1,887,397	1,736,405	919,118
Fuel Production	749,132	43,177	43,177	43,177	43,177
Fuel and Feedstock Transport		149,258	149,258	149,258	149,258
Tailpipe Emissions	3,424,635	30,169	30,169	30,169	30,169
Net Total Emissions:	4,173,768	1,587,696	1,001,019	850,027	32,740
% Change		-62.0	-76.0	-79.6	-99.2

In the following table the impact of all of the changes that are recommended for the direct and indirect emissions for soybean biodiesel are shown.

Table 4-5 Summary of the Impact of the Impact of the Largest Issues

Scenarios (Cumulative)	Emissions[2], g CO_2/mm BTU	% Reduction from Diesel	Percentage Change
Petroleum Baseline	4,173,768		-
Soy Biodiesel EPA	3,255,109	22.0	-
Less nitrogen fixing crops	2,383,009	42.9	20.9
Glycerine co-product	1,652,196	60.4	17.5
Biodiesel Energy	1,587,696	62.0	1.6
No Pasture Replacement	1,001,019	76.0	14.0
HWP rate	850,027	79.6	3.6
Natural Disturbances	32,740	99.2	19.6

It can be seen that there are as many issues with the EPA indirect analysis as there are for the direct analysis. Significantly more effort is required by the EPA to produce a sound, science based estimate of any indirect impacts from an increase in demand for soybeans.

[2] 100 Year Time Frame, 2% discount rate.

5. REFERENCES

FAO. 2002. Environmentally Sound Forest Harvesting in Brazil. http://www.fao.org/docrep/004/Y4345E/Y4345E03.htm

FAO. 2009. FAO Database. http://faostat.fao.org/

FAO. Forest Harvesting Case-Study 17. Financial and Economic Assessment of Timber Harvesting Operations in Sarawak, Malaysia. http://www.fao.org/docrep/004/Y2699E/y2699e00.htm#Contents

FAO. Global Forest Resources Assessment 2005. Data Tables. http://www.fao.org/forestry/static/data/fra2005/global_tables/FRA_2005_Global_Tables_EN.xls

Fulginiti, L. and R. Perrin. 1998. Agricultural Productivity in Developing Countries. Agricultural Economics 19 (1998)

Geist, H.J., and Lambin, E.F. 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52:143–150 (2002).

Government of India. Directorate of Economics and Statistics. Selected Categories of Land Use 1950 to 2005. http://dacnet.nic.in/eands/At_Glance_2008/ch_14/tb14.5.xls

Lambin, E.F., and Geist, H.J. (eds). 2006. Land-use and land-cover change: local processes and global impacts. Springer, Berlin (2006).

Reijnders, L. 2009. Are forestation, bio-char and landfilled biomass adequate offsets for the climate effects of burning fossil fuels? Energy Policy. Volume 37, Issue 8, August 2009, Pages 2839-2841. http://dx.doi.org/10.1016/j.enpol.2009.03.047

Rolf Derpsch. 2008. Area under No- tillage in different countries. http://www.rolf-derpsch.com/

US Census Bureau. 2009. M311K - Fats and Oils: Production, Consumption, and Stocks. http://www.census.gov/cir/www/311/m311k.html

USAID. 2004. Diagnostico De Los Principales Problemas Relacionados Con La Tierra Rural En Paraguay. http://pdf.usaid.gov/pdf_docs/PNADI431.pdf

Tian, Y., Zhao, L., Meng, H., Sun, L., Yan, J. 2009. estimation of Un-used Land Potential for Biofuels Development in China. Appl Energy (2009), doi:10.1016/j.apenergy.2009.06.007.

ATTACHMENT 12

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LIFE CYCLE ANALYSIS OF BIOFUELS & INDIRECT LAND USE CHANGE

Bruce E. Dale
University Distinguished Professor of Chemical Engineering
Michigan State University

Presented at:
National Biodiesel Board
Washington, DC
June 17, 2009

Some Background and Context

- Inexpensive plant raw materials will catalyze the growth of biofuel industries– this will and must happen
- *We can design these biofuel industries for better environmental performance*
- One important tool: life cycle analysis (LCA)
- LCA has great value if used properly, but it is a limited tool and must be used within established rules
- Unfortunately, EPA has not used LCA properly in some of their analysis
- This has undermined the national goals of increased energy security and real environmental improvement
- However, my biggest objection is to the premise of indirect land use change, not to the particulars of the EPA analysis

What does the Law Say?

Section 201 of EISA (42 U.S.C. 211(o)(1)(H) defines lifecycle greenhouse gas emissions as follows:

(H) ***<u>LIFECYCLE</u>*** *GREENHOUSE GAS EMISSIONS. The term "****<u>lifecycle</u>****" greenhouse gas emissions" means the aggregate quantity of gas emissions (including direct emissions and significant* ***<u>indirect</u>*** *emissions such as significant emissions from land use change), as determined by the Administrator, related to the full fuel* ***<u>lifecycle</u>****, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential*

The law correctly describes the fuel lifecycle (large red oval above). However, ILUC occurs <u>outside</u> the fuel life cycle…

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Land use change (LUC) may cause large GHG emissions

U.S. corn farmer switches from corn/soy to corn/corn

U.S. soy exports go down and world soy prices rise

Additional land in Brazil (for instance) is put into soy production

Soy farmers everywhere use more inputs to increase yields

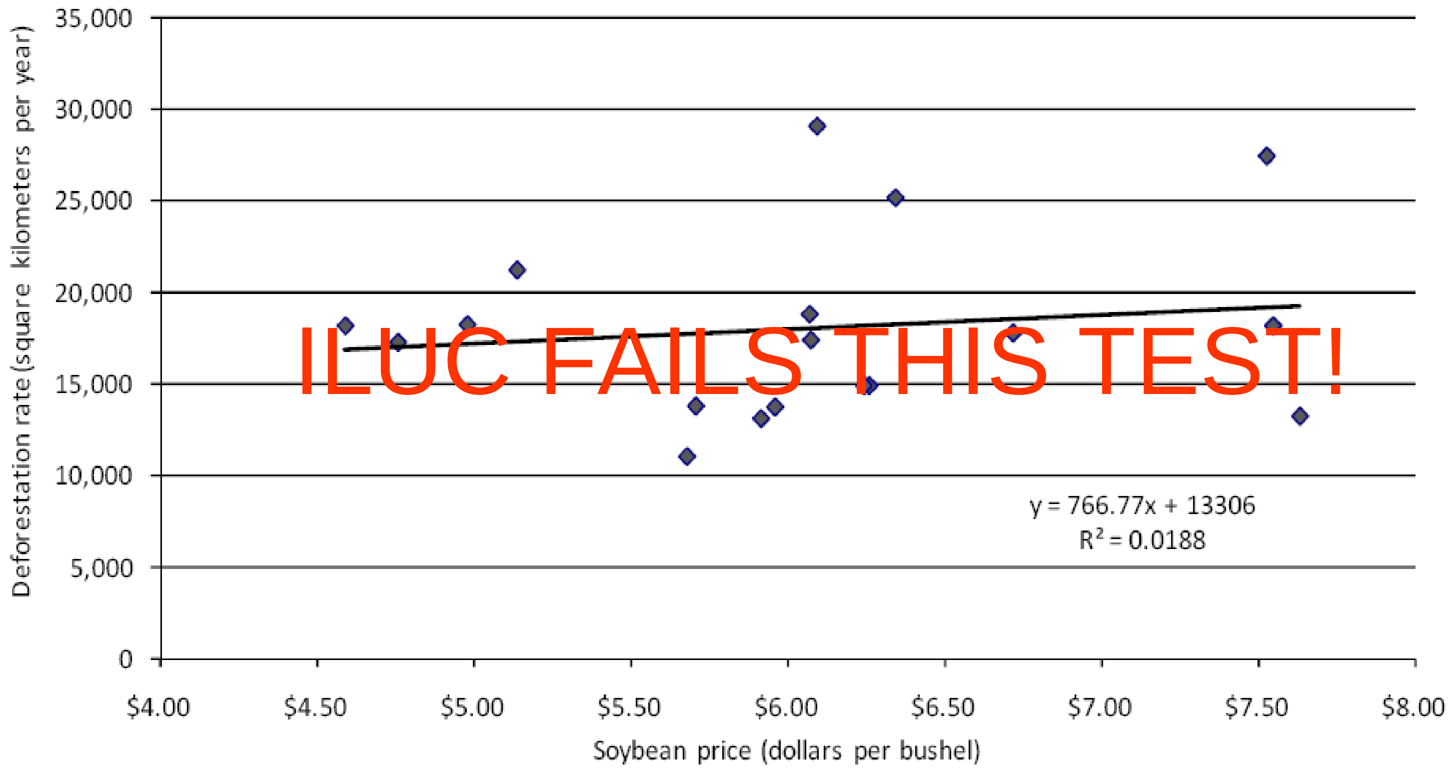
Indirect LUC emissions

Indirect process emissions

Process emissions

This GHG emission incurs a “carbon debt” assessed against biofuels of up to 900 years

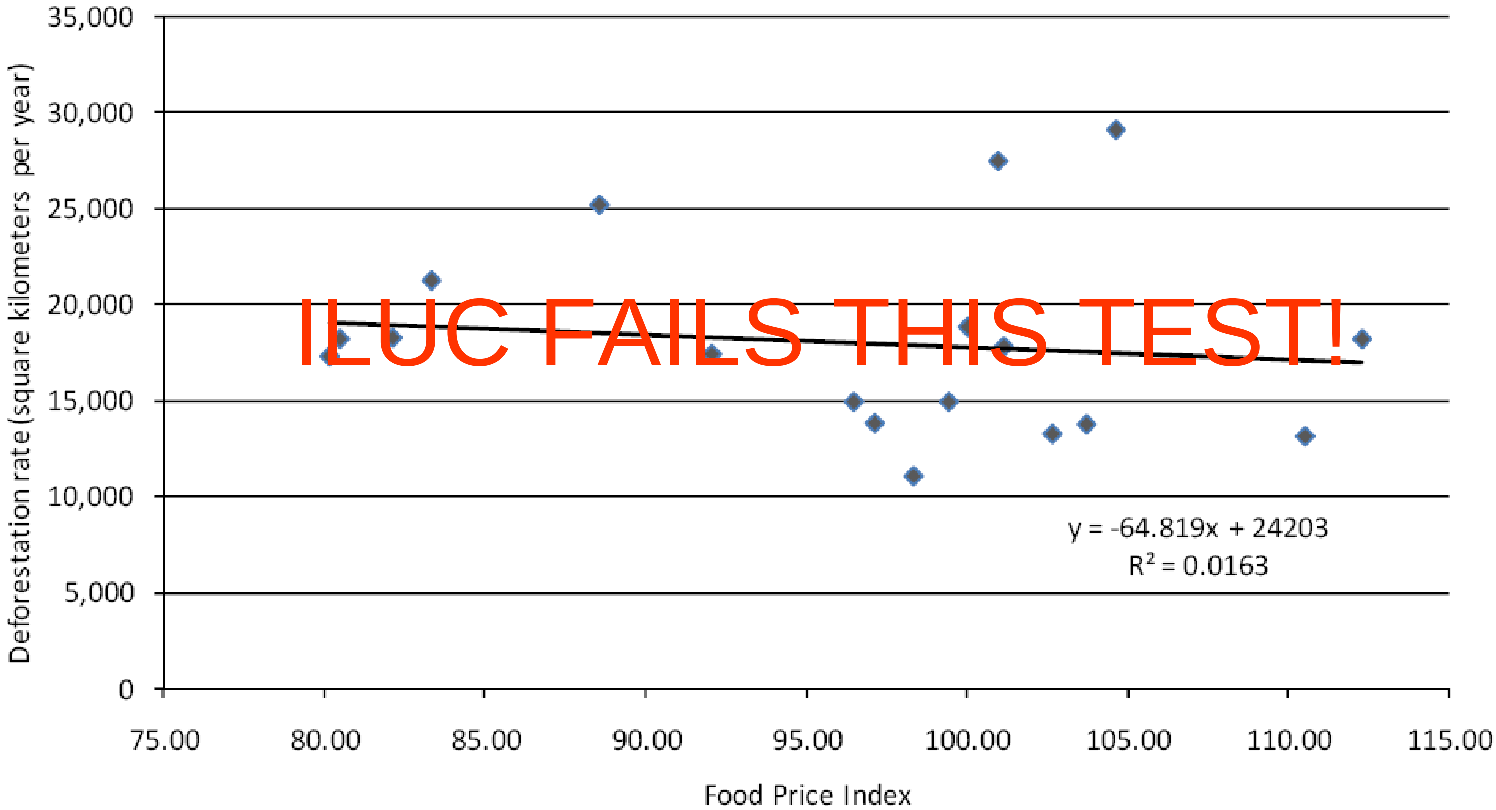
Testing ILUC Theory Against Reality I



There is no correlation between the price of soybeans and the deforestation rate in the Amazonian rainforest of Brazil. The solid line is a "best fit" of the data, which shows a small positive linear correlation. However, the regression coefficient (R^2) of 0.0188 indicates virtually no statistically significant correlation (a value of 1.00 is a perfect correlation). Source: United Nations Food and Agriculture Organization (deforestation data) and Index Mundi (soybean price data).

Courtesy Dr. Robert Brown "Why We are Producing Biofuels" July 2009

Testing ILUC Theory Against Reality II



There is no correlation between the commodity food price index and the deforestation rate in the Amazonian rainforest of Brazil. The solid line is a "best fit" of the data, which shows a small negative linear correlation. However, the regression coefficient (R^2) of 0.0163 indicates virtually no statistically significant correlation (a value of 1.00 is a perfect correlation). Source: United Nations Food and Agriculture Organization (deforestation data) and Index Mundi (food price index).

Courtesy Dr. Robert Brown "Why We are Producing Biofuels" July 2009

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What Are Life Cycle (LCA) Models?

- Set of "accounting" procedures for determining and comparing the environmental impacts of different products
- Goal is environmental improvement
- For example, disposable diapers vs. reusable diapers
- It turns out that disposable diapers have lower environmental impact than reusable diapers
- LCA exists to make proper <u>comparisons</u>
- Like all accounting systems, there are rules that must be followed
- EPA has not (yet) followed some critical LCA rules in their RFS analysis

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INTERNATIONAL STANDARD

ISO 14040

First edition
1997-06-15

Environmental management — Life cycle assessment — Principles and framework

Management environnemental — Analyse du cycle de vie — Principes et cadre

It isn't a life cycle analysis just because someone says it is.

Reference number
ISO 14040:1997(E)

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Some Life Cycle Analysis Standards: *In Plain English*

- Use the most recent/most accurate data possible
- Select the reference system: what exactly are we comparing?
- Make it easy for others to check your data and methods= *transparency*
- Set clear system boundaries (physical & temporal)—must be equal or comparable for reference system and/or reference product of interest
- Multi-product systems must allocate environmental costs among all products
- Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

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Some Problems with EPA's LCA Analysis

- Use the most recent/most accurate data possible
  - EPA is predicting agriculture in 2022 using economic models
  - We must insist on tests of the models against past history
  - So far, they seem to fail such tests
- Select the reference system: what exactly are we comparing?
  - EPA compares future biofuels with petroleum fuels in 1999-2005
- Make it easy for others to check your data and methods= *transparency*
  - It is NOT easy to check their methods, largely due to complex, linked models
- Set clear system boundaries (physical & temporal)—must be equal for reference product of interest
  - Indirect effects are assessed only against biofuels, not petrofuels
- Multi-product systems must allocate environmental costs among all products
  - Entire environmental "cost" of indirect land use change is assessed against biofuels, in spite of the fact that we use land to provide food, feed, fiber, timber, etc…
- Perform *sensitivity analysis*: how much do results vary if assumptions or data change?
  - EPA missed some really important ones. For example….

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Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

- Productive use of existing forest (or grassland) did you make furniture or flooring from the tropical hardwoods or did you just burn the trees down?
- Decreased land clearing rates and/or different ecosystems converted, forest vs. grassland
- Soy yields increase both in the U.S. and abroad
- “Carbon debt” based on GHG of diesel from oil sands in 2022 vs. DOE models in ~1999
- Increasing energy efficiency of biofuel plants
- Uncertainties in global equilibrium models…test through Monte Carlo simulation
- Allocation of environmental burdens among feed and fuel uses of soy (eg. glycerine)—not just to fuel
- How is land managed after conversion?
- These (and other) factors were not adequately considered in the sensitivity analysis

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Some Early Tests of Sensitivity

- Make productive use of forest instead of just burning it down
  - Reduces “carbon debt” by up to 50 years (Dr. Lee Lynd, Dartmouth)
- Better manage the land after you clear it
  - Using no till and cover crops, “carbon debt” is reduced by up to 40 years (my group)
- Combine these two, and there is no carbon debt at all for many forest systems
- No carbon debt for any grassland conversion we have studied

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The Irrationality of Indirect Analysis

By Robert Zubrin Special to *Roll Call* June 3, 2009, 5:32 p.m.

- So to summarize, according to indirect analysis, all measures that improve the economy, education, health, the environment or technology are to be condemned. This result must follow because all of these help humanity, and so long as humanity engages in any activities that cause carbon emissions, anything that helps humanity can also be said to cause global warming.
- Clearly such an absurd theory cannot be accepted as a basis for policy. If it is, we will end up legislating depression, banning all technological and medical advances, and ultimately, perhaps requiring environmental impact statements every time a lifeguard rescues a swimmer or a midwife assists in the birth of a child. Instead, the proper, scientific, ethical and sane way to proceed in assessing carbon emissions, whether of ethanol use or any other human activity, is to base such judgments strictly on the direct effects of the activity itself. These can be measured and therefore reduced in detail as technological alternatives permit. If we operate otherwise, then no constructive solutions will be possible.

Some (More) Silly Consequences of Indirect Effects

- Conservation Reserve Program needs to end immediately…it increases crop prices and therefore increases ILUC
- Agricultural communities (around the world) need to stay poor forever. If they get wealthy, it will be at the expense of the world's forests
- We should cut down all our US forests, use the resulting timber productively, and plant crops on those forest lands instead…that will hold down conversion of the world's tropical forests
- *Does Congress really know it voted for such silliness?*

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Is there a way out of the ILUC mess?

- Our fellow citizens want both energy security and environmental improvements
- Let's try to find some common ground with the environmental movement
- What they mostly want is forest protection. ILUC is their (very poor) means to that end
- Suggestion:
  - Assess fuels on their actual carbon content
  - Account for all fuel GHG emissions throughout direct supply chain, annual accounting, incentivize technological improvement
  - Use other mechanisms to protect tropical forests through financial incentives
- We are at a critical juncture in deciding how we will fuel our society in the next decades

Do we want this fuel future?

SOURCE: PHOTO BY MELINA MARA. © 2005, THE WASHINGTON POST. REPRINTED WITH PERMISSION

Or one that looks like this?

Forage sorghum & velvet bean. Auburn, Alabama. Courtesy D. Bransby

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From This Immature "Cell Phone"ca 1985

To this Mature One ca 2008

Clunky, didn't work well
Only one function

Excellent properties
Multiple functions

ATTACHMENT 13

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April 21, 2009

Mary D. Nichols
Chair
California Air Resources Board
Headquarters Building
1001 I Street
Sacramento, CA 95812

Dear Chair Nichols:

I am writing to share a number of suggestions members of the National Biodiesel Board (NBB) believe would enhance the "Proposed Regulation to Implement the Low Carbon Fuel Standard," published March 5, 2009. Thank you, in advance, for your consideration of our industry's recommendations.

First, I would like to express our appreciation for the high level of cooperation shown by the Air Resources Board (ARB) staff up to this point in time. While we continue to believe the implementation schedule for diesel is unnecessarily back loaded and we continue to have one significant difference of opinion on the lifecycle assessment for soy-based biodiesel, when taken as a whole, we feel the ARB is doing a commendable job, particularly in light of the immensely challenging time constraints the agency has been given. So it is on this basis, and with the understanding that ARB staff will continue to work collaboratively on potentially difficult issues like indirect lifecycle greenhouse gas (GHG) impacts, that we offer our support for moving forward with the draft regulation.

With regard to specific comments, the NBB wishes to communicate the following points related to issues that will be considered by the board for approval this week:

1. We continue to be puzzled by the ARB's resistance to accelerating the diesel implementation schedule, particularly in light of a study we forwarded to staff which conclusively shows price and supply should not be concerns. It is important to note that, under the current schedule, the low carbon fuel standard (LCFS) will not begin requiring more biodiesel to be sold in the state than is currently sold until at least the fourth year of the program. And California biodiesel plants' current production capacity will likely not be exceeded until the fifth year of the program. Ultimately, this overly cautious implementation schedule will only serve to delay development of a California-based industry that has significant potential for improving the environment and supplying green jobs during a historically challenging economic time.

2. With respect to the CA-GREET model for soy-based biodiesel, the ARB should, in our view, use a consistent co-product allocation method. Employing the displacement method for corn-based ethanol and the energy allocation method for soy-based biodiesel defies logic given their inherent and rather obvious similarities. No other government does it this way. This decision is particularly harmful because the chosen methods result in the worst possible assessment for each fuel. And in the case of soy-based biodiesel, the error is compounded because the ARB adds GHG emissions associated with the inefficiency inherent in livestock feed uptake to the oil/biodiesel side of the equation. This is illogical since the amount of energy that animals metabolize has nothing to do with the oil/biodiesel side of the GHG assessment; those GHG emissions should be counted on the meal side since they are related 100 percent to livestock feeding within the animal production industry. Further, it is important to understand that soybean oil has historically been viewed by the soybean industry as a by-product rather than a co-product. Even with the development of biodiesel, the majority of the value of a soybean continues to reside in the meal. As such, it is common knowledge that farmers grow soybeans for the meal and not the oil. This makes it doubly inaccurate to add GHG emissions associated with meal/livestock feed to oil/biodiesel.

3. With respect to the lifecycle analysis for direct emissions related to petroleum-based diesel production, it is difficult to understand why the ARB would only assess the fuels that are produced in-state, since these fuels merely comprise one-third of the fuels sold in California. It has been said that this data is difficult to obtain, so one is left to conclude that the default value in GREET is simply being used by the ARB for the sake of convenience. Given that many view GREET's assessment of petroleum to be favorable to that industry, we urge the ARB to reconsider its decision to not conduct a full lifecycle assessment of petroleum-based diesel fuels produced outside California.

4. We wish to point out that the "system boundaries" of the direct emissions models for petroleum-based diesel and soy-based biodiesel are inconsistent in so far as GHG emissions related to oil exploration and oil well drilling are not included in the ARB's assessment, while GHG emissions associated with soybean planting are included in the ARB's emissions figure. Clearly, a direct parallel exists between oil well drilling and soybean planting. Unfortunately, this goes unrecognized in the ARB's model, compromising its accuracy. As such, we respectfully request that this difference in system boundaries be remedied by adding GHG emissions associated with oil exploration and drilling to the petroleum-based diesel total.

Regarding issues related to indirect impacts associated with GHG lifecycle analysis that were included in the draft regulation but will not be considered for approval by the board this week, we have the following comments.

1. We respectfully urge the ARB to take its time with regard to work on indirect land use change (ILUC) modeling. While we support investigating this issue fully, and wish to participate in and contribute to the effort in any way possible, we are keenly aware that the data and models needed to properly assess this issue are not yet available. Since the LCFS is not, in a real sense, implemented until 2011, and more biodiesel will not be required until 2014 than is currently sold in the state, we see no reason to rush to judgment on this issue in

the very near term. Rather than prematurely publishing a half-baked result, we recommend investigating ILUC until January of 2011 when the LCFS is actually implemented but could still be met quite easily with California-produced ultra low carbon biodiesel from recycled cooking oil. This approach would be much more in keeping with generally accepted scientific principles. It is also interesting to note that the European Commission is employing just such a strategy by moving forward with implementation of its renewable fuels mandate, but not including a factor for ILUC until 2017. While we are not advocating for the ARB to wait until 2017 to address ILUC, we do feel strongly that a one-year deferral would inform thought on this issue significantly by providing more time for data gathering and model improvement and development.

2. In our view, the fact that the ARB has indicated it will not perform an assessment of indirect GHG impacts associated with petroleum-based diesel represents a flaw in the agency's analysis. While ARB staff are on record indicating this information is difficult to find and would likely result in only minor modifications to petroleum's GHG reduction assessment, the same statements could also be made about soy-based biodiesel as it relates to global land use changes and the causes of those changes. In the latter case, rather than using a factor of zero as the ARB has for petroleum-based diesel, the agency has, in truth, simply ventured a guess to derive a "temporary" number – a number which, by the way, is quite large. Ultimately, this is clearly an instance in which petroleum diesel and biodiesel are treated very differently, resulting in a less accurate analysis, in general, and a less favorable analysis for biodiesel, in particular.

3. The ARB does not include historical yield trends in its modeling. With all due respect, this is a catastrophic error that could distort the modeling results by a factor of 80 percent or more. At the most recent ARB public workshop, John Sheehan from the University of Minnesota presented data from a model he developed with the Natural Resources Defense Council which showed that once a historical yield trend is included in the analysis, the ILUC factor becomes zero because the higher productivity of agricultural land means there is more than enough crops available to address both energy and food needs. The NBB, as strongly as possible, encourages the ARB to reconsider its position on this issue. Although the ARB's current approach is simpler and easier, it distorts the final results immensely, perhaps to the point of needlessly cancelling the only compliance pathway capable of meeting the ten percent diesel reduction target.

4. As a follow-on to point number three above, the ARB should recognize the GTAP model's major weakness – that it assumes supply and demand are always in equilibrium. The ARB should address this shortcoming by adding a component to the model that can account for increasing yields, which would allow the model to show greater supply than demand over the long-term. Since substantial data exists showing supply and demand in the agriculture industry are never in balance, it is difficult to understand why the ARB would use this model for long-term forecasting. (Notably, one of the ARB's own peer reviewers made this same point in his recent response to the draft regulation by stating that GTAP should not be used for forecasting periods longer than 15 years.) This limitation of the GTAP model is precisely why the ARB was unable to verify its ILUC model against 2001-2007 corn data. Of course, this is not entirely unexpected since the GTAP model was never intended for the purpose for which it is being used by the ARB.

5. Page X-4 of the proposed regulation states that "The lowest cost way for many farmers to take advantage of these higher commodity prices is to bring non-agricultural lands into production." This assumption causes the ILUC model to predict that a significant amount of new land will be brought into agricultural production, artificially increasing the ILUC factor and thus decreasing biodiesel's GHG benefits. We would be interested in seeing any data the ARB has that shows clearing land for additional plantings is less expensive than improving agricultural practices such as purchasing higher quality seed varieties. Based on our calculations, the math does not come close to supporting this assumption, meaning the ARB believes farmer-businesspeople will consistently – and on a long-term, worldwide basis – make decisions counter to their economic best interest.

6. With respect to GHG modeling, the ARB mentions the words "full transparency" in the draft regulation on multiple occasions. We are pleased to state that this has been the case with regard to the direct emissions model, CA-GREET. To date, however, this has not been the case with respect to ILUC/GTAP modeling. ARB staff have indicated at public meetings that the GTAP model is publicly available. Unfortunately, this is only technically true because to gain access to the model one has to pay Purdue University a sum of approximately $9,000. And even if one musters the financial resources to access the GTAP model data, he or she still would not know what assumptions had been changed by ARB staff and contractors because that information has not been made available to the public. Given the extreme importance of the ILUC modeling effort to the biodiesel industry and the fact that the ARB appears to be moving forward on this issue at a very rapid pace, we would hope all data related to this work would be made publicly available in the very near term so that organizations such as ours could participate meaningfully in the effort. As it stands currently, we have contracted with a noted expert in the field to analyze ARB's work who is unable to do so because no significant information has been released.

7. While we have a high level of confidence in the intellectual integrity of the ARB, we cannot help but note that most governments and organizations which employ a peer review process mismanage it by hand picking a few like-minded junior professors from a small set of geographically diverse institutions. Typically, these exercises have the effect of rubber stamping the agency's views rather than informing the process. As such, we urge the ARB to be exceptionally thoughtful with regard to how it manages the peer review process. Specifically, we suggest a fully transparent and unbiased process that focuses on soliciting opinion from the premier North American experts in this area.

Thank you, in advance, for your kind consideration of our comments. Again, we very much appreciate the cooperation of ARB staff and the opportunity to work with the agency on this important policy. If you should have any questions, I hope you will feel free to call me at any time.

Sincerely,

Shelby Neal

Shelby Neal
Director of State Governmental Affairs

ATTACHMENT 14

Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon

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Contributed by Ruth S. DeFries, July 27, 2006

Intensive mechanized agriculture in the Brazilian Amazon grew by >3.6 million hectares (ha) during 2001–2004. Whether this cropland expansion resulted from intensified use of land previously cleared for cattle ranching or new deforestation has not been quantified and has major implications for future deforestation dynamics, carbon fluxes, forest fragmentation, and other ecosystem services. We combine deforestation maps, field surveys, and satellite-based information on vegetation phenology to characterize the fate of large (>25-ha) clearings as cropland, cattle pasture, or regrowing forest in the years after initial clearing in Mato Grosso, the Brazilian state with the highest deforestation rate and soybean production since 2001. Statewide, direct conversion of forest to cropland totaled >540,000 ha during 2001–2004, peaking at 23% of 2003 annual deforestation. Cropland deforestation averaged twice the size of clearings for pasture (mean sizes, 333 and 143 ha, respectively), and conversion occurred rapidly; >90% of clearings for cropland were planted in the first year after deforestation. Area deforested for cropland and mean annual soybean price in the year of forest clearing were directly correlated (R^2 = 0.72), suggesting that deforestation rates could return to higher levels seen in 2003–2004 with a rebound of crop prices in international markets. Pasture remains the dominant land use after forest clearing in Mato Grosso, but the growing importance of larger and faster conversion of forest to cropland defines a new paradigm of forest loss in Amazonia and refutes the claim that agricultural intensification does not lead to new deforestation.

agriculture | carbon | land use change | soybean

The "arc of deforestation" along the southern and eastern extent of the Brazilian Amazon is the most active land-use frontier in the world in terms of total forest loss (1) and intensity of fire activity (2). Historically, the dominant pattern of forest conversion has begun with small-scale exploration for timber or subsistence agriculture, followed by consolidation into large-scale cattle ranching operations or abandonment to secondary forest (3–5). Recent expansion of large-scale mechanized agriculture at the forest frontier has introduced a potential new pathway for forest loss, generating debate over the contribution of cropland expansion to current deforestation dynamics (5–9). In the nine states of the Brazilian Legal Amazon, mechanized agriculture increased by 36,000 km^2,[††] and deforestation totaled 93,700 km^2[‡‡] during 2001–2004. Recent gains in the area under cultivation and the productivity of locally adapted crop varieties have made Brazil a leading worldwide producer of grains such as soybeans; the agribusiness sector now accounts for more than one-third of Brazil's gross national product (10).

The state of Mato Grosso alone accounted for 87% of the increase in cropland area and 40% of new deforestation during this period. Whether cropland expansion contributes directly to deforestation activity or occurs only through the intensified use of previously deforested areas has important consequences for ecosystem services (11), such as carbon storage, and future deforestation dynamics.

Amazon deforestation is Brazil's largest source of CO_2 emissions (12, 13). Carbon fluxes from deforestation are a function of the area of forest loss (14–16) and related forest disturbances, such as fire (17, 18) and logging (17, 19), variations in forest biomass across the basin (20), and land use or abandonment after forest clearing (3, 21). Land use after forest clearing remains a major source of uncertainty in the calculation of deforestation carbon fluxes because methods to assess deforestation trends in Amazonia have not followed individual clearings over time (4, 5, 22–28). The relative contributions of smallholder agriculture and large-scale cattle ranching to annual forest loss have been inferred from the size of deforestation events (5, 28), but no direct measurements have been available. Rapid growth of large-scale agriculture in Amazonia challenges the historic relationship between land use and clearing size.

We determine the fate of large deforestation events (>25 ha) during 2001–2004 in Mato Grosso State to provide satellite-based evidence for the relative contributions of cropland and pasture to increasing forest loss during this period (Fig. 1). Our approach combines satellite-derived deforestation data, vegetation phenology information from the Moderate Resolution Imaging Spectroradiometer (MODIS; ref. 29), and 2 years of field observations to establish the spatial and temporal patterns of land use after forest clearing.

Direct measurement of land use after deforestation is aided by MODIS, which began near-daily coverage of the entire Amazon Basin at 250-m to 1-km resolution in February 2000. The higher frequency of observations at moderate resolution improves the problem of persistent cloud cover in high-resolution satellite data for Amazonia (30) without sacrificing the ability to characterize land-cover changes in a fragmented forest landscape (31, 32). Time series of cloud-free composite images at 16-day intervals provide vegetation phenology information to identify different land-cover types from the unique patterns of vegetation greenness for cropland, pasture, and forest (33).

Author contributions: D.C.M., R.S.D., and Y.E.S. designed research; D.C.M., R.S.D., Y.E.S., L.O.A., E.A., F.d.B.E.-S., and R.F. performed research; D.C.M. and J.M. analyzed data; and D.C.M. and R.S.D. wrote the paper.

The authors declare no conflict of interest.

Abbreviations: ha, hectares; MODIS, Moderate Resolution Imaging Spectroradiometer; PRODES, Program for the Estimation of Deforestation in the Brazilian Amazon; INPE, Brazilian National Institute for Space Research.

See Commentary on page 14261.

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††Total area planted in soybeans, corn, cotton, rice, sugarcane, and sorghum from municipality data on crop production (IBGE Municipal Agricultural Production, www.sidra.ibge.gov.br).

‡‡Annual deforestation increment from INPE PRODES, www.obt.inpe.br/prodes.

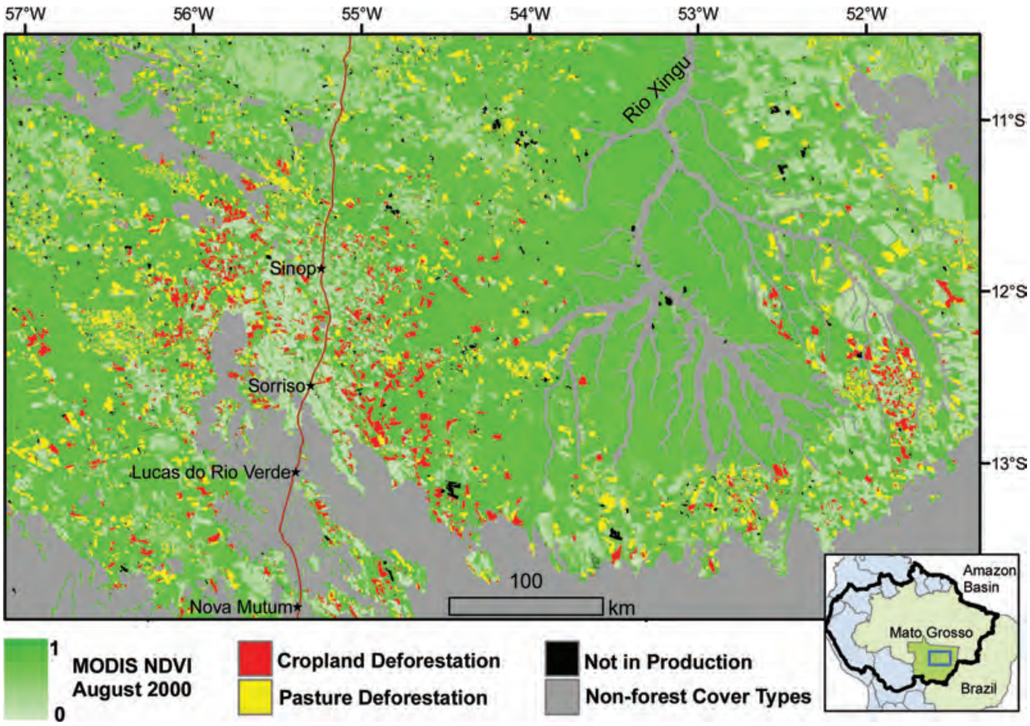

Fig. 1. Tropical deforestation for cropland agriculture in Mato Grosso state (2001–2004) is concentrated along the existing agricultural frontier. (*Inset*) Location of the study area subset within Mato Grosso state and the Amazon Basin.

Results

The expansion of large-scale mechanized crop production contributed directly to 2001–2004 deforestation in Mato Grosso, adding to the existing pressure for forest loss from cattle ranching (Fig. 2 *Upper*). We estimate that the area of tropical forest converted directly to large-scale crop production during 2001–2004 ranged from 785 to 2,150 km^2 per year, peaking at 23% of 2003 annual deforestation in large clearings (>25 ha). Total cropland deforestation during this period exceeded 5,400 km^2 of 33,200 km^2 total deforestation in large clearings.

A shift in clearing dynamics occurred between 2002 and 2003 deforestation. The fraction of deforested area converted to cattle pasture decreased from 78% to 66%, whereas direct transitions to cropland increased from 13% to 23%, and the amount classified as not in production (9–10%) and in small clearings (15–17%) remained nearly constant. Favorable market conditions for agricultural exports, especially for soybeans, may have influenced the patterns in land use after deforestation. The mean annual soybean price during 2001–2004 was related to the amount of deforestation for cropland in Mato Grosso ($R^2 = 0.72$).

For all years, the average clearing for cropland was more than twice the size of that for pasture (cropland mean = 333 ha, SD = 459 ha; pasture mean = 143 ha, SD = 267 ha; $P < 0.0001$). Deforestation for cropland accounted for 28% of the clearings >200 ha in 2003 compared with 6% of clearings <200 ha (Fig. 2 *Lower*). Smaller-size classes showed higher proportions of clearings not in production and slower conversions than larger deforestation-size classes.

The transition from forest to cropland occurred rapidly. Satellite-based vegetation phenology showed evidence of planting on >90% of new cropland areas during the year immediately after forest clearing. Conversions of forest to cattle pasture occurred more slowly than cropland transitions, such that 72–86% of pasture clearings were identified in the year after clearing, with the remainder requiring ≥2 years to develop a clear grass phenology component over the majority of the deforested area. Deforested area classified as not in production diminished in each subsequent year after deforestation, as forest clearings were gradually converted to pastures or cropland.

Cropland deforestation in Mato Grosso during 2001–2004 was concentrated within the Xingu river basin and near the existing centers of crop production (Sinop, Sorriso, Lucas do Rio Verde, and Nova Mutum) along the Cuiabá-Satarém highway (BR-163) in the central Mato Grosso State (Fig. 1). Deforestation for cattle pasture predominated in the northern and western portions of the state, and deforestation that retained or regrew forest cover did not show a specific spatial pattern.

The spatial distribution of large clearings during 2002–2005 shows the gradual advance of very large deforestation events into municipalities in northwest Mato Grosso (Fig. 3). Large clearings near the existing mechanized agricultural frontier in central and eastern Mato Grosso were highest in 2003 and 2004. In 2005, soybean prices fell by >25%, and municipalities in eastern Mato Grosso showed a decrease in large deforestation events, yet the central agricultural zone continued to exhibit a similar degree of large forest-clearing activity.

Discussion

Deforestation for large-scale cropland accounted for 17% of forest loss in large clearings during 2001–2004 in Mato Grosso, signaling a shift from historic uses of cattle ranching and smallholder agriculture. Growth in the number of large deforestation events (>25 ha) was responsible for annual increases in deforestation during the study period, and the relative contribution of cropland to large deforestation events was directly correlated with the price of soybeans in the year of forest clearing. Pasture remains the dominant land use after deforestation in Mato Grosso, but our results show a general trend of increasing cropland deforestation during 2001–2004 and a continuation of the pattern of large forest clearings in the central agricultural region in 2005. The rise in importance of deforestation for cropland signifies a new paradigm of Amazon deforestation defined by larger clearing sizes and faster

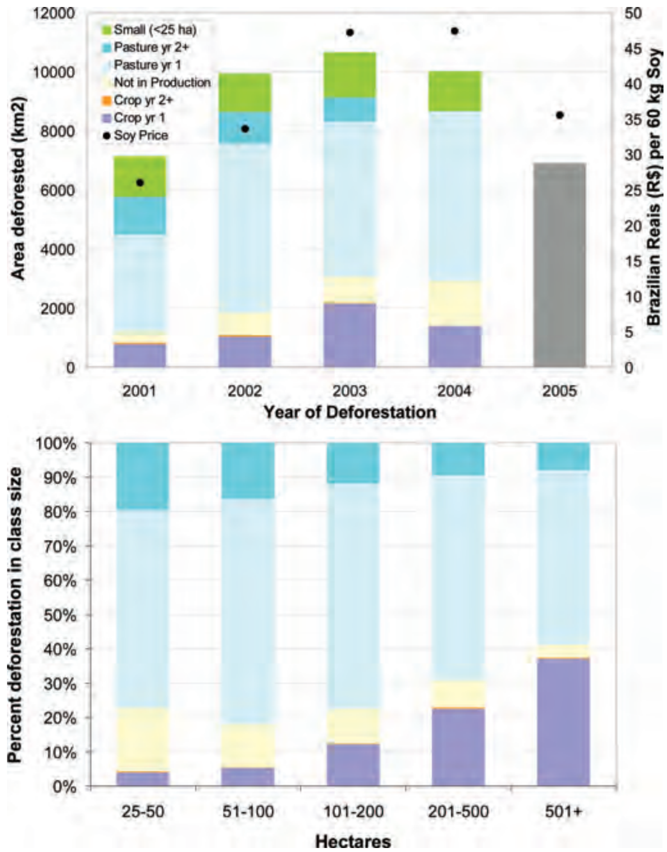

Fig. 2. Trends in land use after 2001–2004 deforestation events >25 ha in Mato Grosso state, Brazil. (*Upper*) Summary of conversion dynamics by post-clearing land cover from satellite-based phenology information in the years after forest clearing. A preliminary estimate of 2005 deforestation is shown in gray (INPE PRODES). Inflation-adjusted prices per 60-kg sack of soybeans for the same period as the annual deforestation increment (September–August) are plotted on the right-hand axis in Brazilian Reais (R$).[§§] (*Lower*) Fate of 2003 deforestation events by clearing size.

rates of forest conversion than previous pathways of forest loss for pasture or smallholder agriculture. Our findings challenge previous assumptions about the fate of carbon after deforestation (3, 21), economic drivers of land-use change in Amazonia (4, 28, 34), and the possibility for land sparing through crop intensification (7, 35).

Implications for Future Deforestation Dynamics. Mechanization of both forest clearing and crop production has encouraged simultaneous expansion and intensification of land use at the forest frontier. Although the growth of high-yield mechanized agriculture can be a land-sparing option compared with lower-yield methods (35), our results suggest that intensification of crop production in the Brazilian Amazon to meet global demand for feed crops (8, 9, 36) does not necessarily lead to local land sparing. Growing production of soybeans and other crops in Amazonia is also a function of expansion into nonforest cover types (33) and increased yields (ref. 7; Fig. 4). Conversion of planted pastures and natural grasslands accounted for 36% of new cropland area in Mato Grosso between 2001 and 2004, and an additional 30% of cropland expansion statewide replaced Cerrado savanna/woodland vegetation (33). Improved yields led to higher corn, rice, cotton, and sorghum production from Mato Grosso during 2000–2004, but soybean yield was 10% lower in 2004 than peak production in 2002 based on Brazilian Institute for Geography and Statistics (IBGE) Municipal Agricultural Production agricultural census data. Declining soybean yields may reflect expansion of cropland into less-productive sites, reductions in soil fertility, or lower harvests because of soybean rust (*Phakopsora pachyrhizi*; ref. 37) and other crop pathogens. Declining yields could be either an incentive or a disincentive to clear more land, but it is not possible to make this distinction from our analysis.

Continued expansion of cropland production in Amazonia is possible. Large areas of the Amazon Basin are projected to have suitable soils, climate, and topography for large-scale mechanized agriculture (U.S. Department of Agriculture, www.fas.usda.gov/current2003.html, January 23, 2003; ref. 38), and many other regions of the world face a shortage of arable land for additional cropland expansion (39). Recent and planned future development of critical infrastructure, such as roadways and ports, is also intended to support ranching and farming operations by reducing the cost of transporting agricultural products to markets (6, 24). The new paradigm of Amazon deforestation makes farmers and ranchers flexible to future opportunities; once an area is cleared to bare soil for mechanized agriculture, it is highly fungible in terms of future land use. The rise and fall of profits for different crops, beef, plantation timber, and other resources will therefore determine future land use on both new deforestation and previously cleared areas.

Implications for Carbon Fluxes from Deforestation. Deforestation dynamics in Mato Grosso during 2001–2004 highlight the need to understand land use after deforestation, rather than just the total area of forest loss, to characterize the timing and magnitude of carbon losses from forest clearing. Carbon losses per area deforested for cropland are potentially greater than other types of forest conversion because of the rapid and complete removal of above-ground biomass and woody roots to permit tractor planting, with little or no net carbon offset from subsequent crop production. Unlike previous estimates of carbon losses during conversion of forest to pasture (3, 21, 40, 41), decomposition may contribute very little to the total carbon lost during the conversion of forest to cropland, because trunks, stumps, and woody roots are completely combusted in multiple fire events during the clearing process. Stratifying land use after deforestation in terms of clearing size, biomass removal, and duration enables more accurate estimates of interannual variation in deforestation carbon fluxes from Amazonia than previously available.

Application to Deforestation Monitoring. Characterizing the fate of individual clearings over time provides input for programs to reduce deforestation (5), projections of future deforestation (42), and efforts to identify priority areas for conservation (43). A similar approach as presented here that integrates moderate and high spatial resolution satellite data was established to identify deforestation events in the Brazilian Amazon in near-real time [Brazilian National Institute for Space Research (INPE) Program for the Estimation of Deforestation in the Brazilian Amazon (PRODES) and Program for Real-Time Detection of Deforestation (DETER)[¶¶] programs]. Linking vegetation phenology data from MODIS with other types of change monitoring, such as logging (19), could be done to characterize the fate of other forest disturbances over time.

[§§]Data sources: Monthly price paid to soybean producers, Fudaçao Getúlio Vargas Agroanalysis; deflator, IBGE Extended National Consumer Price Index. Prices are shown per 60-kg sack of soybeans to maintain consistency with the common unit of soybean production.

[¶¶]INPE Detecção de Desmatamento em Tempo Real, or Program for Real-Time Detection of Deforestation, was started in 2003 to provide regular updates of new deforestation >25 ha in the Brazilian Amazon using data from MODIS sensors and CBERS-2, the Chinese–Brazilian Environmental Satellite. Data can be accessed at www.obt.inpe.br/deter.

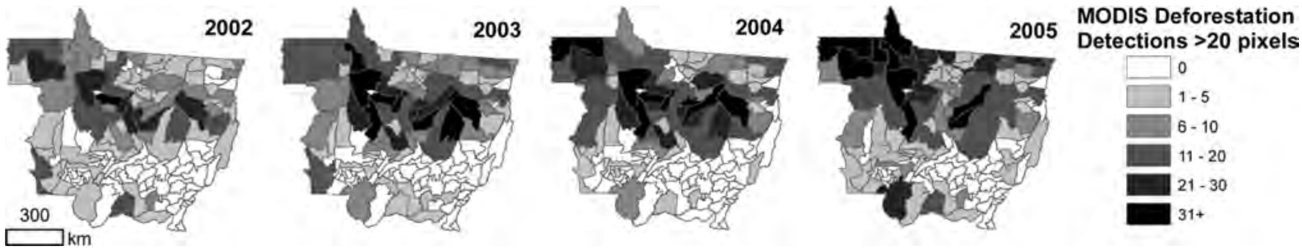

Fig. 3. Spatial distribution of 2002–2005 deforestation events larger than 20 MODIS 250-m pixels (≈125 ha) for municipalities in Mato Grosso (32).

Our ability to fully explore the interannual variability in deforestation dynamics and place recent trends in the context of historic patterns of forest conversion is somewhat limited by the short duration of the MODIS time series. Results showing less regrowth after forest clearing than previous studies (15, 44), the short interval between forest clearing and production, and limited secondary land-use transitions after forest conversion (forest–pasture–cropland) merit further investigation with the growing MODIS data record. The approach is potentially applicable in other areas undergoing conversion to mechanized agriculture but could be limited by absence of high-resolution deforestation maps, clearing sizes too small for isolation of vegetation phenology information with MODIS 250-m resolution data, or land uses after forest clearing without distinct phenologies.

In summary, our findings refute the claim that new crop production in Amazonia is occurring only through intensified use of lands previously cleared for cattle ranching rather than adding a new pressure for forest loss (45, 46). The large clearings and complete removal of above-ground biomass indicate per area carbon emissions to the atmosphere greater than previous clearing for cattle ranching and fewer forest fragments on the landscape as habitat and suggest rapid loss of forest as infrastructure develops for large-scale agriculture. Growing linkages to global market demand for soybeans and other crops have reduced the remoteness of the forest frontier, and the potential exists for a return to higher deforestation in Mato Grosso as seen in 2003–2004 with a rebound of crop prices. Initiatives such as certification schemes for environmental best practices that apply market pressure to ranching and soybean production at the forest frontier (9) would augment existing efforts to reduce illegal deforestation through satellite-monitoring programs. Increasing incentives for intensified use of unproductive pastures or other existing cleared lands will also be essential to balance economic benefits from increasing crop production with ecosystem services from intact forest and Cerrado habitat.

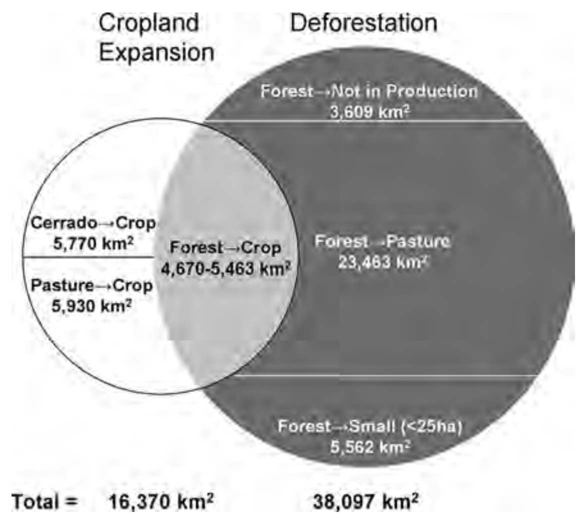

Fig. 4. Relationship between cropland expansion and deforestation in Mato Grosso, Brazil, during 2001–2004. Estimates of forest conversion directly to cropland range from 4,670 (33) to 5,463 km² (this study). Expansion of large-scale mechanized agriculture was estimated from annual land cover maps of Mato Grosso derived from MODIS-based phenology information; only transitions from forest, Cerrado, or pasture/grasslands to double-cropping systems are included in this estimate (33). Estimated cropland expansion from agricultural census data of total planted area is nearly two times the area derived from satellite data, because individual fields are counted separately for each crop rotation in the agricultural census.

Data and Methods

Remote-Sensing Analysis. We combine field observations with satellite-based data on annual deforestation and vegetation phenology to classify the fate of new forest clearings >25 ha in Mato Grosso State, Brazil. Field data on the location and condition of deforested areas, pastures, and cropland were collected during June 2004, March 2005, and July 2005, and scaled from Global Positioning System point observations to polygon training data by digitizing feature boundaries on near-coincident Landsat Thematic Mapper (TM) data. Landsat TM data were provided by INPE before each field campaign and georeferenced to existing Landsat Enhanced Thematic Mapper Plus (ETM+) data provided by the Global Land Cover Facility with a spatial error of less than one pixel (30 m). We used PRODES digital results of the annual deforestation increment mapped using Landsat TM data from approximately August of 2001–2004 for the state of Mato Grosso to identify the location and size of new clearings and summarize total deforested area, limiting our analysis to new clearings >25 ha based on the moderate resolution (250 m) of the MODIS sensor (29, 31, 32). Estimates of 2005 deforestation in Mato Grosso State were generated from MODIS red reflectance data contained in the MODIS/Terra Vegetation Indices 16-day L3 Global product at 250-m resolution (MOD13Q1, version 4; ref. 47) and forest information from the PRODES 2004 deforestation analysis following methods outlined in ref. 33.

Before generating phenology metrics for land-cover classification, we implemented a two-stage method to remove cloud contamination in annual time series of normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) data from the MOD13Q1 product from 2000–2005 for three 10° × 10° spatial tiles (h12v10, h12v09, and h13v10). Clouds, cloud shadows, high aerosols, or other data artifacts were identified by using the Quality Assessment layer available with the MODIS data product and replaced with a predicted value by fitting the remaining high-quality data in each pixel's time series with a cubic spline function. Second, the resulting annual time series were fit with zero to third-order harmonic functions to identify and eliminate any clouds not captured by the image-quality data layer (48). We derived 36 metrics from the cloud-free time series: NDVI and EVI minimum, maximum, mean, median, amplitude, and standard deviation for annual (year^{n-1}: day 273−year^{n}: day

288), wet season (year^{n-1}: day 273−year^{n}: day 112), and dry season (year^{n}: day 113–273) time periods. Harmonic equations provided three additional phenology amplitude and phase metrics for the classification process.

A decision-tree classifier was developed with training data from field observations in July 2004 and MODIS time series metrics from 2003-273 to 2004-288 (Fig. 5, which is published as supporting information on the PNAS web site). Validation of the classification was done by using field data from March and July 2005 and time series metrics from 2004-273 to 2005-288 (Table 1, which is published as supporting information on the PNAS web site). Following accurate classification of 2005 validation data (overall accuracy, 89%), the same classification rules were applied to each year of MODIS metrics. We define the fate of deforested areas as cropland, pasture, or not yet in production using the majority land-cover class within each deforestation polygon based on the improvement in classification accuracy for cropland and cattle pasture with this method. Deforestation classified as forest and degraded forest was combined into a single class, not in production, encompassing damaged forests that were never fully cleared (e.g., logged or burned forest), edge effects from adjacent forest cover, and regrowth.

Interpretation of Remote-Sensing Results. The classification was highly accurate in separating double-cropping systems and pasture. However, the annual phenological patterns of fallow agricultural cycles or single-crop rotations are similar to a pasture phenology and could be misclassified as such. To correct for these land-use patterns, we established a land-use trajectory from classification results for each year after deforestation to eliminate spurious pasture–cropland transitions in the first 2 years after deforestation (Table 2, which is published as supporting information on the PNAS web site). The largest contribution to estimated deforestation for cropland from the trajectory corrections was a single year of pasture classification followed by 1–3 years of cropland classification. Use of deforested lands as pasture for a single year is unlikely, given the high cost of fencing material (49). Trajectory-based modifications accounted for 20–27% of the total deforestation for cropland in 2001–2003. We report statistics and trends based on the corrected trajectories for deforestation in 2001–2003 and unadjusted results for 2004, because only one postclearing MODIS classification (2005) was available.

Soybean Price Data. To estimate the influence of crop prices on deforestation, we adjusted the Fudaçao Getúlio Vargas Agroanalysis monthly price paid to soybean producers for inflation using a standard consumer price index (46), IBGE Extended National Consumer Price Index. Average annual prices were calculated from monthly data for the same period as PRODES deforestation calculations, September through August of each year, and August 2005 was the reference month for inflation adjustment.

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1. Food and Agriculture Organization of the United Nations (2006) *Global Forest Resources Assessment 2005: Progress Towards Sustainable Forest Managment* (Food and Agriculture Organization, United Nations, Rome, Italy).
2. Giglio L, Csiszar I, Justice CO (2006) *J Geophys Res* 111:G02016.
3. Houghton RA, Skole DL, Nobre CA, Hackler JL, Lawrence KT, Chomentowski WH (2000) *Nature* 403:301–304.
4. Lambin EF, Geist HJ (2003) *Environment* 45:22–36.
5. Fearnside PM (2005) *Conserv Biol* 19:680–688.
6. Fearnside PM (2001) *Environ Conserv* 28:23–38.
7. Brown JC, Koeppe M, Coles B, Price KP (2005) *Ambio* 34:462–469.
8. Naylor R, Steinfeld H, Falcon W, Galloway J, Smil V, Bradford E, Alder J, Mooney H (2005) *Science* 310:1621–1622.
9. Nepstad DC, Stickler CM, Almeida OT (2006) *Conserv Biol*, in press.
10. Empresa Brasileira de Pesquisa Agropecuária (2004) *Criação de Empregos Pelo Complexo Agroindustrial da Soja* (Ministry of Agriculture, Brasilia, Brazil).
11. Mooney H, Cropper A, Reid W (2005) *Nature* 434:561–562.
12. Ministério da Ciência e Tecnologia (2004) *Brazil's Initial National Communication to the United Nations Framework Convention on Climate Change* (Ministry of Science and Technology, Brasilia, Brazil).
13. Santilli M, Moutinho P, Schwartzman S, Nepstad DC, Curran LM, Nobre CA (2005) *Clim Change* 71:267–276.
14. DeFries RS, Houghton RA, Hansen MC, Field CB, Skole DL, Townshend J (2002) *Proc Natl Acad Sci USA* 99:14256–14261.
15. Skole DL, Tucker C (1993) *Science* 260:1905–1910.
16. Achard F, Eva HD, Stibig, H-J, Mayaux P, Gellego J, Richards T, Malingreau, J-P (2002) *Science* 297:999–1002.
17. Nepstad DC, Veríssimo A, Alencar A, Nobre CA, Lima E, Lefebre P, Schlesinger P, Potter C, Moutinho P, Mendoza E, *et al.* (1999) *Nature* 398:505–508.
18. Cochrane MA (2003) *Nature* 421:913–919.
19. Asner GP, Knapp DE, Broadbent EN, Oliveira PJC, Keller M, Silva JN (2005) *Science* 310:480–482.
20. Houghton RA, Lawrence KT, Hackler JL, Brown S (2001) *Glob Change Biol* 7:731–746.
21. Hirsch AI, Little WS, Houghton RA, Scott NA, White JD (2004) *Glob Change Biol* 10:908–924.
22. Hecht SB (1993) *Bioscience* 43:687–695.
23. Pfaff ASP (1999) *J Env Econ Mgmt* 37:26–43.
24. Nepstad DC, Carvalho GO, Barros AC, Alencar A, Capobianco JP, Bishop J, Moutinho P, Lefebre P, Silva UL, Prins E (2001) *For Ecol Manag* 154:395–407.
25. Geist HJ, Lambin EF (2002) *Bioscience* 52:143–150.
26. Cardille JA, Foley JA (2003) *Remote Sens Environ* 87:551–562.
27. Chomitz KM, Thomas TS (2003) *Am J Agric Econ* 85:1016–1028.
28. Margulis S (2004) *World Bank Working Paper No. 22: Causes of Deforestation of the Brazilian Amazon* (World Bank, Washington, DC).
29. Justice CO, Vermote E, Townshend J, DeFries RS, Roy DP, Hall DK, Salomonson VV, Privette JL, Riggs G, Strahler A, *et al*. (1998) *IEEE Trans Geosci Remote Sens* 36:1228–1249.
30. Asner GP (2001) *Int J Remote Sens* 22:3855–3862.
31. Anderson LO, Shimabukuro YE, DeFries RS, Morton DC (2005) *IEEE Geosci Remote Sens Lett* 2:315–318.
32. Morton DC, DeFries RS, Shimabukuro YE, Anderson LO, del bon Espírito-Santo F, Hansen MC, Carroll M (2005) *Earth Interact* 9:1–22.
33. Morton DC, DeFries RS, Shimabukuro YE (2006) in *Cerrado Land Use and Conservation: Assessing Trade-Offs Between Human and Ecological Needs*, eds Klink C, DeFries RS, Cavalcanti R (Conservation International, Washington, DC), in press.
34. Kaimowitz D, Mertens B, Wunder S, Pacheco P (2004) *Hamburger Connection Fuels Amazon Destruction: Cattle Ranching and Deforestation in Brazil's Amazon* (Center for International Forestry Research, Jakarta, Indonesia).
35. Green RE, Cornell SJ, Scharlemann JPW, Balmford A (2005) *Science* 307:550–555.
36. Kaimowitz D, Smith J (2001) in *Agricultural Technologies and Tropical Deforestation*, eds Angelsen A, Kaimowitz D (CABI Publishing, Wallingford, UK), pp 195–212.
37. Yorinori JT, Paiva WM, Frederick RD, Costamilan LM, Bertagnolli PF, Hartman GE, Godoy CV, Nunes J, Jr (2005) *Plant Dis* 89:675–677.
38. Jasinski EW, Morton DC, DeFries RS, Shimabukuro YE, Anderson LO, Hansen MC (2005) *Earth Interact* 9:1–18.
39. Food and Agriculture Organization (2003) *World Agriculture: Towards 2015/2030* (Earthscan Publications, London, UK).
40. Fearnside PM, Leal N, Jr, & Fernandes FM (1993) *J Geophys Res* 98:16733–16743.
41. Carvalho JA, Higuchi N, Araújo TM, Santos JC (1998) *J Geophys Res* 103:13195–13199.
42. Soares-Filho BS, Nepstad DC, Curran LM, Cerqueira GC, Garcia RA, Ramos CA, Voll E, McDonald A, Lefebre P, Schlesinger P (2006) *Nature* 440:520–523.
43. Nepstad DC, Schwartzman S, Bamberger B, Santilli M, Ray D, Schlesinger P, Lefebre P, Alencar A, Prins E, Fiske G, *et al.* (2006) *Conserv Biol* 20:65–73.
44. Roberts DA, Numata I, Holmes K, Batista G, Krug T, Monteiro A, Powell B, Chadwick OA (2002) *J Geophys Res* 107, 40:41–48.
45. Mueller CC (2003) in *Série Textos Para Discussão, Working Paper*, eds Bugarin M, Mueller CC (University of Brasilia, Department of Economics, Brasilia, Brazil), no 306.
46. Brandão ASP, de Rezende GC, Marques RW (2005) in *Texto Para Discussão* (Instituto de Pesquisa Econômica Aplicada, Rio de Janeiro, Brazil), no 1103.
47. Huete AR, Didan K, Miura T, Rodriguez EP, Gao X, Ferreira LG (2002) *Remote Sens Environ* 83:195–213.
48. Roerink GJ, Meneti M, Verhoef W (2000) *Int J Remote Sens* 21:1911–1917.
49. de Mendonça MJC, Vera Diaz MdC, Nepstad DC, Motta RS, Alencar A, Gomes JC, Ortiz RA (2004) *Ecol Econ* 49:89–105.

ATTACHMENT 15

Issues Raised by Discussions with EPA

1. The evolution of soybean areas in Argentina

Argentine soybean sector has steadily increased its share of the areas planted to major arable crops. Table 1 and Diagrams 1 and 2 depict the changing composition of the overall areas planted to the leading arable crops since 1996 and, in order to permit a clearer focus on the recent past, the second diagram presents the data solely for the period since 2004.

It is evident that the growth in soybean areas has been, in large part, at the expense of other major arable crops. Of the increase in soybean areas since 1996/97, less than half was the result of an increase in the total areas under the four major arable crops; more than half the increase was the result of switching arable land into soybeans from other crops.

Table 1: Argentine corn, wheat, sunflower and soybean areas, 1996-2009 (million acres)

	Corn	Wheat	Sunflower	Soybean	**Total**
1996/1997	8,401	17,544	7,166	15,320	**48,432**
1997/1998	7,845	14,090	8,231	17,183	**47,349**
1998/1999	6,437	13,341	9,659	20,176	**49,613**
1999/2000	7,660	15,204	8,592	21,209	**52,664**
2000/2001	6,963	15,834	4,660	25,698	**53,156**
2001/2002	6,054	16,865	4,979	28,169	**56,067**
2002/2003	6,054	14,579	5,807	31,135	**57,574**
2003/2004	5,683	14,085	4,522	34,594	**58,884**
2004/2005	6,869	15,073	4,670	35,582	**62,195**
2005/2006	6,029	12,355	5,436	37,559	**61,380**
2006/2007	6,919	13,059	5,930	40,277	**66,186**
2007/2008	8,434	14,826	6,365	40,453	**70,078**
2008/2009	5,560	10,470	4,473	39,536	**60,038**
2009/2010	4,942	7,413	5,683	44,478	**62,516**

Source: USDA

Since 2004/05, the total area planted to the four crops increased by a mere 421,000 acres; yet the area under soybeans grew by 8,896,000 acres.

In other words, since 2004/05, over 95% of the area expansion in soybeans was the result of farmers switching into this crop from corn, wheat and sunflower.

Diagram 1: Argentine soybean areas vs. other major crops, 1996-2009, in million acres

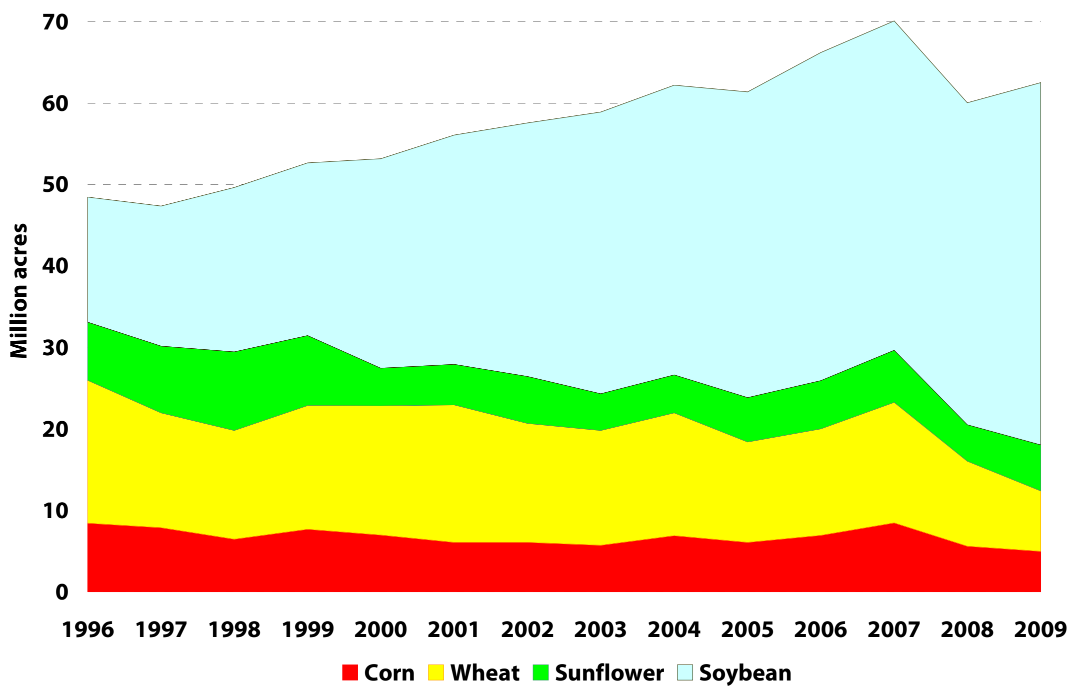
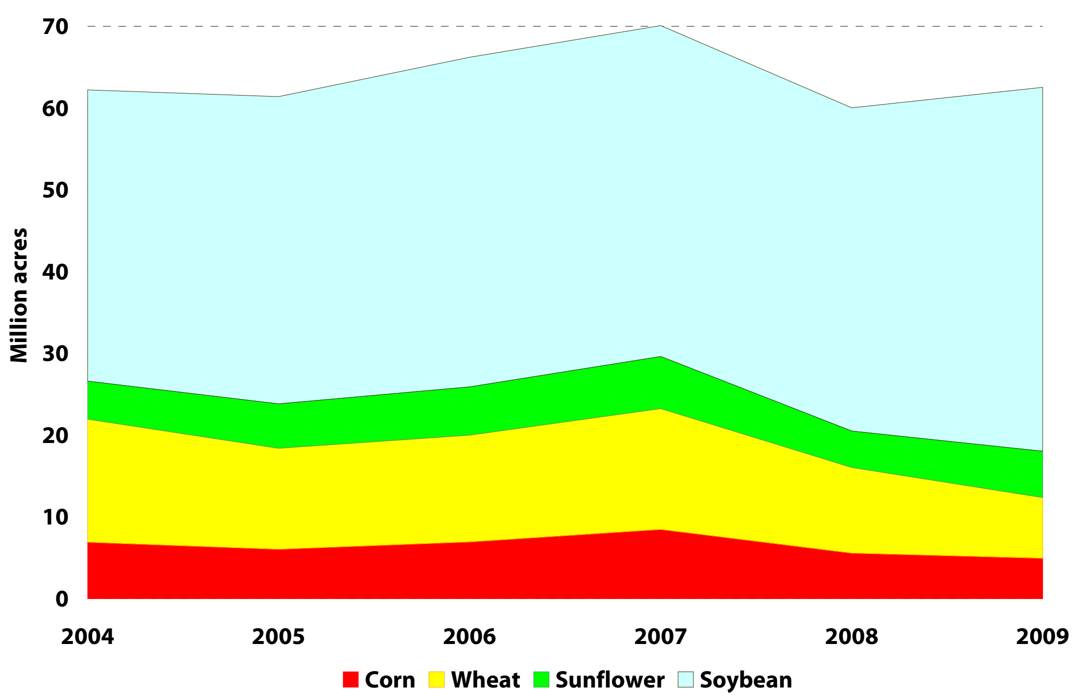


Diagram 2: Argentine soybean areas vs. other major crops, 2004-2009, in million acres



The enhanced importance of soybeans in the Argentine farming sector is the result of more favorable economics of soybean production, when contrasted with the main alternatives. Soybean's stable real (inflation-adjusted) costs per area for chemical inputs, including fertilizer, have become increasingly attractive to producers. This may be seen in Table 2 and Diagram 3.

In the final two columns of the table, we have estimated the environmentally valuable savings in fertilizer and chemical costs per area between 1996 and 2006 (the latest year for which data are available), as a result of the shifting pattern of plantings in favor of soybeans.

If the distribution of areas between corn, wheat, sunflower and soybeans had not altered at all between 1996 and 2006, the average real expenditures per hectare on fertilizer and chemicals would have risen from $55 to $80 in 2007 dollars (from roughly $22 to $32 per acre). The corresponding figure for corn, wheat and sunflower alone (i.e., excluding soybeans) would have risen from $49 to $93 (from roughly $20 to $38 per acre), which contrasts with the fall for soybeans, from $67 to $50 (from roughly $27 to $20) over the same period.

The effect of the expansion in soybean areas and decline in areas under the other three crops was to limit the rise of the actual average real costs of fertilizer and chemicals per hectare over all four crops to one from $55 to $67 in the same decade (from roughly $22 to $27 per acre).

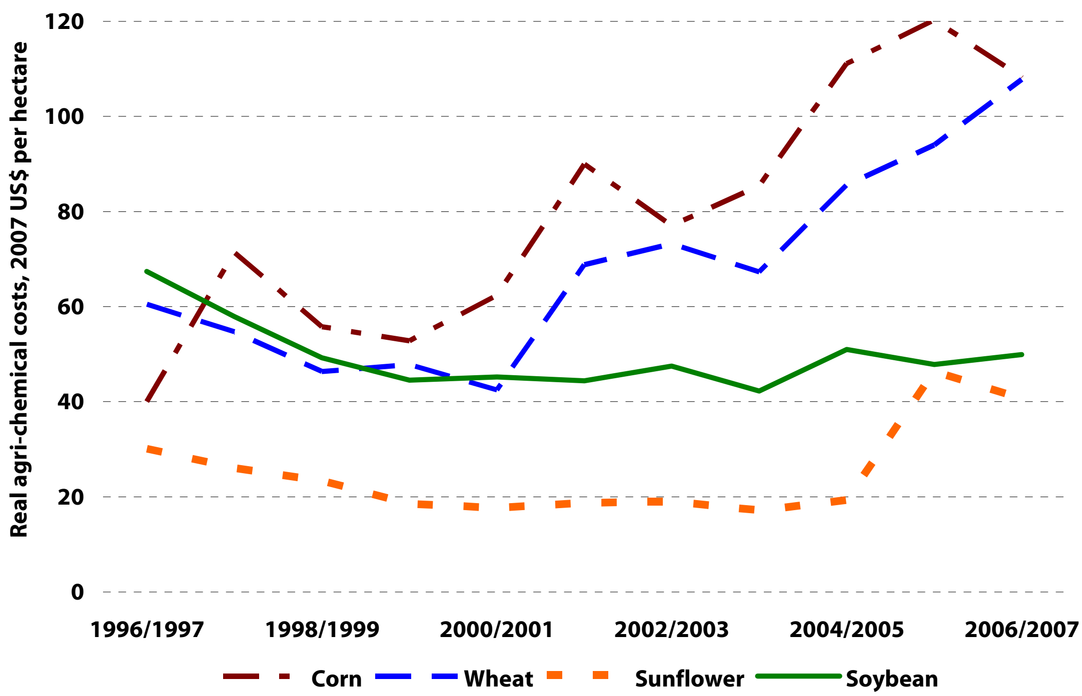
The actual average figure of $67 per hectare (roughly $27 per acre) in 2006/07, as against one of $80 ($32) if the allocation of land between crops had remained unaltered since 1996, represents a decline of 16.3% in the costs, adjusted for inflation, of fertilizers and sprays per hectare for Argentine arable agriculture as a whole. This undoubtedly yielded substantial environmental benefits. Hence, the Argentine example highlights the tangible environmental gains from increased soybean planting; and it must be noted that the advantage from soybeans will have widened since 2006, as input prices rose.

Table 2: Real (inflation-adjusted) costs per hectare of fertilizers and sprays, 1996-2006
(in 2007 $/hectare)

	Corn	Wheat	Sunflower	Soybean	Average, weighted by actual crop areas	Average, weighted by 1996/97 crop areas
1996/1997	40	60	30	67	55	55
1997/1998	71	55	26	58	54	54
1998/1999	56	46	23	49	44	45
1999/2000	53	48	18	45	42	43
2000/2001	62	42	18	45	44	43
2001/2002	90	69	19	44	54	57
2002/2003	77	73	19	47	54	58
2003/2004	85	67	17	42	50	55
2004/2005	111	86	19	51	64	69
2005/2006	120	94	46	48	64	77
2006/2007	108	108	41	50	67	80

Source: SAGPyA (the department of agriculture), whose data are available only up to 2006/07.

Diagram 3: Real (inflation-adjusted) costs per hectare of fertilizers & sprays, 1996-2006



The Argentine experience illustrates a more general point about the analysis of indirect land use.

Even if it were valid to associate expansions in soybean areas in South America with increased biodiesel demand in the U.S., the analysis of the environmental impacts requires a full allowance for the complexities of shifting patterns of cropping and input intensities (with their related environmental impacts). It is difficult to capture these effects properly, even with complex general equilibrium models.

2. The evolution of oil palm areas in Indonesia

Indonesian oil palm areas have grown slightly more rapidly than Argentine soybean areas from 1996 to 2008, and more than tripled during this short period.

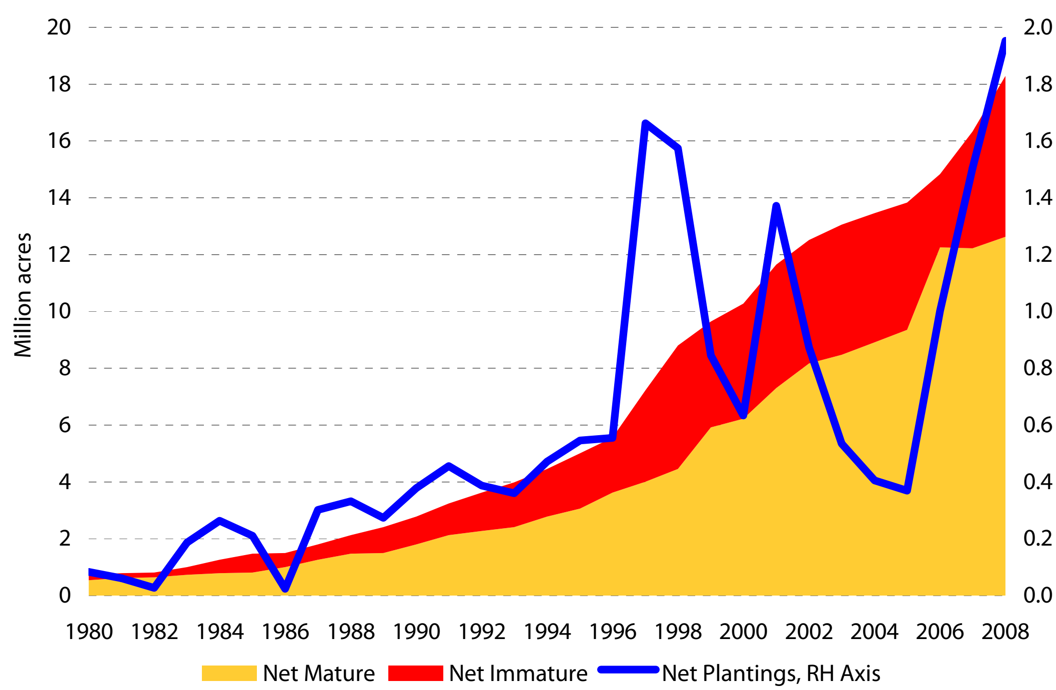
Table 3 and Diagram 4 illustrate the growth in Indonesian oil palm areas, distinguishing between mature areas (whose trees are old enough to be harvested), immature areas (up to four years old, and not yet yielding a crop), the combined total and net plantings (which represent the net increase in the total area after allowing for the replanting of old areas, whose trees have lost their economic attractions).

Table 3: Indonesian oil palm areas, 1996-2008 (million acres)

	Net Plantings	Mature	Immature	Total
1996	555	3,626	1,932	5,559
1997	1,662	4,009	3,212	7,221
1998	1,575	4,458	4,338	8,796
1999	846	5,922	3,720	9,641
2000	633	6,222	4,052	10,275
2001	1,372	7,305	4,342	11,647
2002	874	8,173	4,348	12,521
2003	535	8,472	4,584	13,056
2004	405	8,919	4,542	13,461
2005	370	9,349	4,481	13,831
2006	1,002	12,257	2,575	14,833
2007	1,503	12,222	4,114	16,336
2008	1,952	12,627	5,661	18,288

Sources: Indonesian Oil Palm Research Institute, Indonesian Palm Oil Commission

Diagram 4: Growth in Indonesian oil palm areas since 1980



The mature area under oil palm is very small in relation to US soybean areas. Despite its rapid growth, the mature area in Indonesia was still less than 17% of the US soybean area in 2008/09. However, because of oil palm's high productivity per acre, Indonesia produced more oil than was contained in all U.S. soybeans. The cultivation of oil palm can therefore be seen to allow substantial savings in land use in terms of meeting global demand for vegetable oils, whether for biodiesel or food.

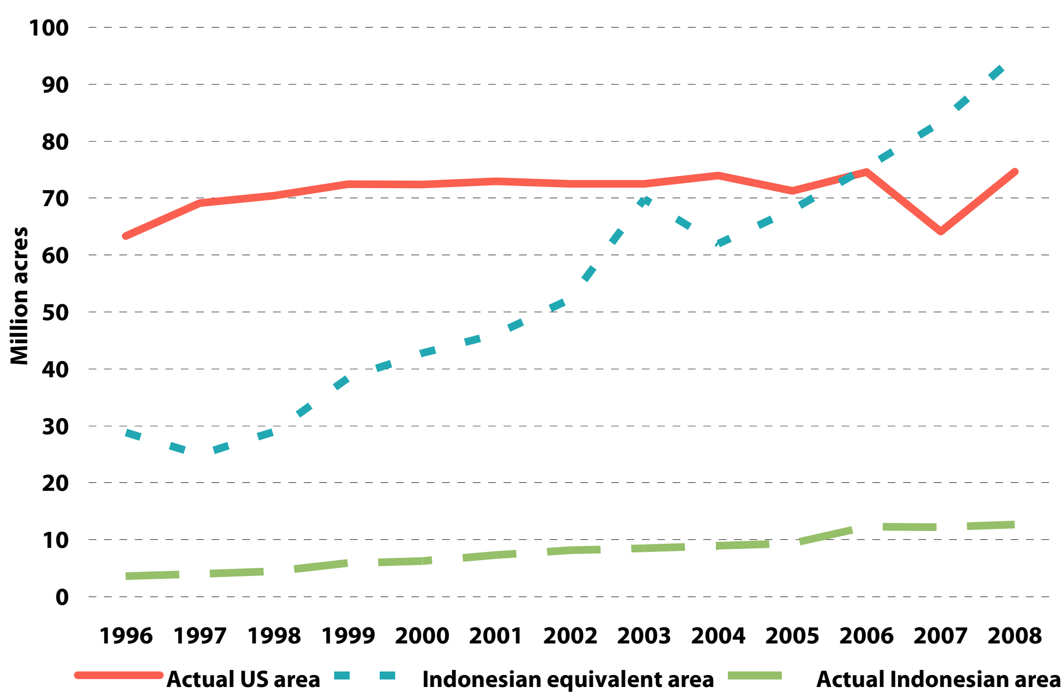
The importance of oil palm as a means of minimizing the pressures on the overall areas planted to soybeans may be gauged from Diagram 5. This compares the actual harvested areas of soybeans in the U.S. since 1996 with the area of U.S. soybeans that would have been required to produce the amount of vegetable oil that was obtained from mature Indonesian oil palm in those years. The actual Indonesian harvested area of oil palm in the same years is included for comparison.

In this diagram we make the (optimistic) assumption that the U.S. soybean area could have been expanded and continue to generate the average yield of oil per acre that was observed in existing U.S. soybean areas.

Even with this generous assumption about productivity, we see that the U.S. soybean area would have had to add over 127% to its actual 2008/09 level (going from 75 to 170 million acres) if it had been called upon to replace all Indonesia's palm oil (which, it may be recalled, was harvested on only 12.6 million acres).

In effect, oil palm, by virtue of its exceptionally high productivity as an oil-bearing crop, plays a major role in holding down the need for land conversion to meet global demand for oils and fats.

Diagram 5: Harvested areas of U.S. soybeans and Indonesian oil palm vs. the extra U.S. soybean area that would have been needed to supply Indonesia's volume of oil



3. The failure of the ILUC methodology to allow for feedback to producers

The most important, and potentially most far-reaching, weakness of the methodologies proposed by the EPA to simulate indirect land use changes and their environmental impacts is that they fail to take account of the many initiatives undertaken by agricultural producers, traders, processors, end-users and NGOs, to respond to the growing concerns expressed about GHG emissions by official agencies in major consuming countries.

On a practical level, these initiatives are a tangible response to the policy proposals being implemented to penalize producers who do not meet environmental thresholds for emission reductions, taking account, in some cases, of indirect land use changes. In effect, criticism of agricultural production that is not viewed as sustainable has been translated into policy "sticks" and "carrots", to which producers in many countries and many sectors are responding.

This is not taken into account in the models being used by the EPA and others. Their models, for obvious reasons, are based upon past information; but the data underlying these models relate to periods when the pressures for environmentally acceptable production were much weaker and lacked teeth.

In economic terminology, the models used by the EPA fail to take account adequately of the <u>endogenous</u> nature of the system that they are trying to simulate. Basing analysis of indirect land use and its environmental impact on data about what happened even two or three years ago is no longer valid.

Examples abound of industry responses that undermine the assumptions underlying the models used by the EPA. Within the vegetable oil sector, we have selected four examples to demonstrate the ways in which the past is no longer a valid guide to behavior in the two most controversial and environmentally sensitive producing regions, South East Asia and Brazil.

Palm oil

1. The oil palm industry responded relatively early to the new realities of environmentalism by establishing the Roundtable on Sustainable Palm Oil. This brought together producers, users and NGOs. The RSPO has now established the sets of principles and criteria for certification and many producers have now gone through the process and received certificates.

In practice, users have proved disappointingly lukewarm in their response to the availability of these certificates, whose value (paid as a premium over and above the cost of uncertified palm oil) in paper trading has fallen from $50 per metric ton at the start to less than $10 now, which barely covers the costs of certification. However, the point to be stressed is that most of the major producers in the oil palm sector have responded to the new climate of opinion and should be able to meet demanding requirements from governments in the U.S. and Europe to demonstrate the sustainability of their production practices.

2. The second example from the oil palm sector is its widespread acknowledgement of the deficiencies of the production process in environmental terms, notably in reductions in emissions. The industry has responded with investment programs to improve its performance.

The EU default values for CO_2 reductions in biofuels have set the thresholds for both palm and soybean oils too low to permit biodiesel made from these oils to benefit from local biodiesel programs unless the supplier can demonstrate that it achieves a better performance than the default assumes. For most palm oil producers, this is comparatively easy to do. By capturing the methane emitted from their effluent ponds, many are able, at a stroke, to exceed the default value threshold and thus be acceptable under the biodiesel program.

In the new global environment, where the Clean Development Mechanism (CDM) allows developing countries to sell Certificates of Emission Reductions (CERs) issued by the United Nations within the Kyoto Protocol framework, oil palm producers are able to generate income from emission reductions. This is in addition to the direct financial benefit they receive from the co-generation of electric power from the methane that was previously emitted.

In Malaysia, the government is going further, making methane capture a pre-condition for approval of all new mill projects. It (and the same is true of Indonesia, the other main palm oil exporter) is also responding to criticism of the development of estates on deep peat soils, whose oxidation after draining and cultivation is considered to be a major source of GHG emissions in life cycle analyses. Bans are now in effect on the development of such estates.

Soybeans

1. The soybean industry has not been left behind in the recognition of the pressures to demonstrate that its agricultural practices are responsible and sustainable. Therefore, the Roundtable on Responsible Soy (RRS) was established to introduce principles and criteria for certification that follow many of the same lines as those developed for the RSPO.

In view of the importance attached to South America, and to Brazil in particular, as environmentally sensitive areas of expanded soybean cultivation, it is significant that Brazilians and other South Americans are the main participants in the process of establishing and implementing a certification scheme under the aegis of the RRS.

2. The fourth example we describe of the endogenous nature of the oilseed sector's response to initiatives on sustainability, environmental concerns and calculations of the impact of indirect land use change is the form of the Brazilian response to the pressures from users and NGOs to resist soybean production in the Amazon region.

The Soy Moratorium initiative, first implemented in July 2006, was signed by Brazil's vegetable oil producers' association and its grain exporting counterpart (who represent exporters of unprocessed soybeans). They agreed not to trade or process soybeans that originated from areas that were deforested in the Amazon Biome after that date.

The Moratorium has been maintained since then, and the latest agreement, extending it to July 2010, has secured the participation of the Federal ministry of the environment, which will help to monitor any changes in land use in the Amazon region. NGOs, too, are fully involved in the moratorium, whose most recent agreement and terms of commitment are attached on the next page.

Conclusions

These endogenous responses within the vegetable oil sector (and they are only a cross-section of the responses that are occurring) to the systems of incentives and penalties being erected by U.S. and EU government agencies are not taken into account in the many models of the direct and indirect impacts of biodiesel production considered by the EPA.

The forms of industry expansion observed in the past in South America and South East Asia, when socially and environmentally insensitive production systems were common, reflected the financial incentives and (limited) official penalties that applied in the past. These are no longer the realities that determine the nature of new production decisions in terms of the land that they farm, their production technologies and hence their environmental impact. However, econometric models inevitable have to rely upon historical data; thus policy is in danger of being made on the basis of a world that no longer exists.

4. Term of Commitment – Amazon Soy Moratorium

Considering that the Soy Moratorium seeks to reconcile environmental conservation with economic development through the responsible use of Brazil's natural resources;

Recognizing that this initiative for a constructive dialogue has had positive results, as can be seen by the public recognition that, with the Moratorium, soy is no longer an important factor in deforestation of the Amazon Biome and the development of a governance process;

In view of this, the parties signing this Term of Commitment have come to the following understanding:

Article 1 *ABIOVE – Associação Brasileira das Indústrias de Óleos Vegetais, ANEC – Associação Nacional dos Exportadores de Cereais and their respective members pledge to renew, until July 23, 2010, their commitment not to trade soy from areas within the Amazon Biome deforested after July 24, 2006, known as the Soy Moratorium.*

The private sector will work with Brazilian government agencies, entities representing the rural producers and civil society to:

a) Monitor the planting of soy crops in the Amazon Biome;
b) Encourage soy producers to comply with the Brazilian Forest Code, and to register their properties and to obtain an environmental license;
c) Collaborate with and encourage the Brazilian government to define, apply and comply with public policies (ZEE – Ecological-Economic Zoning) regarding land use in the region.

Article 2 *The Civil Society Organizations that participate in the Soy Moratorium's Work Group (the GTS) pledge to:*

a) Cooperate with the input of information and specialized technical assistance;
b) Defend, internally and externally, the creation of remuneration mechanisms for environmental services and forest conservation.

Article 3 *The Ministry of the Environment (MMA) supports this initiative of the industry and civil society and pledges to:*

a) Promote and support the registration and environmental licensing of rural properties, together with the state environmental agencies, giving priority to the soy producing towns in the Amazon Biome;
b) Promote and support the implementation of the Ecological-Economic Zoning (ZEE) in the Legal Amazon states, together with the state entities;
c) Ensure the preparation of an Amazon Biome map on an adequate scale for monitoring the rural properties located in this region;
d) Cooperate with other government agencies, defending in international forums the development of incentive programs for sustainable production, including remuneration for environmental services.

Brasília, July 28, 2009

Carlo Lovatelli
ABIOVE
Private Sector Coordinator of the GTS

Paulo Adário
Greenpeace
Civil Society Coordinator of the GTS

Minister Carlos Minc
Ministry of the Environment

Sérgio Mendes
ANEC

ATTACHMENT 16

BIODIESEL MAGAZINE The World of Biodiesel at Your Fingertips

From the May 2009 Issue

Greenpeace: biodiesel not seen as significant driver in Amazon deforestation

Posted 11:00AM CST, May 4, 2009

by Nicholas Zeman

In July 2006, after Greenpeace International authored a report claiming that soya farming was the leading driver of Amazon deforestation, ADM, Cargill and other members of Brazil's vegetable oil and grain exporting industries "agreed to a voluntary moratorium on trading soy harvested from newly deforested areas in the Amazon biome for a period of two years," said Bunge Ltd. in a company statement. "The intent was to relieve pressure on the Amazon biome, so work could be undertaken by government, industry, farmers and environmental groups to ensure its long-term protection." The moratorium is scheduled to end in July after the original agreement was extended last year.

"We hope this moratorium is extended through 2010," said Paulo Adario, director of Greenpeace's Amazon deforestation campaign. "But we haven't begun any serious negotiations as of yet." The sustainable production of biodiesel has been a major focus of the global industry in recent months, as consumer opinion has indicated, especially in Europe – so much so that EU nations do not want to buy biofuels that put pressure on food crops or are made in ways that damage indigenous ecosystems.

"Biodiesel demand for soy oil is not seen as a significant driver of Amazon deforestation" Adario said. "Most of the soya grown in Brazil, including what is grown on illegal plantations, is for animal and human consumption; and right now, the Brazilian government is investing in other feedstocks for the development of its biofuels program."

The South American country, which is looking to grow its export power in the biofuels market, is being very careful about how its feedstocks are grown and sourced. "Sugarcane cultivation for ethanol production is the primary risk to the Amazon right now," Adario told Biodiesel Magazine. "But the Brazilian government is taking steps to fight this because they know that that if the ethanol or biodiesel produced here is found to be supported by land that is responsible for rain forest destruction, the world market is going to say 'no, no, no.'"

While Greenpeace says the moratorium has had a significant impact and soy cultivation is no longer the leading driver of Amazon deforestation, there is still much work to be done. "There is no certification for soy in Brazil and very little traceability," Adario said. "So the question is, 'Are the traders ready to totally exclude the farmers who grow soy illegally from the market?'"

Although the domestic feedstock situation is thin at times, U.S. biodiesel producers are reportedly not looking to South America to source needed raw materials. "We rarely import anything, in terms of agricultural commodities, from South America," said Darrel Good, University of Illinois extension marketing specialist. "We do import some palm oil at times, but that is mostly as a food ingredient."

While soybean prices have been strong in early 2009, partly related to uncertainty over South American soybean production prospects, Bill George of the U.S. Department of Agriculture's Foreign Agriculture Service said limiting expansion of soya on illegal acres is insignificant compared to other factors. "Drought, lack of access to financing, and a decline in yields are the major factors for the Brazilian soybean industry," he told Biodiesel Magazine. "So I would see a decline of illegal soy acres as a drop in the bucket in regard to the overall scenario."

ATTACHMENT 17

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Amazon rainforests pay the price as demand for beef soars

Inquiry highlights concerns over ranching in heartland of Brazil

David Adam in Maraba
guardian.co.uk, Sunday 31 May 2009 22.33 BST

A larger | smaller

Four-year old Daniel Santos da Silva and his older brother Diego Mota dos Santos, 10, heard their first gunshots in April. Their father was shot in a dispute over land on a cattle ranch near the Brazilian town of El Dorado, in the Amazonian state of Para. The boys heard he was taken to hospital, but they have not seen him since.

The ranch is called Espirito Santo, holy spirit, though goodwill to all men is hard to find there. Heavily armed guards protect the thousands of cattle that roam its lush pastures and the hacienda-style complex built on a hill at the farm's centre, complete with swimming pool.

Daniel and Diego live on the muddy fringe of the farm in a hastily erected collection of palm frond-roofed huts to shield them and a hundred-odd other families from regular tropical downpours. They are squatters, but squatters rights are rarely observed in Para.

Espirito Santo and thousands of farms like it raise cattle on Amazonian pasture that was once rainforest. The farms are huge, and so is their impact. The cattle business is expanding rapidly in the Amazon, and now poses the biggest threat to the 80% of the original forest that still stands. Where loggers have made inroads to the edge of the forest in the states of Para and Mato Grosso, farmers have followed.

A report today from Greenpeace details a three-year investigation into these cattle farms and the global trade in their products, many of which end up on sale in Britain and Europe. Meat from the cattle is canned, packaged and processed into convenience foods. Hides become leather for shoes and trainers. Fat stripped from the carcasses is rendered and used to make toothpaste, face creams and soap. Gelatin squeezed from bones, intestines and ligaments thickens yoghurt and makes chewy sweets.

Greenpeace says it has lifted the lid on this trade to expose the "laundering" of cattle raised on illegally deforested land.

The environment campaign group wants Brazilian companies that buy cattle to boycott farms that have chopped down forest after an agreed date. To get the industry onside, it is seeking pressure from multinational brands that source their products in Brazil, and, ultimately, from their customers. Three years ago, a similar exposure of the trade in illegally grown Brazilian soya brought a rapid response from the industry, and a moratorium on soya from newly deforested farms that still holds.

Last month, the Guardian joined Greenpeace on an undercover visit to the cattle farming heartland around the town of Maraba, deep inside the Amazon region. While saving the rainforest is a fashionable cause in faraway developed countries such as Britain, in Maraba it is a provocative and even dangerous ideal.

Many people in Maraba work at the slaughterhouse perched on a hill that overlooks the town. The facility is owned by the Brazilian firm Bertin, one of the companies targeted by Greenpeace for buying cattle from farms linked to illegal deforestation. After slaughter, Greenpeace says Bertin ships the meat, hides and other products to an export facility in Lins, near Sao Paolo. From there, they are shipped all over the world. The firm is Brazil's second largest beef exporter and the largest leather exporter. It is also the country's largest supplier of rawhide dog chews.

Bertin denies taking cattle from Amazon farms associated with deforestation. The company says it "makes permanent investments in initiatives that minimise impacts resulting from its activities" and that it seeks "to be a reference in the sector". It says it has already blacklisted 138 suppliers for "irregularities".

Brazilian government records obtained by Greenpeace show that 76 cattle were shipped to the Bertin slaughterhouse in Maraba from Espirito Santo farm in May 2008. Another 380 were received in January this year.

Standing on Espirito Santo's shady veranda, Oscar Bollir, the farm manager, insists they do nothing wrong.

Under Brazilian law, such farms inside the Amazon region must retain 80% of the original forest within their legal boundary. So why is there pasture for as far as the eye can see? The farm is very big, Bollir says, and most of the required forest is on the other side of some low-slung hills in the distance.

The squatters on the farm, part of a political movement to settle landless people on illegally snatched farmland, are troublemakers, he says. "They don't want land they just want trouble. They want to take all the farms." Earlier that day, he says, he and his men had been forced to visit a neighbouring farm where squatters had killed cattle. Unlike the previous incident on Espirito Santo, when Daniel and Diego's father was shot alongside several others, Bollir says, this time there had been no trouble.

He adds that he is aware of environmental concerns, but that his priority is to produce food and jobs. "Why are these other countries looking at Brazil and telling us what to do?"

The next day, Greenpeace investigators flew over Espirito Santo – the group has a single-engined plane donated by an anonymous British benefactor. Bollir's promised bonanza of forest was not there. GPS data combined with satellite images show that just 20% to 30% of the farm is forested. A local lawyer also reported that during the nearby dispute over the killed cattle, three squatters had been shot and injured.

The Greenpeace report identifies dozens of farms like Espirito Santo that it says break the rules across Para and Mato Grosso to supply Bertin and other slaughter companies. Campaigners say there are probably hundreds or even thousands more.

Cheap pasture from clearing and seeding rainforest is very attractive to farmers without easy access to the expensive agrichemicals and intensive land management techniques used in more developed countries. Within a few years, the planted pasture becomes overrun with native grass, unsuitable for cattle. Many farmers then take the cheap option and knock down adjoining forest to start again, leaving swaths of unproductive deforested land in their wake.

Andre Muggiati, a campaigner with Greenpeace Brazil based in the Amazon town of Manaus, says efforts to protect the forest in frontier regions such as Para are crippled by a lack of effective governance. Government inspections are inadequate and many farms are not even registered so checks cannot be carried out. Casual violence and intimidation are common. "It's totally unregulated and many people behave as if the law does not apply to them. It's like the old US wild west," he says.

Illegal deforestation is not the only problem: farms are regularly exposed as using slave labour, and, like many tropical forest regions, there are regular and violent clashes over land ownership.

The problem is clear a three-hour flight across the patchy forest from Maraba, where a clearing on the side of the river is home to a few hundred Parakana people, a tribe with no contact with the outside world until 1985.

Greenpeace can only reach the village because its plane is equipped to land on the sluggish water, but cattle farmers are steadily intruding. Hundreds of farms have been set up in the surrounding reserve, and they are not welcome.

"Since the invaders arrived there have been many problems," says Itanya, the village chief. Food is harder to find, he says, and discontent is growing. "If the government don't find a solution we will solve it ourselves. We know how to make poison arrows and we are ready to kill people." It is not an idle threat: in 2003 the bodies of three farmers were discovered in the jungle not far from the village. Itanya says it was the work of a neighbouring group.

"We asked them many times to stay away," Kokoa, the chief of the neighbouring group, told the Guardian through an interpreter. "They wouldn't, so one time we said to them that you will never go back and you will stay here forever. We killed them. We are proud that we defended our land."

Food for thought

How much of the Amazon rainforest has been lost and how quickly?

Since the 1970s, when satellite mapping of the region became available, around a fifth of the rainforest has been destroyed, an area the size of California. Greenpeace US estimates that, between 2007 and 2008, another 3m acres (1.2m hectares) of the Brazilian Amazon have been destroyed.

What is driving the destruction?

Logging, cattle farming and soy plantations are key, plus the increased construction of dams and road, and shifting patterns of farming for local people and mining (for diamonds, bauxite, manganese, iron, tin, copper, lead and gold). These factors are often interlinked – trees are cut down for timber and the cleared land can be used for grazing cattle. Soybeans are then cultivated on the same land. Land is also cleared for biofuel crops. According to Greenpeace, around 80% of the area deforested in Brazil is now cattle pasture. Brazil's biggest export markets for beef are Europe, the Middle East and Russia. Friends of the Earth Brazil estimate that cattle farming in Brazil has been responsible for 9bn-12bn tonnes of CO^2 emissions in the past decade, almost equivalent to two years worth from the US. Infrastructure projects such as hydroelectric dams also threaten the forests because they cause large areas to be flooded. Currently, the biggest planned project is the Tocantins River basin hydroelectric dam, the effects of which stretch over a distance of 1,200 miles.

Why are cattle a particular problem?

In 2006, the UN Food and Agriculture Organisation found that the livestock industry, from farm to fork, was responsible for 18% of all anthropogenic greenhouse gas emissions. In addition, livestock-rearing can use up to 200 times more water a kilogram of meat compared to a kilo of grain. Furthermore, global meat consumption is on the rise, having increased by more than two and half times since 1970.

Who is trying to stop the destruction?

At this year's climate change negotiations in Copenhagen, governments will consider the "Redd" mechanism. This is the idea that richer countries could offset their carbon emissions by paying to maintain forests in tropical regions. The idea has roots in the 2006 review of the economics of climate change by Nicholas Stern, who said £2.5bn a year could be enough to prevent deforestation in the eight most important countries. But Friends of the Earth says the proposals seem to be aimed at setting up a way to profit from forests, rather than stop climate change, and fail to protect the rights of those living in the forests.

In 2007, Greenpeace also came up with a plan to stop deforestation in the Amazon by 2015. It included creating financial incentives to promote forest protection; and increased support for agencies to monitor, control, and inspect commercial activities. So far, only some of these proposals have been taken up by the Brazilian government.
Alok Jha

• This article was amended on Tuesday 23 June 2009. We said that according to Greenpeace US, between 2007 and 2008 an estimated 3m acres of the Amazon rainforest have been destroyed. That figure was for the Brazilian part of the rainforest only. This has been corrected.

ATTACHMENT 18

Indirect Land Use Analysis – *The Impacts of a Rise in U.S. Biodiesel Demand*

OVERVIEW

The aim of this report is to analyze the indirect land use impacts of a rise in demand for soybean-derived biodiesel in the U.S.

The analysis is divided into three sections:

1. Part A examines the indirect land use effects in Argentina and Brazil, the principal exporters of soybeans and soybean products outside the U.S. This section also considers the pressure to move soybean production into forest areas in Brazil.

2. Part B analyzes the response by the U.S. biodiesel manufacturing industry to fluctuations in soybean oil prices and its implications for soybean area in the U.S.

3. Part C presents analysis of the global framework linking vegetable oil prices to the consumption and production of soybeans and their use in biodiesel production.

BACKGROUND

Under the Renewable Fuels Standard (RFS2), the biomass-based diesel requirement has been set at 1.0 billion gallons in 2012. With biodiesel production in 2008 at 690 million gallons, output would need to rise by just 310 million gallons to meet the 1.0 billion gallon target. **If this additional volume were met solely using soybean oil, it would require just 1.1 million metric tons of oil, which is a negligible volume globally**. To put this into context, global vegetable oil production from the major oils[1] in 2008 was 107.2 million metric tons.

Assuming biodiesel yields of 65 gallons per acre, the production of 1.1 million metric tons of soy oil would require less than five million acres of land. To put this into perspective, total US farmland was estimated at 922 million acres in 2007.

In early May, the Environmental Protection Agency (EPA) published its proposals on the implementation of the RFS2. A key part of these proposals is its initial conclusions regarding the greenhouse gas (GHG) emissions of various biofuels. The RFS2 stipulates that conventional biofuels produced from corn must achieve GHG savings of 20%. However, advanced biofuels, including biomass-based diesel, must achieve savings of 50%.

EISA defines lifecycle GHG emissions as follows: "The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential."

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[1] Total includes palm oil, soybean oil, rapeseed, and sunflower oil.

The EPA's draft results suggest that, when *indirect* emissions are considered, soybean-derived biodiesel will achieve a reduction in GHGs of just 22%, preventing it from qualifying for the RFS2 as biomass-based diesel. However, if only *direct* GHG emissions are taken into account, soy-based biodiesel would easily meet the 50% GHG reduction target. The EPA's analysis of net GHG emissions suggests that the bulk of emissions from soy-based biodiesel are the result of international land use change. In their preliminary results, these account for over half of the total calculated GHG emissions.

The indirect land use change impacts of biofuels, also known as ILUC, relates to the unintended consequence of releasing more carbon emissions due to land use changes around the world induced by the expansion of croplands in response to the increased demand for biofuels. As farmers worldwide respond to higher crop prices in order to maintain the global food supply and demand balance, pristine lands are cleared and converted to new cropland to replace the crops for feed and food that were diverted elsewhere to biofuels production. Because natural lands, such as rainforests and grasslands, store and sequester carbon in their soil and biomass as plants grow each year, clearance of wilderness for new farms in other regions or countries translates into a net increase in GHG emissions, and due to this change in the carbon stock of the soil and the biomass, indirect land use change has consequences in the GHG balance of a biofuel.

However, measuring ILUC in practice is fraught with difficulty and there is no agreed methodology on how to do it. The European commission has opted to delay inclusion of ILUC into its biofuels directive until it has conducted further research into the concept. The Council of Ministers and the European Parliament have called on the European Commission to study the ILUC equation, and "if appropriate" to draw up a new law by the end of 2010.

The analysis conducted by the EPA assumes that biodiesel production will rise from 0.4 to 0.7 billion gallons. Yet with biodiesel production today just below 0.7 billion gallons, their analysis is based on assumptions which are out of date. This casts doubt over the validity of their findings and in particular on their claims regarding the indirect land use impacts of soy-based biodiesel.

SUMMARY CONCLUSIONS

- **Our analyses, suggest that a rise in U.S. soy-based biodiesel demand is likely to have minimal indirect land use effects in Argentina, Brazil and the U.S., the principal producers of soybeans.**

- **Our analysis of the relationship between the price of oils and supply and demand suggests that a rise in demand for oils for biodiesel production is likely to result in only a very modest rise in soybean areas worldwide.**

LMC'S ANALYSES

Part A: Indirect Land Use Impacts in South America

This part examines the land use impact in South America of higher U.S. demand for soy-based biodiesel.

Argentina

Argentina is the world's largest exporter of soybean oil onto the world market, followed by Brazil. This point is illustrated in Table 1, which presents supply/demand for soybeans and soybean oil in the major producing and exporting countries. In 2007/08, Argentina produced 6.6 million metric tons of soybean oil, the bulk of which was exported. If all of this oil were converted to biodiesel it would equate to 1.9 billion gallons. Thus, the volume requirements of the US could be satisfied with little impact on Argentina's exportable surplus. Moreover, Argentina has no domestic biofuel requirement and therefore the industry is keen to find additional outlets for its oil.

- By using surplus oil and installing new biodiesel capacity or expanding the use of existing capacity, the country could easily increase its biodiesel output substantially *without increasing areas under soybeans*.

By the end of 2009, Argentine biodiesel capacity would exceed 850 million gallons (3 million metric tons), if all projects are completed on time, but this is approximately three times as large as output in 2008.

- This capacity could be comfortably supplied from local soybean oil output *without any need to expand local production of beans*.

- This suggests that the impact of a rise in demand for soy-based biodiesel in the U.S. would have little impact on the area planted to soybeans in Argentina, since Argentine processors could take the simple step of upgrading their soybean oil exports into soybean methyl ester.

Table 1: Soybean Supply/Demand for Major Producers, 2007/08 (million metric tons)

	Argentina	Brazil	EU-27	United States
Soybean Crush	34.6	31.9	14.9	49.0
Oil Equivalent (of the Crush)				
Production	6.6	6.1	2.7	9.3
Imports	0.1	0.1	1.0	0.0
Exports	5.8	2.4	0.3	1.3
Consumption	0.9	3.8	3.4	8.0

Brazil

Brazil is also a major producer of soybeans, and in 2007/08 processed 31.9 million metric tons (mt) of beans, equivalent to 6.1 million mt of oil. In 2007/08, the country exported 12.4 million mt of soybeans, equivalent to 2.4 million mt of oil or almost 690 million gallons of biodiesel.

- By using surplus beans, the country could increase its production of oil and of biodiesel *without expanding its area under soybeans*.

Increasing soy oil production would be relatively easy since the country already has ample oilseed crushing capacity.

Diagram 1 presents total Brazilian soybean crushing capacity split between utilized and spare capacity. The diagram reveals that not only has total installed capacity increased steadily in recent years, but also that utilization rates have declined.

- In 2007, spare capacity exceeded 20 million metric tons, more than sufficient to crush all of the country's soybeans currently exported unprocessed.

Soybean Cultivation is not Responsible for Deforestation

The EPA's analysis of indirect land use impacts is based on the assumption that an increase in demand for U.S. biodiesel results in an increase in the soybean area in Brazil and a loss of rainforest. However, as Diagram 2 reveals, area under soybeans has not increased in recent years. Over the same period, U.S. biodiesel production increased from 25 million gallons to 690 million gallons.

- **Therefore, the causal link suggested by the EPA between U.S. biodiesel output and Brazilian soybean areas, let alone the deforestation of the Brazilian rainforest, is not supported by the evidence from the past five crop years.**

While US biodiesel production has increased over the previous five years, deforestation in Brazil has declined. Figures from Brazil's National Institute of Space Research (INPE), show that deforestation fell from almost 10,600 square miles in 2004 to just over 4,600 square miles in 2008. In addition, a study carried out by the Soybean Work Group (GTS) in early 2009 found that since July 2006, only 2% of deforested area had been devoted to soybean cultivation. The principle uses were for cattle ranching and timber production.

It is not surprising that very little deforested area is used for soybean cultivation since the hot and humid climate of the Amazonas is less than ideal for soybean cultivation. While in recent years new soybean cultivars have been developed that are better adapted to the soil and climate of this region, yields are still below those achieved in the optimal soybean growing areas of Brazil such as in Mato Grosso. Any pressure to increase soybean production is likely to result in pressure to expand soybeans in higher yielding areas rather than in the Amazonas.

- **Very little deforested area in Brazil is used to grow soybeans. This is because the agronomic climate of the Amazonas is not ideally suited to soybean cultivation.**

In Brazil, Embrapa (the Brazilian Agricultural Research Corporation), estimates there are up to 100 million hectares (250 million acres) of savannah (Cerrado) suitable for the cultivation of soybeans, maize and sugarcane. However, it should be noted that the Cerrado is rich in biodiversity and conversion of this land to farmland would also result in substantial emissions penalties.

However, even if the Brazilian soybean area were to expand, it is far from clear that this would put pressure on forest or virgin Cerrado areas. There still exists considerable scope for expanding soybean cultivation into pasture land.

While cattle densities in Brazil have increased steadily, they are still low by international standards. Increasing Brazilian cattle stocking densities could free up additional land for soybean production. There are also synergies between cattle production and soybean production. Soybeans are grown in rotation with second-crop corn (the *safrinha*) in Brazil, and this may be used as feed on feedlots. In addition, the meal from soybean oil production can also be fed to animals. While cattle stocking rates have increased steadily in Brazil, the national average is almost exactly one head per hectare (roughly 2.5 acres per head). Diagram 3 reveals that in 2006 there were close to 170 million head of cattle on 170 million hectares (420 million acres).

ABIOVE, the vegetable oil producers' association, estimates that by 2020, cattle per hectare will rise from 1.0 to 1.4 (or 0.4 to 0.57 head per acre). Even allowing for 1.1% annual growth in cattle numbers, this implies that the area needed for cattle will drop from 172 to 139 million hectares (425 to 343 million acres), freeing up 33 million hectares (82 million acres) of pasture land for agricultural use. This is considerably more than the five million acres (two million hectares) we estimate would be needed if the RFS2 were met solely with soy-based biodiesel.

- **Thus there is considerable scope to increase cattle stocking densities further and release land for soybean farming.**

Diagram 1: Brazilian soybean crushing capacity and utilization

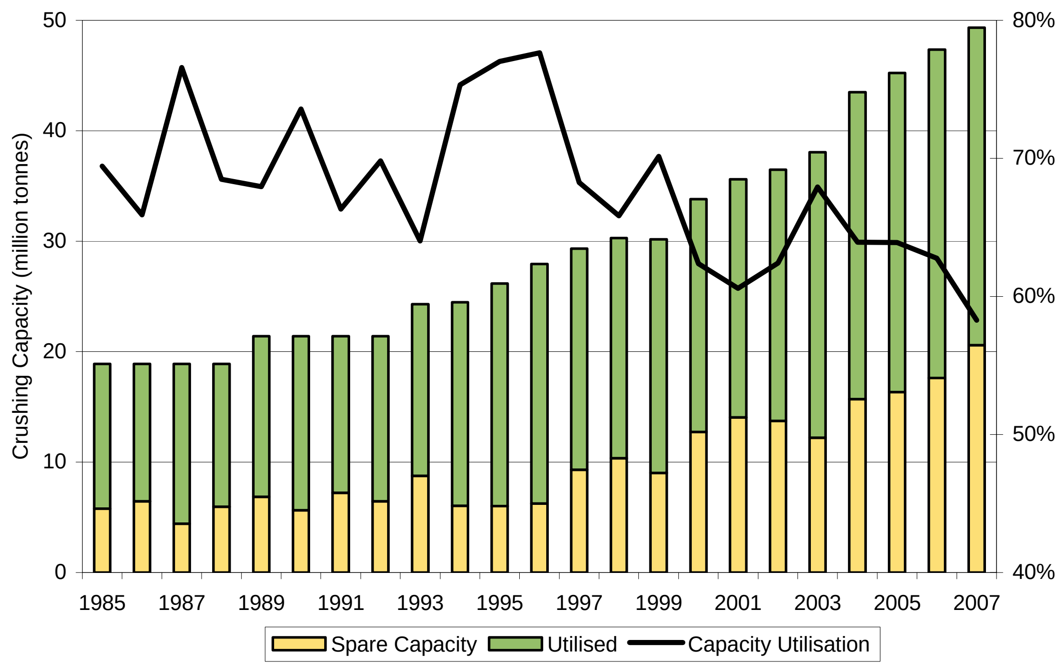


Diagram 2: Brazilian soybean areas and US biodiesel output, 2003/04-2008/09

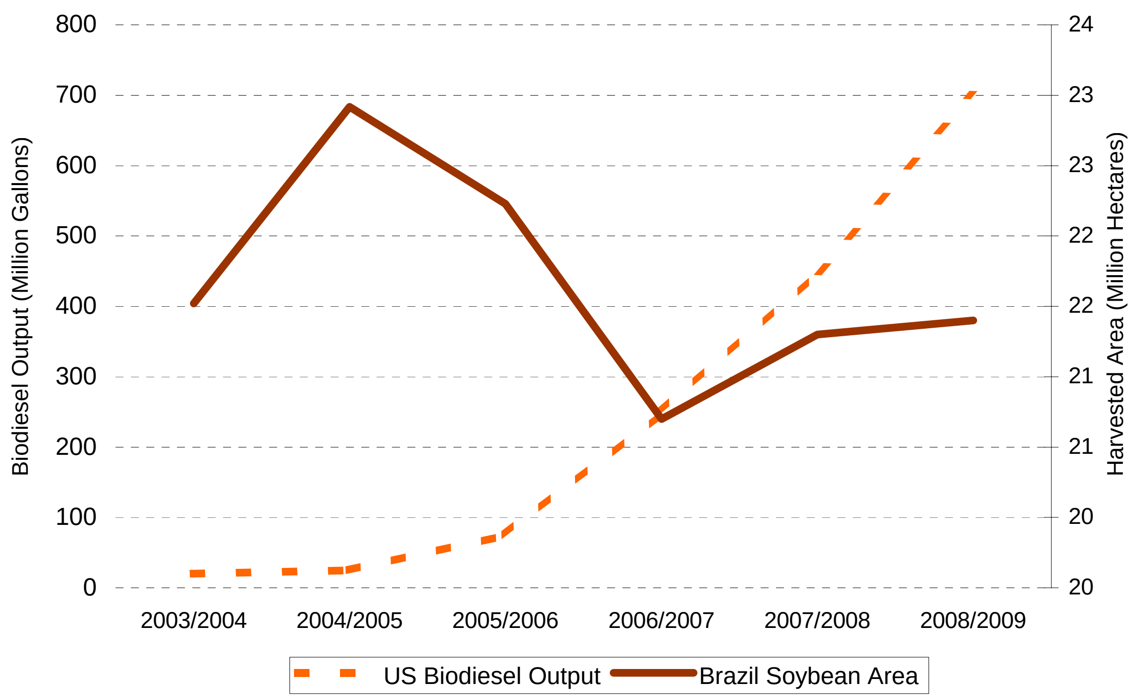
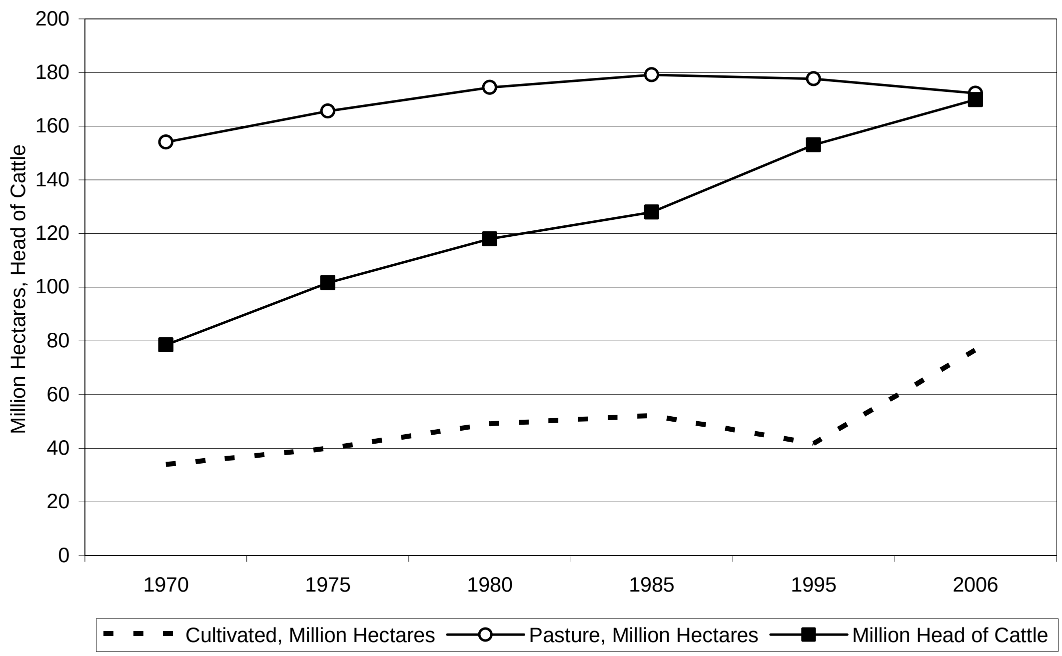


Diagram 3: The growth in cattle numbers and the pasture and cultivated areas from 1970 to 2006, total Brazil



Part B: The Impact of Changes in Soybean Oil Prices on U.S. Biodiesel Production

U.S. *soy-based* biodiesel production has declined in recent months, and peaked in mid-2007, *almost two years ago*. Meanwhile, *total* biodiesel output continued to grow, year-on-year, until the start of 2009, and the peak level of total U.S. output was in mid-2008. This is illustrated in Diagram 4, which implies that non-soy methyl esters have become increasingly important in biodiesel production.

A major part of the reason for the decline in soy-based output is that soybean oil became a relatively expensive raw material for producing biodiesel. Diagram 5 contrasts two curves. One plots the wholesale premium charged on soybean biodiesel over fossil diesel, after crediting biodiesel with the $1/gallon Federal blending credit. The other curve plots the processing margin calculated on soy methyl ester production in the Midwest.

In mid-2008, as well as in early-2009, soybean biodiesel became very expensive in relation to fossil diesel, and yet the processing margin on soy methyl ester production was negative in much of early 2008 and came under pressure again in early 2009. As a result, on simple financial grounds, biodiesel producers and users switched on a large scale to non-soy-based biodiesel, notably from animal fats and yellow grease.

The evidence of the behavior of the U.S. biodiesel market is very clearly that upward pressure on soybean oil prices in response to higher biodiesel demand leads rapidly to a shift towards the use of cheaper oils and fats, typically made from animal fats or recycled cooking oil. As a result, in several recent months, less than half U.S. biodiesel output has been produced from soybean oil.

Diagram 4: U.S. monthly biodiesel production – total volumes and the volume of soy biodiesel alone

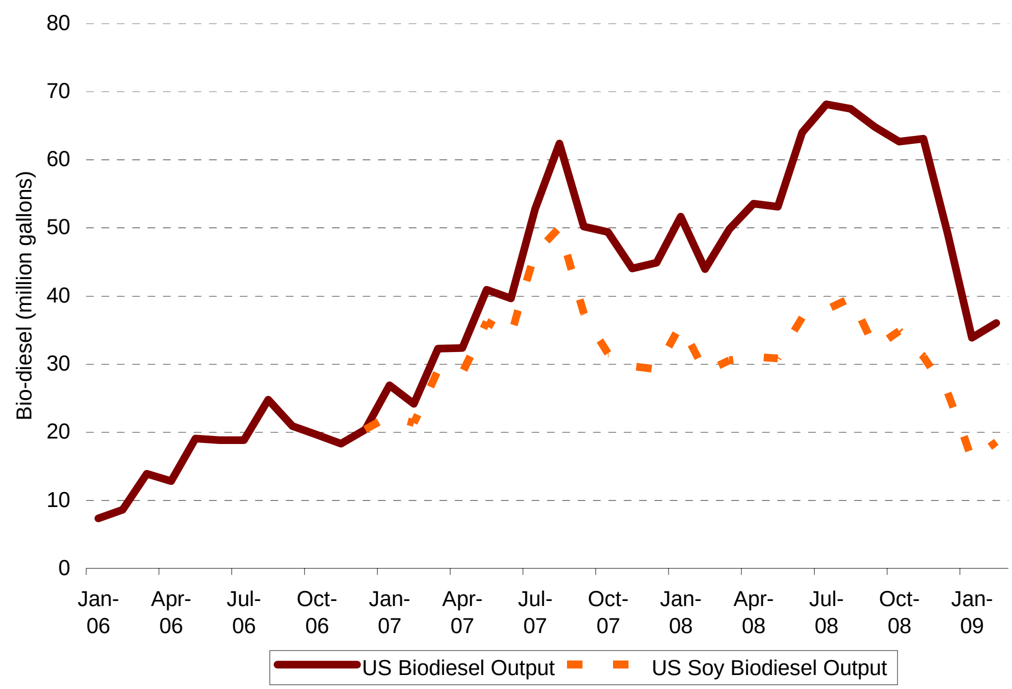
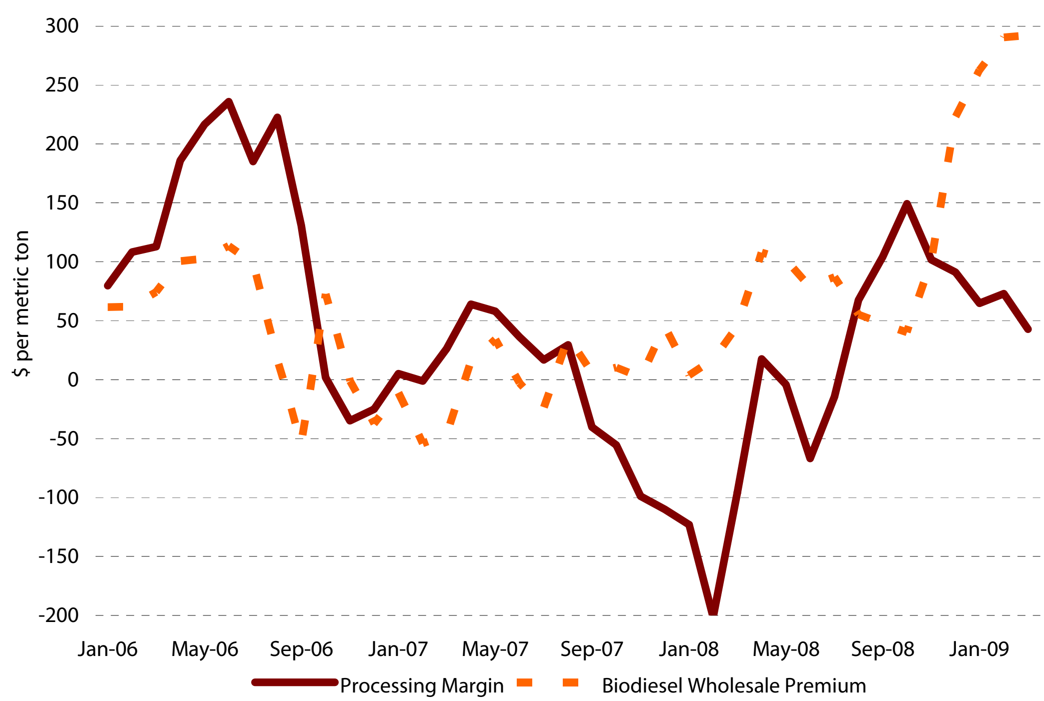


Diagram 5: Midwest premium (allowing for the $1/gallon Federal blending credit) for soy methyl ester over fossil diesel vs. processing margin on soy methyl ester



Part C: The Impact of U.S. Biodiesel Demand on Global Soybean Prices and Output

As has been explained above, both Argentina and Brazil could easily increase their production of biodiesel without increasing their areas under soybeans. In the case of Argentina, it would simply require a switch for soybean oil currently exported as oil to biodiesel plants (where more than enough capacity already exists) to be exported as biodiesel. For Brazil, there would need to be a switch for some of the soybeans exported as beans to domestic crushing plants, for processing and upgrading to biodiesel. Substantial surplus and unused crushing capacity exists, which could easily process the extra beans.

These two examples indicate that an expansion of biodiesel output could be achieved by using surplus world market oil and beans production. It is however, important to establish whether this would result in pressure to plant soybeans elsewhere or whether it would provide a stimulus for the production of other oil bearing crops, instead.

Methodology

The process by which increasing oils consumption feeds through to prices and then to production can be understood as a series of annual steps:

- Higher oil prices will inevitably feed through into oilseed prices.
- In the next round (i.e., in the next crop year), the output of oil-bearing crops will respond to this encouraging price signal, and there will be a knock-on effect upon the output of both oil and its co-product, meal, worldwide.
- The market will have to adapt to this increase in oil and meal supplies, and the form of its reaction will be a reduction in the prices of both products, in order to generate the necessary stimulus to demand that absorbs the extra supply.
- This price response for both oil and meal will feed through to seed prices and, once again, cause farmers to change their plantings for the following year.
- This sequence of demand changes, price changes and subsequent supply responses will continue over time, until the market eventually reaches a new equilibrium, in which the oil and meal supply matches the demand for both products at their new price levels.

The key questions then become, to what extent is the oil price rise transmitted to oilseed producers, and how do they respond?

As regards price transmission, this will be determined by the extraction rates and the relative prices of the oil and meal from each oilseed crop. The returns to a grower from an oilseed crop are indirectly composed of the return from the oil plus the return from the meal, after the processor and trader have taken their margins out of the final revenues from the sale of oilseed products.

Extraction rates

In addition to the price of oil and meal, the return to the grower is determined by the relative proportions of each product derived from the oilseed crop. These extraction rates differ significantly from crop to crop and have a crucial bearing upon the transmission of product prices to the producer.

Table 2 summarizes our assumptions regarding the average extraction rates for each oilseed crop. For soybeans and sunflower seeds, we assume that the hull is used for fuel; for oil palm, we assumed that 90% of the final marketed production consists of the combined palm and palm kernel oil output and 10% represents the palm kernel meal production.

Table 2: Worldwide average extraction rates for oilseed crops by weight

	Meal	Oil
Soy	76%	18%
Rape	60%	39%
Sun	42%	40%
Palm	10%	90%

Note: These are global average extraction rates. U.S. extraction rates are typically much higher.

The table allows one to compare the large amount of meal produced for each metric ton of oil from soybeans and the extreme contrast with oil palm. (Note that these figures are world averages, and the soybean extraction rates are pulled down by the poor performance of crushers in countries such as China and India.)

For every metric ton of oil produced from soybeans, over four tons of meal are produced. For oil palm, little over 0.1 metric ton of meal is produced for every ton of oil. This demonstrates that soybeans are planted for both their oil and protein bearing properties. This also suggests that soybeans would not be the crop of choice for a biodiesel producer because of the relatively low oil content of the beans.

Supply response of producers

The response of producers to any change in price is termed the *price elasticity of supply*. For a given percentage change in price, we can observe a given percentage change in the supply of the relevant product. Our analyses are based on supply elasticities from the USDA.

Demand response of consumers

As producers respond to price signals and increase, or decrease, their supply of oilseeds, so the supply of oilseeds available to crushers varies. Following an increase in prices, therefore, crushers will produce more oil from the increased supply of oilseeds. However, there is an important consequence of producing more oil, and that is an equivalent increase in the production of co-products, in this case, protein-containing oilseed meal.

As we can see from the extraction rates listed in Table 2, for soybeans, for every ton of beans that are crushed, meal production will rise on average around the world by 0.78 tons, while oil output increases by only 0.18 tons. Thus, a consequence of stimulating an increase in soy oil output is a proportionally larger increase in meal production.

World markets for vegetable oil and meal

It is important to recognize that the repercussions of an increase in production of soy oil in the U.S., or rapeseed oil in the EU, or palm oil in Malaysia, or even of animal fats or recycled cooking oil, are not insulated from the overall worldwide market for oil. As vegetable oils are traded freely across the globe and the different oils are close substitutes for one another, one can view the market structure for oil not so much as independent national markets, but rather as part of a single world market. In this way, a significant increase in U.S. soy oil or Malaysian palm oil demand and prices will affect the prices of all vegetable oils worldwide, irrespective of the agricultural raw material used in their production.

Similarly, oilseed meal is freely traded, and the meals derived from different agricultural raw materials are close substitutes for one another. Thus, a significant increase in U.S. soymeal production will have a downward effect on the price of the meal that is derived from sunflower seed in the EU. If this were not the case, opportunities and incentives would arise to substitute U.S. soy meal for EU sunflower meal wherever possible. The markets for individual oilseed meals should also, therefore, be recognized as parts of a single global market.

Price elasticity of demand

If increased supplies of oil and meal are not simply to weigh on the market as stocks, they will have to be absorbed by consumption. That is, demand will have to rise by the equivalent of the increase in supply to the market. In order to stimulate increased consumption, prices will have to fall. The extent of the price fall that is necessary to induce a rise in consumption sufficient to absorb all the additional production is determined by the *price elasticity of demand.*

Modeling supply and demand responses in world oilseed markets

Using the assumptions and elasticities, we have developed a model to illustrate the impact upon producers of an increase in biodiesel demand. The eventual outcome for producers will be felt following a repeated iterative cycle of responses in the oil, meal and seed markets.

The impact upon producers and the oil and meal markets is, therefore, determined by three main factors:

1. The oil and meal extraction rates from oilseeds;
2. The responsiveness of producers to price changes; and
3. The responsiveness of consumption to price changes.

Differences between crops in terms of the first two of these factors explain why the potential outcomes vary for different oil-bearing crops in response to the development of significant biodiesel programs.

The impact of biodiesel programs upon producers

Any impact of biodiesel programs upon the world markets for oilseed products is transmitted to producers through the prices that they receive for their oilseed output. The repercussions upon the seed prices differ from crop to crop, with the results depending upon the price signals in the world markets for oil and meal. Over time, the oscillations in the price will stabilize and converge upon a new equilibrium.

A boost of 5% to global vegetable oil demand generated by biodiesel output

Diagram 6 illustrates this effect for soybeans if there is an initial 5% boost to global oil demand for biodiesel, applying representative world market prices before the surge in commodity prices. A 5% boost to oil demand is roughly equal to 5.4 million metric tons. This is enough vegetable oil to produce 1.5 billion gallons of biodiesel. It is worth noting that this is almost five times the additional quantity required to meet the RFS2.

The initial shock to the markets provided by the increased demand for oil causes vegetable oil prices to rise by 7.6%. The impact on prices of fulfilling the RFS2 is likely to be much smaller, given that the volume requirement is just one fifth of that needed to raise global oils demand by 5%.

The time periods are not defined, but represent notional time periods over which price signals are transmitted and then acted upon in the seed, oil and meal markets. The diagram depicts a stabilizing process of interaction, with large initial fluctuations in price gradually dampened from one cycle to the next, until the soybean price converges upon a revised equilibrium.

The new equilibrium price for soybeans is approximately $4 per metric ton higher than the initial bean price. This represents an increase in the soybean producer price of a modest 1.75%. The outcome for a soybean grower contrasts with that for a palm oil producer. Diagram 7 illustrates the price outlook for palm oil producers in the wake of a 5% increase in global oil demand. The palm oil price rises by 17% as a result of the demand boost from biodiesel, as well as the re-establishment of oil price relativities between the major oils, most notably between palm and soybean oils.

Diagram 8 depicts the impact of a biodiesel-derived boost to vegetable oil demand upon meal prices. The incentive to expand soybean output is translated into an increase in meal supply without a corresponding rise in demand. Meal prices will have to fall to absorb the extra meal availability.

Diagram 6: Impact on Soybean Prices of 5% Rise in Total Oil Demand

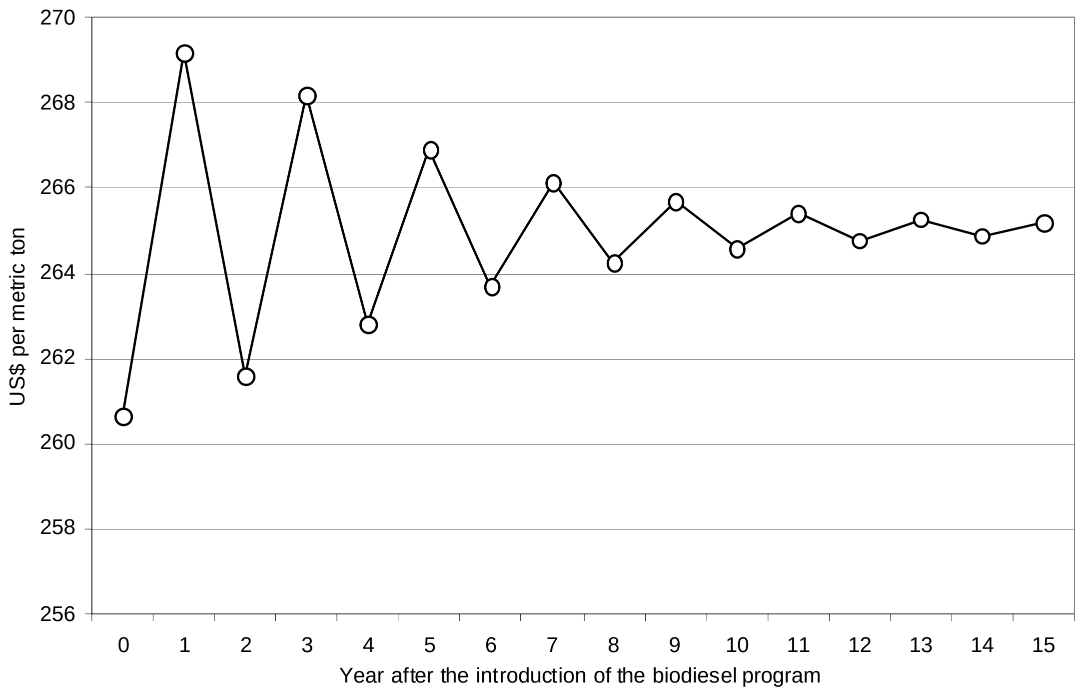


Diagram 7: Impact on Palm Oil Prices of 5% Rise in Total Oil Demand

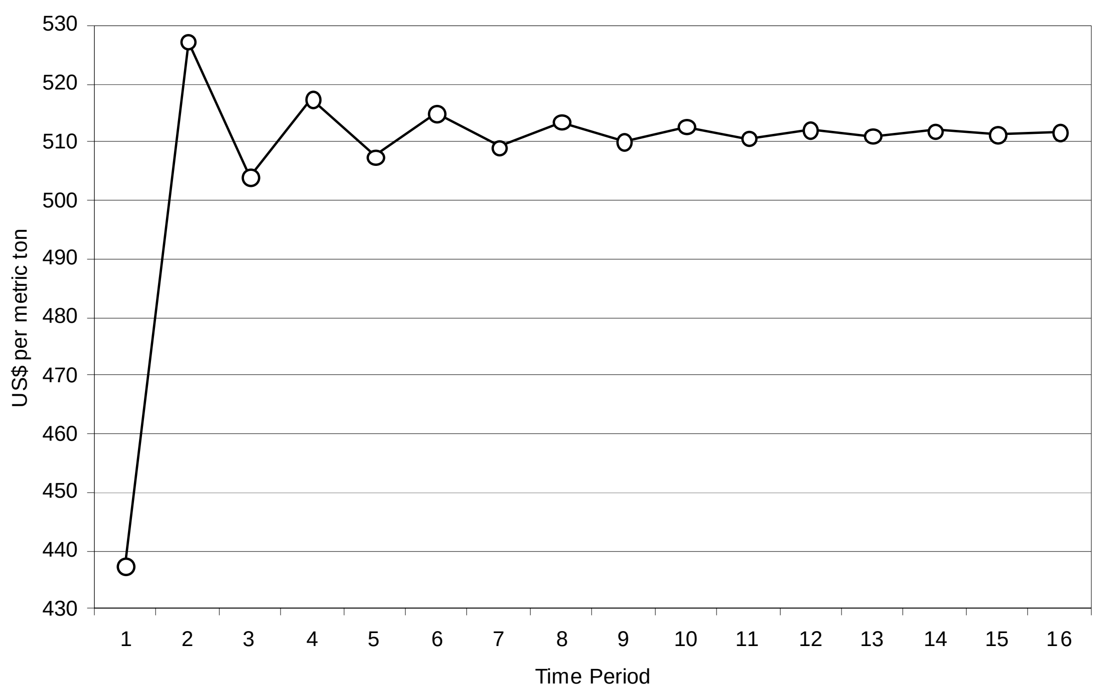


Diagram 8: Impact on Soybean Meal Prices of 5% Rise in Total Oil Demand

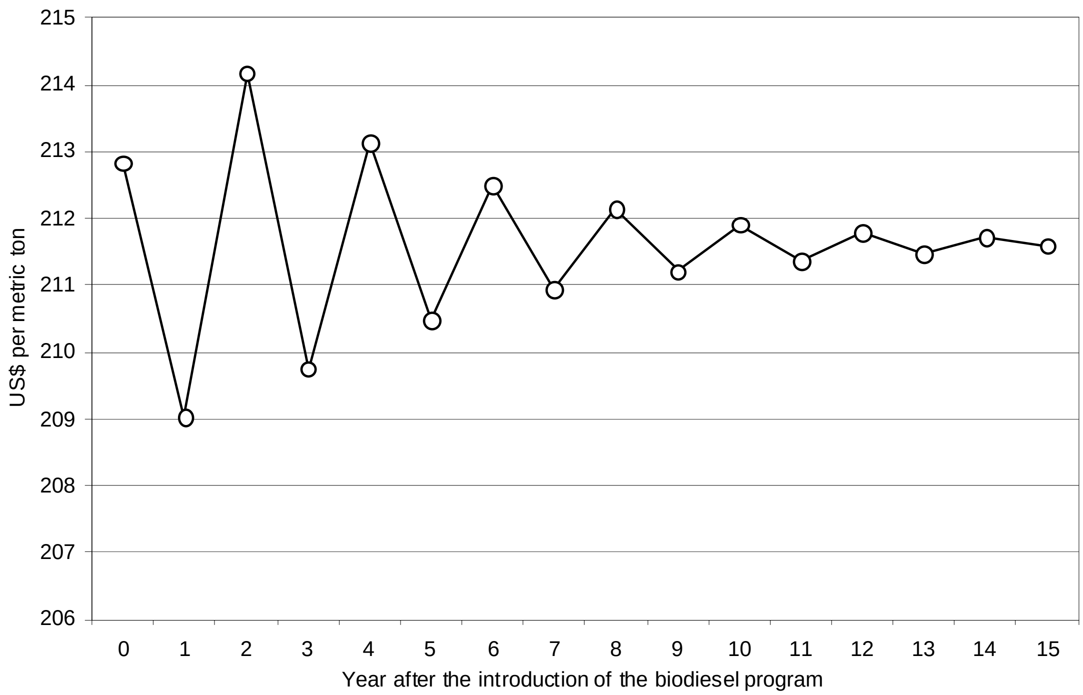


Table 3: Producer outcomes of a rise in oil prices following introduction of a biodiesel program using 5% of world oil output (prices in US$ per metric ton; outputs in '000 metric tons)

	Soy	Rape	Sun	Palm
Seed/Bean				
Initial Implied Price	260.6	379.0	302.3	402.6
Final Implied Price	265.2	337.9	317.6	469.4
% Increase in Implied Price	1.7%	-10.8%	5.1%	16.6%
Initial World Output	199,919	39,495	25,331	30,389
Final World Output	201,864	36,985	26,039	32,235
% Increase in Output	1.0%	-6.4%	2.8%	6.1%
Oil				
Initial Price	555.8	775.7	632.7	437.5
Final Price	586.2	671.3	671.3	511.8
% Increase in Price	5.5%	-13.5%	6.1%	17.0%
Initial World Output	30,938	14,021	8,752	30,389
Final World Output	31,239	13,130	8,997	32,235
% Increase in Output	1.0%	-6.4%	2.8%	6.1%
Meal				
Initial Price	212.8	127.5	114.7	88.2
Final Price	211.7	126.8	114.1	87.7
% Increase in Price	-0.5%	-0.5%	-0.5%	-0.5%
Initial World Output	132,448	21,598	9,718	3,884
Final World Output	133,737	20,225	9,989	4,120
% Increase in Output	1.0%	-6.4%	2.8%	6.1%

Note: It is assumed that the biodiesel program adds 5% to the initial level of world demand for vegetable oils.

Table 3 summarizes the initial and final prices that will face soybean, rapeseed, sunflower and palm oil producers, and it also lists the volumes of production that will occur at the revised equilibrium price.

A very important point to stress is that the simulation assumes that the supply response from the palm oil industry has been given time to occur. In practice, this will take a period of several years but, once it is over, the world market will increase its demand for palm oil substantially (by over 6%), which will eventually put downward pressure upon high cost vegetable oil producers, most notably of rapeseed oil. Palm oil is particularly helped in the simulation by the narrowing of its historical discount on soybean and other oils.

As biodiesel demand increases, palm oil, as the lowest cost vegetable oil, will be the greatest indirect beneficiary, as users for purposes such as food or the production of oleochemicals and biodiesel, will switch to the use of palm oil wherever possible, notably in the fast growing and highly populated countries of Asia.

The table demonstrates the limited long term impact of a biodiesel program on oilseed producers in terms of their overall output volumes:

- After all the repercussions have worked their way through the system, including in the oil palm sector, an initial boost of 5.0% to global oil demand is translated into an increase in vegetable oil production from all four crops included in the table of just 1.5 million metric tons. This represents a rise of only 1.8% from average production levels worldwide before the hypothetical boost to oil demand for biodiesel.

This disparity between the initial 5.0% boost to oil demand and the final 1.8% increase in crop output is explained predominantly by the low eventual rise in soybean production, which accounts for over two-thirds of total worldwide oilseed production, and which will suffer from the drop in meal prices, caused by the need to absorb the extra meal produced in conjunction with the additional soybean oil.

There would also be a decrease in rapeseed output, as its oil price loses the recent exceptional premium it has enjoyed while the market for biodiesel in the EU is assumed in the simulation adapts to the possibility of using other methyl esters for biodiesel. On the other hand, as noted above, palm oil output would increase by over 6%, spurred on by the rise in oil prices. In addition, oil palm benefits from its very low reliance upon meal credits, by comparison with other oilseeds.

Implications for world oil and meal markets

The results of the analysis described above suggest that, if a U.S. biodiesel program were to stimulate global demand for vegetable oil by 5.0%,

- The initial boost to the world price for oil would be 7.6%.
- U.S. soybean producers would eventually experience a price increase of only 1.7% for their beans, together with a modest 1.0% rise in total output.

ATTACHMENT 19

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Office of Energy Policy
and New Uses

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Energy Life-Cycle Assessment of Soybean Biodiesel

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Summary

The first comprehensive life-cycle inventory (LCI) for biodiesel produced in the United States from soybean oil was completed by Sheehan et al. in 1998. The purpose of the study was to conduct a life-cycle assessment (LCA) to quantify and compare the environmental and energy flows associated both with biodiesel and petroleum-based diesel. One of the most often cited results from Sheehan et al. is that the fossil energy ratio of biodiesel is equal to 3.2. In other words, biodiesel yields 3.2 units of energy for every unit of fossil energy consumed over its life-cycle. By contrast, it was found that petroleum diesel's life cycle yielded only about 0.84 units of energy per unit of fossil energy consumed. The purpose of the following analysis is to update the energy life cycle of the model to determine if any significant changes in the original inventory have occurred since the model was first developed 10 years ago.

The LCI of biodiesel in this analysis includes four subsystems: feedstock production, feedstock transportation, soybean processing with biodiesel conversion, and product distribution. All significant sources of energy are included in the inventory, such as the liquid fuel and electricity used to directly power equipment in the system. The energy requirements to produce materials that are made from energy resources, such as fertilizers, pesticides, and other petrochemicals, are also included in the inventory. The soybean crushing model in this analysis uses the hexane extraction method to extract oil from soybean seed, and transesterification is used to convert soybean oil into biodiesel. Oil extraction and transesterification result in the production of two important coproducts, soybean meal and crude glycerin, respectively. A mass-based allocation method is used to account for the energy associated with the soybean meal and crude glycerin.

The fossil energy ratio (FER), which is used in this study to measure the energy balance of biodiesel, is defined as the ratio of the energy output of the final biofuel product to the fossil energy required to produce the biofuel. The energy requirements of biodiesel include all the fossil energy in the LCI and do not include any renewable energy, such as solar or hydroelectric energy. The analysis first constructed a base case, in which the inventory was kept basically the same as the inventory used in the Sheehan et al. report. Then additional inputs that were excluded by Sheehan et al., such as agricultural machinery and energy embodied in building materials, were added to study their impact on the FER.

The Sheehan et al. study used data from a U.S. Department of Agriculture (USDA) conducted survey on soybean production in 1990, and this study used data from a 2002 USDA survey. Given the long time period between surveys, the newer data would be expected to reflect some changes in soybean production practices over time. One major change that has occurred is the increased adoption of no-till practices by soybean farmers, which reduces fuel requirements. Another change is the widespread adoption of genetically engineered (GE) soybeans, which have had a major effect on pesticide use. Soybean yields have been improving over time because of new seed varieties, improved fertilizer and pesticide applications, and new management practices. Energy savings have also occurred in the soybean crushing industry because facilities that have been built in recent times are far more energy efficient than the older plants.

The first subsystem constructed for the LCI was soybean production, which is the feedstock source for the biodiesel examined in this study. Energy requirements for producing soybeans were estimated for both direct energy, such as diesel fuel, and gasoline, and indirect energy, such as fertilizers and pesticides. Diesel fuel use required the most energy on the farm, followed by fertilizers, and herbicides. Next, the energy required to transport soybeans from the farm to processing plants was estimated based on information from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model. It requires about 6,393 British Thermal Units (Btu) to transport 1 bushel of soybeans to a processing facility.

The model used in this study was designed to represent a processing facility that combines a soybean processing plant with a biodiesel conversion unit producing 9.8 million gallons of biodiesel, 151,515 tons of soybean meal, 9,000 tons of soybean hulls, and 4,380 tons of crude glycerin. The soybean crusher uses energy in the form of electricity to power motors and provide lighting. Natural gas and process steam are used to provide heat for drying. Hexane is used for oil extraction. The total amount of energy required for removing the soybean oil is about 23,000 Btu per gallon of biodiesel. The soybean oil is converted into biodiesel using a process called transesterification, which is done by reacting the oil with an alcohol and a catalyst in large reactors. This reaction also results in the production of crude glycerin, which is a valuable coproduct. The conversion of the soybean oil into biodiesel and the treatment of the glycerin requires almost 19,000 Btu per gallon of biodiesel. Energy is also required to ship the biodiesel from the processing plant to marketing outlets. Using the GREET model, it was determined that on average it requires about 1,000 Btu to ship a gallon of biodiesel to its final destination.

Combining the energy input estimates from the four subsystems completed the base case life-cycle assessment for biodiesel. After adjusting the energy inputs by energy efficiency factors and allocating energy by coproducts, the total energy required to produce a gallon of biodiesel was 25,696 Btu. Biodiesel conversion used the most energy, accounting for about 60 percent of the total energy required in the life-cycle inventory. Soybean agriculture accounted for 18 percent of the total energy requirements, followed by soybean crushing, which required almost 15 percent of the total energy. The net energy value (i.e., biodiesel energy output, minus fossil energy input) was about 91,000 Btu per gallon. The estimated FER of biodiesel was 4.56, which is about 42 percent higher than the FER reported by Sheehan et al.

The next step in this analysis was to add secondary energy inputs to the LCI that were not included in Sheehan et al. to determine how they affect the overall results. The secondary inputs added were farm machinery, building materials for a crushing plant, and building materials for a biodiesel conversion plant. When the input energy for both agricultural machinery and building material are added to the inventory, FER declines to 4.40, still considerably higher than the 3.2 FER reported by Sheehan et al. In addition, Sheehan et al. omitted lime from their LCI, whereas this study included lime in the base case LCI. However, lime use only accounted for about 500 Btu per bushel of soybeans, and adding it to the LCI only lowered the FER by 0.22 percent.

The final step in this analysis was to examine the effect of rising soybean yields on the FER of biodiesel. The analysis found that the FER of soybean biodiesel is expected to reach 4.69 when projected soybean yield reaches 45 bushels per acre in 2015. This is about a 3-percent increase compared to the 2002 FER estimate. This result suggests that the FER of biodiesel will continue to improve over time. In addition to higher yields, improvements can be expected to occur in other areas of the life cycle as the agricultural sector, along with the biodiesel industry, continues to make energy efficiency gains in order to lower production costs.

Energy Life-Cycle Assessment of Soybean Biodiesel

A. Pradhan, D. S. Shrestha, A. McAloon, W. Yee , M. Haas, J. A. Duffield, and H. Shapouri

Much of the attention directed toward renewable fuels, such as biodiesel, is focused on the perception that they have superior environmental properties compared to their petroleum fuel counterparts (U.S. Environmental Protection Agency, 2002; Knothe et al.). In addition, developing renewable fuels is desirable because they are derived from sustainable sources of energy, whereas petroleum fuels come from a finite resource that is rapidly being depleted. However, the production of renewable fuels generally involves a significant amount of fossil energy (e.g., petroleum-derived diesel fuel is used to cultivate and harvest the soybeans used to make biodiesel). The amount of fossil energy used for biodiesel must be measured over the entire life cycle of biodiesel production to determine the extent to which it depends on petroleum fuels. The degree to which biodiesel is renewable is largely a factor of the amount of fossil energy used for its production.

It is beneficial to know the renewability of a biofuel for two reasons. First, it is useful to know how much a biofuel relies on petroleum-derived energy for its production; the less a biofuel depends on petroleum energy, the more potential it has for diversifying our total fuel supply. Secondly, the renewability factor is one of many criteria that may be used by policymakers and others to evaluate and compare various biofuels. Renewability is a useful measurement that can be used along with other measurements, including environmental, economic, and social criteria, to assess the benefits of biofuels.

In 1998, the first comprehensive life-cycle inventory (LCI) for biodiesel produced in the United States from soybean oil was completed by Sheehan et al. The inventory and model assumptions were developed by a large stakeholders group and several peer reviewers, including experts from numerous disciplines and institutions. The purpose of the study was to conduct a life-cycle assessment (LCA) to quantify and compare the environmental and energy flows associated both with biodiesel and petroleum-based diesel. The LCI flows examined included greenhouse gases, energy use, and other air emissions. Other biodiesel LCAs have been done since Sheehan et al., but none have matched the detailed information or collaborative effort used to produce the original report (Hill et al. and Huo et al.).

One of the most often cited results from Sheehan et al. is that the fossil energy ratio of biodiesel is equal to 3.2. In other words, biodiesel yields 3.2 units of energy for every unit of fossil energy consumed over its life cycle. By contrast, it was found that petroleum diesel's life cycle yielded only about 0.84 units of energy per unit of fossil energy consumed. The purpose of the following analysis is to update the energy life cycle of the model to determine if any significant changes in the original inventory have occurred since the model was first developed 10 years ago. For example, the adoption of new technologies in the farm sector, the soybean processing sector, and in the biodiesel industry are expected to affect life-cycle energy use.

Methodology

Following Sheehan et al., the formula used in this study to estimate the fossil energy ratio (FER) is defined in equation 1:

$$FER = \frac{\text{Renewable Fuel Energy Output}}{\text{Fossil Energy Input}}. \qquad (1)$$

A biofuel's FER is defined as the ratio of the energy output of the final biofuel product to the fossil energy required to produce the biofuel. The FER as defined above only includes fossil energy in the denominator. For example, it does not include the energy value of the soybeans used to make biodiesel, and it does not include any solar or hydroelectric energy because these sources of energy are renewable.

Estimating FER begins with defining the entire production system of biodiesel, which includes four subsystems in this analysis: feedstock production, feedstock transportation, soybean processing with biodiesel conversion, and product distribution. An inventory is then developed that identifies and quantifies all the fossil energy inputs used in each subsystem. All significant sources of energy are included in the inventory, such as the liquid fuel and electricity used to directly power equipment in the system. The energy content of materials that are made from energy resources, such as fertilizers, pesticides, and other petrochemicals, is also included in the inventory. The energy values of all fossil energy used in the system are adjusted by energy efficiency factors to take into account the energy used to convert fossil resources into usable energy (table A2). The energy efficiency factors also adjust for any energy required to mine, extract, and manufacture the raw energy sources. Estimates of electricity generation used throughout the life cycle are based on the U.S. weighted average of all sources of power, including coal, natural gas, nuclear, and hydroelectric. About 70 percent of the electricity generated in the United States comes from fossil fuel (Energy Information Administration); hydroelectric and other nonfossil sources provide about 30 percent. The efficiency of electricity generation in the U.S. increased from 32 percent as reported in Sheehan et al. to 33.71 percent in 2007 based on data from the Energy Information Administration. In addition to generation loss, there is also a loss of electricity over the distribution lines, which reduces the overall efficiency of electricity to 31.29 percent. Therefore, all electricity used over the life cycle is increased by a factor of 3.2 to account for generation and distribution losses.

Similarly to Sheehan et al., the soybean crushing model in this analysis uses the hexane extraction method to extract oil from soybean seed, and transesterification is used to convert soybean oil into biodiesel. Oil extraction and transesterification result in the production of two important coproducts, soybean meal and crude glycerin respectively. Since this energy life cycle focuses exclusively on biodiesel, the energy associated with the production of the other two coproducts must be estimated and excluded from the inventory. Since detailed information is often not available to measure the exact energy requirements of the individual coproducts, an allocation method can be used to assign coproduct values. There are several allocation methods that can be used to estimate the energy value of coproducts. For example, the energy method uses the energy content of each coproduct to allocate energy. Another example is the economic method, which uses the relative market value of each coproduct to allocate energy. Sheehan et al. used a mass-based allocation method, and to be consistent with their analysis, this study also uses the mass-based allocation method. In general, no allocation method is always applicable, and the appropriate method should be chosen on a case-by-case basis. For more discussion on allocation methods, see Shapouri et al.

The mass-based allocation method is commonly used because it is easy to apply and provides very reasonable results (Vigon et al., 1993). This method simply allocates energy to the various coproducts by their relative weights. This allocation rule separates the energy used to produce the soybean oil from the energy used to produce the soybean meal and glycerin in the following manner:

$$\text{Energy input allocation for biodiesel} = E_1 f_1 + E_2 f_2 + E_3 \qquad (2)$$

where E_1 is energy input for agriculture, soybean transport and soybean crushing, f_1 is the mass fraction of soybean oil used to produce biodiesel; E_2 is the energy used during transesterification and the transport of the soybean oil, and f_2 is mass fraction of the transesterified oil used to produce biodiesel. E_3 is energy input for biodiesel transport.

Over the past several years, the FER, also called energy balance, of soybean biodiesel has been reported by different researchers with considerable variation in results (Hill et al.; Huo et al., and Pimentel and Patzek.). A major cause for the contradicting results is the difference in the amount of energy allocated between the soybean oil used to make biodiesel and the soybean meal. Historically, soybean demand is driven by the demand for soybean meal, which is used as a high-protein animal feed. Crushing soybeans yields considerably more meal than oil, as well as more revenue. Clearly, soybean meal is not a byproduct of biodiesel production. Rather, soybean meal and oil are jointly produced and sold in separate markets. Therefore, an allocation method must be used to determine how the energy used for crushing soybeans should be divided between the two products. Unfortunately, different allocation methods can produce significantly different coproduct energy values. For a detailed comparison and discussion of the different coproducts used in the literature, see Pradhan et al.

Data Description and Trends

At the time of the Sheehan et al. study, the most recent detailed data available on soybean production was from the U.S. Department of Agriculture's (USDA) 1990 Farm Costs and Return Survey (FCRS). The FCRS, which was replaced by the Agricultural Resource Management Survey (ARMS) in 1996, is conducted annually, but to reduce survey costs, USDA does not undertake detailed surveys of every commodity each year. Thus, the ARMS covers a major commodity in detail about every 4 years, with the most recent survey conducted on soybeans in 2006. This study, however, uses the 2002 data, because the 2006 data became available just prior to the release of this study. The ARMS soybean survey only covers major soybean producing States, and detailed data are only reported for a selected number of these States. In 1990, State-level estimates were available for 14 States and the 2002 soybean survey provided detailed State-level data on 20 States. These 20 States are responsible for 98 percent of the soybean production (table 1). The USDA uses other versions of the ARMS to gather annual data for national soybean production estimates, but they are limited compared to the ARMS soybean survey, which is the only USDA source that provides detailed data on machinery and fuel use. Data from the 2002 ARMS soybean survey on chemicals and fertilizers were not made available at the time of this study, so other USDA data sources were obtained (table 1).

To stay competitive, U.S. farmers are continually minimizing their input costs and increasing productivity. Therefore, soybean data would be expected to reflect some changes in soybean production practices over time. One major change that has occurred is the increased adoption of no-till practices by soybean farmers. No-till use increased in soybean production from about 10 percent of acreage in 1990 to about a third in 2000. Thus, significantly fewer soybean acres required fuel for tilling over this time period (USDA Economic Research Service [ERS], 2003). The most significant change in U.S. soybean production since 1990 is the use of genetically engineered (GE) soybeans, which have had a major effect on pesticide (includes herbicides, insecticides, and fungicides) use. The 1990 ARMS soybean production data used in the Sheehan et al. report did not include any GE soybeans because they had not been introduced into U.S. agriculture yet. However, by 2002 the rapid rise in GE soybeans had reached 75 percent of the soybeans planted, and today almost all soybeans in the United States are GE varieties (USDA ERS, 2007). Genetically engineered soybeans with herbicide-tolerant and pest-management traits increase yields through improved weed and pest control. Using GE soybeans also reduces pesticide use and costs (Heimlich et al., 2000). Based on data published in the National Agricultural Statistics Service's (NASS) Agricultural Chemical Usage survey, over the 5-year period from 1990 to 1994; 1995 to1999; and 2000 to 2004, the average herbicide use was 1.18, 1.11 and 1.09 lb/acre/year respectively (USDA, NASS, 1990-2005). However this average decrease in herbicide use may not be realized from year to year because annual pesticide use depends on the level of infestation. For instance, the insecticide application rate was higher for the years 2005 and 2006, mostly because of higher aphid infestation (Thorson). Some herbicides are also less toxic today. For example, most of the herbicide used on soybeans is now in the form of glyphosate, which is about 10 times less toxic in terms of the oral Reference Dose (RfD) established by the Environmental Protection Agency (EPA) than herbicides used in the past, such as Alachlor (EPA, 2008). Kovach et al. found that the environmental impact quotient (EIQ), which encompasses 11 different types of toxicity measurements and environmental impacts, was found more favorable for glyphosate (EIQ =15.3) than for alachlor (EIQ = 18.3).

Table 1 – Soybean agriculture system inputs, major States, 2002

State		AR	IL	IN	IA	KS	KY	LA	MD	MI	MN	MS	MO	NE	NC	ND	OH	SD	TN	VA	WI	Weighted Average*
Input																						
Seed	lbs/ac	59.4	69.9	71.7	63.6	59.5	66.1	54.4	67.4	77.4	67.3	51.4	68.6	67.9	54.1	72.3	84.2	65.1	56.9	84.9	79.7	67.9
Fertilizer																						
Nitrogen	lbs/ac	1.76	3.55	3.00	0.89	4.44	7.44	0.13	5.51	11.9	2.24	2.57	2.34	4.91	10.6	16.5	2.97	7.65	12.5	7.5	5.97	4.26
Phosphorus	lbs/ac	19.6	13.6	11.7	4.64	10.4	23.5	6.96	5.92	15.6	4.75	11.0	12.5	17.0	18.4	18.9	13.2	24.0	26.9	15.2	12.3	12.65
Potash	lbs/ac	22.4	40.1	47.6	15.7	2.15	36.1	9.49	14.3	58.1	5.43	17.9	31.3	3.11	37.8	1.24	58.2	5.74	42.0	38.3	35.5	25.52
Direct Energy																						
Gasoline	gal/ac	1.3	0.90	1.60	1.10	1.10	1.40	1.10	2.10	1.50	1.10	1.20	1.40	1.30	1.50	1.40	1.30	1.40	1.30	1.20	2.40	1.26
Diesel	gal/ac	9.90	2.50	2.30	3.40	2.90	2.10	6.50	2.90	4.00	4.00	4.30	4.30	12.9	2.40	3.20	2.00	2.80	2.20	1.90	5.20	4.06
Propane	gal/ac	NR	0.00	NR	0.00	1.80	NR	NR	NR	NR	NR	NR	NR	4.40	NR	NR	NR	0.00	NR	NR	0.00	0.73
Electricity	kWh/ac	11.2	NR	1.30	0.00	9.10	4.50	NR	0.80	NR	NR	3.80	NR	39.4	0.60	0.80	0.00	NR	1.00	NR	NR	6.62
Natural Gas	Cf/ac	NR	0.00	NR	0.00	349	0.00	NR	0.00	0.00	0.00	0.00	0.00	586	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.41
Chemicals																						
Herbicides	lbs/ac	1.00	1.23	1.35	1.26	1.07	1.15	1.60	1.54	1.22	0.98	1.66	1.17	1.28	1.00	1.26	1.34	1.20	1.29	1.23	0.81	1.21
Insecticides	lbs/ac	0.04	0.00	0.00	0.01	0.00	0.00	0.60	0.34	0.00	0.00	0.02	0.00	0.01	0.07	0.00	0.00	0.02	0.00	0.05	0.00	0.02
Lime	lbs/ac	53.7	595	668.8	286.4	146.7	865.6	70.7	NA	323.3	181.8	120	818.5	123.9	652.9	NR	394.6	NR	828.3	769.7	379.3	357.96
Yield	Bu/ac	33.5	43.0	41.5	48.0	23.0	33.0	32.0	23.0	38.5	43.5	32.0	34.0	38.5	24.0	33.0	32.0	31.0	31.0	23.0	44.0	38.0

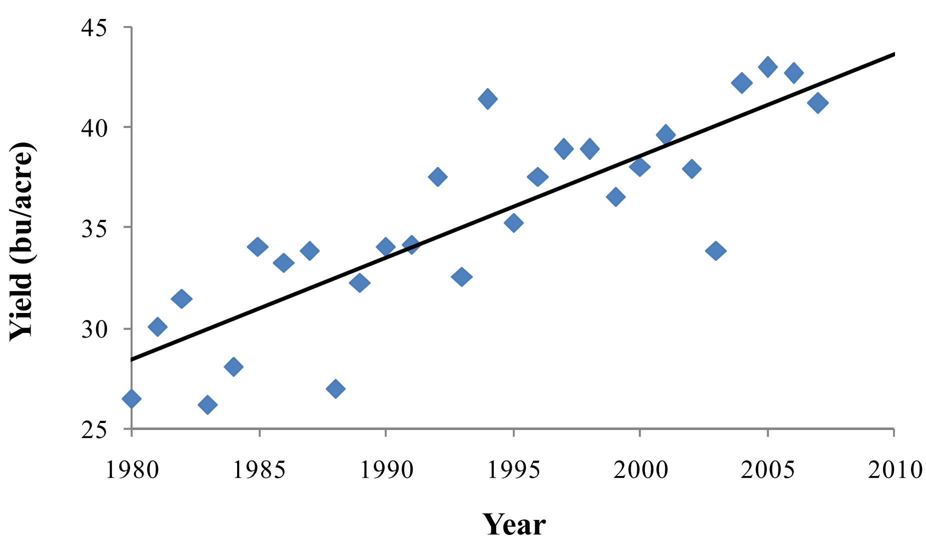
Source: USDA, National Agricultural Statistics Service (NASS), 2005; USDA, Economic Research Service (ERS) (a); USDA, ERS (b); and USDA, NASS, 2003.
*Weighted by area harvested in each State.
NR: Not reported in that State due to small sample size.

Lime use was not reported by Sheehan et al.; however, farmers apply lime periodically to increase soybean yield. In 2002, the average lime application for soybean production was 2 tons per treated acre (USDA, ERS b). About 52 percent of the total planted acres were treated with lime, and the lime was applied on average every 5.9 years. Adjusting for the soybean planted acres and the annual rate, the lime application rate was estimated to be 358 pounds per acre.

Soybean yields also have been improving over time because of new seed varieties, improved fertilizer and pesticide applications, and new management practices (Ash et al., 2006). The data show a significant increase in soybean yield since 1990 (figure 1). Soybean yields have increased steadily since 1990 when the U.S. average yield was 34.1 bushels per acre, and by 2002, U.S. soybean yield increased to 38 bushels per acre (Ash and Dohlman). The latest USDA estimate for soybean yield is 41.7 bushels per acre for the 2007 crop year (USDA, Office of the Chief Economist-b). The data trend shows a continuous increase in yield but there was no significant increase in other agricultural inputs. Consequently, as shown later in this report, the FER increases with crop productivity.

There have also been major changes in the soybean crushing industry that are expected to reduce the energy requirements of biodiesel. Unfortunately, the best data available to Sheehan et al. on oil crushing were based on a single facility that was 17 years old at the time of the study. Although adjustments were made to the model to modernize the plant, it is unlikely that it was a good representative of a typical crusher of the time. Thus, the typical plant in operation today is much newer than the plant modeled by Sheehan et al. For example, the oil extraction rate has increased since the Sheehan et al. study, which used 10.16 pounds per bushel (Table 79, pp 134).

Figure 1 – U.S. national average soybean yield 1980-2007 and expected trend to 2010



Source: Ash and Dohlman; and USDA, Office of the Chief Economist (b).

The oil extraction rate for crop year 2002/2003 was 11.39 pounds per bushel and increased to 11.55 pounds per bushel in crop year 2007/2008 (USDA ERS, 2009). Even though the oil extraction rate for year 2007/2008 was higher, the oil extraction rate of 2002/2003 was used in this report to be consistent with the 2002 ARMS agricultural input data. Furthermore, newer plants are more energy efficient due to the adoption of energy saving technologies that reduce production costs. Process improvement in extraction plants has continued with increasing emphasis on energy efficiency, reducing hexane loss, and increasing capacity. For instance, the current acceptable level of solvent loss is one-third the level used by U.S. extraction plants in 1970 (Woerfel).

Likewise, the amount of energy required to convert soybean oil into biodiesel using transesterification may have decreased over the past decade if producers have adopted energy-saving processing equipment to minimize production costs. The rise in larger biodiesel facilities with corresponding larger energy requirements has prompted greater emphasis on minimizing energy costs. The capital cost of adding energy saving technologies would be justified if the investment cost is less than the savings from lower energy costs. For example, heat integration technologies have resulted in the capture and reuse of heat that was previously discharged. Improvements in the catalytic technology used to produce biodiesel have resulted in higher conversion efficiencies of soybean oil into biodiesel. Reclaiming and reusing the wash-water stream used to purify biodiesel eliminates the need for wastewater treatment.

Energy Life-Cycle Inventory

This section describes the inventory and data used to construct the four subsystems of the biodiesel life cycle: feedstock production, feedstock transportation, soybean processing with biodiesel conversion, and product distribution. The analysis first constructs a base case, in which the inventory was kept basically the same as the inventory in the Sheehan et al. report. Then additional inputs that were not included in Sheehan et al., such as agricultural machinery and energy embodied in building materials, were added to study their impact on the FER.

Feedstock Production

The farm input data for soybean production were obtained from ARMS and the National Agricultural Statistics Service (NASS). The direct energy data came from the 2002 ARMS, which were the most recent soybean survey data available at the time of this study (table 1). The State soybean yield data are USDA estimates reported by NASS (USDA, NASS, 2005). The fertilizer and chemical data for year 2002 soybeans are from the USDA's NASS Agricultural Chemical Survey. The lime-application rates and the seed-application rates shown in table 1 are State averages from the 2002 ARMS (USDA, ERS-a; and USDA ERS-b).

The farm input data in table 1 were weighted by State acreage to derive average energy used for U.S. soybean production. The weighted average soybean yield for the State data equaled 38 bushels per acre in year 2002. The weighted average energy input use and the weighted average yield were used to estimate the energy required to produce a bushel of soybeans in the United States (table 2). The direct energy inputs were converted to British thermal units (Btu) using low-energy heating values, assuming that electricity generation came from a combination of coal, natural gas, nuclear, and hydropower at the same proportion as the national average. Electricity use only includes electricity generated from fossil sources, which on a national average equals 70 percent. The energy used for planting the seed and other farm activities, such as land preparation, plowing, weeding, fertilizer and pesticide application, irrigating, harvesting, and drying, is included in total farm fuels and electricity estimates. The fuel required for hauling the soybeans from the field to the first destination point, either farm storage or local market, is also included in the fuel estimates. The conversion factors used to convert farm energy inputs into Btus are listed in Appendix table 1.

Estimating Energy for Transporting Soybeans to Biodiesel Plant

The amount of energy required to transport soybeans to processing plants came from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model (Argonne National Laboratory). The energy required for transporting soybeans to processing

Table 2 – Energy equivalents for base case soybean agriculture system inputs before allocating coproduct values, 2002

Inputs*	20 States Weighted Average	
	(Btu/bu)	Btu/gal
Seed	3,617	2,428
Fertilizer:		
Nitrogen	2,482	1,666
Phosphorus	1,313	881
Potash	1,721	1,155
Direct Energy:		
Diesel	16,280	10,928
Gasoline	4,782	3,210
Propane	1,817	1,220
Electricity* *	1,330	893
Natural Gas	1,607	1,079
Ag. Chemical Application:		
Herbicid es	4,368	2,932
Insecticides	55	37
Lime	506	340
Total Fossil Energy for Agriculture	39,878	26,769

* Inputs are adjusted by energy efficiency factors.
**Assumes 70 percent of electricity generated from fossil sources.

plants was estimated to be 6,393 Btu/bushel, which is equivalent to about 4,291 Btu per gallon of biodiesel. The estimation was based on a distance of 50 miles for trucking soybeans from a distribution center to the soybean crusher/biodiesel plant.

Estimating Energy for Oil Crushing and Biodiesel Conversion

The production of biodiesel from soybeans occurs in two stages: the soybeans are first treated to remove the oil, and then the soybean oil is converted into biodiesel. The first stage, the removal of the oil from the soybean, is often called crushing, and the most common method used to convert the oil into biodiesel is a process known as transesterification. Since actual industry data for soybean crushing and biodiesel production were not available, this study had to develop a generic model to estimate the energy required to crush soybeans and produce biodiesel using transesterification. The energy requirements for soybean crushing and transesterification were estimated using a computer model utilizing chemical process engineering and cost engineering technology that were developed by USDA's Agricultural Research Service (Haas et al.). The model measures the electrical and thermal energy inputs required for a joint facility that combines a soybean processing plant with a biodiesel conversion plant producing 9.8 million gallons of biodiesel, 151,515 tons of soybean meal, 9,000 tons of soybean hulls, and 4,380 tons of crude glycerin. The model provides a blueprint of a biodiesel plant based on the best information available, but it does not represent an actual plant, since actual industry data were not used.

Oil Extraction From Soybeans

The separation of the soybean into oil and soybean meal, which is generally referred to as crushing, can be done by crushing using mechanical extruders, but more commonly the oil is extracted from the soybeans using chemical hexane extraction (figure 2). A soybean processing facility uses energy in the form of electricity to power motors and provide lighting. Natural gas and process steam are used to provide heat for drying. The model used in this analysis allows the plant to generate its own steam from natural gas with a boiler efficiency of 80 percent. Thus, the energy value for steam is incorporated in the energy value of natural gas used to generate the required steam. Soybeans entering the process are first cleaned and then heated and dried to obtain a 10-percent moisture content (Erickson, 1995). Then the beans are cracked into several pieces by passing them through mechanical rolls. The soybean hulls, which account for about 8 percent of the soybean, are removed by aspiration. The hulls may be blended with the soybean meal that is later extracted in the process or they may be further treated by toasting and grinding and sold as animal feed. The dehulled beans or meats are conditioned by heating, cut into flakes, and fed to the oil extraction unit where the oil from the beans is dissolved with hexane. The oil and hexane mixture is treated with steam to separate the hexane from the oil. Once the hexane is removed, it is recycled for additional processing. Hot air and cooling water are used in the final heating and drying of the oil. The crude soybean oil is degummed and may be deodorized, bleached, and neutralized. The oil-depleted, dried soybeans are ground to a uniform size to make soybean meal, and in some cases, the hulls are blended with the soybean meal. The combined total thermal and electric energy required for preparing the soybeans, extracting the oil from the beans, and drying the soybean meal is 23,151 Btu per gallon of biodiesel (table 3).

Conversion of Soybean Oil Into Biodiesel

The conversion of soybean oil into biodiesel is done by reacting the oil with an alcohol, usually methanol, and a catalyst, such as sodium hydroxide, in large reactors. After the soybean oil, methanol, and catalyst have reacted, the resulting mixture is centrifuged to remove excess methanol, glycerin, and other impurities. After the centrifuge step, the mixture is then washed with a water acid solution and dried to become a methyl ester, which is commercially known as biodiesel (figure 2). The stream of methanol, glycerin, and other impurities is then treated with a small amount of acids and bases to remove any remaining fatty acids. The remaining material is then distilled to recover the methanol and most of the water. The excess methanol and water are recovered and reused to avoid waste and reduce input costs. The crude glycerin is often sold to companies that refine the glycerin to be used in the production of various other products, including fiberglass resin, cosmetics, pharmaceuticals, liquid laundry detergents, soaps, deicers, and antifreeze. Electrical energy is used to drive the pumps, centrifuges, and mixers, while thermal energy is needed in the distillation column to recover the excess methanol and remove the final rinse water from the biodiesel. Thermal energy is also used to heat the soybean oil to accelerate the conversion process. The conversion of the soybean oil into biodiesel, the recovery of the excess methanol, and the treatment of the glycerin requires 18,772 Btu per gallon of biodiesel (table 3).

Figure 2 – Soybean crushing and biodiesel conversion

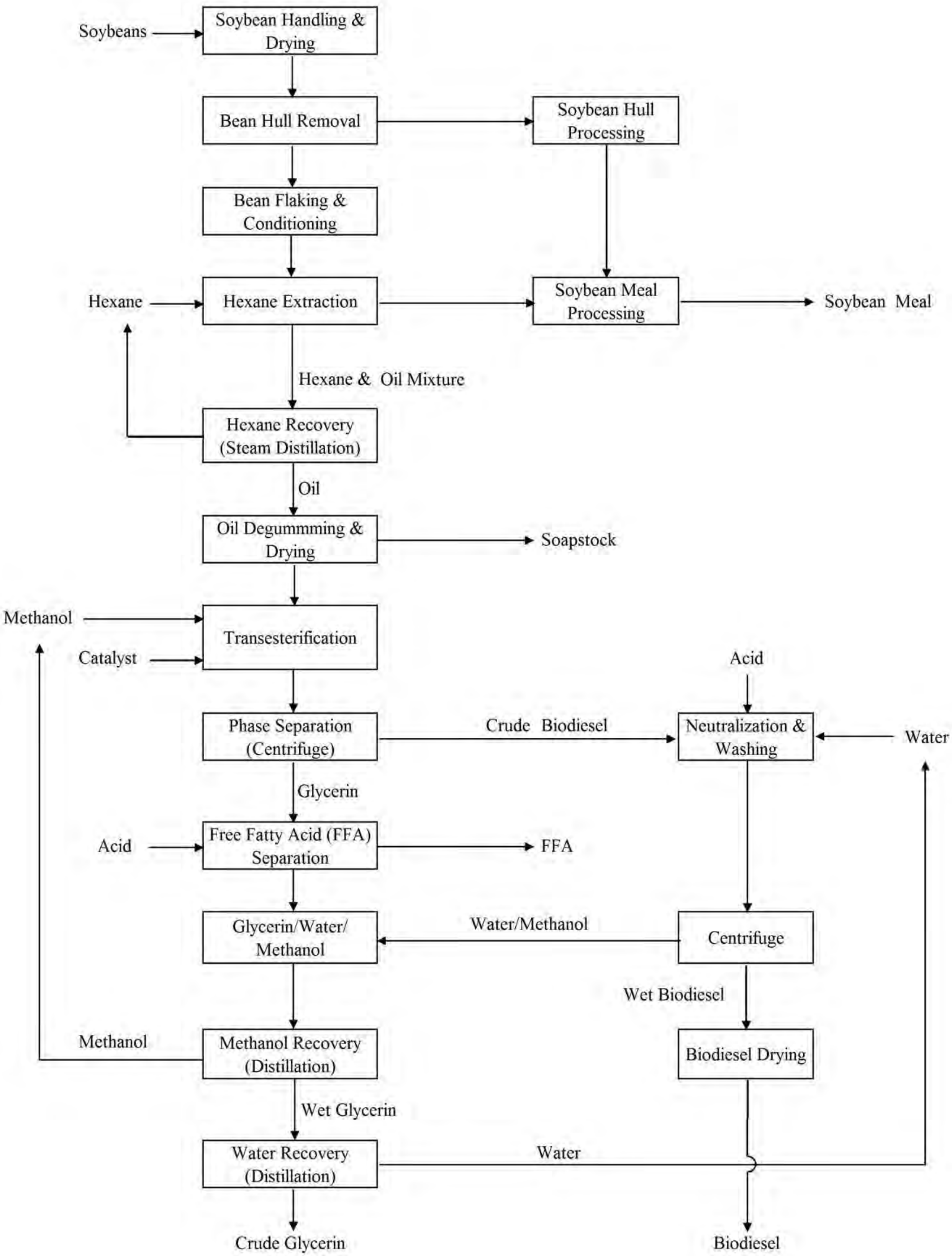


Table 3 – Fossil energy requirements for soybean crushing and conversion before allocating coproduct values, per gallon of biodiesel

Inputs	Equivalent Energy (Btu/gal)	Adjusted Equivalent Energy* (Btu/gal)	Source
Soybean crushing:			
Electricity**	2,738	6,124	ARS
Natural Gas/Steam	14,532	15,460	ARS
Hexane	--	1,567	Huo et al.
Total fossil energy for crushing		23,151	
Biodiesel conversion:			
Electricity	439	981	ARS
NG/Steam	3,551	5,840	ARS
Methanol	7,193	10,633	Huo et al.
Sodium Methoxide	--	1,256	Huo et al.
Sodium Hydroxide	--	24	Huo et al.
Hydrochloric Acid	--	38	Huo et al.
Total fossil energy for conversion		18,772	

* Inputs are adjusted by energy efficiency factors.
**Assumes 70 percent of electricity generated from fossil sources, which is adjusted for generation and line losses.

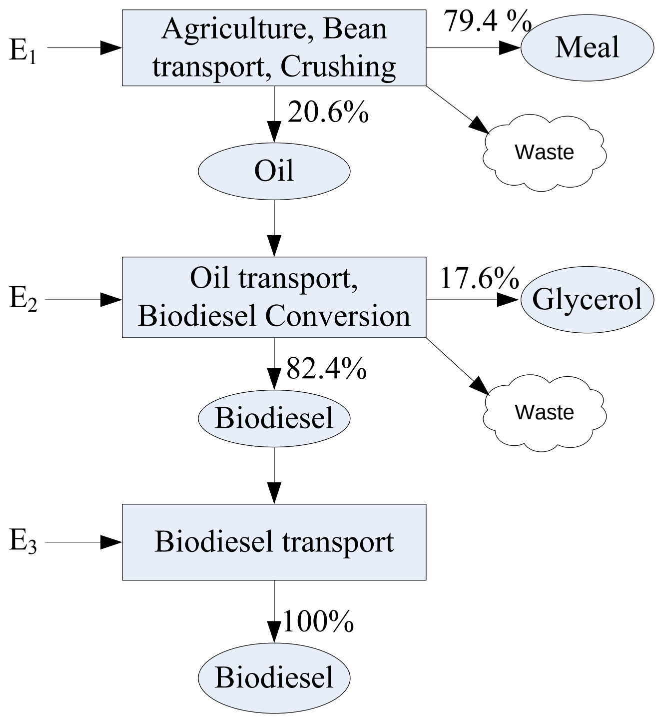
Biodiesel Transport

The GREET model was used to estimate the energy required for transporting biodiesel. Transporting biodiesel to marketing outlets requires 8,767 Btu per million Btu of biodiesel. This is equivalent to 1,027 Btu per gallon of biodiesel transported. The estimation was based on the total distance of 335 miles using a combination of truck, barge, and rail. It required a distance of about 32 miles for truck, 42 miles for barge, and 232 miles for rail to transport biodiesel from the plant to a distribution center, and another 30 miles by truck to get it to its final destination.

Calculating Energy Coproduct Values

The energy used to produce the meal portion of the soybean and the crude glycerin that is produced during the transesterification stage must be excluded from the LCI. Several allocation methods can be used to estimate the energy value of coproducts. The Sheehan et al. study used a mass-based allocation method, which simply allocates energy to the various coproducts by their relative weights. In order to provide a consistent comparison to the original Sheehan et al. study, we also use the mass-based allocation method (figure 3). Soybean crushing produces oil, meal,

Figure 3 ─ Mass-based energy allocation for biodiesel coproducts



gum, and waste material. USDA ERS (2009) reported a U.S. average oil yield of 11.39 pounds per bushel of soybeans, a soybean meal yield of 43.9 pounds per bushel, and a hull yield of 3.27 pounds per bushel in 2002/2003. Excluding the hulls and waste material, 20.6 percent of the total energy used for soybean agriculture, soybean transport, and crushing is allocated to the oil used to make biodiesel, and 79.4 percent is allocated to the meal (figure 3).

Crude degummed soybean oil contains a small amount of unsaponifiable matter and free fatty acids that must be removed because they are detrimental to the transesterification process (Sheehan et al., pp 145). The free fatty acids can turn into soap when transesterified, resulting in more difficult phase separation of the methyl ester and glycerin. The crude degummed oil is treated with sodium hydroxide to obtain dry refined oil, with a yield of about 96 percent (Sheehan et al., pp 146). The other 4 percent is considered waste. Following transesterification, the proportion of refined biodiesel to crude glycerin (with a purity of about 80 percent) is 82.4 percent biodiesel and 17.6 percent crude glycerin. Therefore, 82.4 percent of the total energy used to convert degummed soybean oil into biodiesel is allocated to biodiesel and 17.6 percent is allocated to crude glycerin (figure 3). In addition, the coproduct energy value of crude glycerin must be deducted from soybean agriculture, crushing, and soybean transport, so that f_1 in equation (2) = 0.170 = (0.206×0.824), and f_2 = 0.824. All the energy used to transport biodiesel is allocated to biodiesel (figure 3).

Results

Combining the energy input estimates from the four subsystems completes the base case life-cycle assessment for biodiesel (table 4). As discussed above, the energy requirements for producing the biodiesel coproducts (i.e., soybean meal and crude glycerin) have been removed from the biodiesel inventory. The energy use estimates in table 4 are adjusted by energy efficiency factors (appendix table 2). All estimates of electricity generation were based on weighted average of all sources of power used in the United States, including coal, natural gas, nuclear, and hydroelectric. Electricity use only includes electricity generated from fossil sources, which on a natural average equals 70 percent.

After adjusting the inputs by energy efficiencies and allocating energy by coproducts, the total energy required to produce a gallon of biodiesel is 25,696 Btu (table 4). Biodiesel conversion uses the most energy, accounting for about 60 percent of the total energy required in the life-

Table 4 – Base case energy use for biodiesel and FER with coproduct allocation and adjusted by energy efficiency factors

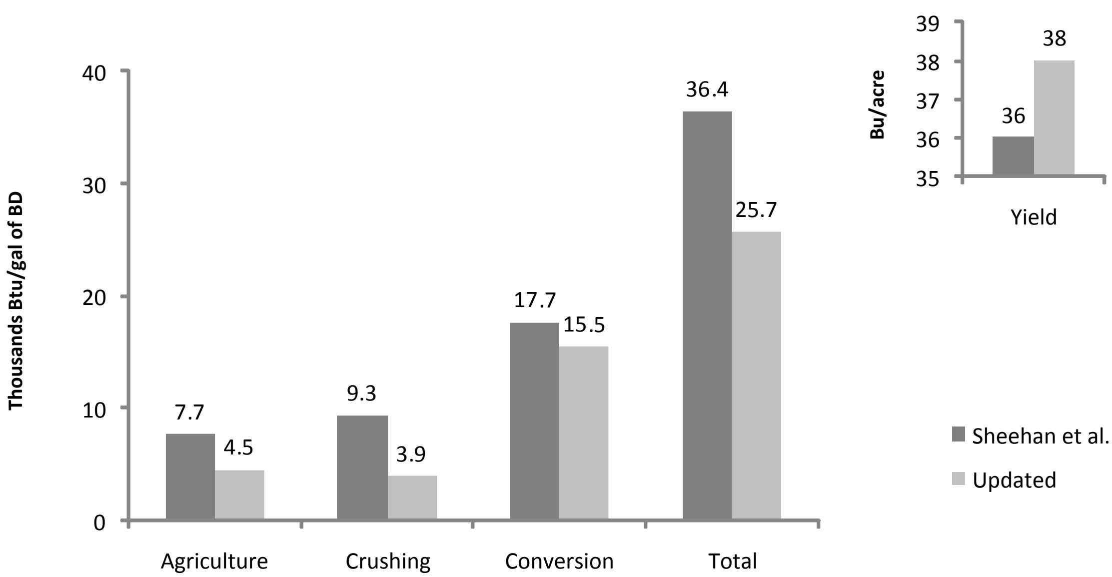
Life-Cycle Inventory	Fossil Energy Use (Btu/gal of Biodiesel)	
	Total	**Biodiesel fraction**[1]
Agriculture	26,769	4,544
Soybean transport	4,291	728
Soybean crushing	23,151	3,930
Biodiesel conversion	18,772	15,467
Biodiesel transport	1,027	1,027
Total Energy Input for Biodiesel Adjusted for Coproducts		25,696
Biodiesel Total Energy Output		117,093
Net Energy Value		91,397
Fossil Energy Ratio (FER)		4.56

[1] Coproducts are allocated as shown in figure 3.

cycle inventory. Soybean agriculture accounts for 18 percent of the total energy requirements, followed by soybean crushing, which requires almost 15 percent of the total energy. The net energy value (i.e., biodiesel energy output, minus fossil energy input) is about 91,000 Btu per gallon. The estimated FER of biodiesel is 4.56, which is about 42 percent higher than the FER reported by Sheehan et al.

A major reason for this improvement is that the soybean crusher modeled for this study more accurately measured the energy used by a modern facility. Soybean crushing facilities that have been built in recent times are far more energy efficient than the older plant used by Sheehan et al. In addition, since 2002, EPA has required soybean plants to limit their hexane use, thus the amount of hexane reported by Sheehan et al. had to be adjusted to reflect the new industry standard (EPA, 2001). The new hexane energy value that was used in this study is one-half of that reported by Sheehan et al. Overall, the energy required for crushing fell from 9,321 Btu to 3,930 Btu per gallon of biodiesel, about a 58-percent reduction (figure 4). The reduction in the crushing energy is primarily due to a reduction in the electricity and natural gas/steam inputs. The fossil energy inputs for soybean agriculture fell from 7,681 Btu to 4,544 Btu (41 percent reduction) per gallon of biodiesel (figure 4). This reduction is primarily due to less diesel, gasoline, fertilizer, and chemical usage. A likely reason for the decrease in fuel use is the increased adoption of less intensive tilling practices by soybean farmers. The lower chemical use in 2002 is partially related to the adoption of GE soybeans; however, differences in weather and other factors unrelated to energy efficiency can cause annual variation in chemical use.

Figure 4 – Comparing energy requirements for selected biodiesel subsystems and total life-cycle energy requirements between this study and Sheehan et al.



The energy required for transesterification estimated in this study was about 12 percent lower than the estimate reported by Sheehan et al. (figure 4). The fossil energy for electricity decreased and methanol usage decreased; however, natural gas and steam usage slightly increased. Overall, the total life-cycle energy required for biodiesel fell from 36,416 Btu to 25,696 Btu per gallon.

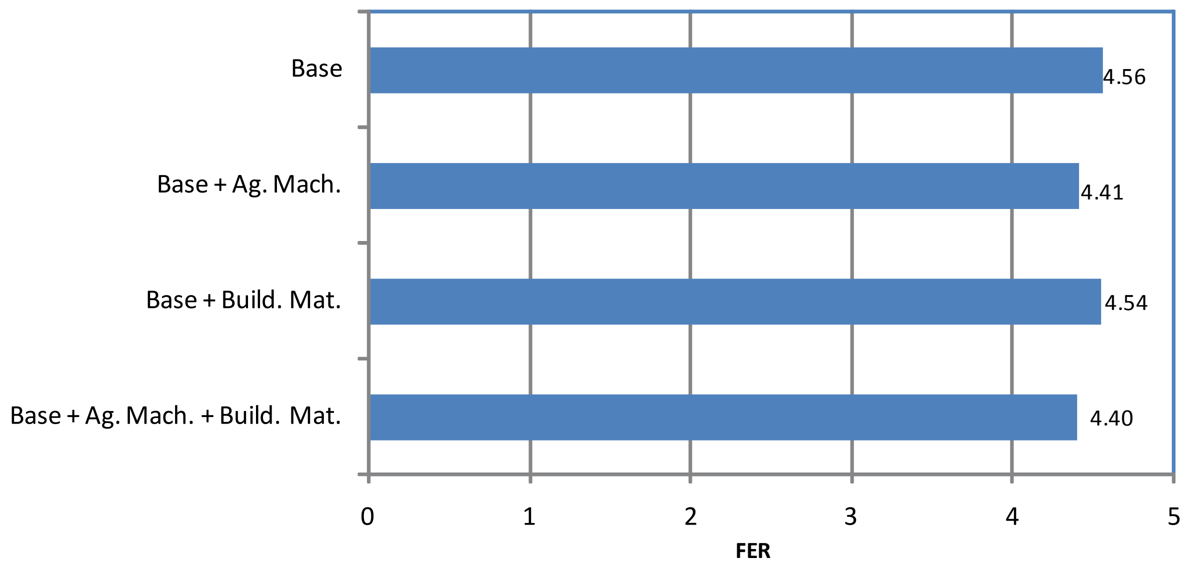
The Effects of Adding Inputs to the LCI

Figure 5 shows the effects of adding secondary energy inputs to the LCI that were not included in Sheehan et al. to determine how they affect the overall results. Hill et al. estimated the energy associated with manufacturing farm machinery to be 7,547 Btu per bushel (5,066 Btu/gal of biodiesel). Adding the biodiesel share of this energy to soybean production reduces the base case FER of 4.56 to 4.41. Hill et al. also estimated the energies associated with building materials- 193 Btu per bushel (129 Btu/gal of biodiesel) for a crushing plant and 100 Btu per bushel (67 Btu/gal of biodiesel) for a biodiesel conversion plant. Adding the biodiesel share of energy related to building materials lowered the FER to 4.54. If the input energy for both agricultural machinery and building material were added to the inventory, FER would decline to 4.40, still considerably higher than the 3.2 FER reported by Sheehan et al.

The Effect of Adding Lime to the LCI

Our base case LCI included lime unlike the Sheehan et al. inventory that omitted lime. Lime is added to soil periodically, and the annual lime application rates reported in table 1 are adjusted by average years between applications.

Figure 5 – Effect on fossil energy ratio from adding the energy from secondary energy inputs to the life-cycle inventory



Since farmers do not apply lime every year and some acreage never receives lime, the adjusted annual average lime application rate is relatively small. Lime use only accounts for 506 Btu per bushel of soybeans and lowers the FER by only about 0.22 percent. Therefore, including lime in the Sheehan et al. inventory would not have changed the results significantly.

Effect of Oil Transport

The generic biodiesel plant modeled in this study combined an oil crushing facility with a biodiesel conversion plant at the same location. Soybeans are shipped to the plant and crushed into oil that is converted to biodiesel onsite; hence oil transport was not included in the baseline inventory. There are many biodiesel plants in the industry that do not have crushing capability, so they must purchase oil and have it transported to their plant. The model used by Sheehan et al. separated the crusher from the biodiesel conversion facility, so their inventory included the energy required to transport the oil to the biodiesel plant, which was 843 Btu per gallon of biodiesel for 571 miles. When adding this energy to our inventory, the FER declines to 4.41 compared to the baseline result of 4.56.

Effect of Soybean Yield

Even though yields have been higher in recent years, yield data for year 2002 were used to calculate FER in this study to correspond to the 2002 ARMS agricultural input data. Yield plays a critical role in the FER calculation because as soybean yields increase over time, the FER of biodiesel is also expected to increase. The USDA projects soybean yield to increase annually by 0.4 to 0.5 bushel/acre through the year 2017 (USDA, Office of the Chief Economist-a). For every 1 bushel increase in soybean yield, FER increases by about 0.45 percent. Holding all other variables constant, the FER of soybean biodiesel is estimated to reach 4.69 in the year 2015, when soybean yield is projected to increase to 45.3 bushels per acre. This is about a 3- percent increase compared to the 2002 FER estimate.

Summary and Conclusion

The fossil energy ratio (FER) of biodiesel is 4.56 based on data from 2002 soybean production. This is a significant improvement over the 1998 Sheehan et al. study that reported a FER of 3.2. A major reason for this improvement is that the soybean crusher modeled for this study more accurately measured the energy used by a modern facility. Soybean crushing facilities that have been built in recent times are far more energy efficient than the older plant used by Sheehan et al. In addition, improved soybean yields and overall less energy used on the farm helped increase the energy balance of biodiesel. When comparing the 2 study years (1990 and 2002), less fertilizers and pesticides were applied in the latter year. The lower chemical use in 2002 can partially be explained by the adoption of GE soybeans that resulted in reduced pesticide use. However, differences in weather and other factors unrelated to energy efficiency may have also partially been responsible for the lower farm energy estimates in 2002.

The life-cycle inventory used for this study was constructed to resemble the Sheehan et al. study in order to make comparisons between the two time periods. To be consistent with Sheehan et al., secondary inputs such as building materials and farm machinery were not included in the base case inventory. However, the results show that the FER of biodiesel changes very little when adding secondary inputs to the life-cycle inventory. The model used to estimate the energy required to convert soybean oil into biodiesel represents a soybean processing plant combined with a transesterification unit with an annual capacity of 9.8 million gallons per year. Although plants under 10 million gallons are quite common, there has been a recent trend in the industry towards larger plants. Larger plants with more capital investment would be expected to be more energy efficient.

Finally, the results from this research suggest that the FER of biodiesel will continue to improve over time. This improvement will occur because increases in soybean yields are expected to continue and for every one bushel per acre increase in soybean yield, the FER increases by 0.45 percent. In addition, the agricultural sector, along with the biodiesel industry, will likely continue to make energy efficiency gains in order to lower production costs. In the future, as the United States develops its renewable energy resources, more non-fossil energy will be included in the biodiesel life-cycle inventory; for example, more electricity may be generated from biomass, wind, and solar power, and more farm equipment may use biofuels. Replacing fossil energy with renewable energy over the life cycle could also significantly increase the energy balance of biodiesel over time.

References

American Methanol Institute. AMI. Properties of Fuels. Available at http://www.methanol.org/pdf/FuelProperties.pdf. Assessed 2009.

Argonne National Laboratory. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model. Version 1.8b. Argonne, IL 2008. Available at: http://www.transportation.anl.gov/modeling_simulation/GREET/index.html

Ash, M. and E. Dohlman. Oil Crops Situation and Outlook Yearbook. Economic Research Service, United States Department of Agriculture. OCS-2007, May 2007. Available at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1289.

Ash, M., Livezey, J., and E. Dohlman. Soybean Backgrounder. Economic Research Service, United States Department of Agriculture. OCS-2006-01, April 2006. Electronic Outlook Report from the Economic Research Service. Available at http://www.ers.usda.gov/publications/OCS/apr06/OCS200601/OCS200601_lowres.pdf

Energy Information Administration. Electricity flow, 2007. Annual Energy Review, 2007. Annual Energy Review, 2007. DOE/EIA-0384 (2007). U.S. Department of Energy. http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_3.pdf, accessed 5/21/2008

Erickson, D.R. 1995. Overview of modern soybean processing and link between processes. In Practical handbook of soybean processing and utilization, 56-64.Erickson, D. R. ed. Champaign,IL: AOCS Press and United Soybean Board.

Graboski, M. Fossil Energy Use in the Manufacture of Corn Ethanol. Prepared for National Corn Growers Association. Unpublished.

Haas, M. J., McAloon, A.J., Yee, W.C., Foglia, T.A. A Process Model to Estimate Biodiesel Production Costs. Bioresource Technology, 97:671-678, 2006.

Heimlich, R. E., J. Fernandez-Cornejo, W. McBride, C. Klotz-Ingram, S. Jans, and N. Brooks. Genetically Engineered Crops: Has Adoption Reduced Pesticide Use? Agricultural Outlook, AGO-273/August 2000. Economic Research Service, United States Department of Agriculture. Available at: http://usda.mannlib.cornell.edu/reports/erssor/economics/ao-bb/2000/ao273.pdf

Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany. Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels. *PNSS*. 103(30): 11206-11210. 2006.

Huo, H., Wang, M., C. Bloyd and V. Putsche. Life-Cycle Assessment of Energy and Greenhouse Gas Effects of Soybean-Derived Biodiesel and Renewable Fuels. United States Department of Energy, Office of Energy Efficiency and Renewable Energy. ANL/ESD/08-2. 2008.

Knothe, G., J. H. Van Gerpen, and J. Krahl. The Biodiesel Handbook. Champaign, Ill: AOCS Press. 2005.

Kovach, J., C. Petzoldt, J. Degni, and J. Tette. A Method to Measure the Environmental Impact of Pesticides. Cornell University: New York State Integrated Pest Management Program. 2007.

Pimentel, D. and Patzek, T. *Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower*. Natural Resources Research, Vol. 14, No.1, March 2005.

Pradhan, A., Shrestha, D. S., J. V. Gerpen, and J. Duffield. The Energy Balance of Soybean Oil Biodiesel Production: A Review of Past Studies. Transactions of the American Society of Agricultural and Biological Engineers. 51(1): 185-194.

Shapouri, H., J. A. Duffield and M. Wang. The Energy Balance of Corn Ethanol: An Update. U.S. Department of Agriculture, Office of Energy Policy and New Uses. Agricultural Economic Report No. 813. 7/2002

Sheehan, J., V. Camobreco, J.A. Duffield, M. Graboski, and H. Shapouri. 1998. Life-cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus. A Joint Study Sponsored by U.S. Department of Agriculture and U.S. Department of Energy. NREL/SR-580-24089 Golden, CO: National Renewable Energy Laboratory. U.S. Department of Energy, 5/1998.

Thorson, T. (Pesticide Expert). Personal communication. United States Department of Agriculture, National Agricultural Statistics Service. 2008.

U.S. Environmental Protection Agency. A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report. Assessment and Standards Division, Office of Transportation and Air Quality. Report. EPA420-P-02-001. 11/2002.

U.S. Environmental Protection Agency. Integrated Risk Information System. Available at http://www.epa.gov/iris/subst/0057.htm

U.S. Environmental Protection Agency. 2001. Rule and Implementation Information for Vegetable Oil Production; Solvent Extraction. Technology Transfer Network Air Toxics. Available at http://www.epa.gov/ttn/atw/vegoil/vegoilpg.html

U.S. Department of Agriculture, Agricultural Research Service. Unpublished data provided by the Fats, Oils and Animal Coproducts Research Unit, 2008.

U.S. Department of Agriculture, Economic Research Service (a). Farm Business and Household Survey Data: Customized Data Summaries From ARMS. Tailored Reports, 2002. Economic Research Service. Available at: http://www.ers.usda.gov/Data/ARMS/app/Crop.aspx

U.S. Department of Agriculture, Economic Research Service. Oil Crops Yearbook 2009. Available at: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID1290

U.S. Department of Agriculture, Economic Research Service (b). Soybean Production Costs and Returns from the 2002 ARMS. Special Tabulations. Economic Research Service. Available at: http://www.ers.usda.gov/Briefing/ARMS/Access.htm.

U.S. Department of Agriculture, Economic Research Service. Agricultural Biotechnology: Adoption of Biotechnology and Its Production Impacts. 2007. Available at: http://www.ers.usda.gov/Briefing/biotechnology/chapter1.htm. Accessed on: 05.28.08

U.S. Department of Agriculture, Economic Research Service. Agricultural Resources and Environmental Indicators: Soil Management and Conservation, 2003, Chapter 4.2, p.33. Available at http://www.ers.usda.gov/publications/arei/ah722/arei4_2/AREI4_2soilmgmt.pdf

U.S. Department of Agriculture, National Agricultural Statistics Service. Agricultural Statistics 2005. United States Government Printing Office, Washington D.C. 2005.

U.S. Department of Agriculture, National Agricultural Statistics Service. Agricultural Chemical Usage-Field Crops Summary, Issues 1990-2005. Available at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1560

U.S. Department of Agriculture, Office of the Chief Economist (a). USDA Agricultural Projections to 2017. World Agricultural Outlook Board, Long-term Projections Report, OCE-2008-1, February 2008.

U.S. Department of Agriculture, Office of the Chief Economist (b). World Agricultural Supply and Demand Estimates. WASDE 469. April 9, 2009. World Agricultural Outlook Board, Office of the Chief Economist. Available at http://www.usda.gov/oce/commodity/wasde/index.htm.

Vigon, B. W., Tolle, D. A., Cornaby, B. W., Latham, H. C., Harrison, C. L., Boguski, T. L., R. G. Hunt and J. D. Sellers. Life-Cycle Assessment: Inventory Guidelines and Principles. Washington D.C. & Cincinnati: United States Environmental Protection Agency, Office of Research and Development. (EPA/600/R-92/245). 1993.

Wang, M. Q. and H. S. Huang. A Full Fuel-Cycle Analysis of Energy and Emissions Impacts of Transportation Fuels Produced from Natural Gas. Center for Transportation Research, Argonne National Laboratory. ANL/ESD-40. December 1999.

Woerfel, J. B. Chapter 6: Extraction, Practical handbook of soybean processing and utilization, 65-92.Erickson, D. R. ed. Champaign,IL: AOCS Press and United Soybean Board. 1995.

Appendix

Appendix Table 1 – Energy coefficients used to convert inputs into British thermal units (Btu)

Inputs	Energy Value	Sources
Fuel Inputs	**Low Heating Value**	
Diesel (Btu/gal)	128,450	Huo et al.
Gasoline (Btu/gal)	116,090	Huo et al.
Propane(Btu/gal)	84,950	Huo et al.
Natural Gas (Btu/cft)	983	Huo et al.
Electricity (Btu/kWh)	3,412	Huo et al.
Material Inputs		
Nitrogen (Btu/lb)	22,136	Hill et al
Phosphorus (Btu/lb)	3,944	Hill et al.
Potassium (Btu/lb)	2,563	Hill et al.
Lime (Btu/lb)	53.72	Graboski
Seeds (Btu/lb)	2,024	Sheehan et al.
Herbicide (Btu/lb)	137,191	Hill et al.
Insecticide (Btu/lb)	139,772	Hill et al.
Methanol (Btu/lb)	9,750	American Methanol Institute

Appendix Table 2 -- Life-cycle energy efficiency factors for fossil fuels and electricity

Inputs	Life-Cycle Efficiency percent
Diesel	84.3
Gasoline	80.5
Propane	89.8
Natural Gas	94.0
Steam	60.8
Electricity	31.3
Methanol	67.7

Source: Shapouri et al.; Energy Information Administration; United State Department of Agriculture, Agricultural Research Service; and Wang and Huang.

Glossary

Allocation Method **—** Rules to determine the fraction of total input energy that is assigned to each coproduct. For example, both biodiesel and glycerin are produced during the transesterification process, but the energy used to produce the two products cannot be easily delineated. Therefore an allocation method has to be used, such as a mass-based rule that allocates energy to the various coproducts by their relative weights.

ARMS **—** USDA's Agricultural Resource Management Survey (ARMS) is sponsored jointly by the Economic Research Service (ERS) and the National Agricultural Statistics Service (NASS). ARMS began in 1996 as a synthesis of the former USDA cropping practice, chemical use, and farm costs and returns surveys, which dated back to 1975. It is USDA's primary source of information on the financial condition, production practices, resource use, and economic well-being of America's farm households. http://www.ers.usda.gov/data/arms/GlobalAbout.htm#Use

British Thermal Units (Btu) **—** British thermal units are widely used in the United States to describe the heat value or energy content of fuels and other types of energy. One Btu is equivalent to 1,055 joules, which is an energy unit in the international system of weights and measures.

Catalyst **—** A substance that enables a chemical reaction to proceed usually at a faster rate or under different conditions (as at a lower temperature) than otherwise possible.

Centrifuge **—** A process of separating liquids with different specific gravities by rotating the fluid at high speed.

Coproduct **—** When a production process results in two or more products, the products are called coproducts. For example, a soybean processing plant crushes soybeans to obtain two marketable coproducts (i.e., soybean oil and soybean meal).

Degummed Soybean Oil **—** Soybean oil after removing phosphotides and some unsaponifiable matter commonly known as gums.

Dehulled Beans or Meats **—** That part of the soybean remaining after removing the hull. The hull is the skin of the soybean, which is removed to facilitate solvent extraction of the oil and improve protein content of the meal.

Direct Energy Inputs **—** Inputs in the form of energy, such as gasoline, diesel, natural gas, and electricity. Inputs that depend on energy for their production, such as fertilizers and pesticides, are indirect energy inputs.

Energy Balance of a Biofuel **—** An energy life-cycle assessment that measures the fossil energy required to produce a biofuel relative to its energy output value.

Energy Efficiency Factor **—** A coefficient used to account for the energy required to bring a raw energy resource from the environment to its final useable form. For example, for every unit of electrical energy produced, it takes on average 3.2 units of energy to get that energy into its final form and transport it to its final destination. Therefore, 3.2 is the energy efficiency factor for electricity, and the electrical energy used to produce a product must be multiplied by this factor to account for the total energy associated with electricity use.

Energy Life-Cycle Assessment — A life-cycle assessment that focuses just on the energy inputs and outputs of a product.

Environmental Impact Quotient (EIQ) — A measurement that estimates the environmental impacts of a pesticide taking into account several environmental variables, including fish toxicity, bird toxicity, bee toxicity, and leaching potential.

Fatty Acids — Fats or triglycerides, which are the primary constituents of vegetable oils and animal fats. When using transesterification, the triglycerides are transformed to esters and crude glycerin. The esters become biodiesel and the glycerin can be further processed to make other products.

Free Fatty Acids — Fatty acid groups that have broken off from the vegetable oil triglyceride molecule. Unless properly accounted for, free fatty acids consume catalyst needed for transesterification, lowering yield, increasing the reaction time, or potentially stopping the reaction altogether. Feedstocks with high free fatty acid levels will often be pretreated to remove free fatty acids before transesterification.

Feedstock — Raw material used in making an energy product. For example, biodiesel can be made from various feedstocks, including soybean oil, animal fat, and recycled cooking oil.

Fossil Energy — Energy derived from fossil fuel, which includes petroleum oil, coal, and natural gas.

Fossil Energy Ratio (FER) — The energy output of a biofuel divided by the life-cycle energy required to produce the product. The FER only includes fossil energy in the denominator, and it is often the measurement used to quantify the energy balance of a biofuel.

Genetically Engineered (GE) Soybeans — A soybean variety that has been genetically modified to make it more resistant to herbicide applications, primarily glyphosate, commercially known as Roundup. GE soybeans were developed to survive the application of glyphosate that previously would have destroyed the crop along with the targeted weeds.

Glycerin or Glycerol — An organic compound present in all animal and vegetable fats that is produced along with biodiesel when using the transesterification production process. Historically, refined glycerin has been a product of the commercial soap industry; however, a synthetic glycerin is also produced on a commercial scale by the petroleum industry. Commercial glycerin is found in many products, including solvents, sweeteners, cosmetics, liquid soaps, candy, liqueurs, and dynamite.

GREET Model — The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model was developed by Argonne National Laboratory, U.S. Department of Energy. It fully evaluates life-cycle energy and emission impacts of advanced vehicle technologies and new transportation fuels.
http://www.transportation.anl.gov/modeling_simulation/GREET/index.html

Life Cycle — Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (ISO 14040). The life cycle of soybean biodiesel is assumed to start from the beginning of the soybean production and end with the delivery of the biodiesel to a gas station or the point of the final use.

Life-Cycle Assessment (LCA) — Also known as life-cycle analysis, it is a technique to assess or measure certain aspects of a product over its entire life cycle. Life-cycle assessments are most often used to assess the environmental aspects of a product, but LCAs can also be used to measure the social impacts of a product.

Life-Cycle Inventory (LCI) — The database that contains the amounts of all inputs and outputs of processes that occur during the life cycle of a product. The LCI is typically organized by a set of subsystems (e.g., biodiesel includes a feedstock subsystem and a conversion subsystem). The LCI sets boundaries for each subsystem to avoid unnecessary data collection.

Methyl Ester — Biodiesel is called a methyl ester if the alcohol used for transesterification is methanol.

Net Energy Value (NEV) — The energy content of 1 gallon of biodiesel minus the life-cycle fossil energy required to produce 1 gallon of biodiesel. A biofuel has a positive energy balance if its NEV is greater than one, and a negative energy balance if the NEV is less than one.

No-Till — A crop residue management (CRM) system that maintains additional crop residue on the soil surface through fewer and/or less intensive tillage operations. CRM is generally cost effective in protecting soil and water resources and can lead to higher farm economic returns by reducing fuel, machinery, and labor costs while maintaining or increasing crop yields.

Pest Management — A set of techniques used to reduce pest populations or prevent their detrimental effect on crops and livestock. A pest is any noxious and damaging organism, including mites, insects, plant pathogens, and weeds. Pest management techniques can be broadly classified into chemical, cultural, and biological.

Renewability — The degree in which a biofuel is renewable. The fossil energy ratio (FER), which is the ratio of renewable energy output to fossil energy input, is a measure of renewability. Biofuels that use less fossil energy per unit of renewable energy output have a higher degree of renewability.

Secondary Inputs — Secondary inputs have no energy value per se, but it requires energy to produce them (e.g., building materials used to construct processing plants and farm vehicles used for cultivation). These inputs are often excluded from the LCI because they do not provide direct energy to the system and they're difficult to quantify. Energy estimates for secondary inputs are generally very small, so their exclusion from the inventory has little effect on the LCA.

Soybean Crusher — A generic term used for a plant that primarily processes soybeans into two products: soybean meal and soybean oil.

System Boundaries — Limits set in the life-cycle inventory (LCI) to prevent boundless production systems and unnecessary data collection. Whether to include or exclude energy used beyond direct inputs, such as energy embodied in labor, building materials, and manufacturing equipment, depends on several factors, including goal and scope of the LCA, availability of data, reliability of data, time and cost of collecting the data, and the extent to which the inclusion will make difference in the final result.

Thermal Energy — The energy required for heating, for example, the heat generated from natural gas to dry soybeans.

Transesterification — A process for producing alkyl esters (biodiesel) by reacting a vegetable oil or animal fat with an alcohol, usually ethanol or methanol. This reaction also results in the production of crude glycerin.

Unsaponifiable Matter — Non-triglyceride part of oil and fat that does not convert into soap. It is removed from the oil because it is detrimental to the transesterification process.

ATTACHMENT 20

SFGate.com

Scientists say oil exploration threatens Amazon

By MICHAEL ASTOR, Associated Press Writer
Wednesday, August 13, 2008

(08-13) 14:47 PDT RIO DE JANEIRO, Brazil (AP) --

Oil exploration in the Amazon rain forest represents the latest, perhaps greatest, threat to preserving what remains of the world's largest remaining tropical wilderness, scientists said Wednesday.

Scientists from Duke University said a new study revealed a Texas-size chunk of rain forest stretching across Bolivia, Colombia, Ecuador, Peru and western Brazil has been approved for petroleum exploration and production.

"Filling up with a tank of gas could soon have devastating consequences to rain forests, their people and their species," said Dr. Stuart Pimm, a professor of conservation ecology at Duke and one of the study's authors.

The study, conducted together with the environmental groups Save America's Forests and Land is Life, was published Tuesday in the open-access journal PLoS ONE.

Dr. Matt Finer, of Save America's Forests, said the study's mapping of oil and gas activities across the western Amazon showed the exploration blocks were concentrated in the most intact jungle regions.

Development of these blocks almost certainly would bring with them roads and pipelines, spelling unparalleled rain forest destruction, Finer said.

The situation is most troubling in the Peruvian Amazon, according to the study, which found 64 oil and gas blocks covering approximately 72 percent of that country's share of the rain forest.

In Brazil, the government recently sold off 25 exploration concessions in remote regions of the western Amazon, close to areas inhabited by some the world's last tribes uncontacted by anthropologists.

The Amazon rain forest covers about 4.1 million square kilometers (1.6 million square miles) or about 40 percent of the South American continent. About 20 percent of the forest already has been razed.

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On the Web:

dx.plos.org/10.1371/journal.pone.002932

http://sfgate.com/cgi-bin/article.cgi?f=/n/a/2008/08/13/international/i144701D34.DTL

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