White Paper

Issues Related to Accounting for Co-Product Credits in the California Low Carbon Fuel Standard

State of California

Air Resources Board

Expert Workgroup Investigating Indirect Effects of Transportation Fuels

Subgroup on Issues Related to Co-Product Credits

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1. Summary

Background and Introduction

Given the importance of proper co-product accounting performed for the Low Carbon Fuel Standard (LCFS), a Co-Products Subgroup was formed by the Expert Workgroup (EWG) that was convened by the California Air Resources Board (CARB) to investigate indirect effects of transportation fuels. Co-product credits were an area specifically noted in the Board resolution approved at the April 2009 Board hearing that called for the formation of the EWG.

The Co-Products Subgroup investigated a number of issues associated with how co-product credits were evaluated under the LCFS and how those estimates might be improved. Central to this effort was a series of conference calls and meetings with experts from the animal feed and nutrition field that included both academia and industry. The primary point of discussion in these meetings was how best to quantify credits from biofuel co-product feeds such as distillers' grains and solubles (DGS). As noted below and later in this paper, consensus was not reached on this topic among the experts. However, open issues, uncertainties, and where to focus future research were highlighted.

Recommendations for Near-Term and Short-Term Modeling and Research

Below are issues that were identified by the Subgroup early in this effort as high-priority items that should be addressed in the short-term. With respect to timing, we have identified issues according to whether they should be considered by CARB staff in the near-term (i.e., in time for the planned Board hearing in the Spring of 2011) or the short-term (i.e., within a year or two). All of the recommendations below have elements included in them that the subgroup found important enough to recommend that they be evaluated in the near-term. However, we recognize that resource constraints may not allow for all of these issues to be evaluated in the near-term timeframe. Thus, they are presented below in order of priority.

Issues Related to GTAP Modeling of Soy Biodiesel – ARB should re-evaluate the iLUC estimates for soy biodiesel based on the most recent GTAP model that has corrected the error that led to negative crush margins for soy biodiesel. Although the Subgroup understands this has been done by an outside group, the results are inconsistent with respect to estimated land use change, i.e., the area converted as a result of the corn shock plus the soy shock is not equal to running the model with the two shocks combined. It may be possible to resolve this issue by holding the corn shock constant and running multiple soybean volume shocks, then hold the soybean shock constant and vary the corn shock. This can generate a surface of results that may identify modeling issues, particularly if there are discontinuities in the surface. If this approach does not identify any issues then the phenomenon may be real and should be accounted for in the determination of the final iLUC emission factors.

In general, there appear to be a number of potential issues with GTAP modeling of soy biodiesel that are expanded upon in Section 4 of this report, and ARB must devote significant effort in the near-term to resolve these potential problems.

Consistency Between GREET and GTAP Modeling of Diet Substitution Effects – Some effort should be made by CARB to ensure consistency in co-product treatment between GTAP and GREET. In particular, this needs to go beyond a single GTAP run that only considers DGS, SBM, and feed corn in economic terms – changes in mass are what matter to the GHG emissions estimates. It may be possible to investigate this issue with a series of GTAP sensitivity runs to better understand model output as a function of different inputs.

Since there is significant uncertainty with respect to the co-product displacement ratios for corn DDG and how the GTAP model elasticities for DDG and corn and DDG and soybean meal were developed, it is appropriate to undertake a series of sensitivity analysis with the elasticity parameters and determine the impact that they have on land use change. In theory, more displacement of soybean meal should lower the land change since soybeans have a lower crop yield than corn.

The GTAP model has a "non zero and small value, 0.3, for the elasticity of substitution between the energy and protein feedstuffs because DDGS could displace a portion of the meals in some feed rations."[*] A matrix should be developed with each of the elasticities ranging from 0.3 to a high value, such as 5.0, and the model run for each combination of the two values. Values of 0.3, 1.0, 3.0, and 5.0 should be adequate so that would entail 15 additional runs. In addition to the impact on land use change, the impact on the cost shares of the major feed items in the U.S. livestock industry should be developed. We suggest that this work be done in the near-term.

Diet Substitution Effects for Biofuel Co-Products Used in Animal Feed – As illustrated in the body of this paper, animal feeding and nutrition is an extremely complex issue. Estimating appropriate displacement ratios to properly account for the co-product credit of DGS in a life-cycle assessment is further complicated by limited real-world data on feed rations, which are highly dependent on locally available feed ingredients and economics.

Nonetheless, CARB should re-evaluate its use of a 1:1 displacement of feed corn by DGS to include other components (e.g., SBM, fat, and urea) and available data on displacement ratios as a function of animal

[*] Tyner, et al. "Land Use Changes and Consequent CO2 Emissions due to US Corn Ethanol Production: A Comprehensive Analysis," July 2010.

type and region. However, ARB needs to be mindful of potential issues associated with translating research results to the real world.

A consensus was not reached among the invited experts on how best to handle DGS substitution ratios. The feeding value of a by-product feed depends on the feeding values of the other feeds used in the ration and the animal species, and it is not absolute; learning is involved. Actual performance is difficult to predict in high performing ruminant animals, perhaps less so in monogastric animals like poultry and swine. If least-cost, optimized ration balancing occurs, there is no large substitution effect to be achieved. Rations with DGS and without DGS can be (and are) created to achieve the same livestock performance targets.

We see three options available to CARB:

1. Develop a baseline close to what ARB is currently using (i.e., 1:1 ratio), which assumes no significant improvement in animal performance with DGS, but which better reflects the fact that DGS displaces both feed corn and SBM.

2. Develop a baseline similar to that recommended in the most recent Argonne paper, which may be a better representation of real-world performance at the current time.

3. An improved Method 2A procedure that would be more dynamic and would allow biofuel producers to suggest alternative co-product credits estimates that are more applicable to their region and how their co-products are used in the animal feed market.

Options 1 and 2 could be implemented in the near-term, i.e., in the next few months, while option 3 would take more time to fully develop and implement. In the longer-term, CARB should continue to monitor the research and available data on biofuel co-product feeds. In addition, we recommend that CARB work to influence the type of data that are collected by USDA in the future to include biofuel co-product feeds specifically.

Recommendations for Long-Term Work and Research

Below are issues that the Subgroup felt could be considered by CARB in the longer-term, as a number of these are likely to take several years to fully develop.

Issues Related to Oilseed Meals – CARB staff should carefully monitor future trends in the oilseed market as it applies to feedstock for biodiesel and renewable diesel used for compliance with the LCFS. CARB needs to be mindful that if biofuels produced from oilseeds beyond soy are introduced into California, work will be needed to properly assess co-product credits.

Issues Related to New Products Developed from Biofuel Co-Products – As new products are developed from biofuel co-products, CARB needs to consider potential new markets for co-products used as feedstock or directly for bio-based products that could displace materials with a much higher carbon footprint. There is no reason not to extend the boundary conditions if it is clear that a new product or process is using a co-product from a biofuel that results in a finished product with a lower carbon footprint than the product it displaces.

Future Directions in Biofuel Processing and Co-Products – Consistent with the discussion of new products above, CARB needs to be aware of potential new uses for biofuel co-products. When those co-products substitute for or displace products with a higher carbon footprint, the analysis boundaries should be re-drawn to capture those co-product credits.

Integrated Bio-Refineries – As integrated bio-refineries come onto the scene, CARB will have to carefully consider the most appropriate methodological approach to estimate the carbon intensity of not only the transportation fuels produced in the bio-refinery but also how best to account for co-products, which, similar to a petroleum refinery, may be many and varied.

2. Introduction

Background

The California Air Resources Board (CARB) adopted regulations implementing the Low Carbon Fuel Standard (LCFS) at the April 2009 Board Hearing. Those regulations, which became effective in January 2010, require fuel providers to achieve a 10% reduction in the carbon intensity of gasoline and diesel (and fuels substituting for gasoline and diesel) sold in the state by 2020. It is anticipated that biofuels will play a significant role in achieving the carbon intensity reductions required by the LCFS.

The LCFS measures carbon intensity in terms of grams of greenhouse gas (GHG) emissions per energy content of the fuel. The GHG species included in the carbon intensity estimates are carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), which are weighted to account for differences in their global warming potentials and summed to arrive at a CO2-eqivalent value (CO2e).[*] The fuel energy content is measured in terms of megajoules (MJ) on a lower-heating value basis. Thus, the LCFS standards were developed in terms of grams of CO2e per MJ of fuel (gCO2e/MJ).

Importantly, the carbon intensity estimates for fuels in the LCFS are based on a full life-cycle analysis (LCA) of GHG emissions from "well to wheels." CARB relied heavily on the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model developed by Argonne National Laboratory to generate carbon intensity estimates for the LCFS, making changes to inputs where appropriate to better reflect California conditions (termed CA-GREET). A key feature of the GREET model, and of LCA in general, is that co-products from the fuel life cycle (e.g., distillers' grains and solubles from corn ethanol production or electricity from sugarcane ethanol production) are accounted for using a number of different methodologies.

The carbon intensity values for crop-based biofuels estimated by CARB also include an "adder" to account for indirect land use change (iLUC) effects. One of the primary tools used by CARB to estimate iLUC is the Global Trade Analysis Project (GTAP) model developed by the Center for Global Trade Analysis in the Department of Agricultural Economics at Purdue University. This model also accounts for co-products from biofuel production in its estimates.

[*] CH4 is multiplied by 25 and N2O is multiplied by 298, consistent with IPCC estimates of the 100-year global warming potential of CH4 and N2O relative to CO2.

Based on the above, it is clear that properly accounting for co-products is important for both the direct fuel cycle emissions calculated by GREET as well as the indirect effects estimated by GTAP. This is particularly true for corn grain ethanol, which results in large amounts of co-products useful in livestock feeding. In addition, it is important to ensure that consistent accounting for co-products between GREET and GTAP is achieved to the greatest degree possible.

Co-Products Subgroup

Given the importance of proper co-product accounting performed for the LCFS, a Co-Products Subgroup was formed by the Expert Workgroup (EWG) that was convened by CARB to investigate indirect effects of transportation fuels. Co-product credits were an area specifically noted in the Board resolution approved at the April 2009 Board hearing:

> "BE IT FURTHER RESOLVED that the Board directs the Executive Officer to convene an expert workgroup to assist the Board in refining and improving the land use and indirect effect analysis of transportation fuels and return to the Board no later than January 1, 2011 with regulatory amendments or recommendations, if appropriate, on approaches to address issues identified. This workgroup should evaluate key factors that might impact the land use values for biofuels including agricultural yield improvements, co-product credits, land emission factors, food price elasticity, and other relevant factors. The Executive Officer shall coordinate this effort with similar efforts by the U.S. Environmental Protection Agency (U.S. EPA), European Union, and other agencies pursuing a low carbon fuel standard."

The following members of the EWG agreed to participate in the Co-Products Subgroup:

- Philip Heirigs, Chevron
- Paul Hodson, European Commission (Oyvind Vessia represented Paul Hodson in several meetings and provided input to this report)
- Stephen Kaffka, Department of Plant Sciences, U.C. Davis and the California Biomass Collaborative
- Don O'Connor, (S&T)[2]
- Mark Stowers, POET, Inc.

Alan Glabe, Jim Duffy, and John Courtis of CARB staff also participated in several meetings of the subgroup and in the animal feed and nutrition expert meetings, providing helpful comments and guidance on how the current structure of the LCFS was developed and outlining several areas of investigation for this subgroup.

Structure of the Report

Following this introduction, Section 3 presents a summary of how co-products are currently treated in the LCFS, with an emphasis on how CA-GREET treats co-product credits. That section also discusses ISO standards for life-cycle analysis and reviews a recent paper on various methods to account for co-product credits. Section 4 presents issues that could be addressed by CARB in the short-term, while Section 5 presents issues that are longer-term in nature. Section 6 contains a brief discussion of several miscellaneous issues related to co-products that were raised by the EWG. A number of appendices contain back-up material referenced in the text of this report.

3. Treatment of Co-Products in the LCFS

This section of the report discusses the current treatment of co-products in the LCFS, with an emphasis on how CA-GREET treats co-product credits. Prior to presenting that information, however, a brief summary of different co-product accounting methods is presented. International Standards Organization (ISO) recommendations for co-product accounting as well as a paper drafted by Michael Wang of Argonne on co-product accounting issues are also reviewed below.

Background on Co-Product Accounting Methods

The question of co-product treatment is linked to a broader question of what is being analyzed. In simplified terms it can be raised as the question of either analyzing the marginal impact or the average impact. The two approaches are called consequential and attributional LCA. The primary difference is that the consequential LCA analyses the marginal change on the overall system, caused by the functional unit (e.g. 1 MJ of biofuels) while attributional LCA attributes the direct impacts to the functional unit.

Consequential LCA provides information about GHGs emitted, directly or indirectly, as a consequence of changes in demand for the product. This approach generally assesses the *marginal* impact, but since the marginal impact is a function of the overall system, it is rarely possible to conclude that the overall average impact equals the consequential result. An example of this phenomenon is the GHG intensity of electricity. The marginal source is (in most competitive power systems) a fossil fired unit (natural gas in California), while the average GHG intensity of the same power system will be different (reduced by the presence of nuclear and renewables that contribute to the “base load”). The answer is thus not the same if you ask "what is the GHG impact of using one more kWh in power system x," as if you ask "what is the average impact of using electricity in power system x." Applying attributional LCA to all commodities and calculating the GHG sum thereof, would in theory result in total global emissions. Applying consequential LCA to all commodities and taking the sum thereof would not equal global emissions. CARB should therefore decide whether the question under LCFS is the impact of using one more MJ of biofuels, or the average impact of using biofuels in California. The decision will be of guidance when decisions on, for example, co-product treatment have to be made, as one should strive for a consistent approach.[*]

[*] The inclusion of iLUC as part of the life cycle impact already points in the direction of a consequential analysis, as the iLUC of biofuels is the direct LUC of another commodity, which in an attributional approach, should be attributed to that commodity.

There are several good papers in the literature that describe methods used in LCA efforts to account for co-product credits.* The two primary methods of co-product treatment, displacement and allocation are described below.

Displacement/Substitution - In this method, co-products emissions are accounted by first estimating the emissions associated with a substitute product (e.g., excess electricity from sugarcane ethanol production displaces electricity that would otherwise be generated for the grid). This results in a numerical credit that is subtracted from the total emissions of the fuel pathway being analyzed. In general, more data are required to estimate co-product credits with this method because a full life-cycle analysis is required for the substitute product. This method is also sometimes referred to as "system expansion."

Allocation - In this method, emissions are allocated across all products of the process according to the mass, energy, or economic value of the products. This approach is commonly used when there is no clear distinction possible between products and co-products in a process (e.g., oil refining), or when data are not available with which to estimate credits based the more detailed displacement method.

Co-Product Accounting Examples from the LCFS

CARB staff have prepared a number of fuel pathway reports that document key inputs for those pathways used in the CA-GREET model. Those reports also highlight assumptions regarding how co-products are credited. Several of those reports were reviewed as part of the Subgroup effort, and the summary results for several selected fuel pathways are presented in Table 1.

Key features regarding the treatment of co-products in the CA-GREET analyses conducted for the LCFS include the following:

Dry Mill Corn Ethanol – CARB's analysis of dry mill corn ethanol uses a displacement approach to account for distillers' grains and solubles (DGS) as the co-product. Further, it is assumed that 1 lb. of DGS displaces 1 lb. of feed corn. Thus, the co-product credit is based on the agricultural and transportation emissions associated with corn production. As shown in Table 1 the value of the credit is approximately 11.5 gCO2e/MJ.

* See, for example: (1) Wang, Michael. "Updated Energy and Greenhouse Gas Emission Results of Fuel Ethanol," 15th International Symposium on Alcohol Fuels, San Diego, CA, September 2005. http://www.transportation.anl.gov/pdfs/TA/375.pdf, and (2) Wang, M., et al. "Methods of Dealing with Co-Products of Biofuels in Life-Cycle Analysis and Consequent Results within the U.S. Context," Energy Policy, 2010 (in press).

Table 1
Current CARB Methodology for Co-Product Credits
(Extracted from CA-GREET Based "Pathway" Documents)

Fuel Pathway	**Co-Product**	**Accounting Method and Assumptions**	**Value of Credit (gCO2e/MJ)**
Dry Mill Corn Ethanol	DGS	Displacement/Substitution Approach 1 lb DDGS displaces 1 lb feed corn DGS yield = 5.34 lb/gallon etoh EtOH yield = 2.72 gal/bushel credit based on AG/transportation emissions associated with corn production	-11.5
Wet Mill Corn Ethanol	Corn Oil	Displacement/Substitution Approach 1 lb corn oil displaces 1 lb soybean oil corn oil yield = 2.08 lbs/bu EtOH yield = 2.62 gal/bu soybean oil displaced = 0.794 lbs per gallon EtOH credit based on emissions associated with soybean oil	-2.6
	Corn Gluten Meal	Displacement/Substitution Approach 1 lb corn gluten meal displaces 1.529 lb feed corn CGM yield = 0.992 lbs per gallon EtOH feed corn displaced by CGM = 1.52 lbs per gallon EtOH	-3.3
		1 lb corn gluten meal displaces 0.023 lb nitrogen in urea N in urea displaced by CGM = 0.023 lbs per gallon EtOH	-0.2
	Corn Gluten Feed	Displacement/Substitution Approach 1 lb corn gluten feed displaces 1 lb feed corn CGF yield = 4.275 lbs per gallon EtOH feed corn displaced by CGF = 4.275 lbs per gallon EtOH	-9.2
		1 lb corn gluten feed displaces 0.015 lb nitrogen in urea N in urea displaced by CGF = 0.064 lbs per gallon EtOH	-0.6
Soy Biodiesel	Soybean Meal	Allocation Based on Mass 80% of AG/extraction emissions assigned to soybean meal 20% of AG/extraction emissions assigned to soy oil	
	Glycerin	Allocation Based on Energy 95.1% of processing emissions assigned to biodiesel 4.9% of processing emissions assigned to glycerin	
Brazilian Sugarcane Ethanol	Electricity	Displacement/Substitution Approach Exported electricity displaces electricity derived from natural gas Electricity displaced = 23.1 kWh electricity per tonne cane processed Electricity displaced = 0.96 kWh electricity per gallon ethanol	-7.0
Sources			
Corn Ethanol: "Detailed California-Modified GREET Pathway for Corn Ethanol," February 27, 2009. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_cornetoh.pdf			
Soy Biodiesel: "Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Biodiesel (Fatty Acid Methyl Esters-FAME)," December 14, 2009. http://www.arb.ca.gov/fuels/lcfs/121409lcfs_soybd.pdf			
Brazilian Sugarcane Ethanol: "Detailed California-Modified GREET Pathways for Brazilian Sugarcane Ethanol: Average Brazilian Ethanol, With Mechanized Harvesting and Electricity Co-product Credit, With Electricity Co-product Credit," September 23, 2009. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_cane_etoh.pdf			

Wet Mill Corn Ethanol – Under the wet-mill ethanol process, the slate of co-products includes corn oil, corn gluten meal, and corn gluten feed. This pathway also uses a displacement method to account for co-product credits, and the displacement ratios are as follows:

- Corn oil: 1 lb. of corn oil is assumed to displace 1 lb. of soy oil.

- Corn gluten meal (CGM): 1 lb. of CGM is assumed to displace 1.529 lbs. of feed corn and 0.023 lbs. of nitrogen in urea.
- Corn gluten feed (CGF): 1 lb. of CGF is assumed to displace 1 lb. of feed corn and 0.015 lbs. of nitrogen in urea.

The total credit for the above co-products amounts to 15.9 gCO2e/MJ.

Soy Biodiesel – In the analysis of soy biodiesel, two co-products are considered by CARB: soy bean meal and glycerin. Soy bean meal remains after soy oil is removed from soybeans, and glycerin is a by-product of the trans-esterification of soybean oil to biodiesel. CARB uses an allocation procedure to account for these co-products in the soy biodiesel lifecycle, however, different allocation methods are used for the soybean meal/soy oil split (which is based on mass) versus the biodiesel/glycerin split (which is based on energy). CARB assigns 80% of the agricultural and oil extraction emissions to soybean meal and 20% to soy oil, as that is the split between the two based on mass. About 95% of the biodiesel processing emissions are assigned to biodiesel and 5% are assigned to glycerin, based on the energy content of these two products.

Brazilian Sugarcane Ethanol – CARB's analysis of Brazilian sugarcane ethanol assigned a co-product credit to excess electricity for two of the three pathways that were investigated. One of the pathways, "Average Brazilian Ethanol," did not receive an electricity co-product credit. For those that did, it was assumed that excess electricity was exported from the ethanol plant back to the grid, and it displaced electricity derived from natural gas. (Note that the bagasse left over from sugarcane processing is used for process fuel and in co-generation facilities in Brazilian sugarcane ethanol plants.) The co-product credit for electricity was estimated by CARB to amount to 7.0 gCO2e/MJ.

Gasoline/Diesel – CARB staff prepared separate analyses of the life-cycle carbon intensity of gasoline and diesel fuel.[*] Although those analyses do not directly address the issue of how petroleum co-products are treated, the treatment of co-products is essentially accounted for in the refining efficiency values that are inputs to the GREET model. The refining efficiency values used in CA-GREET were based on a 2004 analysis performed by Michael Wang of Argonne,[†] with an adjustment downward to account

[*] "Detailed CA-GREET Pathway for California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) from Average Crude Refined in California," February 27, 2009. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_carbob.pdf

"Detailed California-Modified GREET Pathway for Ultra Low Sulfur Diesel (ULSD) from Average Crude Refined in California," February 27, 2009. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_ulsd.pdf

[†] Wang, M., et al. (2004) "Allocation of Energy Use in Petroleum Refineries to Petroleum Products Implications for Life-Cycle Energy Use and Emission Inventory of Petroleum Transportation Fuels." International Journal of Life Cycle Assessment, Vol. 9, No.1, 34-44.

for more severe refining in California versus the U.S. average estimates prepared by Argonne.[*] The values used in CARB's modeling are 84.5% for gasoline (compared to 86.4-86.5% in the 2004 Argonne analysis) and 86.7% for diesel (compared to 88.1-91.0% in the 2004 Argonne analysis).

The methodology developed by Argonne in 2004 to estimate refining efficiency is a two-step process. First, an overall refinery efficiency is estimated based on the energy contained in the refinery output (e.g., gasoline, diesel, jet fuel, LPG, coke, etc.) divided by the total energy input to the refinery (e.g., crude oil, natural gas, purchased electricity, purchased steam, etc.). That overall refining efficiency is then adjusted either upward or downward to reflect the refining efficiency of individual products (which is what the GREET model requires for input) by a factor defined as "product relative energy intensity" (i.e., the ratio of energy use share to production mass, energy, or economic share for a given product). Thus, this can be considered a hybrid allocation approach, but it is not clear exactly which method (mass, energy, or market value) was ultimately used for the refining efficiencies in the LCFS carbon intensity estimates.

It should be noted that Argonne updated its estimates of refinery efficiencies in 2008[†] and then again in 2010.[‡] As a result, CARB should consult these newer sources of information in any potential updates that are prepared for the gasoline and diesel carbon intensity values.

ISO 14044 Life Cycle Assessment: Requirements and Guidelines

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. By 2006, these

[*] This downward adjustment was made as part of an analysis prepared for the California Energy Commission investigating the impact of Assembly Bill 1007 (see http://www.energy.ca.gov/ab1007). However, the basis of this adjustment is not well documented.

[†] Wang, M. "Estimation of Energy Efficiencies of U.S. Petroleum Refineries," Argonne National Laboratory, March 2008.

[‡] Palou-Rivera, I. and M. Wang, "Updated Estimation of Energy Efficiencies of U.S. Petroleum Refineries," Argonne National Laboratory, July 2010. http://www.transportation.anl.gov/pdfs/TA/635.PDF

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).

With respect to co-products and the allocation of emissions between the various products, ISO 14044:2006 reports the following:

Comparisons Between Systems (4.2.3.7) – In a comparative study, the equivalence of the systems being compared shall be evaluated before interpreting the results. Consequently, the scope of the study shall be defined in such a way that the systems can be compared. Systems shall be compared using the same functional unit and equivalent methodological considerations, such as performance, system boundary, data quality, allocation procedures, decision rules on evaluating inputs, and outputs and impact assessment. Any differences between systems regarding these parameters shall be identified and reported.

Allocation Procedure (4.3.4.2) – The study shall identify the processes shared with other product systems and deal with them according to the stepwise procedure presented below.

a) Step 1: Wherever possible, allocation should be avoided by
   1) dividing the unit process to be allocated into two or more sub-processes and collecting the Input and output data related to these sub-processes, or
   2) expanding the product system to include the additional functions related to the co-products, taking into account the requirements of 4.2.3.3.

b) Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationship between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

c) Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationship between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

Some outputs may be partly co-products and partly waste. In such cases, it is necessary to identify the ratio between co-products and waste since the inputs and outputs shall be allocated to the co-products part only.

Allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration. For example, if allocation is made to usable products (e.g. intermediate or discarded products leaving the system), then the allocation procedure shall be similar to the allocation procedure used for such products entering the system.

The inventory is based on material balances between input and output. Allocation procedures should therefore approximate as much as possible such fundamental input/output relationships and characteristics.

CARB's Co-Product Accounting and ISO 14044 – As noted above, the co-product accounting methods used by CARB vary widely across fuel pathways. For direct emissions, corn ethanol uses displacement, soy biodiesel uses allocation by mass as well as allocation by energy, and gasoline and diesel use allocation by process energy. For indirect emissions, displacement is generally used, but that displacement is based on economic inputs in the GTAP model and not physical displacement. (This latter issue is discussed in Section 4.) CARB staff should strive for more consistency in the approach taken in co-products accounting, particularly for fuels with similar pathways. To the extent possible, the displacement approach should be used to account for co-products as that is most reflective of real-world conditions.

Review of Wang et al. Paper on Co-Product Accounting Methods

Summary of Paper – CARB staff requested that the Co-Products Subgroup review a recent paper by Wang, Huo, and Arora entitled, "Methods of Dealing with Co-Products of Biofuels in Life-Cycle Analysis and Consequent Results within the U.S. Context."[*] As noted in the abstract to that paper:

> *Although the International Standard Organization's ISO 14040 advocates the system boundary expansion method (also known as the "displacement method" or the "substitution method") for life-cycle analyses, application of the method has been limited because of the difficulty in identifying and quantifying potential products to be displaced by biofuel co-products. As a result, some LCA studies and policy-making processes have considered alternative methods. In this paper, we examine the available methods to deal with biofuel co-products, explore the strengths and weaknesses of each method, and present biofuel LCA results with different co-product methods within the U.S. context.*

Wang et al. outline five potential methods to address multiple products from biofuel production:

1. Mass-based allocation
2. Energy-content-based allocation
3. Market-value-based allocation
4. Process-purpose-based allocation
5. Displacement (aka "substitution" or "system expansion")

[*] Article in press, to be published in the journal Energy Policy.

Methods 1-3 and 5 were described previously in this section. Method 4 estimates energy use and emissions of individual processes within a facility. However, this can be difficult to implement as individual processes in a facility may produce multiple products, which then requires allocation of energy and emissions among multiple products on a process level.

Although ISO 14040 advocates for the use of the displacement method for dealing with co-products, Wang et al. argue that its implementation can pose some major challenges, which is particularly true when non-fuel products are a large share of the total output and the displacement method can generate "distorted fuel-based results." They cite soy biodiesel as an example fuel pathway that falls into this category, as 82% of the mass from the soybean crushing process is soybean meal and only 18% is soy oil.

Wang et al. go on to say that although the displacement method is generally accepted, this method should not be applied without examining the individual situation. If non-fuel products are the main product and fuel is the byproduct, the displacement method may not be appropriate and other allocation methods may need to be used. They do note, however, that selection on a case-by-case basis could at times be arbitrary.

The authors present results for several biofuel pathways using different co-product accounting methods. For the case of soy biodiesel and soy renewable diesel, the displacement method results in well-to-wheel GHG emissions that are approximately 95% and 130% below conventional diesel fuel, respectively. They note that these results demonstrate the distortion caused by the displacement method when outputs of co-products are so large.

Discussion – Given the results presented by Wang et al. for soy biodiesel and soy renewable diesel, it is understandable that there is trepidation to summarily utilize the displacement method of accounting for co-products without fully considering the implications. However, we are equally concerned about the potentially arbitrary nature of selection on a case-by-case basis. As noted above, CARB should strive to use the displacement method to account for co-products as that is most reflective of real-world conditions. This is particularly important moving forward as new biofuel processes and facilities (e.g., integrated bio-refineries) may have numerous products and co-products that displace materials with widely varying carbon footprints.

This paper was also discussed briefly during the final meeting with the animal feed and nutrition experts. The following comments were made:

- Kirk Klasing noted that he was partial to economic allocation because it better reflects the market. He also said that weight was an issue for SBM, which has a high fiber content that is not utilized by monogastric animals. Phil Heirigs noted that economic allocation has some appeal because it is more consistent with the economic models used to assess land use change.

- Don O'Connor said that all methods have advantages and disadvantages. He noted that the EU has settled on allocation by energy, not because it is the best result, but because it has the fewest unintended consequences. He also stressed the need to get as close to ISO guidance as possible. If one is not consistent with that guidance, the consequences of not being consistent need to be fully understood.

- John Courtis echoed Don's comment that all methods have issues, and there is no clear-cut approach. He noted that allocation by economic value can be problematic because of the potential for price volatility

4. Near-Term and Short-Term Issues for Consideration

This section of the report presents the Co-Products Subgroup activities on issues that could be considered by CARB staff in the near-term (i.e., in time for the planned Board hearing in the Spring of 2011) or the short-term (i.e., within a year or two). By far the bulk of the activity of the Co-Products Subgroup was related to diet substitution effects for co-products used in animal feed. Thus, that topic garners the most discussion below. However, other issues that could be considered by CARB in the near- and short-term include issues related to consistency between GREET and GTAP modeling of animal diet substitution effects and issues related to modeling of soy biodiesel.

Diet Substitution Effects for Biofuel Co-Products Used in Animal Feed

Summary of the Issue - CARB's LCA analysis of dry mill corn ethanol utilizes a displacement/substitution approach to account for distiller's grains and solubles (DGS)[*] in which 1 lb. of DGS is assumed to displace 1 lb. of feed corn.[†] However, research by other parties indicates that:

- DGS typically displaces both feed corn and soybean meal (SBM) in rations for swine, poultry, and dairy (as well as other nutritional components).
- For some animals (e.g., beef cattle), field trials have shown that DGS may displace corn grain on a greater than 1:1 basis (by mass).

For example, the current version of Argonne's GREET model assumes that 1 lb. of DGS displaces 0.947 lb. of feed corn, 0.303 lb. of SBM, and 0.025 lb. of urea.[‡] Because assumptions regarding displacement

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[*] Several acronyms for DGS are used in this paper. DDGS = dried distillers' grains and solubles; WDGS = wet distillers' grains and solubles; DDG = dried distillers' grains (and solubles). However, when comparisons are made to other feeds, those comparisons are on a dry matter basis.

[†] It is important to note that GREET defines and uses the displacement ratio in terms of mass and not energy content, fat content, protein content, or other parameter of the feed. For example, if it was found that 1.0 lb. of DGS on a dry matter basis displaced 1.2 lb. of corn grain, the displacement ratio would be 1:1.2. In this example, each gallon of ethanol (which results in approximately 6.2 lbs. of DGS) would be credited with the emissions associated with growing 6.2 × 1.2 = 7.44 lbs. of corn grain.

[‡] Argonne has recently re-evaluated the DGS displacement ratios for GREET which will result in a lower overall displacement ratio. See "Summary of Expansions and Revisions of the GREET 1.8d Version" at http://greet.es.anl.gov/, which notes the ratio of DDGS and WDGS from dry mill plants to animal farms in the U.S. will be based on Arora, S., M. Wu, and M. Wang, 2010, "Estimated Displaced Products and Ratios of Distillers Corn

of feed corn and SBM by DGS impact both direct and indirect emissions estimates, this was identified as a high priority item for investigation by the Co-Products Subgroup.

Investigation of the Issue – Given the above, two questions were to be answered in this investigation:

1. Should CARB's analysis assume both feed corn and SBM (as well as other nutritional components) are displaced by DGS rather than only feed corn; and

2. Should CARB assume a DGS displacement ratio greater than 1:1 on a total mass basis.

As part of investigating this issue, a number of animal feed and nutrition experts were invited to participate in a series of meetings/conference calls to discuss issues related to feeding DGS to both ruminants (e.g., cattle) and non-ruminant animals (e.g., swine and poultry). In addition, several members of the subgroup prepared independent analyses of the issue. The results of the animal feed and nutrition expert meetings are summarized immediately below, followed by independent analyses of the subgroup.

Summary of Animal Feed and Nutrition Expert Meetings

Nine animal feed and nutrition experts provided input on the issue of DGS displacement ratios during three separate meetings/conference calls that were held on June 30, July 26, and October 21, 2010. In addition, two developers of the GREET model also participated in the discussions. (Note that not all experts were able to participate in every call.) A complete list of experts is summarized in Table 2, and the meeting notes and attendance list from each of the three meetings are contained in Appendix A.

Table 2
Animal Feed and Nutrition Invited Experts

Expert Name	Affiliation	Area of Expertise
Jon Beckett	Cal Poly SLO (retired); now a private consultant	Beef (California Operations)
Galen Erickson	University of Nebraska	Animal Nutrition - Beef Cattle
Dave Fairfield	National Grain and Feed Association	Feed Industry
Kirk Klasing	UC Davis	Poultry and Swine Nutrition
Fred Owens	Pioneer Hi-Bred International (DuPont)	Corn Hybrids/Future Trends in Co-Product Feed
Peter Robinson	UC Davis Extension	Animal Nutrition - Dairy Cattle
Gerald Shurson	University of Minnesota	Swine Nutrition and Management
Hans Stein	University of Illinois, Urbana-Champaign	Animal Nutrition - Monogastric Animals
Michael Wang	Argonne National Laboratory	GREET and Co-Product Credits
May Wu	Argonne National Laboratory	GREET and Co-Product Credits
Richard Zinn	UC Davis - Imperial Valley Agricultural Center	Animal Nutrition - Beef Cattle + Feedlot Issues

Products from Corn Ethanol Plants and the Implications for Life Cycle Analysis," forthcoming in the Journal of Future Biofuels.

The key highlights from the animal feed and nutrition expert meetings are summarized below. Because of the widely varying views of the experts, we strongly encourage the reader to carefully review the meeting notes in Appendix A.

- With respect to displacement of animal feed by DGS observed in field trials:
  - With respect to beef cattle, feed efficiency often is increased when DGS replaces corn. Other species typically see no significant change in feed efficiency.
  - For poultry, swine, and dairy DGS in commercial diets will replace SBM as well as corn and in other species (beef cattle) it will replace corn and urea.
  - For species that showed an increase in feed efficiency in field trials (i.e., beef cattle), DGS replaced corn and urea.

- Recent studies show DGS displacement ratios for dairy cattle are roughly 1:1 on a dry matter basis. This value impacts the overall displacement of feed corn and SBM by DGS assumed in the GREET model.

- High DGS inclusion rates may reduce milk production by dairy cows presumably because products of corn oil fermentation interferes with synthesis of milk components.

- For cattle fed forages, DGS is useful as a supplemental source of energy and protein. For feedlot cattle, DGS is not a satisfactory substitute for dietary roughage. For poultry and swine, the high fiber content of DGS and limited digestibility of fiber sets a ceiling for incorporation of DGS in the diet.

- Inclusion rates for DGS ultimately could be constrained by elevated levels of nitrogen and phosphorus that improve the fertilizer value of animal waste but can accumulate to excessive levels with soil application rates or frequencies are high.

- With respect to saturation of the U.S. DGS market:
  - Although saturation may become a regional issue, it is thought that DGS at the 15 billion gallon per year level can be absorbed into the U.S. feed market because it can partially displace SBM and there is strong export demand for SBM.
  - While the domestic market is important to address, the export market needs attention. Other countries have limited experience with DGS and that may limit their usage level of DGS, at least in the short-term.

- Corn hybrids selected for greater ethanol yield will produce lower amounts of DGS, and the DGS contains less starch. However, concentrations of fat and protein are increased. This in turn increases both the energy content and the nutritional value of DGS, increasing its displacement value relative to corn grain.

- ***Feed rations are highly regionally specific and are critically dependent on economics. This cannot be stressed enough.***
  > California dairy rations may contain 15-20 ingredients.
  > Real-world feed rations are developed based on least-cost models that minimize cost, thus, it is difficult to extrapolate research studies to practice.
  > The feed industry is dynamic and highly dependent on prices of feed ingredients; feed manufacturers often formulate diets on a weekly basis, and some broiler companies and supplement manufacturers re-formulate daily. Information on feed rations is not reported by feed manufacturers, which makes it difficult to obtain real-world data for some species (note that fairly complete feed formulation data are available for the poultry industry).
  > Traditionally, rations were formulated for maximum rates and efficiencies of gain or production. Today, some rations are optimized to minimize cost of production. Economics often dictate that animal rations are not perfectly balanced from a nutritional perspective (i.e., it may be more economical to feed a lower cost ration lower in energy content if the sacrifice in animal performance is minor).

- ***There remains a difference in opinion and concern among the animal feed and nutrition experts regarding the translation of research results on displacement values to the real world.*** Among the issues that need to be addressed are:
  > How roughage is handled (and changed) when DGS is fed. However, no change is expected in feedlot or dairy diets.
  > Whether DGS is fed dry or wet (note that Argonne has developed a dry vs. wet split), and the University of Nebraska has done significant work on dry versus wet DGS.
  > How the protein source replaced by DGS is handled (e.g., urea, SBM, cottonseed meal, etc.). An LCA assessment of urea and SBM is straightforward, other sources are not as data have not been collected on growing these feeds.
  > Whether fat is displaced when DGS is added. Not fully accounting for fat in non-ruminants has a large impact on the displacement value.
  > Because processing of corn grain increases the energy value of the grain, DGS can displace less flaked corn grain than rolled or ground corn grain for ruminants.

- For equivalently formulated/balanced rations (i.e., equivalent protein, fat, energy content, etc.), there is no reason to expect improved performance from DGS relative to diets formulated with equivalent amounts of nutrients provided by other feed ingredients. However, Dr. Erickson noted that when beef cattle rations are formulated for the greater protein and fat levels in DGS, there is not an equivalent performance.

- In the real world, an increase in animal performance is observed when DGS is added to rations if the original/baseline ration is less than optimal. This can occur, for example, if the baseline ration contains suboptimal amounts of fat and no local and economical sources of fat are available to include in the diet. In this case, fat "comes along for the ride" in the DGS and will improve animal performance relative to the baseline ration without added fat. Dr. Erickson noted that if fat was added to the baseline ration, then an LCA would have to be performed on that component, and corn plus fat would have to be compared to DGS.

- There are cases in which the real-world in which DGS displacement ratios can be ***less than*** 1:1. For example, DGS with corn oil removed will have a lower caloric value than rolled or flaked corn, and if DGS displaces SBM in poultry rations without adding additional fat or amino acids to the diet, animal performance could suffer (but may be acceptable because of economics).

- Several reasons can explain the price discount of DGS relative to rolled corn grain:
  - > DGS is a relatively new product on the market (at least in the volumes seen today), so it is not fully valued for its nutritional value – it is still considered a byproduct.
  - > Supply has increased significantly in recent years, keeping prices low.
  - > Variability in DGS is an issue for all applications, and formulation is often based on minimal values (e.g., the mean nutrient or energy content minus one standard deviation).
  - > Bulkiness, transport packing, and handling problems as well as additional risks (e.g., instability due to moisture, presence of mycotoxins) associated with DGS are not encountered with feed corn.

Summary of Independent Analyses by Subgroup Members

Top-Down Assessment of DGS Displacement Ratios – Don O'Connor prepared a top-town assessment of DGS displacement ratios using data published by the U.S. Department of Agriculture (USDA). That analysis is contained in Appendix B, and a summary is presented below.

The USDA collects data on feed usage, but it excludes co-products from fuel ethanol. The data are reported in terms of feed consumption per grain-consuming animal unit (GCAU).* Trends in energy feeds and protein feeds show a visible decline in energy feeds (i.e., corn, sorghum, barley, oats, and wheat) between 2004/05 and 2009/10, while protein feeds (i.e., oil seed meals, animal protein feeds, and grain protein feeds) showed a slight decline. Excluded from the database are co-products from fuel ethanol production. However, U.S. production of corn ethanol increased from 3.4 billion of gallons per year in 2004 to 10.4 billion gallon per year in 2009, resulting in a significant increase in DGS used in the animal feed market. The trends in animal feed consumption in the U.S., excluding ethanol co-product feeds, are shown in Figure 1.

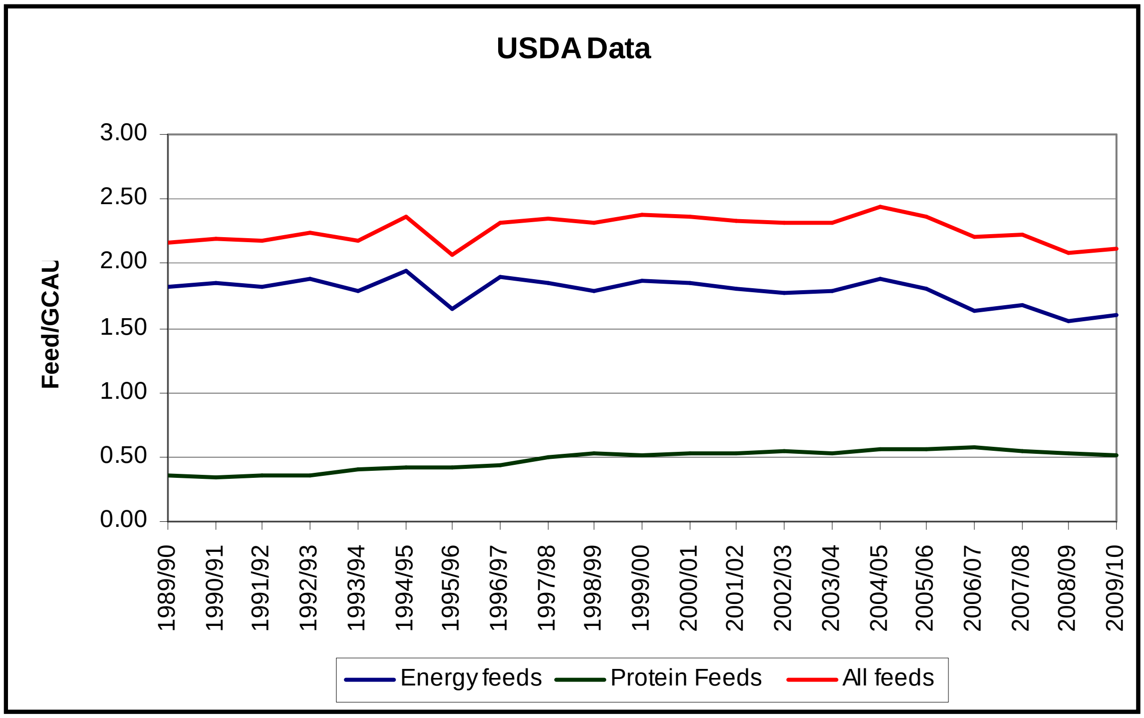
There are two main issues with the USDA dataset: (1) DGS from fuel ethanol plants and co-products from wet milling fuel plants are not included, although co-products from wet milling plants producing

* From http://www.ers.usda.gov/data/feedgrains/Documentation.aspx: A standard unit [GCAU] is used to compare to actual animal numbers for all types of livestock and poultry. An animal unit is based on the dry-weight quantity of a feed consumed by the average milk cow during the base period [early-1970s]. A set of factors is developed for each type of livestock and poultry by relating feed consumption for each type of livestock to the feed consumed by the average milk cow.

food products are included; and (2) feed usage is not typically measured but is calculated from production and other measured disappearances. This means that there can be some year to year variability due to harvest timing. Each of the feedstuffs also has a slightly different starting point for the year.

Figure 1

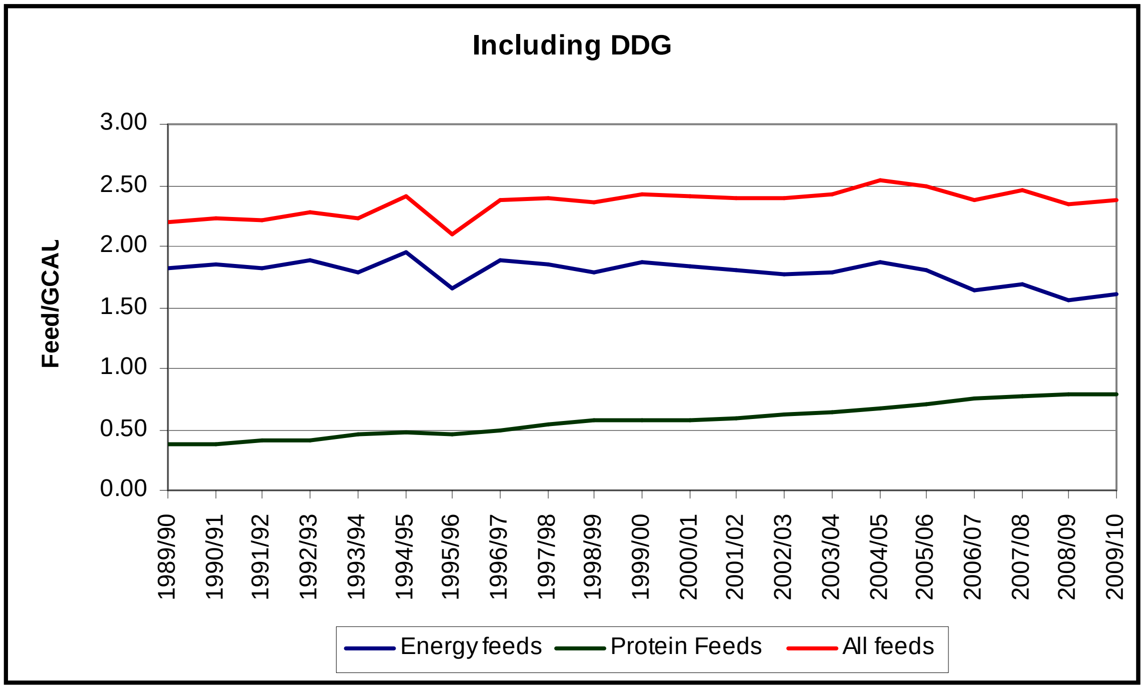
USDA Trends in Animal Feed Consumption Excluding Ethanol Co-Product Feeds



Because DGS is not included in the USDA dataset, it was estimated from fuel ethanol production assuming a DDG yield of 7.7 lb/gallon in 1980 and 6.2 lb/gallon in 2009 (reflecting improved ethanol yield over that time period). Exports of DGS were backed out of this total based on data from the USDA FATUS system (see http://www.ers.usda.gov/Data/FATUS) to estimate the amount used in the U.S. The revised trend line, which includes an estimate for DGS, is shown in Figure 2.

Using the revised dataset, a comparison of the three year average feed consumption in 1999-2002 (to reduce year to year variability in the feed estimates) to the most recent year of data (2009) can be made. The 1999-2002 data were normalized to the same number of GCAU as the recent dataset (although there is very little increase in GCAU over this time period) and then the change in energy feeds and other low protein by-product feeds (mostly corn) and protein feeds (mostly soybean meal) was compared to the increase in DGS usage. The results showed that that for every unit of DGS used, the energy feeds decreased by 1.12 units and the protein feeds decreased by 0.12 units, for a total reduction of 1.24 units of feed for every unit of DG consumed. These results are generally consistent with other bottom up calculations with the exception that less SBM was displaced.

Figure 2
USDA Trends in Animal Feed Consumption Revised to Account for Ethanol Co-Product Feeds



One of the assumptions inherent in this analysis is that the proportions of animal species in the U.S. did not change between 1999 and 2009 and thus there would be a constant baseline. While there are no large changes, USDA data* do show that the swine population has increased relative to all other species. This can be seen in Figure 3. Since swine diets have a higher percentage of soybean meal than cattle diets, the top down assumption of a constant baseline would overestimate the corn displaced and underestimate the soybean meal displaced.

The above discussion is reinforced by considering the gross weight of animals slaughtered each year, which is shown in Figure 4.† This shows that there has been a significant shift from beef feeds to swine and poultry feeds over the time period considered above.

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* Indexes of feed consuming animal units. USDA. 2010 http://www.ers.usda.gov/Data/feedgrains/Table.asp?t=30

† from: http://www.thepoultrysite.com/articles/527/long-term-meat-production-and-consumption-trends

Figure 3
Fraction of Livestock Population in the U.S.

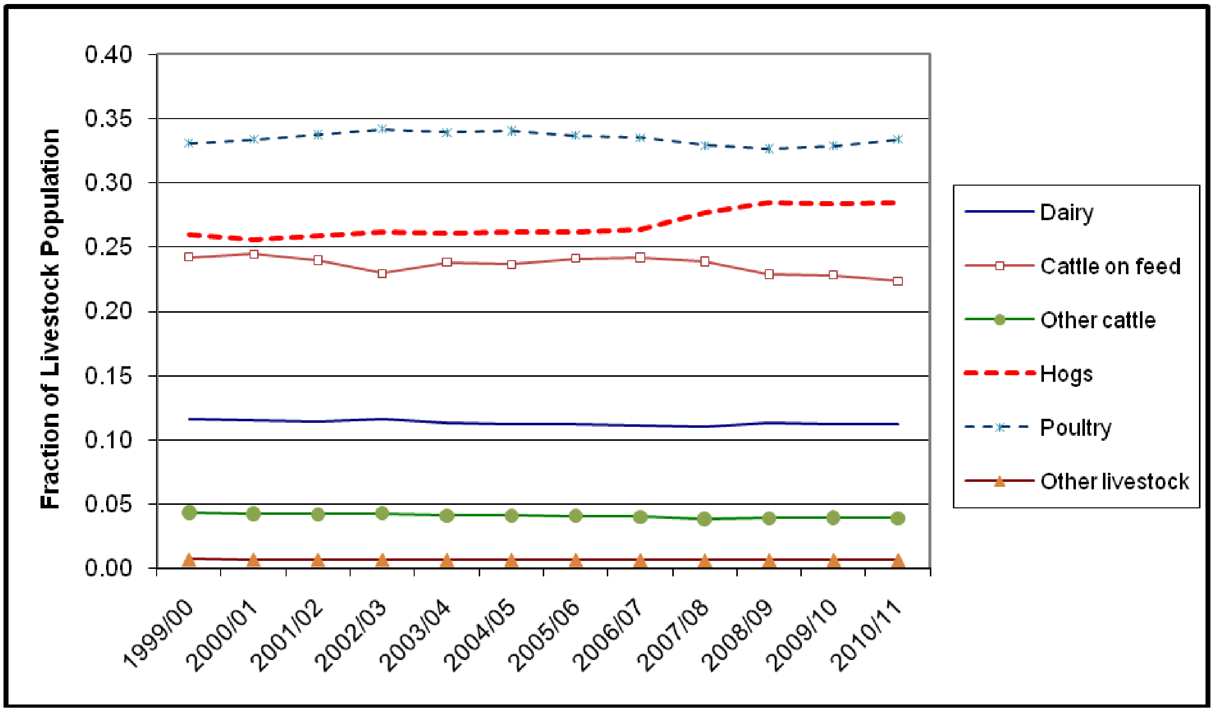
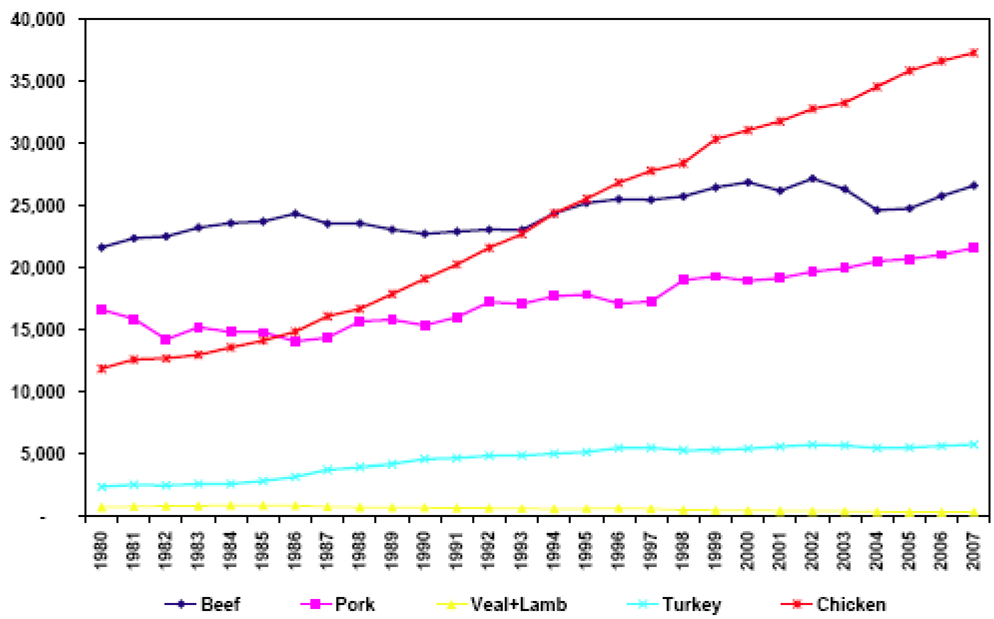


Figure 4
U.S. Red Meat and Poultry Production
(Carcass Equivalent, Million Pounds)



From: http://www.thepoultrysite.com/articles/527/long-term-meat-production-and-consumption-trends

Comparative Feeding Values, As-Fed Rations, and Variability – Steve Kaffka compiled data on feeds from the literature, which are summarized later in this section. Based on these data, the following is observed:

> From the perspective of ration balancing, there is no large substitution effect to be achieved. Rations with DDGS and without DDGS can be (and are) created to achieve the same livestock performance targets.

However, by-product feeds do displace purpose-grown feed crops. The proper questions are (1) how many acres of crops are displaced, and (2) what GHG savings can be attributed to that displacement? Given the dynamic nature of livestock feeding and the diversity of feed options available, this is also difficult to determine with certainty. Actual feed usage at the national scale provides one coarse approach to estimation.

Livestock feeding in the United States is a highly evolved, applied science. Decades of research and experience are combined in current nutritional guidelines (these are called the "NRC Nutrient Requirement" series[*]) and feeding practice with the consequence that livestock production is very efficient. In part this is due to livestock breeding for enhanced performance under intensive management conditions. A national feeding industry has developed which results in significant economies across the agricultural-livestock production system.

In general, livestock feeding is based on the use of optimization models of the (simplified) form:

Minimize $Z = \sum c_j x_j$

Subject to:

$\sum e_j x_j \ x \geq E_{req}$ [energy constraint]

$\sum p_j x_j \geq P_{req}$ [protein constraint]

$\sum x_j \leq F_{max}$ [intake constraint]

$X_j \geq 0$ [non-negativity requirement]

Where x is the quantity of a specific feed with cost c. The parameters e, p, etc. are the per unit energy, protein, etc. requirements, and F is the total feed intake constraint. Specific diets vary by species. An example for poultry was provided by Dr. Kirk Klasing (discussed later in this paper). The solution is arrived at by solving simultaneous equations that mathematically represent all of the known parameters:

1) 2(C) + 4(S) + 4(M) + 10(Y) = minimum
2) 1.5(C) + 1.1(S) + .9(M) + 1.0 (Y) > 1.1

[*] Nutrient Requirements of Poultry, Ninth Rev. Ed., 1994, 0-309-04892-3; Nutrient Requirements of Dairy Cattle, Sixth Rev. Ed., 2005,0-309-03826-X; Nutrient Requirements of Dogs and Cats, Rev. Ed., 2006,0-309-09062-8; Nutrient Requirements of Swine, 10th Rev. Ed., 1998, 0-309-05993-3; Nutrient Requirements of Small Ruminants., 2007,0-309-10213-8)

3) .9(C) + 5(S) + .5(M) + .45(Y) > 0.5
4) 0(C) + .003(S) + 1.1(M) + .001(Y) > 0.3
5) .01(C) + .002(S) + .05(M) + .014(Y) >0.02
6) C + S + M + Y = 1.00

Where c = corn; s = soy; m = meat meal; y = next ingredient of concern. In equations 2-5, the multiplier numbers are the content of various nutrients. The number to the right of the > is the requirement for that nutrient. A typical linear optimization program would solve for 20-50 nutrients simultaneously. Equation 1 is the price of the final diet.

As noted above, the cost of a total mixed ration is minimized, subject to a set of nutritional constraints on the caloric content and disgestibility of the feeds used, their protein and fiber content, and the amounts of minerals and trace elements needed by each species of livestock. Table 3 shows a sample of these parameters for several feeds used in dairy cattle rations.

Table 3. Comparative Feeds/Feeding Values for Dairy Cattle (NRC, 1989)

	Dry, flaked corn grain	Soybean meal (solv. ext.)	Canola meal (solv. ext.)	Corn DDGS (dried)**
DM (%)	89	89	91	92
TDN (%)	88	84	75	88
CP (%)	10	49.9	44	25
NE_L (MJ/lb)	3.9	3.69	3.27	3.9
NDF (%)	9	---	---	44

DM: dry matter
TDN: total digestible nutrients
CP: crude protein
NE_L : Net energy (lactation)
NDF: neutral detergent fiber

In principle, a large set of diverse feeds can be substituted for each other without compromising the performance of livestock because the targeted nutritional values for energy, protein, fiber, etc. are still met. Substituting one feed ingredient for another should not result in any significant change in livestock performance, provided the original diet was well-balanced and sufficient to support the livestock performance objectives desired. For example, in California, Robinson et al. report a wide range of Total Mixed Rations (TMR) for dairy cattle (see Tables 4a and 4b). Other examples for beef cattle, swine and poultry can be found in the literature. One of the many benefits of the integration of livestock feeding with crop agriculture and food processing is the ability of livestock feeding to add economic value to diverse residual products and to buffer swings in the supplies of diverse coarse grains and other suitable feeds.

California is well known as a location where many diverse feeds are available due to its extraordinarily wide range of crops and crop by-products. This is less true for other regions of the U.S. where fewer feed ingredients are available. In the mid-western U.S., where fewer horticultural crops and no cotton are produced, the dominant feeds available are corn, soybeans and forages. Two important consequences are that results from studies carried out in the mid-west on a more limited set of feeds will not necessarily apply to California, and that the mid-western results are themselves constrained by cost effective sub-optimality of the available diets.

Table 4a. As-fed Rations on California Dairies: High Groups, P.H. Robinson (An. Feed Sci. Tech., in press)

Dairy #:	3	5	7	9	Range (1 to 16)
# of Cows in milk	3000	1890	825	1200	825 to 5000
Milk yield (lb/cow/d)	89.6	91.6	92.7	96	72.9 to 114
DM intake (lb/cow/d)	59.6	63.3	63.1	55.6	47.6 to 66.9
CP (%)	17.47	16	17.13	17.98	15.9 to 18.9
NE_L (MJ/lb DM)	3.18	3.14	3.42	3.2	3.06 to 3.42
NDF	44.3	44.1	53.8	46.9	41.2 to 53.8

Table 4b. As-fed Rations on California Dairies: High Groups, P.H. Robinson (An. Feed Sci. Tech., in press)

Dairy #:	3	5	7	9	Range
	% of Total Mixed Ration				
Alfalfa	24	18	0	23.8	0 to 24.1
Almond hulls	2.8	13.4	4.9	0	0 to 15.3
Corn silage	23.1	18.4	12	39.8	0 to 25
Corn grain	20	0	18.7	8.4	8.5 to 26.5
Canola Meal	0	0	7.4	0	0 to 8.3
Cotton seed	8.5	6.3	11.4	6.7	0 to 12.1
Soybean meal	7.7	0	0	0 (7.8)**	0 to7.1
Wheat midds	0	8.2	7.6/13.3*	0	0 to 8.2
DDGS	3.5	6.8	7.1	6.6	0 to 10.3

*beet pulp + barley / ** linseed meal

Livestock feeding is one of the most dynamic and adaptable agricultural industries. Learning is constant and new ingredients are gradually integrated into national markets. DDGS/WDGS supplies have increased significantly in recent years due to the rapid expansion of the corn ethanol industry. The use of DDGS/WDGS is expanding, but with a time lag due to learning, infrastructure development to handle these particular feeds, and gradual market adjustment. Current feed use has not adjusted to this increased supply completely, and the feed industry is still developing ways to most efficiently use these feeds. As a result, there is no way to use market data, even where available, to assess the substitution ratios (SRs)of one feed for another, nor to rely completely on market data to determine SRs.

Attributional LCA, when used to calculate the GHG intensity of corn ethanol, must also account for the consequences of feeding by-products from ethanol production (DDGS/WDGS). LCA relies on the assumption that there are fixed values for substituting by-products for grains (in this case corn and soybeans), and that these can be reasonably estimated. These assumptions are particularly untrue for the livestock feeding industry.

CARB is faced with an objective inability to correctly model the GHG intensity of corn ethanol associated with livestock feeding and SRs. This is due to the incompatibility of LCA methods of attributional analysis used in CA-GREET with the dynamic character of the feeding industry.

The best way to value fuels is with individual assessments for each fuel lot. To be meaningful, CARB must find a way to properly value the particular load of ethanol produced. At best, this will be technically difficult. But average or fixed values cannot be defended.

A conundrum based on current policy would result from detailed accounting by fuel load for fuel blenders, who would have difficulty meeting their own least cost objectives for achieving reduced GHG intensity fuels. Having perhaps widely varying fuel lots would create an unmanageable condition for fuel blenders. Fixing the GHG intensity of particular fuel supplies results in incorrect GHG accounting of fuels.

Major Variables in DGS Displacement Ratios – At the request of Mark Stowers, Kip Karges of POET provided a summary of the major variables in DGS displacement ratios, which is included as Appendix C. In addition, that write-up compares data on DGS usage from POET and industry averages versus averages presented in the literature. As noted in Appendix C, the major variables and issues associated with DGS usage include:

- Market Share for DDGS
- Replacement Ratios
- Inclusion Rates by Species
- Composition of Feed Replaced by DDGS
- Dry-Rolled vs. Steam-Flaked Corn
- Forage Information (Alfalfa Acreage/Hay Acreage)
- New Biofuel Processes (e.g., oil extraction)

- Performance Rates by Species
- Manure Composition and Management

Review of Arora et al. 2010 Paper on DGS Displacement Ratios* – The authors of the GREET model continuously review new information that affects the conversion factors used in the model, and debate more generally about the attributional assessment of GHG intensity values for biofuels. Arora et al. (2010) have recently published a review of the current literature on the feeding of co-products from corn grain ethanol, DDGS and WDGS. In brief, they have evaluated results from recent feeding studies available in the animal nutrition literature, and examined data on current feeding practices in the U.S. livestock industry. Some regard is given to increasing exports and international use of DDGS, but they consider the data available to be inadequate. The authors attempt a synthesis of information from these sources and additional expert opinion to estimate substitution ratios for DDGS and WDGS. A substitution ratio (SR) here means the amount of corn, soybean meal, and urea displaced by the use of DDGS/WDGS in livestock diets on a mass basis. They conclude that livestock species (beef and dairy cattle, poultry, and swine) respond differently to the use of DDGS/WDGS, that there are species-specific limits on the amounts of by-products that can be fed. More specifically, SRs for beef cattle are reported to be > 1.2, for dairy cattle only slightly greater than 1.0, and neutral for swine and poultry. However, as Dr. Klasing noted, fat was not considered in their analysis which resulted in an overestimate in the displacement ratio for poultry and, to a lesser extent, swine. Certain amino acid additions to these diets were also not considered.

A substitution ratio greater than 1:1 means that livestock performance is improved when fed the by-product compared with the original grain. This has consequences for estimating the GHG intensity of corn ethanol, because a >1:1 ratio means that the amount of land needed for the original grain crops and the associated GHG consequences are reduced, providing a larger GHG credit for the use of DDGS/WDGS for the ethanol fuel versus a simple 1:1 displacement ratio. Also, if by-products substitute for corn and soybean meal, then larger amounts of these commodities are available for export, reducing indirect or market-mediated effects on land use change in other locations around the world resulting from diversion of corn grain to fuel pathways.

The literature reviewed by Arora et al. (2010) includes reports or reviews of recent feeding studies of beef cattle and swine in the Midwest or western U.S. where large numbers of cattle and hogs are fattened and where the dominant low cost feeds available are corn grain and soybean meal; similarly for poultry production. Many of these studies report improved animal performance when using either DDGS or WDGS, with WDGS being especially productive for beef and dairy cattle. During discussions of this issue, some expert work group attributed reported superior performance for WDGS to its improved palatability and intake for cattle compared to ground corn/soybean meal alternatives.

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* Arora, S., M. Wu, and M. Wang, "Estimated Displaced Products and Ratios of Distillers' Co-Products from Corn Ethanol Plants and the Implications of Life-Cycle Analysis," Accepted for Publication, Biofuels, 2010.

Since this paper contains analyses that will alter the GREET model's valuation of co-product feeds, and potentially influence GHG calculations by CARB, it was discussed in detail by the work group and invited experts. A number of concerns were identified. Some of the nutritionists consulted suggested that the feeding studies summarized in Arora et al., were not organized to identify feed substitution ratios generally, but rather focused on specific diet comparisons based on likely mixtures in the regions where the studies were conducted. Dr. Fred Owens noted that the heating values of DDGS will change as the fat content changes. In Table 4 of the paper, however, the authors assume the same energy value for DDGS, WDGS, de-oiled DGS, and high-protein DGS. Based on his calculations, he suggested that for beef cattle, (based on caloric or energy content alone) the displacement value for energy from DDGS relative to corn grain can be greater than 1, though a displacement value for corn grain above 1.12 would not be expected unless fat content of DDGS exceeds 11.2%.

Few beef cattle feeding trials comparing DDGS and WDGS with corn grain have added fat to make diets isocaloric so the majority of studies report non-isocaloric comparisons. To properly account for the increased energy content of DDGS relative to corn grain (extra energy is provided by the enriched fat content of DDGS compared to corn), control diets in the studies cited should have contained added fat.* Displacement for energy plus protein then actually should include replacing three components – corn plus fat plus protein. Alternatively, if corn grain is used to provide energy to substitute for added fat (e.g., if fat is unavailable or expensive), some additional corn will be needed. If extra corn is added, then the resulting diet can easily give a displacement ratio of DDGS for corn grain plus protein that will exceed 1:1. Dr. Klasing emphasized that when DDGS is added to poultry, swine or fish rations in feeding trials or in practice, many other ingredients change or must be added in addition to corn and soy, including fat, meat meals, dicalcium phosphate, lysine and methionine. To more accurately estimate substitution ratios, data from experiments that apparently have not been yet conducted are required. After this research is done correctly, the displacement values will be somewhere near 1:1. Currently the displacement value of greater than 1 for beef cattle is driven by experiments that he regards as inadequate for determining displacement values.

Dr. Owens commented that on an energy basis, the displacement value of DGS for ground corn will be greater than 1:1 when the ratio is estimated based on mass because it contains more fat than corn (e.g., Arora et al. report that corn has an energy value of 8059 BTU/lb, while DDGS has an energy value of 8703 BTU/lb). If the displacement value is the sum of energy plus nutrients from corn grain plus fat plus protein in the diet, then DGS likely can displace only a 1:1 combination of those ingredients. The definition of displacement ratio may be causing confusion in this discussion.

Dr. Klasing noted that the displacement ratios presented in Table 5 for poultry report an overall ratio slightly greater than 1:1 (i.e., 0.552 corn + 0.483 SBM). However, this does not account for the fact that fat must be added to the diet when DGS displaces SBM. Fat is the largest factor changing, but also also more lysine, tryptophan, lutein and phytase must be added. When all of the adding and subtracting is

* Dr. Erickson has argued that if fat is added to the control diet, the LCA would have to account for the added fat source when compared DGS (i.e., fat + corn grain versus DGS).

done, the displacement value will be about 1. He notes that DDGS results in the use of less soymeal, but more fat. LCA should account for this ingredient substitution.

Dr. Richard Zinn noted that the 1:1.2 ratio of DGS displacing feed corn in beef cattle rations shown in Table 5 is too high, and cannot realistically be more than 1:1. Comparison diets are sensitive to how the feed corn is processed (steam-flaked versus dry-rolled). The national feeding industry currently uses mostly steam-flaked corn rather than the dry-rolled grain used in the literature cited. If dry-rolled grain is used, then the substitution ratio may be less than 1:1. He estimated 0.85:1, a much different ratio than the 1.2:1 reported in Arora et al., 2010. However, a displacement ratio of less than 1:1 may be the result of quality issues with DGS, and with high quality DGS, a ratio closer to 1:1 would be expected.

Unfortunately, Dr. Galen Erickson of the University of Nebraska was unable to participate in the October 21 animal nutrition and feed expert meeting where much of the above discussion occurred. However, Dr. Erickson participated in the June 30 meeting, during which he presented research from feed trials in the Midwest that showed a performance improvement (i.e., displacement ratio > 1:1) when DGS was added to beef cattle rations. In addition, Dr. Erickson provided comments in a follow-up email correspondence on the issue of displacement ratios. Some excerpts from that email are presented below.

> *While it is puzzling to have a performance response compared to corn … this has been observed in approximately 30 experiments conducted at UNL alone. This would likely go to 45 to 60 experiments if you include others. If you only look at the proximate analysis, the increased fat accounts for about 16% greater energy than corn. The energy calculated from labs should NEVER be used as they are useless. The NEm and NEg calculated from lab assays use the fiber equations which do not accurately calculate energy content from NDF and ADF in high-fiber byproduct feeds (works well only for forages). So, I would argue that if you account for fat and for the excess protein, you should expect better performance than cattle fed corn. The debate is not that, the debatable question is why the energy response is as large as it is.*
>
> *There are 2 other things that go on with distillers fed to cattle. You can have fat included in the control or not. While of interest for comparison to corn plus fat, distillers grains is never priced relative to fat (used in ruminants). What most critics want to do is include fat in the control, then calculate a value relative to corn alone (which is not possible if you replace fat and corn), and price it relative to corn (despite comparison to corn and fat, not corn alone). It should be priced (and value calculated) relative to corn + FAT if you have fat in the control diets. In ideal situations with unlimited experimental units, you would always have 2 control diets. The other major challenge for finishing cattle is that the response to distillers is very dependent on type of corn processing replaced. For some reason, distillers grains does not appear to be as synergistic in diets where steam-flaked corn is replaced, as compared to high-moisture corn or dry-rolled corn. So, when experiments are conducted in diets with steam-flaked corn, the response is less (albeit*

you are starting with a more energy-dense corn as steam-flaked corn is likely 15% greater in energy than dry-rolled corn). If you really want to get into this though, the steam-flaking requires more energy than dry-rolling.

Now, with that said, there are numerous issues that need to be addressed. These include:

1) how roughage is handled (and changed) when distillers are fed
2) whether fed wet or dry (has a huge impact and only impacts cattle as far as I know yet today)
3) disregard the sorghum based distillers as it is not related here (in my opinion).
4) how to handle protein source replaced (urea, soybean meal, cottonseed meal, etc).

Another important issue is what is changed commercially. You can certainly get input from consulting nutritionists, but we can tell you what is changed.

When distillers grains are included in the diet, fat is replaced, corn is replaced, protein is replaced, and usually a roughage source is changed (and maybe reduced some). The protein is the only debatable issue on whether this is urea alone, urea and cottonseed meal, only partial urea, etc.

Lastly, the inclusion of distillers impacts all of this as it will impact how much fat is replaced (all, partial, or none), protein and likely source replaced (for example, a 10% inclusion which is quite low will only partially replace protein and probably the "natural" sources).

Dr. Erickson also provided a number of comments on this paper, many of which were incorporated into the summary of the animal feed and nutrition expert meetings. However, he also commented on several of the points made by Dr. Kaffka in his summary of the assessments of several of the feed nutrition experts. Those are presented below:

- Diets based on corn, SBM, and forages should not be considered sub-optimum. When other byproduct feeds are used, they are often compared to corn, SBM, and forage as these are “gold” standards.

- Dr. Kaffka notes that studies carried out in the Midwest would not necessarily apply to California, as California has a more diverse set of feeds available. Dr. Erickson agreed, noting that ethanol produced in the Midwest and used in California should be based on DGS displacement ratios that are specific to the Midwest.

- Dr. Erickson noted that the BESS model could be used to assess carbon intensity values for individual plants, and therefore Dr. Kaffka's suggestion that the best way to value fuels is with individual assessments for each lot could be implemented.

Finally, Dr. Klasing developed two least-cost rations formulated for growing broiler chicks – one with and one without DGS. The ingredients are typical for broiler production in the southeast U.S. where most are produced. California rations would have a larger number of byproducts (e.g. tomato pumice, sunflower meal, etc.), and this process would be more complicated. Prices are current as of last week (October24, 2010). The feed rations are shown in Table 5, and the physical displacement values are summarized in Table 6.

Based on the results shown in Table 6, the physical displacement of DDGS is 1.98 when only corn and soymeal are considered. When all of the ingredients that change are considered, the physical displacement value is 1.00. In fact, the sum of all of the ingredients must equal 100% and the physical displacement value must be 1.00 by definition. If 10% DDGS is added, 10% must be removed from other feed components. The only way that a physical displacement value could be greater than or less than 1.00 is if the accounting system does not include all of the ingredients.

Table 5

Comparison of Broiler Grower Diets With and Without DDGS

	Without DGS	With DGS
Corn Dent Yel grain	70.08	48.14
Soybean meal, nohul 48.5%	17.06	19.20
Poultry by-product,meal rendered	7.00	0.00
Bakery waste, dried	3.10	1.40
Oyster shells, grnd	1.28	1.59
Calcium, Dical from Cargill	0.66	0.95
Vitamin mix - NRC	0.25	0.25
Mineral mix - NRC	0.25	0.25
L-lysine HCl 95%	0.11	0.17
DL-methionine 99%	0.08	0.11
Salt	0.07	0.09
Threonine	0.05	0.08
Wheat flour middlng	0.00	13.30
Fat, Poultry	0.00	4.47
Distillers Grains w solubles dyh	0.00	10.00

Table 6
Physical displacement values

Corn and soy only	% of diet	All Ingredients	% of diet
Corn + Soy without DDGS	87	All ingredeints without DDGS	90
Corn + Soy with DDGS	67.34	Corn + Soy with DDGS	90
Amount displaced	19.8	Ratio	1
Displacement value	1.98		

To correctly determine the LCA for DDGS, one would have to tally the CO2e for each of the 13 ingredients that changed in the ration (corn, soymeal, poultry by-product meal, bakery waste, oyster shells, dical, lysine, methionine, salt, threonine, wheat middlings, poultry fat, and DDGS). The LCA CO2e for things like poultry fat and poultry byproducts are huge when “weight based” or “energy based” co-product allocation systems are used.

Recommendations – As illustrated in the discussion above, animal feeding and nutrition is an extremely complex issue. Estimating appropriate displacement ratios to properly account for the co-product credit of DGS in a life-cycle assessment is further complicated by limited real-world data on feed rations, which are highly dependent on locally available feed ingredients and economics.

Nonetheless, CARB should re-evaluate its use of a 1:1 displacement of feed corn by DGS to include other components (e.g., SBM, fat, and urea) and available data on displacement ratios as a function of animal type and region. However, ARB needs to be mindful of potential issues associated with translating research results to the real world as noted in the discussion above (e.g., how roughage is handled, whether DGS is fed dry or wet, how protein is handled, least-cost optimization of rations, etc.).

A consensus was not reached among the invited experts on how best to handle DGS substitution ratios. The feeding value of a by-product feed depends on the feeding values of the other feeds used in the ration and the animal species, and it is not absolute; learning is involved. Actual performance is difficult to predict in high performing ruminant animals, perhaps less so in monogastric animals like poultry and swine. If least-cost, optimized ration balancing occurs, there is no large substitution effect to be achieved. Rations with DGS and without DGS can be (and are) created to achieve the same livestock performance targets.

We see three options available to CARB:

1. Develop a baseline close to what ARB is currently using (i.e., 1:1 ratio), which assumes no significant improvement in animal performance with DGS, but which better reflects the fact that DGS displaces both feed corn and SBM.

2. Develop a baseline similar to that recommended in the most recent Argonne paper, which may be a better representation of real-world performance at the current time.*

3. An improved Method 2A procedure that would be more dynamic and would allow biofuel producers to suggest alternative co-product credits estimates that are more applicable to their region and how their co-products are used in the animal feed market.

Options 1 and 2 could be implemented in the near-term, i.e., in the next few months, while option 3 would take more time to fully develop and implement. In the longer-term, CARB should continue to monitor the research and available data on biofuel co-product feeds. In addition, we recommend that CARB work to influence the type of data that are collected by USDA in the future to include biofuel co-product feeds specifically.

Consistency Between GREET and GTAP Modeling of Diet Substitution Effects

Summary of the Issue - Even if physical displacement ratios for DGS can be determined from available data, there remains the issue of translating those into GTAP, which uses elasticity parameters to determine the substitution of DGS with feed corn and protein meals. The change in price of DGS determines the substitution rate for the competing feeds in the GTAP model.

DGS selling price is the price which matches the supply and demand. The value of DGS is different in the different market segments depending on what is being displaced, and the price is set by the lowest value market segment. For the other market segments, value is transferred from the producer to the consumer. Therefore DGS price alone may not allow the model to determine what is physically displaced and thus provide the real changes in land demand.

As noted above, There are a number of reasons for the price discount of DGS relative to feed corn, e.g., DGS is a relatively new product on the market (at least in the volumes seen today), so it is not fully valued for its nutritional value, supply has increased significantly in recent years, keeping prices low, etc. As a result, price alone does not sufficiently reflect displacement of feed corn and other feed ingredients by DGS.

Recommendations – Some effort should be made by CARB to ensure consistency in co-product treatment between GTAP and GREET. In particular, this needs to go beyond a single GTAP run that only considers DGS, SBM, and feed corn in economic terms – changes in mass are what matter to the GHG emissions estimates. It may be possible to investigate this issue with a series of GTAP sensitivity runs to better understand model output as a function of different inputs.

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* As noted above, not all of the animal feed and nutrition experts agreed that the recent Argonne work represented real-world performance. For example, Dr. Klasing noted that the values for poultry were completely unrealistic and the values for beef cattle appeared highly inflated.

Since there is significant uncertainty with respect to the co-product displacement ratios for corn DDG and how the GTAP model elasticities for DDG and corn and DDG and soybean meal were developed, it is appropriate to undertake a series of sensitivity analysis with the elasticity parameters and determine the impact that they have on land use change. In theory, more displacement of soybean meal should lower the land change since soybeans have a lower crop yield than corn.

The GTAP model has a "non zero and small value, 0.3, for the elasticity of substitution between the energy and protein feedstuffs because DDGS could displace a portion of the meals in some feed rations."* A matrix should be developed with each of the elasticities ranging from 0.3 to a high value, such as 5.0, and the model run for each combination of the two values. Values of 0.3, 1.0, 3.0, and 5.0 should be adequate so that would entail 15 additional runs. In addition to the impact on land use change, the impact on the cost shares of the major feed items in the U.S. livestock industry should be developed. We suggest that this work be done in the near-term.

Issues Related to GTAP Modeling of Soy Biodiesel

Summary of the Issues - The GTAP modeling that was performed for soybean biodiesel has some fundamental economic issues. Specifically, the crush margin, i.e., value of the products (soy oil and soybean meal) less the cost of inputs (soybeans) goes negative in the modeled scenario, driven by the modeled output indicating a drop in soybean meal price of 44%. However, soybean meal prices in linked economies are vastly different.

A second issue is related to synergistic effects of a soy biodiesel and corn ethanol shock modeled by GTAP. The GTAP model (as used in the July 2010 Purdue/Argonne work) has been run for both a corn ethanol and a soybean biodiesel shock and a combined corn and soybean shock. The sum of the land use impacts of the corn shock and the soybean shock has a higher cropland demand than the demand for a run that combines the corn and soybean shocks in a single run. This issue needs to be resolved to determine if it is a real phenomenon or a modeling issue.

Finally, there appear to be some unusual results in the land area changes and the type of land converted (i.e., forest versus grassland) in the various GTAP runs associated with a soy biodiesel shock alone and with a combined soy biodiesel and corn ethanol shock. That issue is also discussed below.

Investigation of the Issues

Negative Crush Margins - Don O'Connor prepared a brief analysis of the negative crush margin issue, which is contained in Appendix D, and a summary of the modeled crush margins are shown in Table 7

* Tyner, et al. "Land Use Changes and Consequent CO2 Emissions due to US Corn Ethanol Production: A Comprehensive Analysis," July 2010.

below. As observed in the table, the post-shock crush margins are negative for both 2001 and 2006, which clearly is not a sustainable result.

At the August EWG meeting this issue was discussed, and Wally Tyner noted that the version of GTAP used for ARB's previous analysis included two errors that have since been corrected:

- When soy oil and SBM was split, the SBM did not go into the correct economic sector, and

- The trade linkages for DGS and SBM were not handled correctly.

Table 7
Crush Margins in ARB's GTAP Modeling of Soy Biodiesel

	2001	2006	Post Shock	
			2001	2006
Soybeans	$4.77 /bu	$5.70/bu	$4.90/bu	$5.85/bu
Soybean Meal	$165.60/ton	$174.71/ton	$92.24/ton	$97.31/ton
Soybean Oil	13.99¢/lb	23.38¢/lb	16.02¢/lb	26.77¢/lb
Margin	$26.04 /ton	$32.17 /ton	$-27.70 /ton	$-14.58 /ton

Synergistic Impact of a Corn and Soybean Shock – As noted above, the latest GTAP model (as used in the July 2010 Argonne work) has been run for both a corn ethanol and a soybean biodiesel shock and a combined corn and soybean shock. The sum of the land use impacts of the corn shock and the soybean shock has a higher cropland demand than the demand for a run that combines the corn and soybean shocks in a single run.

A similar phenomenon was reported by the Renewable Fuels Association in their analysis of the U.S. EPA RFS2 modeling work.[*] In this work, the sum of the individual shocks for corn ethanol, soybean biodiesel, and sugar cane ethanol required 62% more land than the EPA control case that determined the land requirements for a simultaneous shock of all three fuels.

The GTAP results taken from the Group 2 results from the latest model are summarized below in Table 8. The corn ethanol shock is for 13.25 billion gallons (2001 consumption to 15 billion gallons) and the

[*] See http://renewablefuelsassociation.cmail3.com/t/y/l/mjjkid/ilwyujty/r.

soybean biodiesel shock is 0.995 billion gallons (as CARB has previously modeled). These results show that the difference in land use required is 34% higher for the sum of the separate cases than for the combined case.

The difference in the GTAP results is large enough to be a concern. The current approach used by CARB of modeling the systems independently, even though both fuels will be used in the marketplace, may be overestimating the land use impact. This issue needs to be resolved to determine if it is a real phenomenon or a modeling issue.

Table 8
Comparison of Land Use Changes from "Only" Cases Versus Combined Case
(1000s of Hectares)

	"Soy Only Case"	"Corn Only Case"	Sum of "Only" Cases	Combined Case
Domestic	43,056	482,352	525,408	450,816
Foreign	1,183,838	1,554,972	2,738,810	1,993,512
Total	1,226,894	2,037,324	3,264,218	2,444,328

<u>Land Conversion Estimates from GTAP</u> – Don O'Connor also investigated this issue, and the detailed results from that effort are contained in Appendix E. As noted in that appendix, the latest GTAP model (as used in the July 2010 Purdue/Argonne work) has been run for soybean biodiesel shock of 0.995 billion gallons. Two scenarios were run, one with soybeans alone and one with a soybean shock modeled on top of a corn ethanol shock. The results for the two scenarios are very different and provide little comfort that the model is producing valid results. The results for the two scenarios using the Group 2 results are tabulated in Appendix E and are described below.

Biodiesel-Only Scenario - In this case, only the biodiesel shock is modeled. There are three unusual features with this scenario:

1. Almost all of the land use change occurs outside of the United States.
2. The area required for the 2001 to 2006 change is an order of magnitude lower than the subsequent shocks.
3. There is a huge shift of grassland to forestland in the first segment of the shock and that is reversed as the other segments of the shock are modeled.

Ethanol and Biodiesel Scenario - This scenario has some of the same unusual features as the biodiesel-only case but with differences in the details and in some cases the direction of the change:

1. The U.S. loses cropland through each of the stages of the shock.

2. The area required for the 2001 to 2006 change is two to five times higher than the subsequent shocks.
3. There is a huge deforestation in the first stage of the shock and subsequent reforestation in the later stages.

Recommendations - ARB should re-evaluate the iLUC estimates for soy biodiesel based on the most recent GTAP model that has corrected the error that led to negative crush margins for soy biodiesel. Although the Subgroup understands this has been done by an outside group, the results are inconsistent with respect to estimated land use change, i.e., the area converted as a result of the corn shock plus the soy shock is not equal to running the model with the two shocks combined. It may be possible to resolve this issue by holding the corn shock constant and running multiple soybean volume shocks, then hold the soybean shock constant and vary the corn shock. This can generate a surface of results that may identify modeling issues, particularly if there are discontinuities in the surface. If this approach does not identify any issues then the phenomenon may be real and should be accounted for in the determination of the final iLUC emission factors.

In general, there appear to be a number of potential issues with GTAP modeling of soy biodiesel, and ARB must devote significant effort in the near-term to resolve these potential problems.

5. Long-Term Issues for Consideration

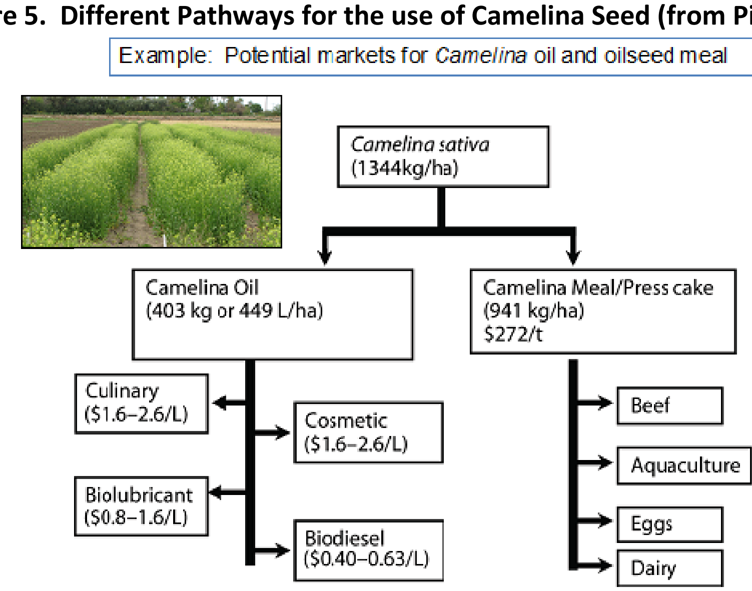
This section of the report presents the Co-Products Subgroup activities on issues that should be considered by CARB staff in the longer term (i.e., more than a year or two). In general, these issues are related to biofuel feedstocks, processes, and co-products that are not yet on the market in large volumes, but may appear in the future.

Issues Related to Oilseed Meals

Summary of the Issue – The bulk of the work on oilseeds used for biodiesel and renewable diesel production has been on soybeans, soy oil, and soybean meal as soy oil is the most common biodiesel feed currently used in the U.S. However, soybean, canola, Camelina, palm, jatropha, and other novel virgin oils are being and will be used in the manufacture of biofuels. These result in residues (oilseed meals that vary in quality depending on crop species and processing methods, and will have different uses and feeding values in ruminant diets and monogastric diets, depending on livestock species. Different substitution ratios will be appropriate and necessary.

In addition, new oilseed crops may be produced because they are enriched in specific fatty acids with special properties useful in human nutrition, cosmetics, pharmaceuticals or other purposes. An example for Camelina is reported in Figure 5. Accounting for residues from multiuse feedstocks like Camelina will present challenges for current LCA methods.

Figure 5. Different Pathways for the use of Camelina Seed (from Pilgeram et al., 2007)



Recommendations – CARB staff should carefully monitor future trends in the oilseed market as it applies to feedstock for biodiesel and renewable diesel used for compliance with the LCFS. CARB needs to be mindful that if biofuels produced from oilseeds beyond soy are introduced into California, work will be needed to properly assess co-product credits.

Issues Related to New Products Developed from Biofuel Co-Products

Summary of the Issue - Markets are always changing and responding to new opportunities and threats. Glycerine from biodiesel production worldwide has led to the closure of most synthetic glycerine production facilities, and a continued increase in glycerine supply may create unique opportunities. For example, a 100,000 tpy glycerine-to-propylene glycol facility has been built and is being commissioned. This facility will process glycerine from the production of about 430 million gallons of biodiesel annually. It has been estimated that the GHG emissions from this bio-process are 1.72 kg CO2e/kg propylene glycol vs. 8.61 kg CO2e/kg for a petroleum-based process. The GHG savings are about 12.2 gCO2e/MJ biodiesel if a substitution approach is used to estimate co-product credits from bio-based propylene glycol versus 0.24 gCO2e/MJ if a simple energy allocation approach is used to account for glycerin generated in the trans-esterification step in biodiesel processing (which is CARB's current approach of accounting for glycerin in biodiesel production).

Recommendations – As new products are developed from biofuel co-products, CARB needs to consider potential new markets for co-products used as feedstock or directly for bio-based products that could displace materials with a much higher carbon footprint. There is no reason not to extend the boundary conditions if it is clear that a new product or process is using a co-product from a biofuel that results in a finished product with a lower carbon footprint than the product it displaces.

Future Directions in Biofuel Processing and Co-Products

Summary of the Issue – There are a number of biofuel co-products that may be new to market, or may find a different market, over the next several years:

- Corn oil, as a biodiesel feedstock
- Zein protein, as a petrochemical feedstock replacement
- DDG(S) as a filler (replacing high density polyethylene)
- Energy from landfill gas or biomass

In addition, future co-products that may replace petrochemicals include fermentation products using carbohydrate in DDG(S) such as lactic acid and succinic acid as well as the use of corn oil to offset petrochemicals. Other future co-products may include lignin and other waste stream components for biogas, steam, or electricity production, and lignin as a bio-based petrochemical replacement.

Recommendations – Consistent with the discussion of new products above, CARB needs to be aware of potential new uses for biofuel co-products. When those co-products substitute for or displace products with a higher carbon footprint, the analysis boundaries should be re-drawn to capture those co-product credits.

Integrated Bio-Refineries

Summary of the Issue - Bio-refineries, with multiple inputs and multiple products, complicate lifecycle analysis. For multi-feedstock, multi-product bio-refineries, the difficulties associated with LCA are more complex than for a single feedstock-fuel pathway. Methodological difficulties have not been resolved, but are more difficult for consequential analysis, which with respect to biofuels and the reality of by-product feeding, may be more appropriate, but much more difficult and uncertain. CARB uses attributional LCA to estimate direct GHG intensity values for individual biofuels. In contrast, U.S. EPA uses consequential analysis for this purpose.

Recommendations – As integrated bio-refineries come onto the scene, CARB will have to carefully consider the most appropriate methodological approach to estimate the carbon intensity of not only the transportation fuels produced in the bio-refinery but also how best to account for co-products, which, similar to a petroleum refinery, may be many and varied.

6. Miscellaneous Issues

This section of the report presents a discussion of several issues that were brought up during EWG meetings and for which the Co-Products Subgroup was asked to comment on.

Negative Effects Associated with Biofuels Co-Products - At the October 15 Expert Workgroup (EWG) meeting, one of the EWG members asked if there were negative side effects associated with biofuels co-products, citing nitrogen/ammonia run-off, dairy methane emissions, and transport of DGS as potential issues. The first issue was discussed during the final animal feed and nutrition expert meeting, and below is a summary of comments:

- If the nutritionist is doing his job (e.g., nitrogen balancing), there should not be an issue in monogastrics (Kirk Klasing).
- It is difficult to attribute nitrogen from dietary inputs. There are many other processes separate from diet that are more important, e.g., composting, bedding, etc. (Steve Kaffka).
- Constraints on elevated concentrations of phosphorus and nitrogen are locality and species dependent; excretion from beef cattle can be an issue (Fred Owens).

Note that a discussion of this issue was also included in POET's write-up that is included as Appendix C.

In terms of emissions from transportation of DGS, as the export market expands, CARB should be mindful of additional emissions from transportation of DGS. However, transportation emissions are typically relatively small inputs to the overall lifecycle, and we would expect the same to be true in this case.

Recommendations on How to Deal with Corn Oil as a Co-Product Extracted from DGS – In EPA's analysis of corn ethanol for the RFS 2 rulemaking, they assumed that in the timeframe evaluated for that rule (2022) corn oil would be extracted in the process, which would then be used as a feedstock for biodiesel or renewable diesel. As noted in Section 3 of this report, we would recommend that CARB evaluate the co-product credit from corn oil with a displacement method, and corn oil used for biodiesel production would likely displace soy oil.

Impact of Displacement Ratios on Carbon Intensity – This issue can readily be evaluated for direct emissions based on modifying inputs to the CA-GREET model. However, the impact on indirect emissions (i.e., indirect land use change) is much more complicated as numerous GTAP runs would be required and the issues related to properly reflecting displacement ratios in GTAP would need to be worked out (described in Section 4).

Appendix A

Summaries from Animal Feed and Nutrition Expert Meetings (June 30, July 26, and October 21)

REVISED Meeting Notes (Revisions Highlighted in Red)

Biofuels Co-Products Used for Animal Feed
Discussion with Animal Nutrition and Feed Experts

Co-Products Subgroup of the LCFS Expert Work Group

UC Davis and via Conference Call
30-Jun-2010, 1:00 p.m. PDT

Participants

Invited Experts: Galen Erickson (University of Nebraska-Lincoln), Dave Fairfield (National Grain and Feed Association), Kirk Klasing (UC Davis), Fred Owens (Pioneer Hi-Bred International), Richard Zinn (UC Davis)

Co-Products Subgroup: Alan Glabe (ARB), Jim Duffy (ARB), Phil Heirigs (Chevron), Steve Kaffka (UC Davis), Don O'Connor ($S\&T^2$)

Background and Introductions

As this was the first meeting of the Feed Experts, Jim spent a little time covering the general make-up and charter of the LCFS Expert Workgroup. Phil covered the Co-Products Subgroup, outlining the membership and the work plan that was developed for this effort. The invited experts then spent a few minutes describing their background and research focus:

Galen Erickson (University of Nebraska-Lincoln) – Has worked on DGS issues for 10+ years investigating different diet formulations for beef cattle; to a lesser extent has also investigated dairy and swine. Has run 30 to 40 experiments over the years utilizing campus-based feedlots. He will be able to provide expertise on current and future feeding practices and displacement ratios, with an emphasis on the Midwest.

Dave Fairfield (National Grain and Feed Association) – NGFA member companies represent ~75% of the feed in the U.S. Has gotten involved with the ethanol industry in the last five years as volumes have increased. Will be able to help with new/emerging co-products as well as current practices.

Kirk Klasing (UC Davis) – Expert in poultry/swine nutrition, particularly as that relates to intestinal health and immune response. Member of an NRC committee investigating the economic and environmental impacts of increasing biofuels production. He will be able to provide insight on poultry/swine feeding issues, particularly as they relate to California.

Fred Owens (Pioneer Hi-Bred International) – Has been studying animal nutrition for 30+ years. His current research is focused at how variability in grain may influence ethanol yields and resulting byproducts (e.g., grain with a higher starch content results in higher ethanol yield). Also investigating how sulfur, phosphorus, and oil content of DGS varies. He will be able to provide insight on both current and future feed issues.

Richard Zinn (UC Davis) – Is a professor of animal science who conducts research on many different types of animal feeds and distillers grains. One issue of particular interest is excess nitrogen as a result of elevated nitrogen content of DGS vs. grain. He will be able to provide insight on California-based beef cattle operations.

Presentation by Fred Owens

Dr. Owens presented information on his research into variability of DGS and its impact on nutritional value and trace compounds. Below is a summary of key points.

- High variability of DGS is a concern; feedlots want a material that is consistent as possible to prevent metabolic upsets in animals.
- Waste management of phosphorus is a concern. Corn hybrids differ in phosphorus level, and therefore DGS differs in phosphorus level.
- Nutritional value of DGS varies as a function of extent of fermentation (i.e., residual starch), amount of solubles added to DGS solids, and whether oil is removed during processing.
- For swine, data indicate that particle size impacts digestibility; smaller particles = more efficient use of feed.

Presentation by Galen Erickson

Dr. Erickson presented data on recent work he and others at UNL have done on animal feed displacement for DGS, noting that these are not final numbers. He also noted that there are differences in dry-rolled vs. steam-flaked corn (and therefore displacement of those feeds with DGS), and it will be hard to get consensus on that issue. A summary is provided below.

- The UNL work shows that wet DGS is used more efficiently than dry DGS for inclusion rates ranging from 20% to 40% on a dry-matter basis. This has implications for the carbon intensity estimates for corn ethanol pathways that sell wet DGS as a co-product.

- Depending on inclusion rate (10 to 40%) and whether dry, modified, or wet, DGS displaced from 110% to 150% of corn in beef cattle diets on a dry matter basis. The highest displacement ratios were associated with the lowest inclusion rates.

- For dairy cattle, 1 kg DGS replaces 0.55 kg soybean meal and 0.45 kg corn.

- For finishing pigs, 1 kg of DDGS replaces 0.57 kg of corn and 0.43 kg of soybean meal.

- The greatest displacement is for wet DGS fed to beef cattle (1.28 to 1.45 ratio).

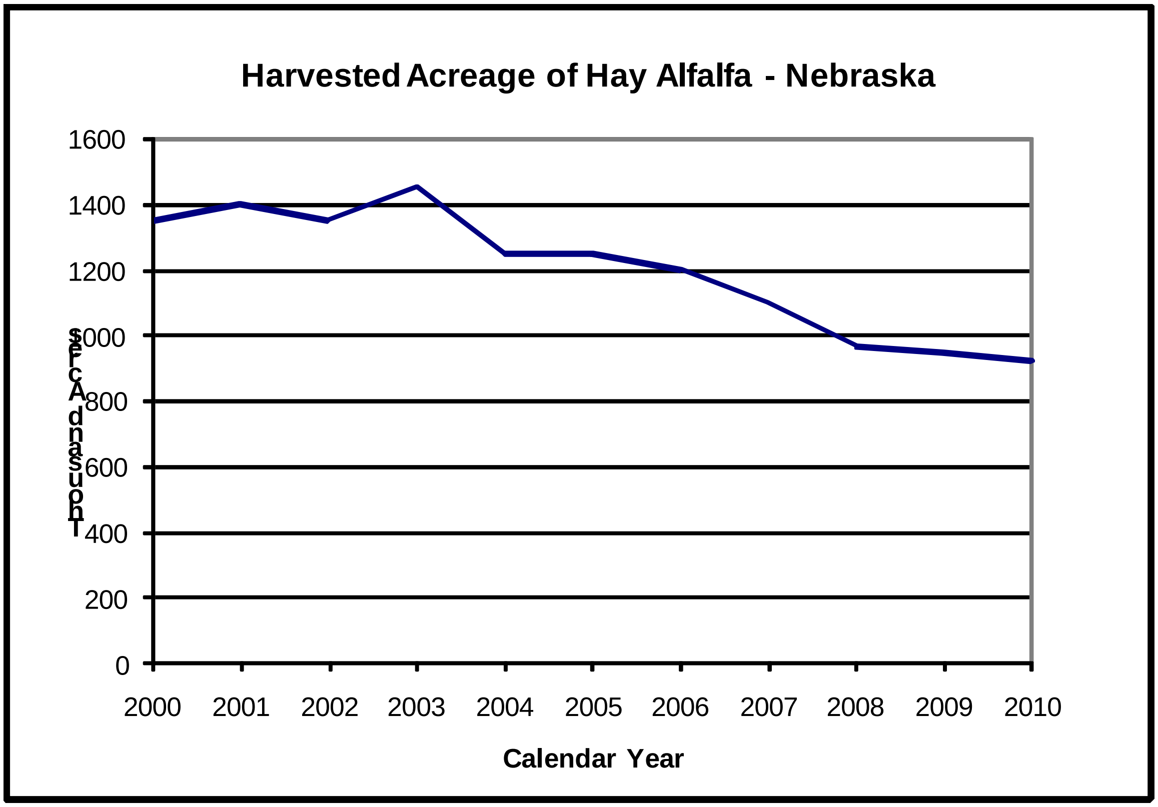
- Results from the BESS model showing the reduction in the CI of ethanol vs. gasoline as a function of feeding wet vs. dry DGS and dairy/swine vs. beef cattle were presented. As inferred from the above, feeding wet DGS to beef cattle showed the largest reduction.

Discussion Points and Key Take-Aways

- In response to a question about variability in DGS used in feedlots, Dr. Erickson noted that it typically ranges from 20% to 25% on a dry basis, but inclusion rates can vary from 0 to 50%. Some feedlots make use of gluten feed in addition to DGS; the picture is quite variable across the U.S. Dr. Zinn noted that 15 to 20% is typically optimal, and if high levels of WDGS is included variability in overall feed characteristics generally increases because of the other feed added to the diet. This is consistent with a point Dr. Owens made that at inclusion levels above 20% the protein value from DGS is excess.

- An issue that is often not considered in lifecycle analyses that should be accounted for is the forage diet used in conjunction with DGS. Corn stocks and other agricultural residue are being used, particularly in Nebraska and Iowa. Dr. Erickson noted that this should be observable in the trends in alfalfa acreage. Don confirmed that there has been a drop in hay acreage in Nebraska as DGS plus crop residues replace corn and alfalfa in beef rations. The drop coincides with the increase in DGS availability, which is shown in the figure below. It was also noted that California feedlots, because of the diverse agriculture in the state, tend to use a wider variety of agricultural residues than the Midwest.

- Dr. Klasing indicated that use of DDG for swine would also change the amount of tallow and fat added to those rations, noting that the ultimate mix of feed material depends on the price – not surprisingly, feedlot operators look to minimize cost. As a result, one cannot simply assume that DGS displaces corn and soybean meal.



- The above discussion led to a suggestion from Dr. Klasing on how to best to proceed given the variability in feed rations when DGS is used. He thought it would be possible for experts within the beef cattle, dairy cattle, poultry, and swine arenas to formulate four or five different diets that reflect different combinations of diverse feed mixtures reflecting possible feed price changes. This would allow for estimating a range of potential co-product estimates for different animal types. We will proceed on this path.

- As most of the discussion focused on dairy and beef cattle (ruminants), Dr. Klasing described the DGS situation for poultry and swine (non-ruminants), noting that these were late in coming to the party. However, the use of DGS for poultry has come on strong in the past few years, and most growers are using about 10% DGS in poultry rations. There has also been a large increase in the use of DGS in swine operations over the last two to three years. However, young animals do not utilize DGS well, and DGS is typically used for finishing for poultry and swine.

- There was a discussion of whether the U.S. feed market might become saturated with DGS as corn ethanol volumes increase to 15 billion gallons per year (BGY). Dr. Owens noted that saturation may be a regional issue, for example, Illinois may already be saturated. Dr. Erickson believes that DGS at the 15 BGY level can be absorbed into the U.S. feed market, but there would need to be careful consideration for the high protein and phosphorus content of DGS.[*] Although DGS displaces the use of soybean meal (SBM), there is a huge demand for SBM on the world market (especially China). As a result, although it is conceivable that the U.S. market for biofuels feed products could become saturated, it is not an issue because of high demand on the global market.

- As noted above, there is consensus that there will be a very strong demand for SBM in the export market and a weaker demand for soybean oil. Given this situation, Don suggested that an interesting GTAP scenario that could be run would be to model an equivalent increase in SBM demand. This could be compared to the results from an increase in soy oil. This would help guide the discussion of whether soy oil is a product or by-product.

- As Don noted, several points are worth highlighting with respect to Dr. Erickson's work:

  1. Some species see an increase in feed efficiency and some do not.
  2. For some species DDG will replace SBM and in other species it will not.
  3. But there are no species where DDG replaces only corn and does not show an increase in feed efficiency.

  The latter point is the assumption that is in the CA-GREET model and was the original basis of the GTAP model. The latest work that Wally Tyner presented at the last EWG meeting includes some SBM substitution in GTAP, and that is one of the reasons for the decrease in ILUC emissions.

Next Steps

- Phil to draft summary of meeting (this document).

- Don to complete his write-up on USDA feed data vs. DGS introduction. This will be circulated to the invited experts for comment.

- Experts to develop four or five different feed formulations based on economic considerations to allow for a range of co-product benefits estimates. A separate email will be sent detailing this request.

- Phil to query group for a date for the next meeting. Likely to be first week of August.

[*] Note that phosphorus is a particular problem in poultry manure, as it increases the phosphorus load in the soil upon which it is applied and is a concern with respect to leaching.

- Dr. Owens suggested a couple of swine experts that will be asked to participate. Phil will follow-up with those requests.

Meeting Notes

(Note: Red Font Reflects Clarification from Original Draft)

Biofuels Co-Products Used for Animal Feed
2nd Discussion with Animal Nutrition and Feed Experts

Co-Products Subgroup of the LCFS Expert Work Group

UC Davis and via Conference Call
26-Jul-2010, 8:30 a.m. PDT

Participants

Invited Experts: John Beckett (Consultant, formerly of Cal Poly San Luis Obispo), Dave Fairfield (National Grain and Feed Association), Mark Jenner (UC Davis), Kirk Klasing (UC Davis), Fred Owens (Pioneer Hi-Bred International), Peter Robinson (UC Davis), Jerry Shurson (University of Minnesota), Hans Stein (University of Illinois, Urbana-Champaign), Michael Wang (Argonne), May Wu (Argonne)

Co-Products Subgroup: John Courtis (ARB), Jim Duffy (ARB), Alan Glabe (ARB), Phil Heirigs (Chevron), Steve Kaffka (UC Davis), Don O'Connor (S&T)[2]

Background and Introductions

This was the first meeting for several of the invited experts, and therefore they were asked to give a brief description of their background and research interests:

Peter Robinson – Focus of work is on lactating dairy cows and nutrition with a focus on commercial operations.

Jerry Shurson – Has spent 12 years on swine nutrition and use of DGS in swine rations.

John Beckett – A consulting nutritionist with clients in many locations both nationally and internationally.

Hans Stein – Focus of work is also on swine nutrition and DGS in swine rations.

Mark Jenner – An economist who works with Steve Kaffka. Expertise in manure management.

Presentation by Don O'Connor

Don presented a summary of the work he has done on estimating displacement ratios using a "top-down" approach that analyzed USDA data on feed usage. Key points in his presentation included the following:

- USDA collects data on feed usage, but it excludes co-products from fuel ethanol. The data are reported in terms of feed consumption per grain-consuming animal unit (GCAU).[*] Trends in energy feeds and protein feeds show a visible decline in energy feeds (i.e., corn, sorghum, barley, oats, and wheat) between 2004/05 and 2009/10, while protein feeds (i.e., oil seed meals, animal protein feeds, and grain protein feeds) showed a slight decline. Excluded from the database are co-products from fuel ethanol production.

- DDG was estimated from fuel ethanol production assuming a DDG yield of 7.7 lb/gallon in 1980 and 6.2 lb/gallon in 2009 (reflecting improved ethanol yield over that time period). Exports of DDG were backed out of this total based on data from the USDA FATUS system (see http://www.ers.usda.gov/Data/FATUS) to estimate the amount used in the U.S.

- DDG was added to the feed data from USDA and the following was observed:
  - > Energy feeds decreased by 1.12 units for each unit of DDG.
  - > Protein feeds decreased by 0.12 units for each unit of DDG.
  - > The overall displacement (1.24) is consistent with other bottom-up estimates except that less SBM is displaced in this estimate.

- Caveats:
  - > Did not consider exports of corn gluten feed and corn gluten meal from wet mill ethanol plants; if those are substantial, the calculated displacement ratios above would be higher.
  - > Assumes no other changes to feed systems in past 10 years.
  - > Relatively constant GCAU in past 10 years.

Discussion Points

[*] From http://www.ers.usda.gov/data/feedgrains/Documentation.aspx: A standard unit [GCAU] is used to compare to actual animal numbers for all types of livestock and poultry. An animal unit is based on the dry-weight quantity of a feed consumed by the average milk cow during the base period [early-1970s]. A set of factors is developed for each type of livestock and poultry by relating feed consumption for each type of livestock to the feed consumed by the average milk cow.

- Dr. Klasing asked if there were changes to other energy feeds or whether only corn was displaced. Don responded that data for other grains are available, but for this analysis we don't necessarily need to look at other grains because the yield of corn is the highest and therefore this is a more conservative estimate.

- Dr. Klasing noted that corn comes out of the animal ration when DGS is used because corn doesn't work well with DGS. He suggested that other feeds need to be considered. Don noted that what he is calling corn is actually total energy feeds.

- Dr. Robinson asked if forage feeds and byproduct feeds were considered. Don noted that some are included in the dataset.[*] Dr. Robinson noted that forage and byproduct feeds in CA could be byproducts from citrus and nut operations.

- Michael Wang suggested that since there are CA-specific ethanol pathways in the LCFS, we might want to look at co-products specific to CA. Don noted that iLUC is considered on a global basis, so this may not be appropriate.

Presentation by Jerry Shurson

Dr. Shurson covered a presentation he originally prepared last year for a National Corn Growers conference. Below is a summary of key points.

- Estimated DGS market share for dairy (42%), beef (38%), swine (14%), and poultry (6%).

- The opportunity for increased DGS use for both swine and poultry exists, particularly during periods of high grain prices. Economics, DGS supply, and research to develop solutions for overcoming nutritional barriers for increased DGS use will influence future market penetration of DGS.

- Current DGS inclusion rates range from 10-20% for lactating diary cows, 20-40% for beef cattle, 10-40% for swine, and 5-30% for poultry.

- Accounting for species differences is important in estimating an overall average displacement ratio as different animal types show different responses to DGS. Improved performance is observed in beef and dairy cattle, while growth performance is unchanged for swine and poultry.

- Estimated displacement ratios:
  - > Dairy = 1.364 (0.731 corn; 0.633 SBM)
  - > Beef = 1.252 (1.196 corn; 0.056 urea)

[*] Note that the specific feeds included in the USDA data can be found in Table 29 of the Feed Grains Database at http://www.ers.usda.gov/Data/FeedGrains/Table.asp?t=29.

> Swine = 1.000 (0.669 corn; 0.295 SBM; + trace nutrients)
> Poultry = 0.997 (0.589 corn; 0.446 SBM; + trace nutrients)
> Overall Average = 1.249 (compares to 1.271 from 2008 GREET analysis)

Discussion Points

- Steve asked why the apparent energy content increase for DGS even though the starch has been removed (in the ethanol production process). Dr. Shurson responded that it has more fat (higher caloric value) and the corn fiber is digestible in ruminants. Steve also asked about the attitude of Midwest feedlots with respect to increasing volumes of corn ethanol and the potential for feed price increases. Dr. Shurson noted that there was some frustration about ethanol subsidies and fear of change. He also noted that the EU uses a lot of high-fiber/low-energy feeds and have been able to make it work.

- Dr. Robinson indicated that SBM is not used in dairy rations in CA (canola and cottonseed meal are used instead), and CA dairy rations may contain 15-20 ingredients. Thus, it is difficult to extrapolate Dr. Shurson's analysis to CA. Additionally, with high DGS inclusion rates they have seen a reduction in animal efficiency because corn oil interferes with ruminant nutrition. Above about 8-10% DGS led to a <u>decrease</u> in efficiency for lactating dairy cows. Dr. Shurson noted that he relied on a review paper of 30 studies prepared by South Dakota State researchers for the dairy displacement ratios, which did show some variability across studies. Dr. Robinson noted that there is a big difference between research studies and real world practices. In the real world feed rations are developed based on linear programming models that minimize cost. As a result, it is difficult to estimate displacement ratios.

- John asked if there are any data for specific areas or regions where the displacement ratios presented by Dr. Shurson are really applicable, or are these just theoretical. Dr. Shurson responded that he does not know if specific data from the feed industry exits, but the diets he used in his analysis are typical of those being fed currently.

  [NOTE: Later in the discussion Dave Fairfield of NFGA noted that the feed industry is very dynamic and highly dependent on prices of the ingredients in feed rations. In fact, feed manufacturers will formulate on a <u>weekly basis</u>. Unfortunately, no information is reported by his membership on usage. Thus, there are many challenges to obtaining real-world data. He did note, however, that he had contacted an Iowa feed producer prior to the meeting and was told that they were currently formulating swine rations with 40% DGS, which displaced 85% corn and 15% SBM]

- John also asked if there were other factors that could constrain the use of DGS and how the market might change moving forward. Dr. Shurson noted that elevated levels of nitrogen and phosphorus in DGS could result in manure management issues, and that may play a role in DGS usage rates.

Also, if high DGS inclusion rates caused an issue with respect to pork fat quality, then they would cut down on inclusion rates.

- Dr. Klasing said that outside of CA a lot of DGS was being used for poultry, with consumption this summer up near that of swine.

- Dr. Klasing also noted that current displacement values quantify how much corn and SBM leave a formula when X units of DDGS are added. But the reality is that many things change besides these 3 players. In a poultry ration, you cannot pull out corn and soy and add DDGS very easily because DDGS have a low metabolizable energy value due the high fiber/low starch (if you did this, feed efficiency would plummet). Because of the energy bottleneck, additional fat must be added to the diet in order to keep the metabolizable energy level at an acceptable level (this is illustrated in Dr. Shurson's example in the powerpoint that he showed). For broiler integrators, poultry grease is usually the cheapest source of fat because the integrators have it left over from the slaughter process. Obviously, it took a lot of corn and a little soy to make this poultry grease. A robust and defendable LCA should include the corn and soy used to make the added fat. Poultry grease is not a waste product, but a co-product, of poultry production. The pet food industry buys all they can and then switch to lard when the price gets too high. Because it takes 4 or so pounds of corn and a pinch of soy to make a pound of poultry grease, the displacement value of DDGS for poultry is lower than is currently being suggested.

<u>Presentation by Michael Wang and May Wu</u>

Michael Wang and May Wu of Argonne discussed their recent work on biofuel co-product displacement ratios. Key points of that discussion follow.

- Dr. Wang began the discussion by noting that from the demand side of the equation they knew they needed to address DGS as a co-product and first started working on displacement ratios for GREET in the late-1990s. The displacement ratios were updated in 2008, but they have since discovered that they need to update their 2008 estimates. They have submitted a paper with revised estimates to the *Journal of Animal Science*, so they cannot share their revised numbers yet.

- There are two aspects of co-product displacement ratios to consider: (1) the direct credit that can be calculated within GREET (emissions and energy effects); and (2) the impact on iLUC estimates because of the displacement effect. Under the direct effect, more corn displacement leads to greater credits, while for iLUC the opposite is true: if SBM displacement is higher, the credit against iLUC is greater.

- They are not feed experts, but they need co-product estimates for LCA purposes. GREET is a bottom-up model, and they are still unclear if a bottom-up approach to feed co-products reflects the marketplace. Perhaps the way to get to a resolution of the issue is looking at both bottom-up and top-down methods.

- Dr. Wu then discussed the changes to displacement ratios that they have made since their 2008 report:

  - Primarily used data from three board-invited reviews for beef (Klopfenstein, 2008), dairy (Schingoethe, 2009), and swine (Stein and Shurson, 2009), which covered a much broader range of studies than their 2008 report. The inclusion rate and performance evaluation were based on recommendations from these reviews.
  - 3-yr moving average of wet and dry co-product split were calculated and 2009 of that moving average was used for the estimate.
  - 3-yr moving average of animal share for the co-product was calculated and 2009 of that moving average was used.
  - Swine – inclusion rate increased to 20%; same performance as with conventional feed.
  - Dairy – remains 20% inclusion rate; <u>no performance change</u> based on the 2009 review by Dr. Schingoethe.
  - Beef – remains 20% and 40% inclusion rate for dry and wet DGS respectively; 1.313 displacement ratio. Slight change in numbers due to recalculated market share.
  - Added poultry – inclusion rate of 10%; displacement ratio similar to that used in Dr. Shurson's analysis (~ 1).
  - Considered displacement of corn, SBM, and urea based on the above assumptions; did not consider phosphates.

- They are still finding uncertainties in their estimates, especially in consumption reporting which is very inconsistent. Dr. Wu indicated that they would like to get input from this group when their recent paper was through the review process.

Discussion Points

- Don asked about the impact that these estimates might have on direct and indirect emissions. Dr. Wang noted that direct emissions are covered in GREET (via changes to displacement ratios), but the indirect emissions are more difficult to assess as they are typically handled via changes in the elasticity of substitutions. GTAP only considers corn displaced, and elasticities drive the displacement ratios with price signaling market demand. FASOM/FAPRI treat animal feed as a single industry and do not incorporate detailed estimates across biofuel co-product feeds. It will take some time for economic models to incorporate a more detailed representation of the animal feed market.

- Don also asked if Wally Tyner's recent work included changes so that SBM is considered. Dr. Wang replied that in theory, yes, but the reality is different.

- Steve noted that the feed market is very dynamic, and this is not captured in the agricultural economic models used to estimate iLUC impacts. A key question is how the feed industry will adapt and change moving forward, and how that plays into the LCFS is very uncertain. Steve also noted that we are using fairly static data with large error bars; we will need to figure out how to incorporate that learning into the LCFS regulations.

<u>Next Steps</u>

- Phil to draft summary of meeting (this document).

- Experts to continue development of four or five different feed formulations based on economic considerations to allow for a range of co-product benefits estimates.

- Experts to review the new Argonne analysis when it is finalized; will be forwarded by May Wu when it is completed.

- Phil to query group for a date for the next meeting. Likely to be early September.

Meeting Notes

(Note: Red Font Reflects Clarification from Original Draft)

Biofuels Co-Products Used for Animal Feed
3rd Discussion with Animal Nutrition and Feed Experts

Co-Products Subgroup of the LCFS Expert Work Group

UC Davis and via Conference Call
21-OCT-2010, 8:30 a.m. PDT

Participants

Invited Experts: Kirk Klasing (UC Davis), Fred Owens (Pioneer Hi-Bred International), Jerry Shurson (University of Minnesota), May Wu (Argonne), Richard Zinn (UC Davis)

Co-Products Subgroup: John Courtis (ARB), Jim Duffy (ARB), Jordan Fink and Kip Karges (POET, representing Mark Stowers), Phil Heirigs (Chevron), Steve Kaffka (UC Davis), Don O'Connor (S&T)[2], Oyvind Vessia (European Commission)

Background and Introduction

This was the final meeting of the animal feed and nutrition experts. The key outstanding issue for which consensus had not been previously reached among the experts is related to distillers' grains and solubles (DGS) displacement ratios greater than 1:1. There was significant discussion of this issue during the meeting as highlighted below. Other issues discussed included:

- Impact of DGS on excreted phosphorus and nitrogen levels and potential manure management issues.
- Review of key take-aways from the two previous animal feed and nutrition expert meetings and follow-up email correspondence.
- Comments on the recent Argonne re-assessment of DGS displacement ratios for GREET.
- Comments on the Wang, et al. paper on methods of dealing with biofuel co-products in life-cycle analysis.

DGS and Manure Management Issues

In the previous feed expert meetings it was noted that rations containing DGS may lead to increased phosphorus and nitrogen intake and excretion. Manure is typically disposed of by applying it as fertilizer to cropland. However, there are a number of regions where elevated soil phosphorus level is a concern. Thus, on a regional basis, phosphorus may limit DGS inclusion rates in animal rations.

At the October 15 Expert Workgroup (EWG) meeting, one of the EWG members asked if there were negative side effects associated with biofuels co-products, citing nitrogen/ammonia run-off, dairy methane emissions, and transport of DGS as potential issues. The first issue was discussed by this group, and below is a summary of comments:

- If the nutritionist is doing his job (e.g., nitrogen balancing), there should not be an issue in monogastrics (Kirk Klasing).
- It is difficult to attribute nitrogen from dietary inputs. There are many other processes separate from diet that are more important, e.g., composting, bedding, etc. (Steve Kaffka).
- Constraints on elevated concentrations of phosphorus and nitrogen are locality and species dependent; excretion from beef cattle can be an issue (Fred Owens).

Note that a discussion of this issue was also included in POET's write-up distributed to the group before the call which includes citations to several studies on this issue.

Review of Key Take-Aways from Previous Meetings

Before delving into specific issues related to DGS displacement ratios, the group covered some of the key take-aways from the previous meetings and shared via email correspondence. These had been presented to the EWG at the August meeting. Only a few of the specific issues garnered additional comments:

- Potential Saturation of DGS Market in U.S.
  - Although a potential regional issue, longer-distance transport (e.g., via rail) is a solution both within the U.S. and outside of the U.S.

- DDGS Export Market
  - May Wu and Don O'Connor both noted that there has been a significant increase in the DDGS export market over the past few years (e.g., DDGS exports tripled between 2006 and 2008).
  - Data on the export market should be available from the U.S. Grains Council.
  - Jerry Shurson noted that DGS is a fairly new ingredient overseas, and therefore inclusion rates are generally lower (~10%) and probably will stay that way until feedlots get more experience with it. Outside of the US and EU, little attention is given to phosphorus and

nitrogen excretion, and those compounds are not a high priority in formulating diets. In regions outside of US/EU, rations are formulated based on crude protein and energy and therefore a different displacement ratio is observed vs. the US/EU.

- Regional Differences in DGS Usage
  - Kip Karges noted that east of the Mississippi there is a larger fraction of monogastric animals and therefore more DGS goes to those animals in that region, while west of the river the product flows into ruminant diets (usually fed wet).

- Potential Changes to the Nutritional Value of DGS as Corn Hybrids are Formulated to Maximize Ethanol Yield
  - Fred Owens noted that a 10% increase in ethanol yield would decrease the DDGS yield, for example, from 17 lb/bu to 15 lb/bu. However, the energy value of the DDGS (in BTU/lb) under the higher ethanol yield case would be greater because the fraction of oil would be greater. Corn hybrids might also impact the protein content of DGS.
  - A related issue is the impact on DGS feeding value under processes that remove corn oil (e.g., to use as a feedstock for biodiesel). Fred Owens noted that the removal of fat from DGS will reduce its feeding value.

<u>Issues Related to > 1:1 Displacement Ratios</u>

Steve Kaffka introduced this issue by noting the dynamic character of the animal feed market and how regionally specific it is. In the real world, feed ingredients reflect what is available locally, and the least-cost diet may not be the optimum diet. This led to lengthy and wide-ranging discussion of issues related to displacement ratios. Individual comments are captured below, followed by a summary of key points.

<u>Individual Comments</u>

Richard Zinn

- Feedlots strive for the least-cost ration, and costs will determine how much of various ingredients get included. DGS could be higher in fat/protein so it will displace other feed ingredients. Low inclusion vs. high inclusion rates is based on relative cost.
- Important to realize that certain feed ingredients may be more acceptable to animals and an increase in rate of gain could be a result of increased acceptability and efficiency of the diet. For example, wet DGS may have a positive effect when added to dry diets.
- Fat and protein may be lacking in some diets because there are no local options for adding fat and protein to the ration. DGS overcomes some of these deficiencies when added to the diet and there are no other local/economical fat sources.
- All DGS and soy bean meal (SBM) will be used in the animal feed market; prices will clear these products from the market. DGS is less per lb. of feed corn, so it is used. Upper limit of inclusion rates will be based on economics or excretion of some compounds (e.g., phosphorus or nitrogen).

- DGS is still new enough in the market that it is considered a byproduct feed and sells at a discount relative to feed corn; it is not appreciated for its full nutritional value.
- One of the biggest concerns about DGS is contamination (e.g., salmonella). Moisture is an issue, even with dry DGS, and that leads to constraints on its use. There are practical issues with its use as well, such as handling, which again results in a discounted price relative to feed corn.
- The nutrient value of DGS is not the issue; comparative analysis is the issue. The control diets in feed studies may not have been optimal.

Kirk Klasing

- There is a fundamental problem with a ratio > 1:1. Nutritionists strive for optimal growth rates given a set of feed ingredients. If a > 1:1 ratio is observed, the base diet was not optimal due to economics and available ingredients.
- If nutrition and palatability can be improved, that means the starting point was non-optimal.
- Animal diets are very regional specific and may change as new biofuels (and resulting co-products) are introduced to the market.
- Because of the variables involved, suggests a 1:1 displacement ratio. There can be regional situations where the ratio can be >1:1 as well as situations where it can be <1:1.
- The price of DGS is less than corn, so nutritionists value it less. Variability in DGS contributes to the price discount relative to feed corn. However, as more poultry are fed, the price is likely to increase because DGS displaces the more expensive SBM.
- Control diets in animal feed studies are often not very realistic from a real-world perspective.
- DGS displaces SBM for poultry and that industry is starting to use a lot of DGS. However, the nutritional value of DGS is lower than for SBM, so when DGS is sufficiently cheap growers accept a lower weight gain and keep the animals longer.

Fred Owens

- DGS has an 8% greater energy value relative to corn grain for ruminants. As fat is removed (e.g., by corn oil removal), DGS can drop to 90% of the energy value of corn grain. Addition of DGS may make a diet more optimal because of the fat content in the DGS.

Steve Kaffka

- LCA is based on averages, while the feed market is regional and variable. DGS provides better nutrient value than corn grain, but the reality on the ground is site-specific.
- Site-specific issues are key to accurately reflecting the animal feed market, but the LCFS regulation needs a point value which misses important variables.
- If there are regional differences in the feed market and use of DGS, those should be accounted for.
- Dr. Kaffka offered three options for evaluating biofuel co-product feeds in the LCFS:
    1. Baseline close to what ARB is currently using (i.e., 1:1 ratio), which assumes no significant improvement in animal performance with DGS.
    2. Baseline similar to that recommended in the recent Argonne paper, which may be a better representation of real-world performance.

3. An improved Method 2B procedure that would be more dynamic and would allow biofuel producers to suggest alternative co-product credits estimates that are more applicable to their region and how their co-products are used in the animal feed market.

Don O'Connor

- Although there are some uncertainties in the data and analysis, the top-down analysis that he prepared gives some indication of what has been displaced by DGS (i.e., energy vs. protein feeds).
- The DGS supply was doubled in a short time, which has contributed to its discounted price relative to feed corn.

Kip Karges

- Variability in DGS is an issue, but it comes down to consistency within an ethanol plant, which is a point of focus every day. The value/price relationship will come together over time.

John Courtis

- ARB must assess DGS credit based on current conditions. They recognize that some issues are dynamic, and they have committed to revisit those periodically.

Key Points from Displacement Ratio Discussion

- As noted in previous meetings and this meeting, feed rations are highly regionally specific and are critically dependent on economics. Rations are optimized to reflect the best animal performance from the lowest price ingredients. Economics often dictate that animal rations are not perfect from a nutritional perspective (i.e., it may be more economical to feed a lower cost, less nutritious ration and keep the animal in the feedlot for a slightly longer period of time).

- For equivalently formulated/balanced rations (i.e., equivalent protein, fat, energy content, etc.), there is no reason to expect improved performance from DGS relative to other feed ingredients.

- In the real world, an increase in animal performance could be observed when DGS is added to rations if the original/baseline ration was less than optimal. This can occur, for example, if the baseline ration is lacking in fat and there are no local economical sources of fat to add to the diet. In this case, fat "comes along for the ride" in the DGS and may result in improved animal performance.

- Real-world DGS displacement ratios are not necessarily greater than 1:1. For example, DGS from processes that remove corn oil could have a lower caloric value than feed corn, and if DGS displaces SBM in poultry rations without added fat in the diet, animal performance could suffer (but may be accepted by the feedlot, integrator, or enterprise because of economics).

- There are a number of reasons for the price discount of DGS relative to feed corn:
    - > New product on market, so it is not fully valued for its nutritional value – still considered a byproduct.

> Supply has increased significantly in recent years, keeping prices low.
> Variability in DGS is an issue for all animal species.
> There are handling and other risks (e.g., moisture) associated with DGS that are not present with feed corn.

<u>Comments on Argonne's Recent Re-Assessment of Displacement Ratios</u>

There were a number of comments on Argonne's re-assessment of displacement ratios for their GREET model:

- Steve Kaffka noted it was a good piece of work but market dynamics were not factored into the estimates.
- Fred Owens noted that the heating values of DGS will change as the fat content changes, whereas Table 4 of the paper assumes the same energy value for dry DGS, wet DGS, de-oiled DGS, and high-protein DGS. Dr. Owens followed up after the meeting with an email and spreadsheet that re-calculated the energy values based on the fat content shown in Table 4 of the paper. Dr. Owens went on to say:

  Based on caloric content alone, I believe that the displacement value for energy from DDGS relative to corn grain can INDEED be greater than 1, though on an energy basis alone, a displacement value for corn grain above 1.12 would not be expected unless fat content of DDGS exceeds 11.2%. Few cattle feeding trials comparing DDGS and WDGS with corn grain have added fat to make diets isocaloric. To properly account for the increased energy content of DDGS relative to corn grain (for the extra energy being provided by the fat in DDGS), control diets should have contained added fat. Displacement for energy plus protein then actually should include replacing three components – corn plus fat plus protein. Alternatively, if corn is providing energy to substitute for added fat, some additional corn will be needed. That can easily give a displacement ratio of DDGS for corn grain plus protein that will exceed 1:1.
  [Note that the above is for beef cattle and not for swine or poultry, which cannot use the fiber.]

- Kirk Klasing noted that the displacement ratios presented in Table 5 for poultry gives an overall ratio slightly greater than 1:1 (i.e., 0.552 corn + 0.483 SBM). However, this does not account for the fact that fat must be added to the diet when DGS displaces SBM. Fat is the biggest issue, but other nutritional components must be added (e.g., lysine, tryptophan, etc.) must be added, and when all components are summed, the ratio will be close to 1:1.

- Richard Zinn noted that the 1:1.2 ratio of DGS displacing feed corn in beef cattle rations shown in Table 5 is too high and one cannot realistically say it is more than 1:1. Dr. Zinn said that this depends on how the feed corn is processed (steam-flaked versus dry-rolled) and potential problems with the control diets in the studies upon which this was based (as discussed above).

Comments on Methods of Dealing with Biofuel Co-Products in Life Cycle Analysis

There was a short discussion of the Wang et al. paper on methods of dealing with biofuel co-products:

- Kirk Klasing noted that he was partial to economic allocation because it better reflects the market. He also said that weight was an issue for SBM, which has a high fiber content that is not utilized by the animal. Phil Heirigs noted that economic allocation has some appeal because it is more consistent with the economic models used to assess land use change.

- Don O'Connor said that all methods have advantages and disadvantages. He noted that the EU has settled on allocation by energy, not because it is the best result, but because it has the fewest unintended consequences. He also stressed the need to get as close to ISO guidance as possible. If one is not consistent with that guidance, need to fully understand the consequences of not being consistent.

- John Courtis echoed Don's comment that all methods have issues, and there is no clear-cut approach. He noted that allocation by economic value can be problematic because of the potential for price volatility.

Appendix B

Top-Down Assessment of DGS Displacement Ratios
Prepared by Don O'Connor, (S&T)[2]

Feed Usage Data – Co-Product Substitution Rates

The lack of data on the feed grain and DDG usage has been identified as an impediment to determining the proper treatment of corn ethanol co-products in the direct and indirect modelling efforts undertaken by CARB. There is some data that is publicly available from the USDA on feed grain usage in the US livestock sector (http://www.ers.usda.gov/data/feedgrains/Table.asp?t=29). The most recent portion of this data is shown in the following table.

Table 1 USDA Feed Consumption Data

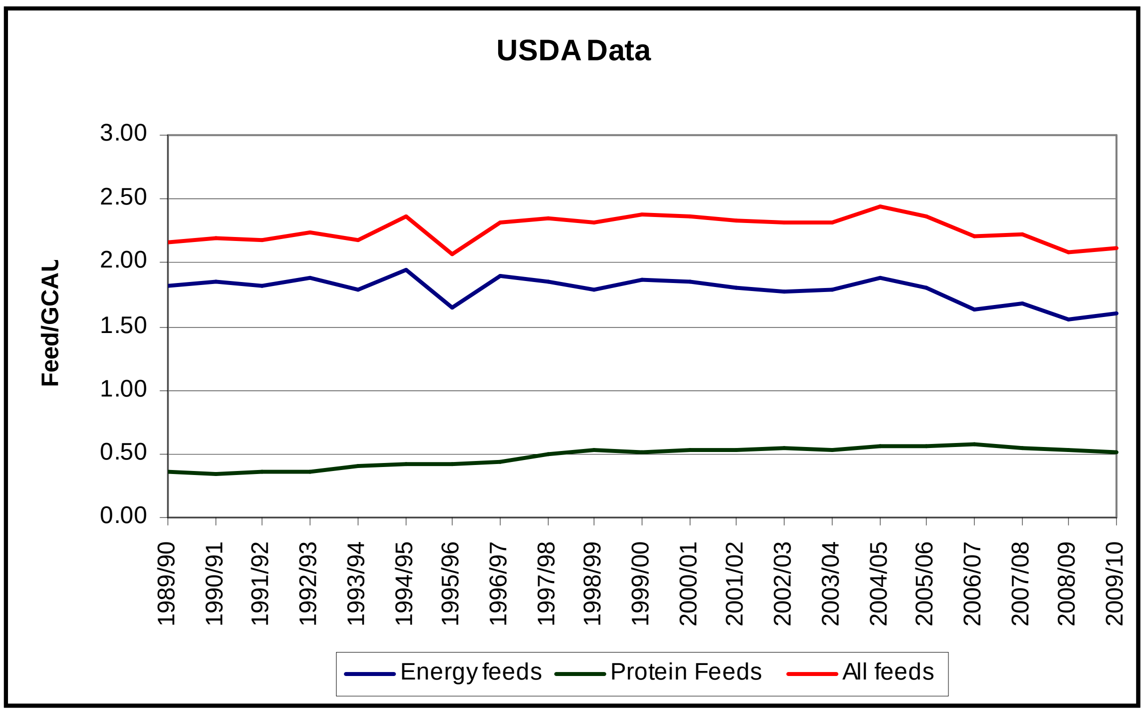
		2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
		1,000 tonnes									
Energy feeds	Corn	147,887	148,565	140,934	146,850	155,838	155,330	140,726	148,793	132,220	136,531
	Sorghum	5,652	5,843	4,328	4,623	4,859	3,548	2,868	4,188	5,896	3,429
	Barley	2,350	2,102	1,999	1,723	1,428	1,041	1,360	911	990	1,130
	Oats	2,946	2,250	2,518	2,279	2,215	2,137	2,088	2,024	1,977	1,757
	Wheat	5,999	3,500	6,700	4,121	4,850	2,720	4,601	4,133	3,402	4,466
	Total energy feeds	164,833	162,259	156,479	159,596	169,190	164,776	151,643	160,049	144,485	147,314
Oilseed meals	Soybean meal 2/	28,706	30,001	29,357	28,530	30,446	30,114	31,186	30,148	27,890	27,216
	Cottonseed meal	2,590	3,030	2,441	2,527	3,133	3,044	2,766	2,349	1,631	1,551
	Rapeseed (canola) meal	1,519	1,247	1,244	1,883	1,869	2,018	2,030	2,373	2,296	1,939
	Linseed meal	178	112	161	179	187	244	250	190	117	148
	Peanut meal	100	131	161	111	86	106	108	105	93	84
	Sunflower meal	450	358	232	317	133	278	323	311	324	308
	Total oilseed meals	33,543	34,879	33,598	33,546	35,855	35,804	36,663	35,476	32,350	31,247
Animal-protein feeds	Meat and bone meal tankage	1,925	1,750	1,721	1,906	1,984	2,062	2,154	2,147	2,064	2,018
	Fishmeal and solubles	214	255	234	186	172	187	194	178	203	181
	Milk products	275	227	393	339	243	225	285	325	227	227
	Total animal-protein feeds	2,413	2,232	2,349	2,431	2,399	2,475	2,634	2,651	2,493	2,427
Grain-protein feeds	Corn gluten feed and meal	1,299	1,338	2,064	2,197	2,625	3,187	4,194	4,137	4,687	4,019
	Total grain-protein feeds 3/	1,299	1,338	2,064	2,197	2,625	3,187	4,194	4,137	4,687	4,019
Other byproduct feeds	Wheat millfeeds	6,647	6,257	6,287	6,155	6,131	6,203	6,218	6,119	5,929	5,987
	Rice millfeeds	627	618	628	543	558	592	497	511	628	522
	Fats and oils	1,195	1,228	1,222	1,310	1,448	1,427	1,354	1,301	1,083	1,184
	Miscellaneous byproduct feeds 4/	1,490	1,506	1,521	1,536	1,552	1,567	1,583	1,588	1,592	1,597
	Total other byproduct feeds 5/	9,959	9,609	9,658	9,544	9,690	9,789	9,652	9,518	9,232	9,290

Total		212,048	210,317	204,147	207,314	219,758	216,031	204,786	211,831	193,248	194,296
	GCAU 6/	89,437	89,771	88,236	89,438	90,143	91,490	92,749	95,118	92,748	91,637

1/ Adjusted for stocks, production, foreign trade, and nonfeed uses where applicable. Latest data may be preliminary or projected.
2/ Includes use in edible soy products and shipments to U.S. territories.
3/ Excludes brewers' dried grains and distillers' dried grains due to unavailability of production data.
4/ Includes hominy feed, oat millfeeds, and screenings.
5/ Excludes dried beet pulp, molasses beet pulp, and inedible molasses due to unavailability of production data.
6/ GCAU = Grain-consuming animal unit. Total is calculated from Data.
Source: USDA, World Agricultural Outlook Board, World Agricultural Supply and Demand Estimates; U.S. Department of Commerce, Bureau of the Census, Fats and Oils: Production, Consumption, and Stocks (M311K), Flour Milling Products (MQ311A), Flour Milling (EC02-311-311211), and Wet Corn Milling (EC02-31I-311221); U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Fishery Market News; Rice Millers Association; Whey Products Institute; and ERS calculations of feed per GCAU.

This dataset is not perfect but it does provide some evidence of what feeds are consumed and trends in the consumption of feed. The raw data from this shown in the following figure.

Figure 1 Feed Usage Trends



This figure does clearly show that in recent years (2004 onwards) the apparent feed consumption per grain consuming animal unit has been reduced. This of course coincides with the increased availability of ethanol plant co-products.

Two of the main issues with this dataset are:

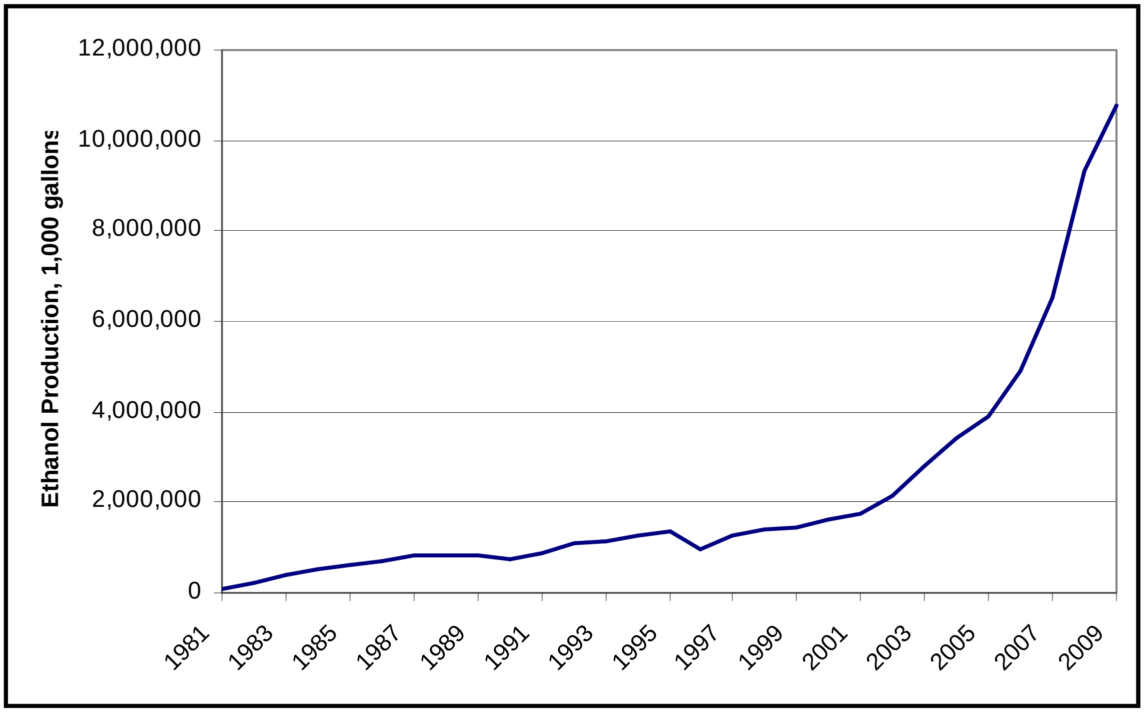
1. DDG from fuel ethanol plants and co-products from wet milling fuel plants are not included, although co-products from wet milling plants producing food products are included.
2. Feed usage is not typically measured but it calculated from production and other measured disappearances. This means that there can be some year to year variability due to harvest timing. Each of the feedstuffs also has a slightly different starting point for the year.

Little can be done about the second drawback with the data but estimates can be made for the missing DDG information.

The quantity of DG produced can be estimating from the quantity of ethanol produced. There are estimates of the quantity of DDG that is exported and therefore the quantity of DG consumed can be estimated from the difference of the two values.

Ethanol production data is available from the US DOE Energy Information Administration (http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=M_EPOOXE_YOP_NUS_1&f=M). This information is shown in the following figure.

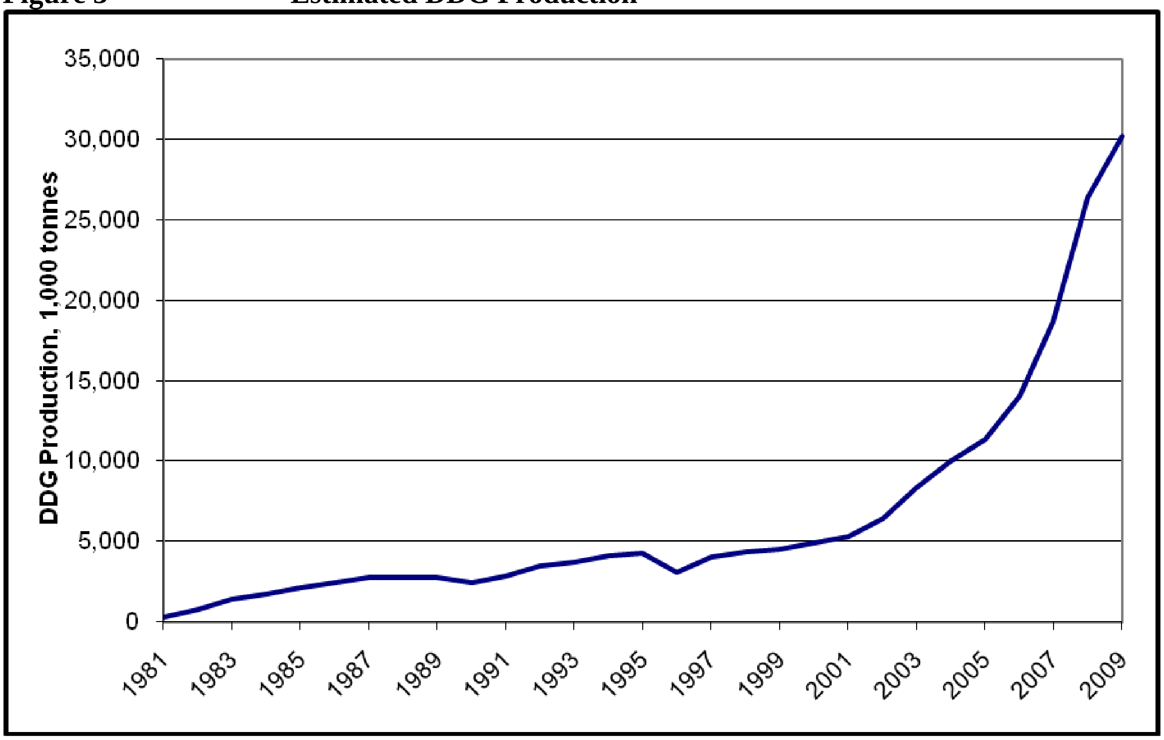
Figure 2 **US Ethanol Production**



Most ethanol (>80%) is produced via the dry mill process where distillers grains is the co-product but some is made using the wet mill process where a larger number of co-products are produced, the two most important from a feed perspective are corn gluten meal and corn gluten feed. Since most of the wet mill co-products are used for feed, it will be assumed that estimating the co-products based on the dry mill process will give a reasonable estimate of the total co-products available.

Over time, the ethanol yield from corn has improved slightly as plants become more efficient and also as corn starch contents have increased. It is assumed that the ethanol yield in 1980 was 2.6 gallons/bushel and in 2009 it was 2.8 gallons/bushel, with a linear trend over that 30 year period. The DDG yield will move the other way, as increased ethanol yield will produce less DDG. When the DDG rate is calculated based on ethanol production the trend is more pronounced since over time less DDG and more ethanol have been produced from the same quantity of corn. The factors are that in 1980, 7.7 pounds of DDG were produced for every gallon of ethanol manufactured and in 2009, the factor is 6.2 pounds/gallon. It is assumed that the trend has been linear during this time period. The estimated DDG production is shown in the following figure.

Figure 3 Estimated DDG Production



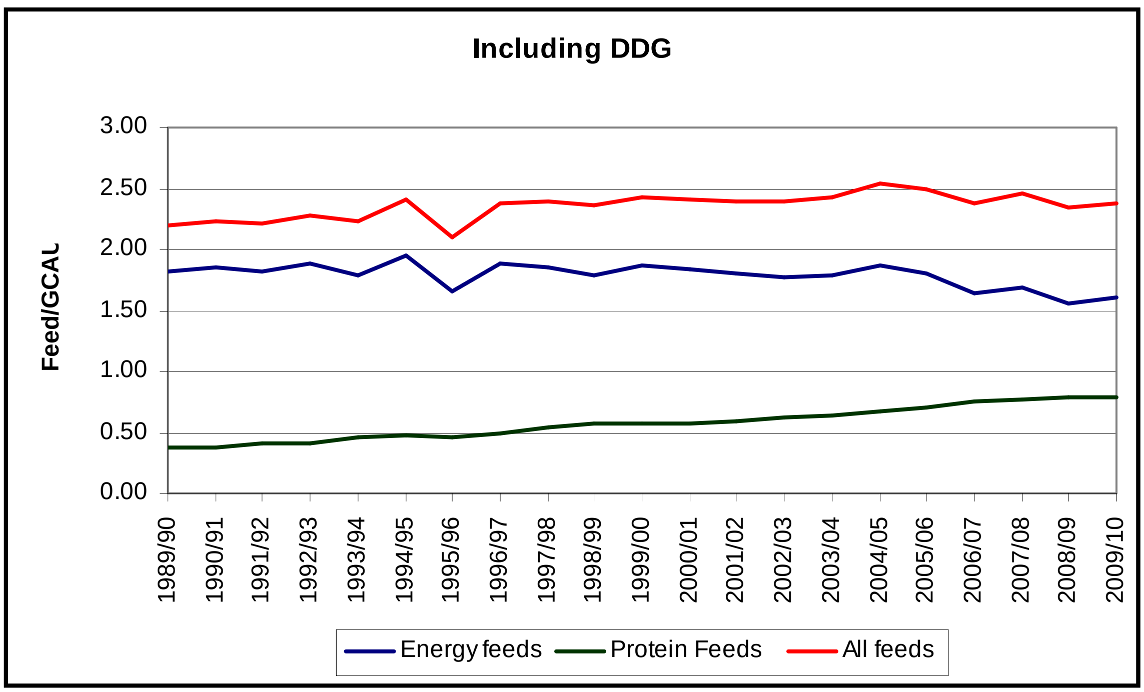
In recent years, increased quantities of DDG have been exported from the United States. Export data from the USDA Fatus system has been extracted (http://www.fas.usda.gov/gats/ExpressQuery1.aspx). The following table summarizes DDG production exports and implied consumption over a ten year period.

Table 2 **Calculated DDG Production and Use**

Year	DDG Production	DDG Exports	Apparent DDG Consumption
	1,000 tonnes		
1999	4,475	715	3,760
2000	4,916	808	4,108
2001	5,306	797	4,509
2002	6,382	842	5,540
2003	8,294	742	7,552
2004	9,980	788	9,192
2005	11,358	1,069	10,288
2006	14,090	1,254	12,836
2007	18,653	2,358	16,295
2008	26,400	4,532	21,868
2009	30,250	5,641	24,609

When this DDG consumption is included in the feed usage data from the USDA, the trends of consumption per GCAU are more consistent and there is no significant trend to improving feed efficiency.

Figure 4 **Feed Consumption Including DDG**



The feed consumed per GCAU is now much more uniform and there is no apparent trend to improved feed consumption. There is an increase in protein consumption since this is where the DDG is added into the table.

Using the revised dataset, a comparison of the three year average feed consumption in 1999-2002 (to reduce year to year variability in the feed estimates) to the most recent year of data (2009) can be made. The 1999-2002 data was normalized to the same number of GCAU as the recent dataset (although there is very little increase in GCAU over this time period) and then the change in energy feeds and other low protein by-product feeds (mostly corn) and protein feeds (mostly soybean meal) was compared to the increase in DG use. The results were that for every unit of DG used, the energy feeds decreased by 1.12 units and the protein feeds decreased by 0.12 units, for a total reduction of 1.24 units of feed for every unit of DG consumed.

The results from the analysis of the data would indicate that DG is displacing both corn and soybean meal in the rations. Co-product methodology that assumes that DG displaces only corn underestimates the value of the DG in both direct and indirect analyses. The quantity of grains displaced is greater than the quantity of DG consumed. There are two possible reasons for the later point. The first is that feed efficiency is improved in the animal and there is documented evidence from numerous feed trials that show that this is the case. The second is that there is some evidence from feed trials supported by reports from the field that the combination of DG and roughage (corn stover, cereal straw, low quality forage) is being used to displace higher quality energy feeds. To the degree to which this forage is a "co-product residue" then it has no land use impact and the way that this would be treated in direct analysis would depend on the co-product allocation method used.

The other interesting fact from the data is that feed usage in the livestock sector in the United States is static and is not significantly different than it was 15 years ago. Feed production has increased significantly over this time period and would have resulted in growth in exports, had biofuel markets not grown.

Appendix C

Major Variables in DGS Replacement Ratios
Prepared by Kip Karges, POET

Major Variables in Replacement Ratios

I. Market Share for DDGS

a. Shurson – (42% Dairy, 38% Beef, 14% Swine, 6% Poultry); Room for expansion in swine and poultry market

b. Observed Industry Ranges (POET): Dairy 30-42%; Beef 8-42%; Swine 11-20%; Poultry 5-42%

II. Replacement ratios

a. *Beef feedlot* -- 99 corn:1 protein, urea SBM etc. On average a 30% percent inclusion in diet with 125% the feeding value of corn

b. *Dairy cows* – 80 corn: 20 protein, SBM Canola Meal, Sunflower Meal, Cottonseed meal: an average inclusion in diet of 12%

c. *Swine* – 68 corn:32 SBM; average inclusion of 17% with an equal energy value of corn

d. *Poultry* – 52 corn: 48 SBM; average inclusion of 9% with an energy value of 80% of corn

III. DDGS Inclusion Rates per Species

a. Shurson – Lactating Dairy Cattle (Up to 30%); Beef Feedlot Cattle (Up to 40%); Swine Grower-Finisher (Up to 30%), Poultry (Up to 15%)

b. *Observed Industry Inclusion Rates (POET):* Dairy cows - range 10 to 15% on a dry matter basis

i. Beef Finishing cattle – for WDG on a dry matter basis 30 to 40 % for DDGS on a dry matter basis 20 to 30%

ii. Swine – grow/finish rates of 15 to 25%

iii. Poultry- Layers 10 to 15% and Broilers 7 to 12%

IV. Composition of Feed DDGS Replacement

a. Nutritional Value of DGS varies as a function of extent of fermentation, amount of solubles added to DGS, oil removal, sulfur use

b. Also the type and functionality of drying system used by plants is critical in determining digestibility of key amino acids such Lysine, Methionine, Threonine, Cysteine, Iosleucine. Through the development of new technologies and more consistent plant production has allowed for high quality DDGS penetration into the monogastric sectors.

i. Soy-Bean Meal replaced

ii. This predominantly occurs in monogastrics especially in poultry diets.

Parsons, C. M., and D. H. Baker. 1983. Distillers dried grains with solubles as a protein source for the chick. Poult. Sci. 62:2445–2451.

V. Dry-Rolled vs. Steam-Flaked corn

a. Animal performance varies for DDGS and WDGS when fed with dry rolled corn or steam flaked corn. In a recent meta-analysis of 9 experiments, where various levels of wet DGS were fed to feedlot cattle, wet DGS produced higher average daily gain (ADG) and higher average gain to feed ratios (G:F) when compared with cattle fed corn-based diets without DGS. In a similar analysis dry DGS showed similar type of response but with lower feeding value for dry DGS compared with wet DGS. Metabolic studies suggest the fat in DGS may be partially protected from ruminal degradation leading to greater proportion of unsaturated fatty acids reaching the duodenum resulting in greater total tract fat digestibility. Both the fat and the undegradable protein in DGS appear to explain some but not all of the greater feeding value of DGS compared with corn (Klopfenstein et al., 2008).

b. The greater energy value of WDGS compared with dry-rolled corn (DRC) or high-moisture corn (HMC) has been reported (Ham et al., 1994; Lodge et al., 1997a; Klopfenstein et al., 2008). Stock et al. (2000) suggested that the greater energy value of WDGS may be due to controlling sub-acute acidosis, greater fat content, or overall increased energy utilization. Lodge et al. (1997b) fed fat or protein with wet corn gluten feed (WCGF) to mimic distillers grains and observed that G:F was slightly reduced when either fat or protein were removed, which suggest that fat contributes to the higher energy value of WDGS.

c. The fat content of WDGS is roughly 3 times that of the grain from which it was derived (Klopfenstein et al., 2008), with fat providing more energy than other nutrients (Zinn, 1994). Additionally, free unsaturated fatty acids that enter the rumen are subject to biohydrogenation (Russell, 2002), with duodenal flow of fatty acids being comprised mainly of saturated fat. Absorption of fatty acids is dependent on the formation of micelles, with unsaturated fatty acids forming micelles with a greater surface area, allowing more efficient utilization (Zinn et al., 2000). It is plausible that fat within WDGS may be partially protected from complete biohydrogenation, allowing an increased flow of unsaturated fatty acids to the duodenum, which can then be utilized by the animal more efficiently.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246–3257.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997b. Evaluation of wet distillers composite for finishing ruminants. J. Anim. Sci. 75:44–50.

Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. BOARD INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223–1231.

Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. 2000. Review of new information on the use of wet and dry milling feed by-products in feedlot diets. J. Anim. Sci.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997a. Evaluation of corn and sorghum distillers byproducts. J. Anim. Sci. 75:37–43.

Zinn, R. A. 1994. Effects of excessive supplemental fat on feedlot cattle growth performance and digestive function. Prof. Anim. Sci. 10:66–72.

Zinn, R. A., S. K. Gulati, A. Plascencia, and J. Salinas. 2000. Influence of ruminal biohydrogenation on the feeding value of fat in finishing diets for feedlot cattle. J. Anim. Sci. 78:1738–1746.

VI. Forage Information (Alfalfa acreage, Hay Acreage)

a. Supplementation with dried distillers grains (DDG) can increase ADG and reduce forage intake in cattle consuming both high- and low-quality forages (Morris et al., 2005). There appears to be an additive response to both protein and energy supplementation in forage-fed cattle (Corrigan et al.,2009). Results also indicate that roughage levels can be reduced in feedlot diets containing 25% DDG with no adverse effects on BW gain, feed efficiency, or carcass quality (May et al., 2010; Uwituze et al., 2010). Researchers have determined that for every 1 lb of DDGS supplemented to cattle grazing pasture the forage replacement rate0.76 lbs or reduced forage intake which can result in huge economic savings for the producer as more lbs of beef can be produced on fewer acres (Griffen et al., 2009).

Morris, S., Klopfenstein, T. & Adams, D. 2005. Effects of dried distillers grains on heifer consumption of low or high quality forage. J. Anim. Sci. 82(Suppl. 2):52.

M. E. Corrigan, T. J. Klopfenstein G. E. Erickson, N. F. Meyer, K. J. Vander Pol, M. A. Greenquist, M. K. Luebbe, K. K. Karges and M. L. Gibson. Effects of level of condensed distillers solubles in corn dried distillers grains on intake, daily body weight gain, and digestibility in growing steers fed forage diets. 2009. J. Anim Sci. 2009. 87:4073-4081

M. L. May, M. J. Quinn, B. E. Depenbusch, C. D. Reinhardt, M. L. Gibson, K. K. Karges, N. A. Cole, and J. S. Drouillard Dried distillers grains with solubles with reduced corn silage levels in beef finishing diets J Anim Sci 88: 2456-2463.

S. Uwituze, G. L. Parsons, M. K. Shelor, B. E. Depenbusch, K. K. Karges, M. L. Gibson, C. D. Reinhardt, J. J. Higgins, and J. S. Drouillard. Evaluation of dried distillers grains and roughage source in steam-flaked corn finishing diets J Anim Sci 88: 258-274.

W. A. Griffen, V.R. Bremer, T.J. Klopfenstein, L. A. Stalker, L.W. Lomas, J.L. Moyer, and G.E. Erickson. 2009. Summary of grazing trials using dried distillers grains supplementation. UNL-Beef Report: 37-39.

b. Predictions of the impact on Corn Co-Products (DDGS) after new technologies (i.e. Front End Fractionation and Back End Oil Extraction)

   i. These new processes will impact co-products in a variety of ways from a nutrient perspective (Robinson et al., 2008; Tedeschi et al., 2009). Poet's front end fractionation has resulted in the development of new products: HP-DDG (High protein distillers grains), corn germ dehydrated, and corn bran. Each of these fit into a variety of different species markets. The HP predominantly flows into monogastrics replacing soybean meal and to an extent the Dairy industry will also us HP for a protein replacer in diets (Hubbard et al., 2009). Corn germ is a high protein, high energy feed ingredient used heavily in poultry for a replacement of corn in diets. It also has been used an alternative fat source in dairy cow diets (Abdelqader et al., 2009) Corn Bran is strictly used in ruminant diets where in dairy cows it can be used as a roughage replacement (Janicek et al., 2007). In Beef finishing and growing diets it has been shown that corn bran can replace corn directly at up to 40% inclusion levels with no loss of performance (Buckner et al., 2007; Larson et al., 2007).

ii. Oil extraction effects on co-products has yet to be evaluated in terms of animal performance. Initial results indicate that a higher protein and lower fat DDGS would be of lower economic and animal performance value as compared to current DDGS in the animal sectors which it is normally fed to.

Hubbard, K.J., P.J. Kononoff, A.M. Gehman, J.M. Kelzer, K. Karges, and M.L. Gibson. 2009. The effect of feeding high protein distillers dried grains on milk production of Holstein cows. J. Dairy Sci. 92:2911-2914.

Janicek, B. N., P.J. Kononoff , A.M. Gehman, K. Karges, and M. L. Gibson. 2007 Effect of increasing levels of corn bran on milk yield and composition. J. Dairy Sci. 90: 4313-4316.

Abdelqader, M.M., A.R. Hippen, D.J. Schingoethe, K.F. Kalscheur, K. Karges, and M.L. Gibson. 2009. Evaluation of corn germ as an alternative fat source in dairy cow diets. J. Dairy Sci. 92: 1023-1037.

Robinson, P.H. K. Karges, M. L. Gibson. 2008. Nutritional evaluation of four co-product feedstuffs from the motor fuel ethanol distillation industry in the Midwestern USA. J. Anim. Feed Sci. and Technol. 146:345-352.

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Buckner, C. D. T. J. Klopfenstein, G. E. Erickson, K. J. Vander Pol, K. K. Karges, and M. L. Gibson. 2007. Characterization of a modified dry distillers byproduct and dry distillers grains for use in growing beef cattle. J. Anim. Sci. Vol. 85 Suppl. 2:131

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VII. Performance Rates per Species

a. High variability of DDGS is concern; Different DDGS make-up could mean different performance

i. Acceptable growth performance achieved by adding up to 30% DDGS in diets for nursery pigs and grower-finisher pigs; Dietary inclusion of up to 50% DDGS in gestation diets and up to 30% in lactation diets does not affect sow and litter performance, and may even increase litter size and improve reproductive performance of the sows

Stein, H.H. and G.C. Shurson. 2009. BOARD-INVITED REVIEW: The use and application of distillers dried grains with solubles in swine diets. J. Anim. Sci. 87:1292-1303.

ii. Feeding WDGS to feedlot cattle is optimum feed use of DGS; DDGS is less beneficial than WDGS or MDGS for beef or dairy cattle; partial drying or complete drying of DGS reduces feeding value and increases GHG emissions relative to WDGS

Studies by Liska and Cassman, UNL (BEEF) [From UNL Banner]

VIII. Manure Composition and Management

a. Information specifics on manure when livestock manure is applied to crop land vs. synthetic fertilizer

   i. Studies have indicated fertilizer value increases as the concentration of N and P increase in the diets of feedlot cattle. Both of these nutrients are found in large concentrations in WDG. When fed to feedlot cattle WDG has been shown to improve the fertilizer value of manure over and above of feeding just a corn based diet. Net back values for manure by itself increased 39% when cattle were fed WDG (Bremer et al., 2009)

   ii. WDG are a common feed ingredient in cattle **feedlot** diets with increased N, P, and S contents relative to cattle nutrient needs. A study by Spiehs and Varel, 2009, indicates that **feedlot** cattle fed increasing amounts of WDG had increased P, N, and S intake and excretion, which may contribute to the production of odorous compounds (primarily long- and branched-chain VFA, and phenol) as well as increased ammonia and H_2S emissions from the **feedlot**. Increased P concentration in livestock waste will increase the amount of land necessary to utilize manure P. Because of increased urinary P excretion, producers should consider environmental implications of liquid runoff from the feedlot surface as well as solid manure when WDGS are fed to feedlot cattle.

V.R. Bremer, T.J. Klopfenstein, G.E. Erickson, R.K. Koelsch, R. E. Massey, J. Vasconcelos. 2009. Effects of feeding wet distillers grains plus solubles on feedlot manure value. UNL-Beef Report: 89-93.

M. J. Spiehs and V. H. Varel. 2009. Nutrient excretion and odorant production in manure from cattle fed corn wet distillers grains with solubles. J. Anim Sci. 2009. 87:2977-2984

b. Manure composition after DDGS is included in diet (i.e. Nitrogen and Phosphorus levels)

    i. Adding DDGS to swine diets seems to have a minimal impact on gas and odor emissions from manure and with the exception of the concentration of phosphorus, the chemical composition is not changed

Stein, H.H. and G.C. Shurson. 2009. BOARD-INVITED REVIEW: The use and application of distillers dried grains with solubles in swine diets. J. Anim. Sci. 87:1292-1303.

Appendix D

Issues Related to GTAP modeling of Soy Biodiesel (Negative Crush Margins)

Prepared by Don O'Connor, (S&T)²

Issues with GTAP Soybean Biodiesel Modeling and Results

There were several issues with the results of the GTAP modeling of soybean biodiesel that was performed for CARB.

1. The system shock was very large, going from the 2001 value of 5 million gallons to 1 billion gallons, a 20,000% increase.
2. The price of soybean meal in the US decreased by 44%, while the price of oil for biodiesel feedstock increased by 14.5% and the price of oilseeds increased by 2.7%. Since the meal makes up 80% of the output, this would result in negative crushing margins, an unsustainable outcome.
3. Even more troublesome is that the price of soybean meal in other regions did not change significantly. A situation that cannot happen with free trade. The following table shows the typical responses to the shock in each of the GTAP regions.
4. The increase in Oilseed area in the US was only 3.7%, yet it drove down the meal price by 44%. This does not seem reasonable.

Region	% Price Change		
	Oilseeds	Crude Veg Oil	Oil meals
1 USA	2.69	14.5	-44.3
2 CAN	0.75	1.4	0.6
3 EU27	0.50	0.5	-0.4
4 BRAZIL	0.58	0.5	0.4
5 JAPAN	0.25	1.1	1.4
6 CHIHKG	0.38	0.4	0.5
7 INDIA	0.18	0.2	0.1
8 LAEEX	0.76	1.0	0.9
9 RoLAC	0.71	0.5	0.6
10 EEFSUEX	0.19	0.1	0.3
11 RoE	0.32	0.4	0.9
12 MEASTNAEX	0.16	0.1	0.7
13 SSAEX	0.30	0.4	-0.5
14 RoAFR	0.33	0.2	0.4
15 SASIAEEX	0.92	0.3	1.3
16 RoHIA	1.08	1.0	1.7
17 RoASIA	0.45	0.3	0.4
18 Oceania	0.81	0.1	1.3

While this version of GTAP has different categories for crude and refined vegetable oils, to differentiate between the food and fuel markets, it is suspected that this is not sufficient to allow for changes in the composition of the oilseed market to utilize the increased meal production. What then happens is that the meals are forced by the model to compete with coarse grains on an energy basis. The only way that it can do this is if the price drops significantly.

In spite of relatively small changes in oilseed prices in countries other than the US, there were still some relatively large land use changes in those countries as shown in the following table. Interestingly, the land change in the US was less responsive to the US price shock than was the land change in Canada, the EU, and Brazil (these four regions account for most of the land use change) to the price changes in each of those countries. This doesn't seem reasonable.

Region	% Price Change Oilseeds	% Land Change	% Land Change/% Price Change
1 USA	2.69	3.70	1.38
2 CAN	0.75	2.59	3.47
3 EU27	0.50	1.49	2.96
4 BRAZIL	0.58	1.25	2.14
5 JAPAN	0.25	0.71	2.84
6 CHIHKG	0.38	0.46	1.20
7 INDIA	0.18	0.09	0.52
8 LAEEX	0.76	0.93	1.22
9 RoLAC	0.71	0.97	1.35
10 EEFSUEX	0.19	0.50	2.59
11 RoE	0.32	0.65	2.01
12 MEASTNAEX	0.16	0.69	4.22
13 SSAEX	0.30	0.95	3.16
14 RoAFR	0.33	0.97	2.95
15 SASIAEEX	0.92	0.55	0.59
16 RoHIA	1.08	0.90	0.84
17 RoASIA	0.45	0.34	0.76
18 Oceania	0.81	1.85	2.30

Questions for Ag Experts

1. What would the feed market response be to an increase in oil meal production of 3.7% be?
2. If there were no oilseed protein available, what would the alternative source of protein be?
3. Is the domestic protein market saturated?

The GTAP modelling of soybean biodiesel is a recent addition to the model. The current CARB proposed value is the third attempt to use GTAP for this sector and it obviously still has issues. The criticism of the first attempt was that "Oilseeds" were a blend of all oilseeds types and it couldn't be used to model soybeans specifically. The second attempt tried to make it soybean specific but it had issues with how the meal was handled. The third version does not appear to be soybean specific.

Appendix E

Issues Related to GTAP modeling of Soy Biodiesel (Land Use Change and Land Type Conversion) Prepared by Don O'Connor, (S&T)^2

Soybean Biodiesel Modelling Results

The latest GTAP model (as used in the July 2010 Argonne work) has been run for soybean biodiesel shock of 0.995 billion gallons. Two scenarios were run, one with soybeans alone and one with a soybean shock modelled on top of a corn ethanol shock. The results for the two scenarios are very different and provide little comfort that the model is producing valid results. The results for the two scenarios using the Group 2 results are described below.

Biodiesel only Scenario

In this case, only the biodiesel shock is modelled. There are three unusual features with this scenario:

1. Almost all of the land use change occurs outside of the United States.
2. The area required for the 2001 to 2006 change is an order of magnitude lower than the subsequent shocks.
3. There is a huge shift of grassland to forestland in the first segment of the shock and that is reversed as the other segments of the shock are modelled.

The results are shown below.

Regional Changes

Changes in US biodiesel production		Land use changes (hectare)			Distribution of land use changes (%)			Hectares per 1000 Gallons
		Within US	Other Regions	World	Within US	Other Regions	World	
2001 to 2006 level	0.141	-11,232	33,546	22,314	-50.3	150.3	100.0	0.158
2006 level to 0.300 B gal	0.154	9,600	225,609	235,209	4.1	95.9	100.0	1.532
0.300 B to 0.475 B gal	0.175	7,664	223,572	231,236	3.3	96.7	100.0	1.321
0.475 B to 0.650 B gal	0.175	9,760	227,194	236,954	4.1	95.9	100.0	1.354
0.650 B to 0.825 B gal	0.175	12,448	234,064	246,512	5.0	95.0	100.0	1.409
0.825 B to 1.000 B gal	0.175	14,816	239,853	254,669	5.8	94.2	100.0	1.455
0.995 BG (2001 to 1.000 BG)		43,056	1,183,838	1,226,894	3.5	96.5	100.0	1.233

Forest vs. Grassland Distribution

Changes in US biodiesel production		Land use changes (hectare)			Distribution of land use changes (%)		
		Forest	Grassland	Crops	Forest	Grassland	World
2001 to 2006 level	0.141	368,195	-390,277	22,314	-1650.1	1750.1	100.0
2006 level to 0.300 B gal	0.154	-164,080	-71,187	235,209	69.8	30.2	100.0
0.300 B to 0.475 B gal	0.175	-142,577	-88,608	231,236	61.7	38.3	100.0
0.475 B to 0.650 B gal	0.175	-137,995	-99,046	236,954	58.2	41.8	100.0
0.650 B to 0.825 B gal	0.175	-137,193	-109,358	246,512	55.7	44.3	100.0

0.825 B to 1.000 B gal	0.175	-137,785	-116,824	254,669	54.1	45.9	100.0
0.995 BG (2001 to 1.000 BG)		-351,435	-875,300	1,226,894	28.6	71.4	100.0

Ethanol and Biodiesel Scenario

This scenario has some of the same unusual features as the biodiesel only case but with differences in the details and in some cases the direction of the change:

1. The US looses cropland through each of the stages of the shock.
2. The area required for the 2001 to 2006 change is two to five times **higher** than the subsequent shocks.
3. There is a huge deforestation in the first stage of the shock and subsequent reforestation in the later stages.

The results are shown below.

Regional Changes

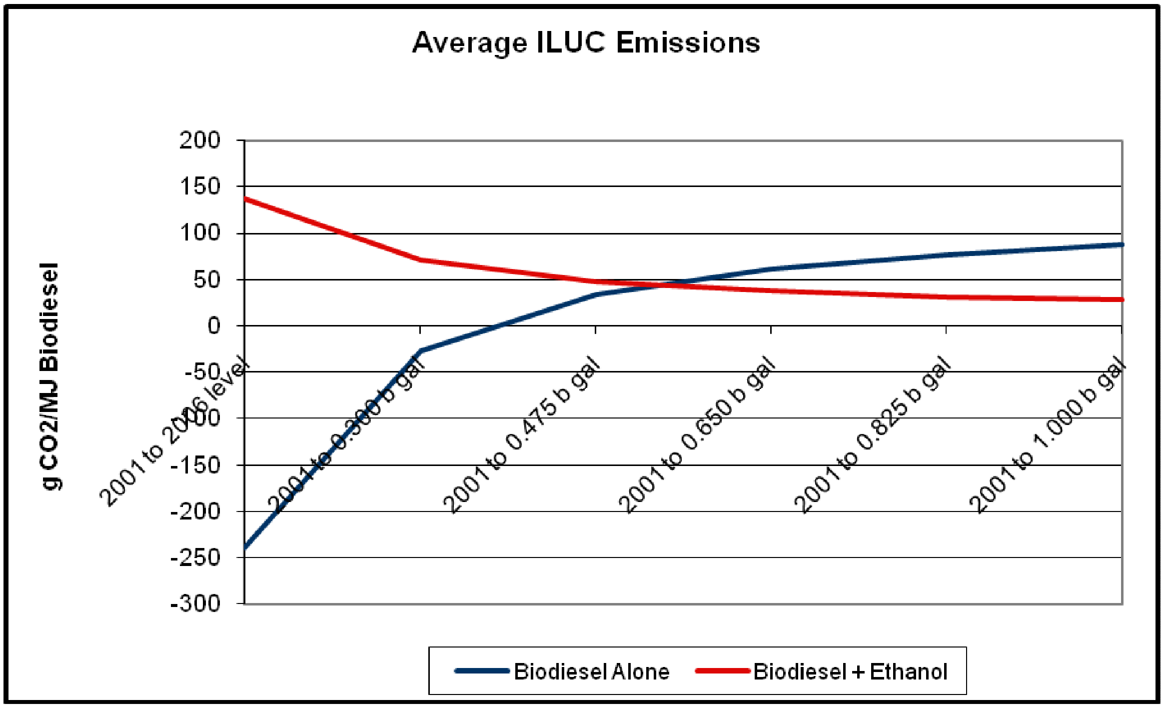
Changes in US biodiesel production		Land use changes (hectare)			Distribution of land use changes (%)			Hectares per 1000 Gallons
		Within US	Other Regions	World	Within US	Other Regions	World	
2001 to 2006 level	0.141	-80	129,359	129,279	-0.1	100.1	100.0	0.914
2006 level to 0.300 B gal	0.154	-9,056	41,745	32,689	-27.7	127.7	100.0	0.213
0.300 B to 0.475 B gal	0.175	-9,264	55,805	46,541	-19.9	119.9	100.0	0.266
0.475 B to 0.650 B gal	0.175	-6,768	63,884	57,116	-11.8	111.8	100.0	0.326
0.650 B to 0.825 B gal	0.175	-4,240	70,945	66,705	-6.4	106.4	100.0	0.381
0.825 B to 1.000 B gal	0.175	-2,128	76,802	74,674	-2.8	102.8	100.0	0.427
0.995 BG (2001 to 1.000 BG)		-31,536	438,540	407,004	-7.7	107.7	100.0	0.409

Forest vs. Grassland Distribution

Changes in US biodiesel production		Land use changes (hectare)			Distribution of land use changes (%)		
		Forest	Grassland	Crops	Forest	Grassland	World
2001 to 2006 level	0.141	-141,892	12,701	129,279	109.8	-9.8	100.0
2006 level to 0.300 B gal	0.154	10,711	-43,442	32,689	-32.8	132.8	100.0
0.300 B to 0.475 B gal	0.175	14,904	-61,326	46,541	-32.0	132.0	100.0
0.475 B to 0.650 B gal	0.175	16,238	-73,357	57,116	-28.4	128.4	100.0
0.650 B to 0.825 B gal	0.175	16,754	-83,465	66,705	-25.1	125.1	100.0
0.825 B to 1.000 B gal	0.175	17,218	-91,914	74,674	-23.1	123.1	100.0
0.995 BG (2001 to 1.000 BG)		-66,067	-340,803	407,004	16.2	83.8	100.0

ILUC Emission Comparison

The ILUC emission results are also very different for the two cases as shown in the following figure.



The soybean results are so different from the corn ethanol results and the two soybean scenarios are so different that there is a high probability that there is an error in the model. This issue needs to be urgently discussed with the GTAP model developers. It is noted that the modellers have acknowledged that there were errors in the previous model use by CARB for modelling soybean biodiesel.