RFA
Renewable Fuels Association

April 17, 2009

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

Dear Chairwoman Nichols,

The Renewable Fuels Association (RFA) respectfully submits the attached comments on the California Air Resources Board's (CARB) Proposed Regulation to Implement the Low Carbon Fuels Standard (LCFS).

As the national trade association for the U.S. ethanol industry, RFA appreciates the opportunity to comment on the information presented in the documentation published March 5, 2009. As you will see in the attached comments, we have prepared detailed remarks about the land use modeling framework, key assumptions, and fundamental approach CARB is using for its current lifecycle analysis of ethanol. We also offer comments on other aspects of the regulation, such as the decision to include corn ethanol in the baseline gasoline formulation.

In general, we continue to believe CARB's analysis of indirect land use change is insufficient. Ongoing scientific discourse and research clearly suggest we are not currently able to estimate indirect land use changes (particularly international land conversions) with an acceptable degree of certainty. Additionally, we continue to believe the Global Trade Analysis Project (GTAP) model employed by CARB for this analysis requires significant refinement and validation before it can be reasonably used in the development of a policy framework such as the LCFS. Our attached comments are quite detailed in this regard, as we have been independently experimenting with the GTAP model and interacting with other GTAP modelers for much of the last year.

Among the major concerns we have with the GTAP modeling used to produce the results presented in the Initial Statement of Reasons are: inconsistency of projected average grain yields and the period of the "shock"; underestimation of the significant land use "credit" provided by distillers grains (the feed co-product of grain ethanol); and assumptions on carbon emissions from converted forest. Several other concerns are discussed as well.

Our attached comments show that GTAP modeling runs with reasonable adjustments to certain assumptions performed by Air Improvement Resource, Inc. results in corn ethanol ILUC emissions in the range of 8 g CO2-eq./MJ. This is significantly lower than CARB's current estimate of 30 g CO2-eq./MJ.

We sincerely appreciate CARB's consideration of these comments and look forward to further interaction with the agency as it continues development of the LCFS regulation. We welcome further dialog and look forward to responses to any of the comments offered in the attached documentation. We will continue to analyze the GTAP model, review the information provided by CARB, and respond with comments as appropriate.

Sincerely,

Bob Dinneen

Bob Dinneen
President & CEO
Renewable Fuels Association

Review of
CARB's Low Carbon Fuel Standard Proposal

April 17, 2009

Prepared for:

RFA
Renewable Fuels Association

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Table of Contents

Review of Low Carbon Fuel Standard
Initial Statement of Reasons (ISOR)

1.0 Summary and Recommendations

The ISOR develops carbon intensity (CI) values for corn ethanol and other biofuels that are the sum of direct emissions and indirect emissions. The direct emissions for corn range from 50 to 69 g CO2 eq/MJ, and the indirect (land use) emissions are estimated at 30 g/MJ. The ISOR also contains a brief analysis of the food versus fuel issue.

Our comments and recommendations focus on four areas: land use change analysis, direct emissions analysis, food versus fuel analysis, and the LCFS baseline. These are further described below.

Land Use Change Analysis

In developing the indirect land use change (ILUC) emissions values, CARB claims to have followed a "fair and balanced process." We concur that CARB followed a fair and balanced process by holding workshops, developing draft materials and encouraging stakeholder input. However, we do not think CARB has arrived at a fair and balanced result; we think the 30 g/MJ is too high based on a number of factors. The following are our overall comments on the corn ethanol ILUC value:

- GTAP is not a mature model for estimating land use changes
- The land use values estimated by CARB do not appear to include a carbon "storage derating factor"
- The biofuels "shock" implemented in GTAP is inconsistent with USDA projected crop yields
- The method used to estimate effects of exogenous yield trends overestimates land use changes
- GTAP co-product land use credits result in overestimation of land use changes
- Other GHG benefits of co-products are ignored (or "still being evaluated")
- Missing land sets in the GTAP database result in extra forest land being converted
- The analysis does not consider relative costs of converting different land types, resulting in overestimation of forest land converted
- Key GTAP model elasticities were "guessed," and are not supported by empirical data
- There is no narrative explanation provided of how the Woods Hole emissions factors are applied to converted lands
- The accounting methods applied to timing of emissions are flawed
- Existing pasture intensification in other countries could further reduce land conversion

We examined factors that would both raise and lower the ILUC value from CARB's estimate. We considered10 factors, that if included (or included at more reasonable levels), would lower overall ILUC emissions. Only two factors (if included) could increase the emissions.

To develop alternative estimates of ILUC emissions, we incorporated the effects of four of these 10 factors that would lower emissions:

- Increased yield elasticity with respect to area expansion
- Improved GTAP U.S. land database analysis
- Improved distillers grain land use credit
- Improved exogenous yield adjustment

The first factor was incorporated by including the change in the GTAP model. The yield elasticity with respect to area expansion range was increased from CARB's assumption of 0.5-0.75 to 0.7- 0.9, based on an analysis by the agricultural economics firm Informa Economics, LLC on area expansion in Latin America that indicated that the elasticity was close to 1.0 in the period from 1988-90 to 2006-2008.

For the improved U.S. land use database, we assumed that only grasslands were converted in the U.S. The current GTAP model used by CARB omits Conservation Reserve Program (CRP) land, idle land, and cropland pasture. If these land types were included in the model, the amount of forest converted would be much lower. CARB included this additional land case in their June 30 workshop results, but it was omitted without explanation from the ISOR.

In our analysis, the improved distillers grain credit was included as an external adjustment. We examined two increases in this credit from the CARB assumption of 33% to 55% and 70%. The 55% is based on 1 lb. of distillers grains replacing 1 lb. of feed where the feed consists of 27% soybean meal and 63% corn (weighted average across all animal types). The sensitivity case using the 70% credit assumes 1 lb. of distillers grains replaces 1.24 lbs. of animal feed. A review of CARB's distillers grain land use credit by Prof. Gerald Shurson from the University of Minnesota, an independent animal science expert, indicates that a displacement ratio of 1 lb. of DG replacing 1.24 lbs. of feed (leading to the 70% credit) is most appropriate.

Finally, for the improved exogenous yield adjustment, we made the adjustment consistent with the year of the ethanol shock used for GTAP (2015). CARB assumed in the ISOR that corn yields in the U.S. were unchanged between 2006-08 and 2015 at about 152 bushels/acre. The USDA projects that corn yields will improve to about 169 bushels/acre by 2015.

Results of this analysis (based on the adjustments explained above) show corn ethanol ILUC emissions of between 4 and 18 g/MJ, with a mean of about 8.2 g/MJ, significantly lower than CARB's 30 g/MJ. Notably, we did not include all of the factors that would reduce ILUC emissions from corn.

Economists from National Economic Research Associates (NERA) also examined CARB's time accounting for ILUC emissions. They determined that the Fuel Warming Potential approaches were arbitrary, and should not be used by CARB. In addition, they recommended that the time accounting for ILUC emissions should include the increasing social cost of carbon, which was omitted from the CARB analysis of time accounting.

Our recommendations on the ILUC issue is to refine the analysis assuming a more balanced and less pessimistic set of assumptions influencing the overall ILUC emissions.

Direct Emissions

We also have concerns with CARB's determination of some of the direct emissions for corn ethanol, and have research programs that are starting to address some of these issues. However, one overarching concern here is that the direct emissions are typically based on agricultural and ethanol production data collected in the 2001-2006 timeframe. CARB selected the baseline year for the LCFS as 2010, and it is very likely many of these inputs will change dramatically from the levels assumed in the CA-GREET model. This will have a significant effect on the direct emissions. Thus, we believe CARB must update the direct emissions analysis to 2010 to be consistent with its chosen baseline year.

Food vs. Fuel

CARB's food versus fuel analysis entirely omitted the significant contribution of distillers grains co-products from ethanol plants. These co-products greatly reduce the land use and food demand impact of corn ethanol. For example, CARB estimates that it takes 110,000 acres of corn to support a 100 million gallon per year ethanol plant. However, on a net basis, after subtracting the land use credit of distillers grain fed to animals, we estimate that impact is closer to 33,000 acres. At 15 billion gallons per year, we estimate the area impact on U.S. cropland at about 4%. This number is likely to go lower with time as yields improve even beyond 2015 due to advancements in seed technology. CARB's food vs. fuel analysis should be updated to account for the contribution of feed co-products and the impact of yield improvements.

LCFS Baseline

The LCFS gasoline baseline includes corn ethanol as well as CaRFG gasoline. As a result, corn ethanol must compete with itself for GHG reductions, as well as with fuels from other feedstocks. CARB should revise the baseline so that corn ethanol is competing fairly with other ethanol feedstocks. This is similar to what CARB has done with biodiesel (i.e. there is no biodiesel in the diesel fuel baseline).

2.0 Introduction

On March 16, CARB released its Initial Statement of Reasons (ISOR) for its proposal for the Low Carbon Fuel Standard. This proposal is scheduled to be considered at a CARB Hearing on April 23-24, 2009. The proposal contains regulations that purport to lower the carbon content of the state's motor fuel (both gasoline and diesel) by 10% in calendar year 2020.

Ethanol made from corn is currently supplying about 4% of the state's car and light truck energy needs (on a BTU basis), and by 2010 , this will expand to about 7%, when it is expected that most fuel providers will provide reformulated gasoline meeting CARB's specifications that contains 10% ethanol by volume.

The LCFS includes estimates of direct greenhouse gas emissions (GHG), and also estimates of indirect land use change emissions for a number of biofuel feedstocks, including corn, sugarcane, cellulose, and soybeans. CARB evaluated four compliance scenarios for 2020. These compliance scenarios rely heavily on the development of ethanol production facilities using forest residue and cellulose. These facilities are yet to be built. In the four compliance scenarios, ethanol from corn represents about 10% of the total ethanol in 2020. In other words, the corn feedstock share of ethanol in California would be expected to decline from 100% in 2010 to 10% in 2020. If the direct emissions of corn ethanol are improved, then this percentage could be higher (however, direct emissions from other feedstocks could also be lowered). But the estimated ILUC GHG emissions from corn ethanol are estimated by CARB to be approximately 33% of the total lifecycle emissions, so even if the direct emissions are reduced significantly, there still remains a significant emissions penalty from the ILUC estimate.

Estimating the impact of biofuels on land use changes is a science in the early stages of development. The author has reviewed the few studies available on this topic in the last year, and has obtained and used Purdue's Global Trade and Analysis Project (GTAP) model, which CARB used to make its land use estimates. The land use numbers can vary widely depending on many highly sensitive input assumptions.

The purpose of this paper is to provide our comments and recommendations on the CARB LCFS proposal. The majority of these comments pertain to corn ethanol. This is because much of CARB's work on ILUC has focused on corn ethanol. Further, corn is the feedstock for more than 95% of U.S.-produced ethanol. However, some of our comments focus on CARB's limited analysis of other biofuel feedstocks.

Our comments are divided into the following sections:

- Background
- Indirect Emissions from Indirect Land Use Change
- CA-GREET Model Values for Corn Ethanol (Direct Emissions)
- Food vs. Fuel
- LCFS Baseline

The first topic presents background information that provides a contextual setting for our comments and recommendations. The second topic is the LCFS baseline. The proposal has corn ethanol in the baseline, which disadvantages corn ethanol more so than other feedstocks since it must compete with itself. In other words, the proposal is not "fuel neutral" as was intended. The section provides numerical examples of the dilemma created by including corn ethanol in the LCFS gasoline baseline, and contains recommendations for a change to the baseline for gasoline only.

The next section contains a discussion of land use issues, which affect the indirect emissions from corn ethanol. The third section covers issues with the direct emissions for corn ethanol from the CA-GREET model. The last section provides our recommendations for modifying the LCFS proposal.

There are four appendices:

Appendix A: RFA's Comments on January 30 ARB LCFS Workshop
Appendix B: Informa's Review of the Exogenous Yield Adjustment
Appendix C: Dr. Gerald Shurson's Distillers Grain Review
Appendix D: NERA's Review of Time Accounting Methods

3.0 Background

3.1 Overview

Through this proposal, CARB has established carbon intensities (CI) for various fuels. The carbon intensities are summarized in Table 1. We have shown the ILUC emissions values separately from the direct emissions. The units for all values in Table 1 are grams of CO2 equivalent (or GHG) per mega-joule (MJ) of fuel (CO2eq/MJ).

Table 1. Carbon Intensity Values for Various Fuels (g CO2eq/MJ)

Fuel	Direct Emissions	Land Use Emissions	Total Emissions
CARBOB gasoline	95.9	0	95.9
Midwestern corn ethanol	69.4	30	99.4
California Low CI ethanol	50.7	30	80.7
CaRFG Baseline fuel	95.9	–	95.9
Cellulosic ethanol	2.4	18	20.4
Forest residue ethanol	22.2	0	22.2
Sugarcane ethanol	27.4	46	73.4
Electricity	34.9	0	34.9
Hydrogen	33.1	0	33.1
Diesel fuel	94.7	0	94.7
Biodiesel-soybeans	26.9	42	68.9
Biodiesel-waste derived	15	0	15
CNG	75.6	0	75.6
Electricity	38.8	0	38.8

There are several items to note. First, the ILUC emissions estimates range from 18 g/MJ (cellulosic ethanol) to 46 g/MJ (sugarcane ethanol)[1]. Second, the direct emissions of the biofuels are lower than gasoline and diesel, but when the land use values are added in, the emissions are much higher. The lowest overall emissions are for cellulosic and forest residue ethanol (20-22 g/MJ) and waste-derived biodiesel (15 g/MJ), but CARB's estimates for these are considered "preliminary" in the ISOR.

The CaRFG baseline fuel is a mixture of CARBOB and 10% corn ethanol, with the ethanol being 80% from the Midwest and 20% from California. In order to meet the 2020 requirement of a 10% reduction, fuel marketers must provide fuel with a 10% reduction from the baseline value of 95.9 g/MJ, which is a CI value in 2020 of 86.3 g/MJ.

It is clear from the above table that one cannot meet the LCFS for gasoline by blending in Midwest corn ethanol with a CI of 99.4 g/MJ. Only by blending in prodigious amounts of cellulosic and forest waste residue ethanol, along with the use of some electricity for plug-in hybrids and/or hydrogen, can the 10% reduction be met for gasoline. The major

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[1] In this report, wherever we indicate g/MJ, it is understood to mean g CO2eq/MJ.

reason why corn ethanol cannot be used is the ILUC emissions value (30 g/MJ). Of course, if corn ethanol plants can reduce their direct emissions from the 69 g/MJ level, then some corn ethanol could be used. But ethanol plants have little to no control over the ILUC number that they are assigned. [2]

Even if direct emissions were cut in half to approximately 35 g/MJ, the total would still be 65 g/MJ with the land use change effect. Therefore, not much corn ethanol can be used to help meet the 2020 LCFS standard. This is the reason why determining the proper land use change emissions values are so critical, and this is a major focus of our comments.

3.2 Further Analysis of Corn Ethanol Land Use Change Emissions

The indirect land use change (ILUC) emissions proposed by CARB are 30 g/MJ. There were seven sensitivity scenarios with different inputs that were used to estimate this value, and the ILUC emissions ranged from 18.3 g/MJ to 44.3 g/MJ. Total land converted ranged from 2.68 million hectares (mha) to 5.48 mha. [3] The U.S. land converted ranged from 1.16 mha to 2.03 mha. For the world, the average (for the seven scenarios) forest converted was 0.86 mha and pasture converted was 3.03 mha. Thus, forest converted was 22% of total land converted and pasture was 78%. However, emissions from forest accounted for (on average) 64% of emissions, and pasture 36% of emissions. It is clear, therefore, that the ILUCs are driven largely by estimated forest converted, even though this represents one-fifth of the estimated converted land by volume.

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[2] As discussed later, CARB is considering allowing yield improvement adjustments to the land use values if they can be demonstrated. But due to flaws in the accounting method, the impact of yield increases is lower than it should be.

[3] There are approximately 2.5 acres in one hectare

4.0 Indirect Land Use Change

4.1 Overview

Estimating GHG emissions related to indirect land use changes has been one of the most difficult parts of this proposal. The reasons for this are that the models used to estimate these changes are still in the early stages of development. The model used by CARB to estimate these changes is the Global Trade and Analysis Project (GTAP) model, developed by Purdue University with input from many others. The U.S. EPA is using a different modeling system for its analysis of ILUC pursuant to the rulemaking process for the Renewable Fuels Standard.

Because the modeling systems are still in the early stages of development for estimating the land use effects of biofuels, AIR conducted a “top-down” study of the potential land use changes associated with 15 billion gallons per year of corn ethanol in 2015.[4] This was done to provide another “reality check” on the modeling efforts. The report was released on February 25, 2009, and is available at www.ethanolrfa.org. This report concludes that the land use requirements for 15 bgy of ethanol from corn in 2015 can be met without converting pasture and forest to crops. The reasons for this are (1) significant yield increases between 2001 and 2015, (2) the U.S. has, maintained exports to other nations of major grains and is expected to continue to do so, (3) the distillers grains produced from ethanol plants are a high quality animal feed (actually, higher quality than the animal feed going into the plant) that replaces much of the land used to produce corn used in the ethanol plants, and (4) the availability of other cropland such as land used previously for cotton and wheat.

The first part of this section discusses many concerns with CARB’s GTAP modeling (4.2). The second part estimates new ILUC emissions for corn ethanol based on modified GTAP modeling. The third part contains our recommendations at this time on indirect land use emissions for corn ethanol.

The work in this section also references additional research performed by three other entities. Dr. Gerald Shurson from the University of Minnesota, a leading animal science expert, reviewed information in the ISOR on the use of distillers grains from ethanol plants. Informa Economics, LLC, reviewed CARB’s exogenous yield improvement methodology and elasticity of yield with respect to area expansion. Finally, National Economic Research Associates (NERA) reviewed CARB’s methods for time accounting of emissions.

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[4] A “top- down” study is a study that looks at overall aggregates of land demand and land supply to determine the necessity of land conversion. A “bottom-up” study estimates land demand and supply from (hopefully) detailed data and equations and interactions between different variables affecting demand and supply. When the two methods don’t agree, one is wrong. When they do approximately agree, there is greater confidence in the result. For example, CARB’s on-road emission model EMFAC has predicted continued reductions in light duty carbon monoxide for the past 20-30 years. This prediction has been validated by trends in ambient carbon monoxide concentrations. The downward trend in ambient CO is a top-down confirmation of the bottom-up trend estimated by EMFAC model.

4.2 Summary of CARB's GTAP Modeling of Land Use for Corn

CARB's indirect land use emissions for corn ethanol are shown in Table 2, which come directly from Table IV-10 in the CARB ISOR (Volume 1). These results were generated by the Global Trade and Analysis Model (GTAP).

TABLE 2. CARB's Table IV-10 from ISOR – LUCs for Corn Ethanol

Scenario	A	B	C	D	E	F	G	Mean
Economic Inputs								
ETOH prod increase	13.25	13.25	13.25	13.25	13.25	13.25	13.25	
Elasticity of crop yields wrt area expansion	0.5	0.75	0.5	0.5	0.5	0.66	0.75	0.59
Crop yield elasticity	0.4	0.4	0.2	0.4	0.4	0.25	0.2	0.32
Elasticity of land transformation	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.2
Elasticity of harvested acreage response	0.5							0.5
Model Results								
Total land converted	4.03	2.68	5.48	4.56	3.01	3.83	3.66	3.89
Forest land	1.04	0.37	1.46	0.89	1.00	0.73	0.55	0.86
Pasture land	3.00	2.32	4.02	3.65	2.01	3.10	3.10	3.03
US land converted	1.74	1.16	2.01	2.12	1.14	1.46	1.32	1.56
Forest land	0.7	0.36	0.82	0.81	0.48	0.46	0.40	0.58
Pasture land	1.04	0.79	1.19	1.31	0.66	1.00	0.92	0.99
LUC carbon intensity (g CO2 eq/MJ)	**33.6**	**18.3**	**44.3**	**35.3**	**27.1**	**27.4**	**24.1**	**30**

The results, shown in the bottom line, show a wide range of effects from 18.3 g/MJ (Scenario B) to 44.3 g/MJ (Scenario C), with an average of 30 g/MJ. ARB explains that:

> "The 30-year annualized value for carbon intensity (30 gCO2e/MJ) differs from the value previously reported by ARB in October (35 gCO2e/MJ). As discussed previously, our current analysis removes the results obtained from the most improbable combinations of input elasticity values by establishing "most reasonable" ranges for these elasticity values. As reflected in the sensitivity analysis, GTAP model output is most sensitive to the *elasticity of crop yields with respect to area expansion*. A major concern expressed about our October result was that the range chosen for this parameter (0.25 to 0.75) extended too low. ARB agreed with this opinion and has excluded all modeling runs for which this elasticity was less than 0.5. Application of these new elasticity criteria reduces the carbon intensity from 35 to 32.9 gCO2e/MJ. The carbon intensity value is further reduced to 30 gCO2e/MJ by applying the external adjustment for increase in corn yield."

Thus, the above estimates are corrected from the January 30 estimates in two ways – the removal of the low elasticity with respect to area expansion values, and for the exogenous yield improvements.

The ISOR goes on to list the acreage requirements for U.S. corn ethanol in its Table IV-19, which is reproduced below in Table 3.

TABLE 3. ISOR Table IV-19

Year	Gallons of Ethanol Produced	Acres of Agriculture Land Required (millions)	Percentage of 2008 Planted Corn Acres
2006	5	11.8	13.8%
2009	10	22.6	26.3%
2015	15	31.8	37.0%

This table assumes 2.8 gal/bushel yield for ethanol, and the implied corn yields are 156.7 bu/acre for 2009 and 168.5 bu/acre for 2015.[5] Unfortunately, the ISOR fails to point out that these are gross acreage requirements, not net requirements after subtracting for a distillers grain land use credit which is included in CARB's GTAP modeling. So the numbers shown above are not very useful for anything other than to communicate the mistaken impression that corn used for ethanol is requiring prodigious amounts of land. We will say more about this later in section 4.2.4.

The ISOR goes on to say that CARB is performing ongoing analyses on corn ethanol, including:

- "The possible inclusion of Conservation Reserve Program Land in the analysis
- The use of improved emission factors, as they become available
- The evaluation and possible use of data and analyses provided by the stakeholders, and
- Characterization in greater detail of the land use types that are subject to conversion by the GTAP model (forest, grassland, idle and fallow croplands, etc.)"

We are pleased that CARB is still open to input from stakeholders, because we have many concerns with CARB's land use analysis, which are discussed in section 4.2.2 through 4.2.13 below. Following this section, we discuss in Section 4.3 modifications we would make to GTAP input and output, and how this would affect CARB's land use results. In Section 4.4, we discuss factors that could increase ILUC emissions. Finally, in Section 4.5 we discuss or recommendations.

The concerns we have are as follows:

- GTAP is not a mature model for estimating land use changes
- The land use values estimated by CARB do not appear to include a carbon "storage derating factor"
- The biofuels "shock" implemented in GTAP is inconsistent with USDA projected crop yields
- The method used to estimate effects of exogenous yield trends overestimates land use changes

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[5] The 2015 yield that CARB uses for this table (168.5 bu/acre) is higher than the value used by CARB to correct the land use results for exogenous yield increases (~155). bu/acre). CARB should use the 168.5 bu/acre for both estimates, which would increase the exogenous yield effect. For further discussion on this, see sections 4.2.3 and 4.2.4.

- GTAP co-product land use credits result in overestimation of land use changes
- Other GHG benefits of co-products are ignored (or "still being evaluated")
- Missing land sets in the GTAP database result in too much forest land being converted
- The analysis does not consider relative costs of converting different land types, resulting in overestimation of forest land converted
- Key GTAP model elasticities were "guessed," and are not supported by empirical data
- There is no narrative explanation provided of how the Woods Hole emissions factors are applied to converted lands
- The accounting methods applied to timing of emissions are flawed
- Existing pasture intensification in other countries could further reduce land conversion

4.2.1 GTAP is not a mature model for estimating land use changes

CARB chose GTAP for several reasons, but indicated in the ISOR that it was a relatively mature model with a "long history." This is indicated by CARB in the passage from the ISOR below:

> "The GTAP has a global scope, is publicly available, and has a long history of use in modeling complex international economic effects. Therefore, CARB staff determined that the GTAP is the most suitable model for estimating the land use change impacts of the crop based biofuels that will be regulated under the LCFS. The GTAP is relatively mature, having been frequently tested on large-scale economic and policy issues. It has been used to assess the impacts of a variety of international economic initiatives, dating back to the Uruguay and Doha Rounds of the World Trade Organization's General Agreement on Tariffs and Trade. More recently, it has been used to examine the expansion of the European Union, regional trade agreements, and multi-national climate change accords."

We would not take issue at all with the assertion that the GTAP model has been used repeatedly over a period of years for examining trade agreements between nations. However, its use for estimating the land use impacts of biofuels – the subject for which it is being used in the LCFS – is very young, so CARB's statement here is misleading. For example, the model did not have a distillers grains land use credit until June of 2008. This is a basic factor that is tremendously important to ILUC modeling. And the distillers grain land use credit that was incorporated into the model is based on outdated information; namely, that DGs are only fed to beef cattle (even with this incorrect assumption, the DG credit still reduced the land use impact of corn ethanol by 33%). Second, another issue raised by stakeholders is the fact that the model does not include exogenous crop yield improvements. This was not addressed by GTAP modelers until January of 2009. Many other items are still missing, for example, the model does not include approximately 35 million acres of Conservation Resource Protection (CRP) Land, and 24.9 million acres of "idle" land. Until these major land areas in the U.S. are included in the model, its predictions of land use change are highly suspect. Other issues that are of concern will be discussed below.

Our primary point is that the GTAP model is still very much in the early stages of development when it comes to assessing land use impacts of biofuels policies, quite the contrary to CARB's claims. CARB seems to be very determined to set the LUCs from

GTAP at this time while the model is still being developed for this purpose, which means that the numbers proposed by CARB could change significantly over the next few years as additional development work is conducted.

4.2.2 ILUC values do not appear to include “storage derating factor”

Initially, CARB was assuming that all above-ground carbon mass on lands converted from forest or grassland was converted to CO2. RFA and others pointed out that much of the above-ground mass was for trees. Because GTAP assumes conversion of commercial forests, it is logical that much of this wood mass would be used in consumer and other products. These products would eventually find their way into landfills, where carbon conversion to CO2 is very slow or nonexistent. In response to this, CARB indicated in the ISOR that “our current modeling assumes 90 percent conversion of the above-ground carbon is released to the atmosphere.” (This is the same thing as saying that 10% of the carbon from converted forest is stored indefinitely in landfills.) Yet, there is no evidence that this assumption was truly integrated into the modeling, because the overall corn ethanol ILUC value of 30 g/MJ was unchanged from earlier when CARB was assuming 100 percent of above-ground carbon is released.

RFA presented published evidence in previous comments that approximately 25% of above-ground mass from forests would be stored in landfills, so the 10% value being assumed by CARB is much lower than 25%. [6] As a reason for not including a higher value, CARB indicated “ARB staff also notes that decay of biomass in landfills will more likely lead to release of methane (a more potent GHG) rather than carbon dioxide. This would have to be considered if a non-trivial percentage of biomass from converted lands is placed in landfills.” While we acknowledge that methane needs to be considered in this, it is also true and verifiable that growing numbers of landfills are using methane to generate power. Since 64% of CARB’s ILUC emissions value for corn ethanol is due to forest conversion, a difference between 10% and 25% is 3 g/MJ, or 10% of the CARB ILUC value. As explained in later sections, we think there is little if any forest converted to crops for 15 bgy of corn ethanol in 2015. If this is the case, this is not an important issue. But if CARB thinks that forest is being converted, then we recommend that CARB make a priority of further research into this area since it does have a significant impact on the ILUC emissions value, not just for corn, but for every feedstock grown on land to make ethanol (cellulose, corn, and sugar).

While CARB’s new assumption that 10% of above-ground carbon is stored (and not attributable to biofuels) is certainly an improved estimate over 0%, we cannot find evidence that this adjustment was actually made to CARB’s estimates for corn ethanol ILUC emissions in Table IV-10 of the ISOR. We were able to replicate CARB’s scenario A-G values with our own GTAP modeling to within 0.1 g/CO2 eq/MJ for each scenario, when the only adjustment we made was for exogenous yields, and before we had updated our modeling with the latest emission factors from CARB that are contained in an Excel file called “ef_tables.xls.” This comparison is shown in the first two rows of the Table 1 below.

The 10% adjustment is included in the Excel file “ef_tables.xls,” available on the CARB website. CARB multiplies the forest above-ground emissions by a “storage derating factor” of 90% (which is the opposite of the 10% credit we refer to, but accomplishes the

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[6] See Appendix A, the RFA Comments on the ARB January 30 workshop

same thing).[7] However, when we compare the emission factors in this spreadsheet with the emissions in our GTAP model, which was used to create the first two rows in Table 4, we find that the emissions in our GTAP model for forests are higher. When we use all of the emissions in the spreadsheet, which presumably are the latest data used in CARB's model, we obtain the results in the third row of Table 4 below. These results are, on average, 1.7-1.8 g/MJ lower than the first two rows (all rows are corrected for the 8.7% exogenous yield improvement). *Therefore, we do not think Table IV-10 of the ISOR was updated for the CARB storage derating factor of 90%.*

Table 4. Corn Ethanol Land Use Values With and Without Storage Derating Factor

	A	B	C	D	E	F	G	Mean
ARB ISOR Table IV-10	33.6	18.3	44.3	35.3	27.1	27.4	24.1	30.0
GTAP (AIR run)	33.6	18.2	44.4	35.4	27.1	27.5	24.2	30.1
GTAP with EFs from ef_tables.xls	31.6	17.2	41.7	33.2	25.4	25.9	22.9	28.3

These modifications need to be made to the CARB values for corn, since they were already apparently intended by CARB to be included.

4.2.3 The biofuels "shock" implemented in GTAP is inconsistent with USDA projected crop yields

This section discusses general yield trends for corn, and the next section discusses CARB's approach for modifying GTAP output for changes in yields over time. Improvements in crop yields significantly relieve the pressure for land use change by allowing more production on the same acres. Generally, corn yields are much lower outside the U.S. as compared to the U.S., but even non-U.S. yields are improving with time.

The GTAP model includes a price-yield relationship that is governed by the price-yield elasticity. When the model is "shocked" with the 13.25 bgy ethanol increase, prices increase, and yields increase with prices. This is an endogenous response. But this price-yield response does not account for long-term changes in yields that are the result of technology improvements such as improved seed (so-called exogenous effects). This is particularly important because GTAP starts with a 2001 database, and is straining to try to adequately predict the situation in 2015 when corn ethanol reaches 15 bgy. The effect of the shock on endogenous yields (utilizing a 0.6 price yield elasticity, much higher than the elasticity used in the final GTAP modeling) is shown in Figure 1 at the left hand side of the figure. Yields increase only marginally on the shock.

Also shown in Figure 1 are actual average yields for 2001-2007 with USDA projections through 2015. Yields start at about 138 bu/acre in 2001 and are expected to increase to 170 bu/acre by 2015. This is an increase in yields of 23.9% over this period.

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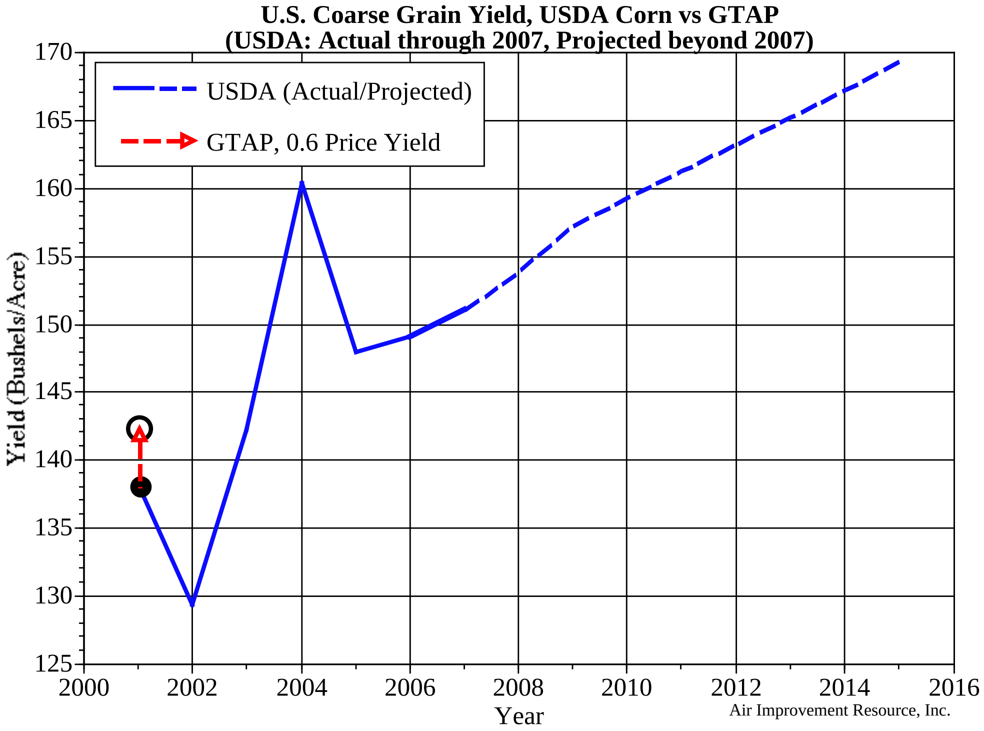
[7] CARB's "storage derating factor is actually an emissions derating factor, because it is not carbon storage that is being "derated" it is actually being improved. It is the emissions release that is being derated.

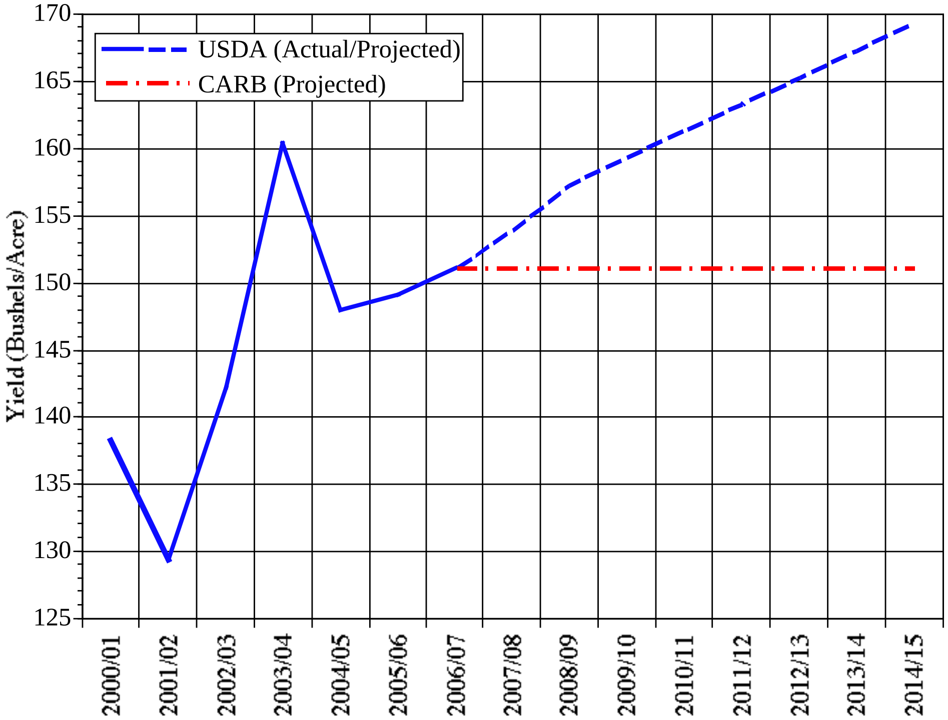
Figure 1



In taking this factor into account, GTAP modelers devised a way to correct the model results outside of the model. This procedure and its limitations are discussed in the next section. The procedure requires knowing the percent improvement in yields over a specified period of time, estimating the percent impacts on land use, and multiplying that by the land converted.

In applying this correction, CARB estimated the yield improvement only from 2001 to the average yield of the period from 2006-2008, even though the ethanol shock being applied to the model is to calendar year 2015. Therefore, CARB is currently ignoring the expected yield improvements between 2006-2008 and 2015. In other words, CARB is assuming that technological improvements will "stand still" for the next 7-8 years. This assumption significantly increases the ILUC impact of corn. This is shown in Figure 2.

Figure 2. Corn Yield Trends, USDA vs. CARB



Air Improvement Resource, Inc.

Initial yield increases for corn (which began in earnest in the 1940s) were due to a variety of improvements in fertilization, seed breeding, improved herbicides, better mechanization, better information on planting decisions, etc. More recently in the U.S., however, increased yields are driven by biotechnology-derived improvements in seed, such as "triple stack" hybrid seeds that are resistant to three different types of pest infestations. This is very clearly described in a recent paper by Edgerton. [8] The penetration of these hybrid seeds is accelerating in the U.S. quickly. This is the technology that CARB appears to be discounting. We think CARB ought to, at a minimum, use the USDA projections between the 2006-2008 time period and 2015 to estimate its land use impacts for corn ethanol. This would also be consistent with the approach taken by CARB to estimate Table IV-19 of the ISOR, which uses a yield very close to 169 bu/acre in 2015.

Detractors of the positive effects of yield improvements frequently assume that the reason for yield improvements in the U.S. is "increased intensification," which means more fertilizer, insecticides, herbicides, and water. This assertion is clearly answered in the Edgerton paper, which shows that much of the projected improvement in the U.S. in the future is not due to increased intensification, but due to greatly improved seed with higher productivity and enhanced stress tolerance. Further evidence of this is shown in trends in fertilization rates in Figure 3 below, which are trending *down* on a per bushel basis, and have been for some time. [9]

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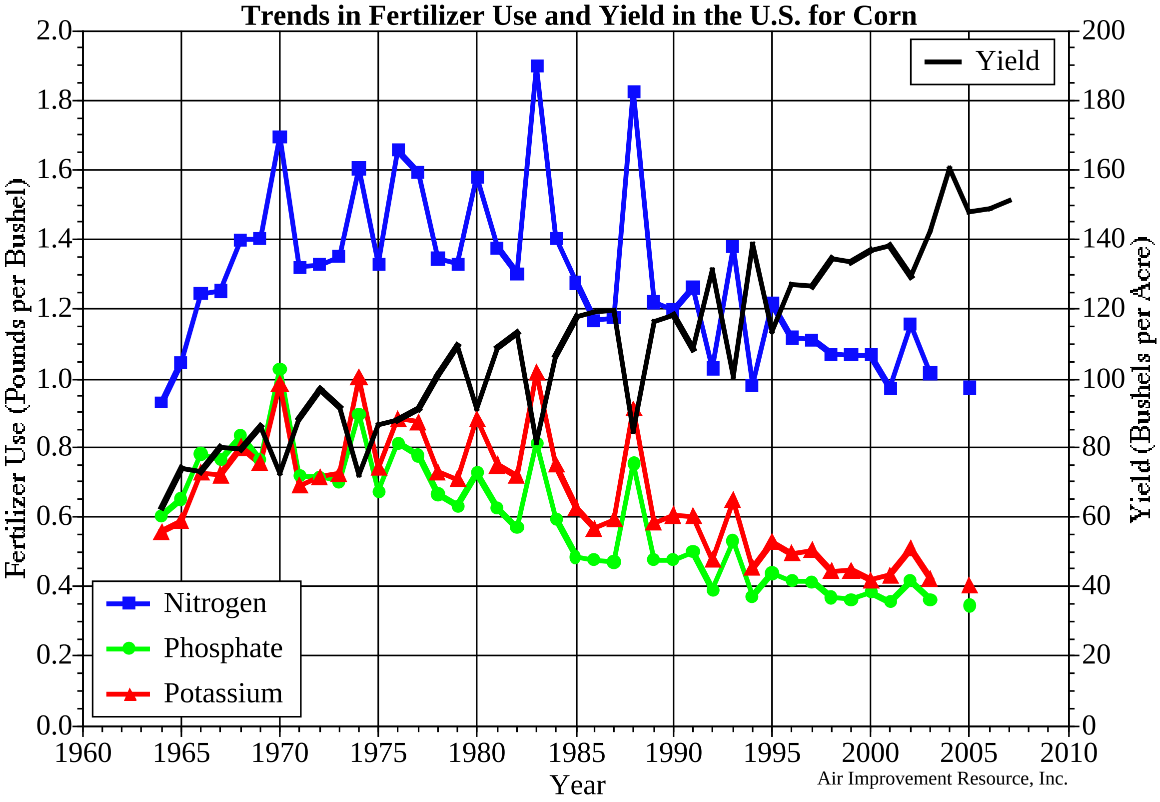
[8] Edgerton, "Increasing Crop Productivity to Meet Global Needs for feed Food, and Fuel", Plant Physiology, January 2009, Vol. 149, pp 7-13.

[9] In two years, 1983 and 1988, fertilizer use appeared to spike. But this was because yields dropped in those two years due to weather shocks, not because fertilizer use increased.

Figure 3

Trends in Fertilizer Use and Yield in the U.S. for Corn



Air Improvement Resource, Inc.

4.2.4 CARB's method of correcting for exogenous yield trends overestimates land use changes

CARB proposes to estimate the exogenous yield increase (as in the previous section), and estimate the percent reduction in land converted directly from this exogenous yield increase, and apply the percent reduction to the land use change emissions. For example, CARB estimates the increase in yield from 2001 to 2006-08 at 9.5%. The reduction in land use and emissions is therefore 1/1.095 = 0.913 which corresponds to an 8.7% decrease (1-0.913 = 0.087). ARB estimates that 3.9 mha in the world will be converted from either forest or grass to crops because of the ethanol increase to 15 bgy. The new land use change volume after the exogenous yield adjustment would be 3.9 * 0.913 = 3.57 mha. The reduction in land converted based on this yield increase is therefore 3.9-3.57 = 0.33 mha.

Informa Economics LLC, reviewed this methodology for RFA, and their complete analysis is contained in Appendix C (see point 1 in the Informa memo). Basically, the CARB method assumes that crop yield growth is the same in the rest of the world as in the U.S. Informa shows that the yield growth for corn in the ROW is 30% greater than in the U.S. (partly because yields start at a much lower level in the ROW for many crops), and this leads to an over-estimate of land converted. A second point is that the external adjustment method does not incorporate cross-crop interactions like the GTAP model does (see point 3 in the Informa analysis). Both of these factors can lead to significant errors in this adjustment.

4.2.5 GTAP co-product land use credits result in overestimation of land use changes

Our previous comments detailed the problems with CARB's current land use credit for distillers grains, a coproduct of a dry mill ethanol plant.[10] Basically, CARB is assuming that 1 lb of DGs replaces 1 lb of corn only in livestock and poultry feed rations. This results in a 33% land use credit for corn ethanol. At this level, it has a very significant land use impact. For example, in Table IV-9 CARB estimated that ethanol would require 31.8 m acres, or 37% of the corn land. But this estimate did not account for the land use credit for distillers grains. Not including the co-product credit when discussing ethanol's land use impact is akin to a person saying they paid $400 for a television when, if they had received a 33% discount, they actually only paid $268 for it. So, if the 33% land use credit is included in the values in Table IV-9, the land use impact is 21.3 m acres, which is 25% of the corn land, not 37%.

But there is ample evidence to suggest the land use impact of feed co-products may be greater than 33%. The latest research from Argonne National Laboratory shows that 1 lb of DGs from an ethanol plant replaces 1.28 lbs of base feed for beef, dairy cattle, swine, which consists of both corn and soy meal. Thus, we have raw corn going into an ethanol plant, and a higher-quality processed animal feed *and* ethanol coming out of the plant. This was covered in detail in our previous comments. CARB rejected this analysis, and chose to remain with the 1 lb of DGs replaces 1 lb of corn assumption. Their rationale for this was described in Appendix C11. However, CARB indicated that:

> "Clearly, studies such as those cited by Michael Wang and others support the suitability of DDGS as a replacement for both corn feed and soy meal."

Later, CARB indicates:

> "In fact, DDGS appears to face significant barriers to widespread adoption as a replacement for corn and soybean meal. For this reason, staff feels that providing a co-product credit equating 1 lb of DDGS to 1 lb of feed corn is generous."

In other words, DG could clearly replace corn and soy, but would not (in the judgment of CARB) because of "significant barriers."

To address this issue in more detail, RFA contracted with Dr. Gerald Shurson from the University of Minnesota to (1) provide an independent review of the Argonne analysis, and (2) review the ISOR Appendix C11 rationale for utilizing the 1 lb of DG for 1 lb of corn meal assumption.[11] Dr. Shurson performed his own independent analysis of both sources, and found that the Argonne analysis is basically correct; that is, DGs are replacing more than 1 lb of the base feed (he found it replaced 1.22 lbs of base feed vs. Argonne's 1.28), and that it replaced more soybean meal than Argonne estimated. The reasons for the increased share of soybean meal replacement are that Dr. Shurson expanded the analysis to include poultry, where Argonne did not include poultry. Dr. Shurson also had slightly different numbers for beef cattle, dairy cattle, and swine. Dr. Shurson also completely disagreed fundamentally with CARB's assessment of DG applicability in Appendix C11 of the ISOR. Additionally, if there are "significant barriers"

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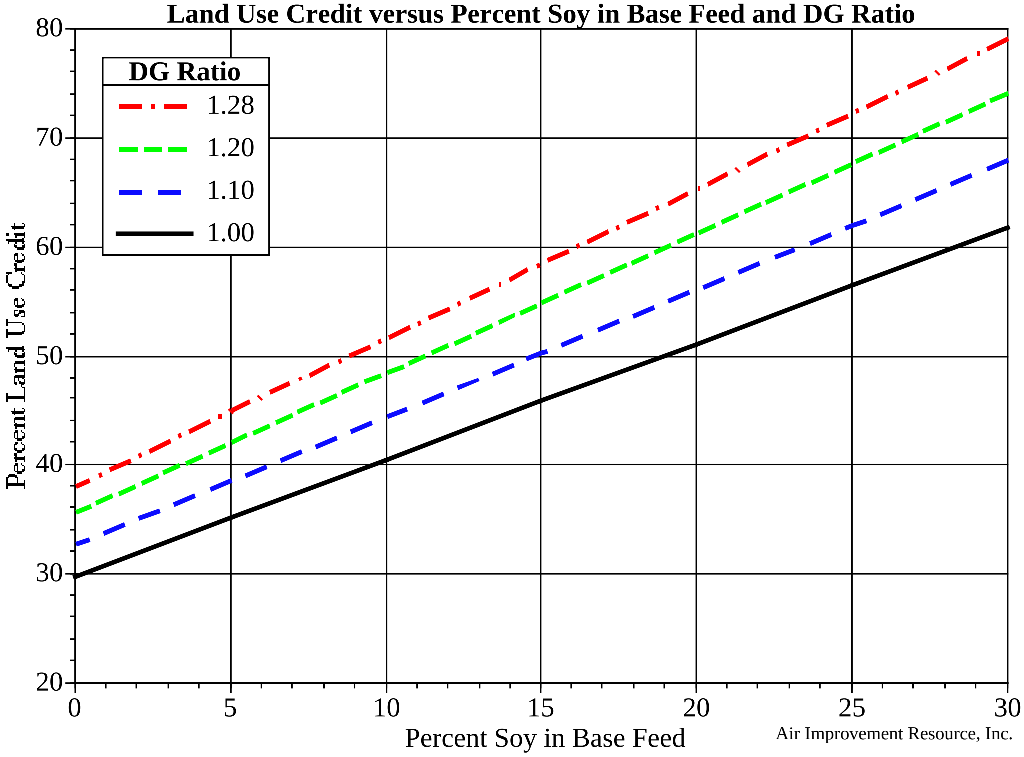
[10] With a dry mill ethanol plant, there is animal feed going into the plant, and animal feed and ethanol coming out of the plant.

[11] See Appendix B for Dr. Shurson's report.

to the use of DGs, it is logical that enormous excess supplies of DG would be accumulating as ethanol production increases. Obviously, this has not happened. Domestic use of DGs has expanded rapidly with ethanol production capacity because it is becoming much more recognized that DGs are an excellent supplement or replacement for the base feed for many animals. Further, DG exports to a number of countries have expanded rapidly as well.

These differences in DG feed replacement have a very significant effect on the land use credit for corn ethanol. The primary reason for this is that the yield for soybeans is much lower than the yield for corn. This is shown in the Figure 4 below, which was presented by RFA at the January 30 CARB workshop (see Appendix A), and is also shown and explained in detail in the AIR Land Use Report.

Figure 4



The “DG Ratio” in this chart is the ratio of the mass of DGs to mass of feed replaced. So, if 1 lb of DGs replaces 1.28 lbs of feed (as supported by the Argonne report), that would be found on the upper (red) line. We show the percent land use credit on the vertical axis and the percent soybean meal replaced in the base feed on the horizontal axis.

At 0% soybean meal replaced in the base feed, and a DG ratio of 1.0 (CARB and GTAP assumption), we see that the land use credit is about 30%. As the percent of soybean meal is increased that DGs replace, the land use credit increases rapidly. This is because the land use credit for soybean meal is higher than the land use credit for corn (because the soybean yield is lower than the corn yield). If we use the values in the Argonne report (1.28 DG ratio and 24% soybean meal replacement), we obtain a land use credit of 71%. If we use the values developed by Shurson, we obtain a land use credit of 74%. The land use credits by CARB, Argonne, and Shurson are compared in Table 5. The figure also shows that if we assume a 1.0 DG ratio (CARB assumption), and that 20% of the meal being replaced is soy, the land use credit would be 50%, well above ARBs 30-33%.

Table 5. Comparison of DG Land Use Credits			
Source	% Soybean Meal Replaced (remainder is corn)	DG Mass Replacement Ratio (DG:Base Feed)	Land Use Credit
CARB, GTAP	0%	1.00	30%
Argonne	24%	1.28	71%
Shurson	25%	1.25	74%

The implications of these differences are the largest item affecting land use of corn base ethanol. At a land use credit of about 33%, according to CARB, on a net basis 21 million acres are used to make 15 bgy of corn ethanol, which is 25% of the corn land. But if the land use credit is 70%, then only 11 million net acres are used to make ethanol, or about 13% of the corn land, and only 4% of the U.S. farmland. The 13% of corn acreage figure is about 1/3 of the land that ARB said would be needed for corn ethanol in Table IV-19 of the ISOR.

Clearly, this factor, along with the assumed GTAP elasticity of crop yields with respect to area expansion, are the two largest factors impacting CARB's land use estimate for corn (the elasticity discussion is in section 4.2.9).

4.2.6 Other GHG benefits of co-products are ignored

There are other GHG benefits associated with the DG co-product. One is that it reduces methane emissions from enteric fermentation in ruminant animals by shortening the animals' lifecycles. This benefit was developed in the Argonne report, and the previous RFA comments (Appendix A) quantified this effect as a GHG reduction credit of 4-5 g/MJ. CARB indicates in the ISOR that they are still studying this issue. A second benefit from DGs is that it helps animals digest phosphorous, an essential nutrient, thus, the animals need less synthetic phosphorous added to their diets. This displaces some GHGs used to produce phosphorous supplements for animal diets. We have not yet quantified this effect.

4.2.7 Missing land sets in the GTAP database result in too much forest land being converted

The GTAP model used to develop the land use impacts contains three types of land – crop land, pasture, and forest. Forest in this case is commercial forest, and does not include state and national forest land.

The GTAP land database does not include Conservation Reserve Program (CRP) lands. Also, as a part of developing the indirect land use change emissions values for cellulosic ethanol, Purdue identified two new land categories that are not in the GTAP inventory – cropland pasture and idle land. [12] The exclusion of these lands from the GTAP model, and the possible impacts of the exclusion of these lands, is discussed in turn below.

4.2.7.1 CRP Land

Since June 30, 2008, CARB and Purdue have indicated that they were working on incorporating CRP land into the GTAP model. In the ISOR, CARB states:

> "The GTAP model does not include Conservation Reserve Program land in the pool of available land in the US for agricultural expansion. ARB staff and GTAP modelers are updating the GTAP to include CRP land, *as appropriate.* (emphasis added) We will then analyze the effect that this change has on the estimate for amount and location of land converted within the U.S."

CARB further says this about the expansion of corn due to ethanol:

> "The GTAP brings new land into agricultural production from forest and grassland areas. It isn't specific about exactly where that land will come from. Some could come from the Conservation Reserve Program (CRP). Most CRP lands are in the arid far west and could support soybean production but not corn. Although the penalties for breaking CRP contracts are steep enough to prevent CRP lands from being used before their contracts expire, contracts are currently expiring on two million acres due to provisions contained in the recent Farm Bill. The USDA has the authority to make additional CRP lands available. If sufficient CRP land is not available to indirectly support an expansion of corn acreage, a large supply of non-CRP pasture land that was formerly in crops could be brought back into production. It is the availability of this non-CRP former crop land that is behind the GTAP's projection that about 40 percent of the land converted worldwide in response to the increased demand for corn ethanol biofuel will occur in the U.S.
>
> The GTAP modelers assumed that no CRP land would be converted in response to increased biofuel demand. Although some CRP land has been released for cultivation, an abundance of previously farmed pastureland is also available. These pasture lands are generally more productive than the lands released from the CRP system. Before it becomes economical to convert the least productive domestic land areas, land use change tended to shift overseas. The staff is continuing to analyze the effects of including CRP land in the land pool used by the GTAP model.

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[12] Tyner, W., et al, "Preliminary Analysis of Land Use Impacts of Cellulosic Biofuels", Purdue University, February 2009.

CARB indicates that GTAP is not specific about where the land will come from, and admits that some could come from the CRP.[13] But then CARB states that most CRP lands are in the far west, and could support soybean production but not corn. We examined the FY2007 CRP program statistics. [14] While much of the CRP land is indeed in the West, we also determined that there are 10 million acres of CRP grasslands in the top 10 producing corn states, as shown in Table 6 below.

Table 6. CRP Enrollment By Practice Category, All General and Continuous Sign-Ups, FY 2007

	Water Quality Buffers	Wellhead Protection Areas	Wetland Practices	Grass Plantings	Tree Plantings	Other Practices
Top-10 Corn producing states	1,122,076	124,954	1,090,288	9,984,347	324,082	1,398,425
All states	1,901,658	170,273	2,063,851	28,496,992	2,275,215	2,032.320

Top-10 corn producing states in 2004 were: Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin (USDA Production Figures).

Grasslands represent 78% of CRP plantings, and trees represent 6% (the remainder are water quality buffers, wellhead protection areas, etc.). Renormalizing for grassland and trees, 93% are grassland and 7% are trees. Therefore, if some land owners decided not to renew their land enrolled in the CRP, it does appear that there is substantial CRP grassland in areas that would support both corn and soybeans, and it would not have to be acquired from the more sensitive categories.

CARB further states that contracts are currently expiring on 2 million acres of CRP land. We examined the CRP contracts expiring in the FY2007 CRP program. Contracts were due to expire on 2.5 million acres in 2007, 1.3 million acres in 2008, 3.8 million acres in 2009, 4.4 million acres in 2010, 4.4 million acres in 2011, 5.5 million acres in 2012, and between 1.7 and 3.3 million in each of the years between 2012 and 2015. Clearly, there is much more land for which contracts are expiring over the period of simulated ethanol expansion than CARB states.

Next, CARB indicates that there is an abundance of previous farmed pasture land that is available that would be more productive than CRP land. We don't know where CARB obtained this information about the difference in productivity, but we do not disagree with the fact that there is an abundance of pastureland available for conversion, in addition to some CRP land.

If GTAP were to include CRP land (and also idle land and cropland pasture as indicated below), there would have to be an elasticity of land transformation assigned to the land

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[13] CARB assumes that no CRP land would be converted as a result of the 15 bgy, but admits that "some CRP land has been released for cultivation." The facts clearly contradict the assumption.

[14] "Conservation Reserve Program, Summary and Enrollment Statistics", FY2007, April 2008.

in GTAP (just like there is for pasture and forest), and the model would convert some CRP land to crops, along with pasture and forest. But the key factor here is the net change would be *less conversion of forest with the CRP land added in (in the U.S.) than without. And since forest conversion largely drives the corn ethanol ILUC emissions, less forest conversion means a lower ILUC emissions value.*

Anytime one introduces a new land type into GTAP that is not forested, it will result in some conversion of that new land type that has the net result of subtracting from overall forest converted. Thus, we still believe CRP land should be included in GTAP (as we did in June 2008, at which time CARB indicated it was contemplating this addition), since it is a significant land inventory that is available to farmers if they want to expand production.

Another factor is that in the June 2008 workshop, CARB performed a CRP sensitivity case where it assumed all the converted land resulting from the biofuels shock in the U.S. was grassland. The emissions of this case were much lower than the others, as expected. However, CARB left this case out of the ISOR, without explaining why.

4.2.7.2 Omission of Idle Land and Cropland Pasture

In addition to omitting CRP land, the GTAP model also does not include idle land and cropland pasture. As a part of its assessment of cellulosic land use impacts, Purdue University examined these land sources as possible land for cellulosic feedstocks.

These land sources are very significant. Purdue estimates there are 14.7 mha of idle land and 22.7 mha of cropland pasture. Together, this is more than twice as much land as in the current CRP (about 14.9 mha). Perhaps not all of these lands would support crops, but a significant portion of them probably would. If these land sources were added to GTAP, the amount of forest converted would be even less than if just the CRP land were added to GTAP.

4.2.8 The analysis does not consider relative costs of converting different land types, resulting in overestimation of forest land converted

GTAP also does not incorporate the costs to convert land in deciding how much forest and how much grassland to convert. GTAP simply maximizes total rents in each Agricultural Ecological Zone (AEZ), as if the cost to convert grassland and forest would be the same. However, GTAP does have an elasticity of substitution that is different for forest than for grassland. This introduces some additional "friction" in the equations for converting forest as opposed to converting grassland. It is not clear if this adequately represents the costs of converting forests.

4.2.9 Key GTAP model elasticities were "guessed," and are not supported by empirical data

One of the key elasticities that influences the amount of land converted is the "elasticity of yield with respect to area expansion." As indicated in the ISOR:

> "As discussed in the results section, model output is moderately to highly sensitive to the crop yield elasticity; elasticity of land transformation across cropland,

> pasture, and forest land; and elasticity of crop yields with respect to area expansion (relative productivity of marginal land). In calculating a value for land conversion, ARB staff and GTAP modelers have determined what we believe to be the most reasonable ranges for these elasticity values. These ranges are derived from appropriate research results, unless no such results are available. In the absence of research findings, the best professional judgment of experts has been relied upon. In particular, model outputs are highly sensitive to the value assigned to the relative productivity of marginal land. The land conversion predicted by the model is inversely proportional to the relative productivity assumed for marginal land. A range from 0.25 to 0.75 was originally assigned to this elasticity (e.g. marginal land is 25 to 75 percent as productive as land currently used for agriculture). Based on feedback from stakeholders, ARB staff and GTAP modelers decided that 0.50 to 0.75 was a more appropriate range for this elasticity value which resulted in a lower estimate for land conversion. We will continue to analyze available evidence for this key input parameter."

Further, at a January 26, 2009, GTAP workshop at Purdue University, in regard to this elasticity, an author of the GTAP model stated there is "little empirical evidence" to guide the use of this elasticity and that "more work needs to be done."

Clearly, CARB and GTAP modelers are speculating (another word for "best professional judgment") on the elasticity of crop yields with respect to area expansion, and this is the elasticity with the greatest impact on land use. There has been little to no land converted in the U.S. as a result of biofuels increases (most of the land has come from cross-crop conversions and yield improvements; and DGs from ethanol plants have nearly eliminated the need for additional land), so the U.S. is not necessarily a good place to look for these data.

To examine this issue further, Informa Economics examined the increase in soybean production, which doubled in the world from 1989-1991 to 2006-2008, with much of the increase coming in Latin America (see point 2 in the Informa analysis in Appendix C). If the elasticity of crop yield with respect to area expansion was low, then we should expect to see yields drop significantly. Informa's analysis indicated:

> "…the combination of substantial soybean area growth and increasing yields in Brazil and Argentina demonstrated that it is mathematically unlikely that the assignment (based on judgment) of a value of 0.5 to the elasticity of crop yields with respect to area expansion is correct….it cannot be determined that yields on new area have been meaningfully different than yields on area previously planted to crops (i.e., that the elasticity is less than 1.0)."

There may be areas of the world where if crops are expanded, yields would drop significantly, but these may be areas where crops are not likely to expand. These data indicate that the CARB and GTAP assumption on this elasticity is overly pessimistic, and it should be increased from the 0.5 to 0.75 range to a somewhat higher range. In the next section (4.3) we will use an elasticity of yield with respect to area expansion of 0.7 to 0.9, which is significantly less than 1.0, to determine the land use impacts utilizing this range.

4.2.10 There is no narrative explanation provided in the ISOR of how the Woods Hole emissions factors are applied to converted lands

CARB provided no technical appendix discussing the emissions from forest and grasslands that are converted around the world. CARB did provide a spreadsheet that listed all the emission factors and included some notes on why certain emission rates were used, but this was not adequate to allow a thorough review of the emissions from forests and grasslands. The emissions from these areas are critical inputs for reviewing the ILUCs for all feedstocks.

Regarding grassland, a recent study by Follett, et al. indicates that when CRP-type grasslands are re-commissioned using no-till farming techniques, that there is no release of soil carbon. [15] Release of soil carbon (i.e., below-ground carbon) accounts for most of the carbon release from grasslands, and the ISOR analysis assumes 25% of below-ground soil carbon is released. Thus, if CRP grasslands are re-commissioned, the question is what is the percent of no-till farming used? This issue needs to be examined further by CARB.

4.2.11 The accounting methods applied to timing of emissions are flawed

CARB estimated its primary case for the land use change emissions from a 30-year averaging (annualized) approach. CARB also developed emissions estimates using three other accounting methods, which included:

- Net Present Value (NPV) method
- Fuel Warming Potential (FWP)
- Economic Fuel Warming Potential (FWPe)

For corn ethanol, the annualized approach results in ILUC emissions of 30 g/MJ, the NPV approach results in a value of 37 g/MJ, and the FWP approach results in a value of 37-48 g/MJ. So, the alternative approaches all yield higher emissions than the annualized approach, because these approaches give more weight to the early emission releases more than the later releases.

To evaluate these methods, RFA contracted with National Economic Research Associates (NERA) to review the time accounting of emissions in the ISOR. NERA's report is included as Appendix D, and shows two major findings. One is that the two fuel warming approaches (FWP and FWPe) are arbitrary and should not be used to provide carbon intensity comparisons. The second is that the calculations of carbon intensity should account for the well-established projection that the social cost of carbon (SCC) will increase over time. NERA utilized an SCC value from IPCC of 2.4%. Results comparing the different approaches are summarized in Table 7.

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[15] "No-Till Corn after Bromegrass: Effect on Soil Carbon and Soil Aggregates"
Ronald F. Follett,* Gary E. Varvel, John M. Kimble, and Kenneth P. Vogel, Agronomy Journal • Volume 101, Issue 2 • 2009

Table 7. Corn Ethanol LUCs Derived by NERA with Different Accounting Methods	
Approach	Corn ethanol LUC (g/MJ)
Annualized (no discount) – CARB proposed	30
NPV with 2%	36.9
FWPe-30, 2%	52.2
Value-Adjusted, 2% (NERA approach that takes into account the social cost of carbon)	28.7

The value-adjusted approach, which takes into account the increasing social cost of carbon with a 2% discount rate, results in ILUC emissions of about 29 g/MJ.

4.2.12 Pasture intensification may be occurring in other countries that would further reduce LUC emissions

UNICA is developing data that may show that as crops expand onto pasture, stocking rates are increasing and pasture is being used more efficiently, rather than pasture expanding into forest. This would also reduce the ILUC impact of corn ethanol.

4.3 Adjusted GTAP ILUC Emissions for Corn Ethanol

Section 4.2 discussed many of the problems with the current CARB estimates of LUC for corn ethanol (and other feedstocks). This section modifies some of the inputs, and estimates new ILUCs with these modified inputs.

There are a number of factors we wish to take into account, as follows:

- Increased yield elasticity with respect to area expansion
- Improved U.S. land database analysis
- Improved distillers grain land use credit
- Improved exogenous yield adjustment

The reader should know we are not including all the items that would lower ILUC emissions, such as (1) a correction to CARB's method for incorporating exogenous yield adjustment, (2) other credits for DGs such as reduced enteric fermentation, and (3) an increased credit for the storage derating factor (25% instead of 10%). Also, emissions would be 4% lower for including the increasing social cost of carbon, utilizing a 2% discount rate, as indicated in the NERA analysis. We think these are justified adjustments to make to emission rates, but have not included all of these in the interest of arriving at a "fair and balanced" estimate.

For the improved yield elasticity with respect to area expansion, we use a value of 0.7 to 0.9, in place of CARB's assumption of 0.5 to 0.7. The value is probably closer to 1.0 (or higher than 1.0, as demonstrated by the Brazil soybean case outlined in Appendix C), but we are using 0.7 to 0.9 to account for a few areas where it may be slightly less than 0.9. This change is made to the GTAP model inputs. We retain all of CARB's other GTAP elasticities. The updated area expansion elasticities are shown in Table 8.

Table 8. Scenario Modifications

AIR Scenario	Same as CARB Scenario:	But with "Elasticity of crop yields wrt area expansion" changed:	
		From	To
A1	A	0.5	0.7
B3	B	0.75	0.9
C1	C	0.5	0.7
D1	D	0.5	0.7
E1	E	0.5	0.7
F1	F	0.66	0.8
G1	G	0.75	0.9

Regarding the U.S. land database, we propose to estimate the effects of an improved U.S. database by assuming that the land converted would be grassland, either from the CRP or from land that has been idled. The method of making this change is to output the land use changes (forest and grassland) by region of the world, and substitute the grassland emissions for the U.S. for the forest emissions. This is similar to the CARB analysis that was conducted in June of 2008 but omitted from the ISOR. The results of the above two adjustments are illustrated in Table 9. The first two columns (USA, World) are the results assuming both forest and grassland are converted in the U.S. and ROW. The second two columns assume only grassland is converted in the U.S. and ROW. The last two columns scenario assumes only grass or pasture is converted in the U.S. and both forest and grass are converted in the ROW. These results also include the 8.7% CARB exogenous yield improvement adjustment for 2001 to 2006-08. The mean of the scenarios is shown at the bottom.

For the GTAP case, where both forest and grass (In Table 6 “Livestock”= Grass) is converted, the mean emissions are 18.3 g/MJ. The only change from the ARB mean of 30 g/MJ for this case is the change in the expansion elasticity from the CARB range (0.5 to 0.75) to less pessimistic values (0.7 to 0.9). For the scenario where only grass is converted in the U.S. and ROW, the emissions are 10 g/MJ. Finally, for the scenario where forest and grass are converted in the ROW, but only grass is converted in the U.S., the emissions are 11.2 g/MJ.

Table 9. Emissions and LUC for AIR Scenarios

		Emissions (Million Grams) and LUC					
		Grass, forest converted		Only grass converted		Grass, forest converted in ROW, grass converted in U.S.	
Scenario	Cover	USA	World	USA	World	USA	World
A1	Forestry	316.05	-373.55	-44.25	-62.74	-44.25	-101.75
	Livestock	87.82	-254.10	-87.82	-254.10	-87.82	-254.10
	gCO2/MJ	12.36	-19.21	-4.04	-9.70	-4.04	-10.89
B3	Forestry	195.61	-181.91	-27.38	-23.94	-27.38	-13.69
	Livestock	75.19	-222.26	-75.19	-222.26	-75.19	-222.26
	gCO2/MJ	8.29	-12.37	-3.14	-7.54	-3.14	-7.22
C1	Forestry	344.92	-490.55	-48.29	-93.11	-48.29	-193.92
	Livestock	102.69	-343.72	-102.69	-343.72	-102.69	-343.72
	gCO2/MJ	13.70	-25.54	-4.62	-13.37	-4.62	-16.46
D1	Forestry	352.76	-304.52	-49.39	-36.58	-49.39	-1.15
	Livestock	111.14	-319.56	-111.14	-319.56	-111.14	-319.56
	gCO2/MJ	14.20	-19.10	-4.91	-10.90	-4.91	-9.82
E1	Forestry	223.85	-379.25	-31.34	-78.09	-31.34	-186.74
	Livestock	55.12	-158.23	-55.12	-158.23	-55.12	-158.23
	gCO2/MJ	8.54	-16.45	-2.65	-7.23	-2.65	-10.56
F1	Forestry	263.10	-325.22	-36.83	-56.23	-36.83	-98.95
	Livestock	90.62	-293.93	-90.62	-293.93	-90.62	-293.93
	gCO2/MJ	10.83	-18.95	-3.90	-10.72	-3.90	-12.03
G1	Forestry	207.79	-241.65	-29.09	-39.64	-29.09	-62.95
	Livestock	88.15	-299.76	-88.15	-299.76	-88.15	-299.76
	gCO2/MJ	9.06	-16.57	-3.59	-10.39	-3.59	-11.10
Mean	Forestry	272.01	-328.10	-38.08	-55.76	-38.08	-94.16
	Livestock	87.25	-270.22	-87.25	-270.22	-87.25	-270.22
	gCO2/MJ	11.00	**-18.31**	-3.84	**-9.98**	-3.84	**-11.15**

For the improved distillers grain land use credit, we estimate the effects of a 56% credit (this assumes a 1 lb. for 1 lb. replacement, with 27% being soy meal) credit and 70% credit (1 lb. of DG replaces 1.27 lbs. of base feed, with 27% being soy meal). The method used to implement this change is to divide the CARB assumed 33% land use credit emissions by 0.67 (1-0.33) to estimate the emissions without the land use credit, and then reduce these emissions by either 56% or 70%.

For the improved exogenous yield adjustment, we assume the USDA's projection of yields to 2015, instead of CARB's assumption of only correcting to 2006-2008. The CARB estimated effect of this adjustment to 2006-08 is an 8.7% reduction in area converted. Extending this to 2015 results in a 15.4% reduction instead of an 8.7% reduction.

Table 10 shows the impacts of these two adjustments on the LUCs for corn ethanol. In Table 10, we carry across the means from Table 9 for three cases in Table 8.

Table 10. ILUC Emissions Adjusted for Improved DG Credit and Exogenous Yield Adjustment (uses 30-year averaging)

	Case	Grass, forest converted in U.S. and ROW	Only grass converted, U.S. and ROW	Grass, forest converted in ROW, only grass converted in U.S.
Line 1	Mean LUCs From Table 9 (uses DG credit of 33%)	18.3	10.0	11.2
Line 2	55% DG credit	12.3	6.7	7.5
Line 3	70% DG credit	8.2	4.5	5.0
Line 4	55% DG credit, yield adjustment to 2015	10.9	6.0	6.7
Line 5	70% DG credit, yield adjustment to 2015	7.3	4.0	4.4

Again, the values in Line 1 of Table 10 are based on changing only the elasticity of expansion to 0.7-0.9. The values in Lines 2-5 are calculated off of the values in Line 1 and account for various assumptions on the DG credit and exogenous yield adjustment.
For the case where both grass and forest are converted in the U.S. and ROW, the ILUC emissions range from 7.3 to 18.3 g/MJ. For the case with only grass converted, the emissions range from 4 to 10 g/MJ. For the case where grass and forest is converted in the ROW, and only grass is converted in the U.S., the range is 4.4 to 11.2 g/MJ. The mean of all these values is 8.2 g/MJ.

Based on these very appropriate adjustments, our view is that the land use change emissions from corn ethanol using GTAP modeling are likely in the range of 4-7.3 g/MJ. It is notable that these values are close to the results of the AIR "top down" analysis that concluded the ILUC emissions are close to 0 g/MJ. A more pessimistic view would be to use the mean of all these values, which is 8.2 g/MJ. The most pessimistic view would be to estimate the emissions as the average of Line 1, or 13.2 g/MJ. It should be recalled that there are several other items that would lower these emissions further which we have not included here.

4.4 Factors that could increase emissions

In the ISOR, CARB mentioned several items that could increase the overall carbon intensity value for corn ethanol, as follows:

- Time accounting methods for LUCs
- Uncertainties associated with the nitrogen cycle affecting direct emissions

In addition, a comment was submitted by Michael O'Hare that if a 20-year project time horizon were used for corn ethanol, the ILUC emissions would roughly double. One particular concern with the project time horizon is that it appears O'Hare and others are using the "project horizon" to characterize the full useful life of a particular production facility or technology type (e.g. corn ethanol). However, in the context of emissions from land use change, the project horizon should apply to the land itself—not to the technology type of facility.

NERA's study answers the questions on the time accounting for LUC. When CARB incorporates increased damages (social cost of carbon) with time – which it should – this does not increase ILUC emissions; rather, it reduces them.

Regarding O'Hare's suggestion about the 20-year project horizon for corn ethanol, we do not agree that 20 years is an appropriate project horizon to use for corn ethanol, but if the 20-year horizon is used with the value-adjusted approach (which takes into account the social cost of carbon) the emissions are 45% higher than the 30-year project horizon, not double. If we use our central value of 8.2 g/MJ, a 45% increase is 11.9 g/MJ.

Regarding uncertainties with the nitrogen cycle, CARB is using the IPCC's recommendation for emissions from fertilizer (conversion of N2O from fertilizer). Of course, the LUC emissions for corn should not be made unnecessarily high just to account for some perceived uncertainty in emissions from the nitrogen cycle.

4.5 Recommendations

CARB characterizes its ILUC analysis of corn ethanol in the ISOR as generally "fair and balanced":

> "Although one may argue that there is no scientific consensus as to the precise magnitude of land use change emissions and that the methodologies to estimate these emissions are still being developed, scientists generally agree that the impact is real and significant. Our analyses support this conclusion. We believe that we have conducted a fair and balanced process for determining reasonable values for land use change carbon intensity and we will continue to investigate many of the issues presented above through discussion with stakeholders and analysis of current and new scientific data"

We concur that CARB has conducted a fair and balanced overall process in that it has encouraged input from stakeholders, held a number of workshops, released draft materials for comment, and so on. However, we would differentiate between holding a fair and balanced "process" and attempting to achieve a fair and balanced "result." CARB has not arrived at a fair and balanced result, as evidenced by the information in Table 8.

The table shows most of the sources of uncertainty that are raised in the ISOR, and whether they increase or decrease the ILUC emissions from corn ethanol from CARB's ISOR estimate. [16] An asterisk indicates an affirmative answer to the question stated at the top of the table, and an increased number of stars indicate a relatively larger effect. As the table shows, nearly all of the omissions would reduce the ILUC emissions; very few would increase the emissions.

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[16] We did not include the albedo issue or neglecting to account for converting grassland into forest as a cap and trade measure to offset emissions in this list. We are not sure of the direction of the albedo issue, but converting grassland into forest is a GHG mitigation strategy that would reduce any land use emissions.

Table 11. Summary of Directional Impacts of Un-quantified Items in CARB's ILUC for Corn Ethanol		
Factor	Correction would lower LUC emissions?	Correction would increase emissions?
Storage derating factor (CARB including this, although not included yet)	*	
Yield trends not consistent with biofuels shock	*	
Exogenous yield method overestimates emissions	**	
Coproduct land use credit	***	
Other coproduct benefits ignored	*	
Missing land in GTAP	**	
Land expansion elasticity	***	
No inclusion of land conversion costs	**	
Increased yields lead to increased intensification?	*	*
Include social cost of carbon in time accounting?	*	
Pasture intensification in other countries?	*	
20-year project horizon using value adjusted approach		**

As indicated above, CARB's analysis of corn ethanol ILUC emissions appears considerably biased on the high side, so some corrections should be made to achieve a fair and balanced result.

5.0 GREET Factors for Corn Ethanol

There are several areas where we are still evaluating the CARB GREET model estimates for corn ethanol direct emissions, as follows:

- GREET should not attribute the energy to produce silage to the ethanol plant, since it is used as animal feed and fodder
- There may be issues with CARB's lime application rates. RFA is conducting additional research in this area
- CARB should use an allocation approach instead of a displacement approach with respect to energy allocation for corn ethanol so that it is consistent with what CARB is doing for biodiesel and its co-products
- GREET does not properly reflect agricultural practices that will be in place in 2010, the base year for the LCFS

5.1 CARB GREET should subtract energy to produce silage

A significant amount of stover and silage is produced from corn grown to produce ethanol, and these products are often fed to animals. A portion of the total energy used to produce the corn should be attributed to the stover or silage and not to the ethanol plant. RFA is conducting additional research to determine how much energy this should be, to help inform CARB's decision making.

5.2 Energy assumed for lime is too high

We still have concerns with the lime application rates and the assumed lime types (whether it is applied as limestone or CaCO), and are reviewing these assumptions as well. Since GREET assumes all of the carbon in lime eventually reacts to form CO2, this is an important area.

5.3 CARB should use allocation method for coproducts instead of displacement method

We are concerned with the allocation treatment of distillers grains for corn ethanol in California GREET 1.8B. There are two issues with how CA-GREET1.8B estimates the energy credit of distillers grains. First, the CA-GREET 1.8b model assumes that DGs replace only corn. This has been shown to be faulty assumption based on the detailed research by Argonne referenced earlier in these comments.

Further, this parameter varies from the default Argonne GREET 1.8b assumptions. DGs replace both corn and soybean meal. Second, CARB is utilizing the displacement approach for allocating energy to ethanol and DGs. However, CARB should use the BTU-based allocation method instead, and for two reasons: 1. CARB is using the BTU-based method for the soybean meal co-product produced at a biodiesel plant. 2. DGs produced at an ethanol plant have higher energy content than the corn used in the plant to produce ethanol. This is clearly shown in Table 2 of the Argonne report, and demonstrated by the fact that 1 lb of DGs replaces 1.28 lbs of feed. Therefore, some of the energy used in the plant to produce both ethanol and DGs, which is now all being allocated only to ethanol, should be allocated to DGs as well. And, the best method of doing this is to utilize the BTU-based allocation method.

The impacts of utilizing the BTU-based approach are significant. With the current displacement method, the GHGs associated with ethanol production from a natural gas dry mill are 69 g CO2eq/MJ (excluding land use change emissions). With the BTU-based approach, where the energy used in farming and at the plant is allocated to the products on the basis of their final energy content (consistent with the CARB biodiesel approach), the GHGs associated with ethanol production from the same plant are 47 g CO2eq/MJ, according to our modeling with CA-GREET1.8B. This represents a 32% decrease from the carbon intensity value derived from using the displacement method.

5.4 CARB GREET does not reflect agriculture practices that affect direct GHGs for baseline year of 2010

According to the CARB GREET model, about 35% of the energy used in corn farming is for diesel fuel used to operate equipment during farming operations, and farming GHG represents 14% of total direct GHGs from corn ethanol [17] Thus, the use of diesel fuel for farming operations represents 5% of total direct GHGs.

An increasing trend in corn farming is no-till or low-till practices. This would significantly reduce diesel fuel consumption. It is unclear from the report what level of no-till practices are assumed in the direct CI values, and whether those are representative of no-till farming practices in the base year for the LCFS, which is 2010. This area should be examined.

Also, agriculture chemical production and use account for 41.2% of total direct GHGs from corn ethanol, and N2O emissions from nitrogen fertilizer accounts for half of this 41%, or about 20%. The use of cover crops almost completely offsets N2O emissions from fertilizer, according to recent research from Kim and Dale. [18] The California GREET model for ethanol may assume no use of cover crops, so N2O emissions could be overestimated in GREET based on this factor. RFA is conducting additional research in this area.

CARB has selected the baseline year for the LCFS as 2010. The GREET model CI for corn ethanol is based in large part on farm survey data conducted in the 2001-06 timeframe. The use of old survey data should not carry-over into 2010, without adequate validation. CARB must update the direct CI values for corn ethanol for the year 2010 to be consistent with the baseline year for the LCFS.

6.0 LCFS Baseline

6.1 Corn Ethanol in Baseline

As noted in the Background section, Midwest corn ethanol is in the baseline fuel for gasoline. Originally, the baseline gasoline discussed by CARB was E6, because this was the fuel in use in 2006 when the LCFS Executive Order was signed. Later, when it became possible that the land use change emissions values could have resulted in the CI of gasoline/ethanol mixture increasing from 2006 to 2010 as marketers used more ethanol to meet the 2010 Predictive Model requirements, the baseline was changed to

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[17] Table 1.02 of CARB Ethanol GREET report.

[18] “Biofuels, Land Use Change and Greenhouse Gas Emissions: Some Unexplored Variables”, Kim, Kim, and Dale, Environmental Science and Technology.

E10 and 2010. The diesel baseline has always been based on 100% diesel fuel. The problem with having corn ethanol in the baseline is that the fuel must effectively compete with itself. If it is determined, as we have done in these comments, that there is little or no land use change for corn ethanol and the CI value of corn ethanol is lower than gasoline, then no credit is given for the GHG reductions for E10 in 2010, or even the expansion from E6 in 2006 to E10 in 2010. If the CI of ethanol is higher than gasoline, then including it in the baseline raises the overall CI, and marketers could lower their CI by removing corn ethanol altogether from the gasoline. If it is nearly equivalent to gasoline, which it is as shown in Table 1 (Background), then marketers have no incentive to remove it or use more (because it does not provide any GHG reductions).

The following table presents an analysis of the sensitivity of the LCFS percent reductions to the baseline fuel and land use assumptions. For baseline fuel, we are estimating reductions from CaRFG with ethanol, and from CARBOB. The current CARB proposal is to estimate reductions only from CaRFG with (corn) ethanol. RFA thinks this may disadvantage corn ethanol, by including corn ethanol in the baseline. As a point of reference, the baseline for diesel fuel is 100% diesel, and includes no biodiesel. In this analysis, we use the CARB Compliance Model to perform the estimates of AFCI. The analysis is summarized in Table 12. Values in bold italics are from the ARB Compliance Model using the inputs shown

In the top row of the table, we are estimating LCFS emission reductions assuming two different levels of California Low CI corn ethanol: 10.75%, which is the percent used in Scenario 1, and 30% California corn ethanol. We also examine the LCFS percent reductions for two levels of ILUC emissions: 0 g/MJ, and 30 g/MJ (the current CARB assumption). Zero is used to show a lower value for ILUC for example purposes.

The baseline AFCI values are shown in the second and third rows. The values that are not in italics are taken directly from the ISOR, the values for CaRFG must be estimated from the CARB Compliance Model, since the ILUC value has been removed. The next set of four rows shows the percent of corn, cellulose, advanced, and sugar making up the ethanol mix. These values must add to 100%.

The next row shows the resultant AFCI from the compliance model for each case. We assume the MSCD recommended levels of plug-in hybrids, BEVs, and FCVs in this analysis. The next two rows show the difference in the LCFS AFCIs and the two baseline AFCIs. The bottom two rows show the percent reductions from the baseline values.

Table 12. Analysis of Percent Reductions and Sensitivity to Baseline Fuel Composition and LUC Values

	Ca Corn Ethanol = 10.75%		Ca Corn Ethanol = 30%	
	ILUC = 30	ILUC = 0	ILUC = 30	ILUC = 0
CARBOB Baseline AFCI	95.86	95.86	95.86	95.86
CaRFG Baseline AFCI	95.85	***92.62***	95.85	***92.62***
% Ca Corn	10.75	10.75	30	30
% Cellulose	39.25	39.25	29.62	29.62
% Advanced	39.25	39.25	29.62	29.62
% Sugar	10.75	10.75	10.75	10.75
AFCI	***85.07***	***84.63***	***86.61***	***85.39***
Difference, CARBOB Baseline	10.79	11.23	9.25	10.47
Difference, CaRFG Baseline	10.78	7.99	9.26	7.23
% Reduction, CARBOB base	11.2	11.7	9.6	10.9
% Reduction, CaRFG base	11.2	8.6	9.6	7.8

6.2 Analysis

For ILUCs=30 g/MJ, or the CARB current values, the percent reductions from both baselines is the same, because the CaRFG AFCI baseline is the same as CARBOB, and the LCFS reduction is the same. But for LUC=0, the LCFS reductions are much less when compared to CaRFG with ethanol baseline than when compared to CARBOB baseline. Note that the 30% California ethanol fuel passes when compared to CARBOB, but does not when compared to baseline CaRFG. This is because the baseline has dropped much more significantly than the controlled LCFS level. The percent reductions of a 10.75% California ethanol or 30% California ethanol fuel would be lower when compared to a CaRFG baseline than to a CARBOB baseline *at any level of LUC less than 30 g/MJ*.

6.2 Ethanol Plant Mix Type in Baseline

Another baseline issue concerns the percentages of wet and dry mill plants, and the percentages of wet and dry distillers grains. This issue is not relevant if CARB modifies the baseline to be CARBOB, as recommended above.

This issue was covered in our February 13, 2009 comments. CARB assumes that for dry mills, the percent of dried distillers grains is 95% and wet distillers grains is 5%. The latest data indicate that this should be 63% dried distillers grains and 37% wet distillers grains. In addition, CARB assumes 20% of current ethanol production comes from wet mills, and 80% from dry mills, where the latest data indicate 12% comes from wet mills and 88% from dry mills. Both of these incorrect assumptions by CARB make the CI of

Midwest corn higher than it should be. With CARB's assumptions, the CI of Midwest corn ethanol is 98.41 g/MJ, but with the updated assumptions, the CI of Midwest corn ethanol is 96.49 g/MJ, or 2% lower.

6.3 Recommendations

Our overall recommendation is that CARB change the baseline to the CI of CARBOB. This would take care of the first issue.

Regarding the issue of ethanol plant type in the baseline, as indicated in Section 5, CARB has selected a 2010 base year for estimating the 10% LCFS reduction. So, what matters is the mix of plant types in 2010, not some other year like 2008 or 2006. For this reason, we believe that CARB must estimate the plant types providing ethanol in 2010 to properly determine the starting CI of ethanol for the LCFS reduction. The values that are currently being used will be out-of-date and inappropriate by 2010

7.0 Food Versus Fuel Analysis

7.1 CARB's Analysis

The ISOR poorly presents a food versus fuel analysis where the costs and benefits of a 50 million gallon ethanol plant operating in California are summarized. However, the analysis omits the benefits of the feed co-products, which greatly affects the land needed. It also affects the land converted, the release in GHG emissions due to land conversion, and the net GHG benefits. Also, to the extent CARB's land conversion estimates are too high, it also overstates the land converted.

Table 13 below compares the CARB food versus fuel analysis with and without co-products. When including co-products, we have shown two cases – a 55% co-product land use credit, and a 70% co-product land use credit. In addition, we show land converted assuming a yield elasticity with respect to area expansion of 0.9, instead of CARB's average modeling value of about 0.59.

Table 13. Benefits and Costs of a 50 Million Gallon Corn Ethanol Plant

Factor	CARB Analysis No co-product credit assumed in analysis, GTAP with expansion elasticity of ~0.59	With 55% Co-product land use credit, GTAP with expansion elasticity of 0.9	With 70% Co-product land use credit, GTAP with expansion elasticity of 0.9
E85 vehicles fueled	85,000	85,000	85,000
Petroleum displaced (gal)	34 million	34 million	34 million
Non-domestic petroleum displaced (gal) – (assumes 60% imports)	Not included in CARB's estimate	20 million	20 million
Direct GHG reduced (mmt)	0.19	0.19	0.19
Corn input required bu/year	18 million	18 million	18 million
Distillers grain output to animals (tons)	Not included in CARB's estimate	162,000	162,000
Land required to produce feedstock acres (160 bu/acre)	110,000	49,500*	33,000*
Indirect land conversion	36,000	16,200 (7% commercial forestry, 93% pasture)**	10,900 (6% commercial forestry, 94% pasture)**
GHG release from land conversion (mmt)	3.6	<1.6***	<1.1***
Payback period (yrs)	19	<9***	<6***

* On net basis, after subtracting DG land use credit

** Would be less forest if other missing land sources included in GTAP model

*** Would be even less if ARB modified its direct emissions methodology for co-products to be consistent with biodiesel, and also subtracted energy to produce silage, as covered in Section 6

A 50 million gallon per year ethanol plant produces 162,000 tons per year of high quality animal feed used for beef, dairy, swine, and poultry. As shown in the table above, the net land required to produce the feedstock, and the indirect land conversion are 55% to 70% lower than CARB's estimates. The GHG emission releases from converted land are much less, and the payback times much shorter.

7.2 Influence of CARB's LCFS Policy on ROW yield trend growth

One of the keys to adequate food supplies in the future is yield growth in the rest of the world (ROW). Yields for many crops are much lower outside of the U.S. and western Europe. As covered in Section 5 in the discussion of Informa's comments, yields for some crops in the ROW are growing faster than in the U.S., but much of this is because they are starting at much lower levels.

CARB assumes that if corn ethanol is eventually discontinued due to high direct and indirect emissions, that there will be increased land available in the U.S. for food exports. These increased exports may result in less land conversion in the ROW in the short term, and a downward pressure on commodity prices. For example, in the ISOR, CARB states:

> "…the conversion of agricultural land to the production of biofuel feedstocks has the potential to increase the price for food, increase food price volatility, and increase pressure on water supplies…"

If the conversion of agriculture land to the production of biofuel feedstocks has the potential to increase the price of food (commodities), then the reversion of that land has the potential to reduce food prices. This is usually thought of as being "good." However, one issue not examined by CARB is whether the reversion of this land would really lead to increased U.S. exports, which would drive down prices of commodities, lowering farm income in the ROW and thereby slowing the rate of yield growth on crops in the ROW (ROW farmers will have less income to improve yields), thereby canceling out any perceived GHG benefit, and exacerbating food and land use problems.

7.3 Recommendations

CARB should update its food versus fuel analysis to show the significant influences of distillers grains co-products on the results.

8.0 Conclusion

As these comments have explained, there is a significant amount of uncertainty associated with the lifecycle and land use change analyses performed by CARB. The results of CARB's analysis are highly sensitive to a number of key assumptions and model inputs. As we have shown, even slight adjustments to certain assumptions would radically alter the final modeling outcomes. We have provided significant support for making adjustments to several of these key assumptions.

Our general recommendations are that:

- CARB should refine the ILUC analysis assuming a more balanced and less pessimistic set of assumptions.

- CARB must update the direct emissions (CA-GREET) analysis to 2010 to be consistent with its chosen baseline year.

- CARB’s food vs. fuel analysis should be updated to account for the contribution of feed co-products and the impact of yield improvements.

- CARB should revise the baseline so that corn ethanol is competing fairly with other ethanol feedstocks.

Appendix A

RFA's Comments on January 30 CARB Workshop

Comments by the Renewable Fuels Association (RFA) on ARB's January 30, 2009 Workshop on the Low Carbon Fuel Standard

February 19, 2009

On January 30, 2009, the California Air Resources Board (ARB) held a workshop on the Low Carbon Fuel Standard (LCFS), and asked for comments on the information presented at the workshop by February 13, 2009. RFA presented initial oral comments at the workshop, which have been posted on ARB's website. This document expands on those comments, and provides additional detail and references.

Most of these comments are concerning the ARB staff presentation entitled "Indirect Land Use: Technical Considerations." The subjects addressed in these comments are:

- Effect of Increase in Coarse Grain Yields
- Distillers Grain Land Use Credit
- Emissions from the Conversion of Forest
- Effects of Reduced Enteric Fermentation
- Summary of Effects
- CA-GREET
- ARB's LCFS Baseline Change

I. Effect of Increase in Coarse Grain Yields

At the Jan. 30 workshop, ARB explained that stakeholder comments indicated concerns that exogenous yield improvements were not included in ARB's estimate of land use change impacts. In responding to this concern, ARB estimated that yields have improved by 9.5% between 2000/2001 and 2006-08, so that land use change emissions are reduced by 8.7%. ARB is therefore reducing the land use change emissions attributed to corn ethanol by 8.7% to account for exogenous yield improvements.

We have three concerns with this adjustment: (1) the adjustment is not made with respect to the same year as the ethanol increase, which is 2015; (2) the yield improvement between 2001 and 2006-2008 was greater than estimated by ARB; and (3) there is a logical flaw in the method used to make the adjustment. These are discussed further below.

Inconsistency of Years

The 13.25 bgy ethanol shock applied to the GTAP model to estimate land use effects simulates the ethanol volume from 2000/01 to 2015/16. Over this period, the USDA indicates yields will increase 23.4%, from 136.9 bu/acre in 2000/2001 to 169 bu/acre in 2015/16.[1] In making the exogenous yield adjustment, ARB is going only from 2001 to a 2006-2008 average yield. This is inconsistent with the years of the ethanol shock. This also suggests ARB's best estimate of average corn grain yields in 2015 is that they will be unchanged from 2006-08. What are the specific reasons for the belief that yields will not continue to increase after 2006-08? What are the impacts on the land use changes if yields

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[1] USDA Agricultural Long-term Projections to 2018. http://www.usda.gov/oce/commodity/ag_baseline.htm

go significantly higher, as indicated by the recent USDA projections? At a minimum, ARB should perform a sensitivity analysis of the land use impacts to this assumption.

2006-2008 Yield Improvement from 2000/01

ARB estimated a 9.5% yield improvement from USDA data. The yield data from the USDA website which ARB referenced is shown in Table 1 below.

Table 1. USDA Corn Yield Data by Crop Year	
Crop Year	Corn Yield
2000/01	136.9
2005/06	147.9
2006/07	149.1
2007/08	151.1
2008/09	153.9
2005/06-2007/08 average	149.4
2006/07-2008/09 average	151.4
% Improvement of 2005/06-2007/08 average	9.1%
% Improvement of 2006/07-2008/09 average	10.6%

As indicated above, the percent improvement from the 2000/01 crop year (which starts in September 2000 and extends through August 2001) to the three-year average of 20005/06-2007/08 is 9.1% and to 2006/07-2008/09 is 10.6%. We are not sure how ARB arrived at 9.5% (even if the average yield for 2006/07-2008/09 is weighted based on acres harvested and total production for each respective year, the weighted average is still 151.3 bu/acre—a 10.5% increase over 2000/01). In any case, this is not critically important because we believe ARB should use the USDA projection of a 23.4% increase from 2000/01 to 2015/16 to be consistent with the ethanol shock implemented in GTAP.

We assume that the 30 g CO2eq./MJ land use change emissions estimate that ARB presented on January 30 utilizes the exogenous yield adjustment. Therefore, the base level that ARB started with in the absence of the exogenous yield adjustment is 32.8 g/MJ (30/0.913). A 23.4% improvement in yield would reduce the LUC by 19%, so a 19% reduction of 32.8 is 6.2 g/MJ. ***Thus, accounting for 2015 projected yields would reduce corn ethanol LUC emissions by 6.2 to 26.6 g/MJ.***

Exogenous Yield Adjustment Based on Faulty Logic

ARB proposes to estimate the exogenous yield increase (as in the previous section), and estimate the percent reduction in land converted directly from this exogenous yield increase, and apply the percent reduction to the land use change emissions. For example, ARB estimates the increase in yield from 2001 to 2006-08 at 9.5%. The reduction in land use emissions is therefore 1/1.095 = 0.913 which corresponds to an 8.7% decrease (1-0.913 = 0.087). ARB estimates that, without an exogenous yield improvement, 3.9 mha in the world will be converted from either forest or grass to crops because of the ethanol increase to 15 bgy. The new land use change total after the exogenous yield adjustment would be 3.57 mha (3.9 * 0.913). The reduction in land converted is therefore .33 mha (3.9-3.57 mha).

There are major problems with this adjustment, which is conducted external to the model. One is that the yield adjustment is only applied to the area of converted land, and not to all land growing corn. There are implicit assumptions in the method that the increase in exogenous yield on the current land (worldwide) is balancing demand, and that the rate of increase in yield outside the U.S. is the same as the rate of increase in within the U.S. All of these are untested assumptions.

Related to this, the ARB adjustment method breaks down severely at significantly higher yield levels. And, if it breaks down at higher yields, then it is also inappropriate at lower yield increase levels. To illustrate this, suppose hypothetically that a technological breakthrough allowed corn yields worldwide to double overnight. The USDA estimates that worldwide, corn production in 2007/08 was 786 million metric tons of corn. So, a doubling of yields and the use of the same amount of land worldwide would produce twice as much corn, or 1,572 million metric tons of corn. Approximately 131 million metric tons of corn will be needed to produce 15 bgy of ethanol in 2015, so the amount needed for 15 bgy is much less than the amount that the doubling of yields would produce (131 mmt is roughly 17% of 786 mmt). Certainly, this additional supply would be more than enough to take care of any increase in demand for corn for non-fuel needs and for the 15 bgy in the U.S., so there would be no need to convert any new land to crops for the 15 bgy. *However, using the ARB yield adjustment method, the reduction in land use change resulting from a doubling of yield is only 50%, from 3.9 mha to 1.95 mha, for the 15 bgy scenario.* This exercise demonstrates the pratfalls associated with this yield adjustment method.

II. <u>Distillers Grain Land Use Credit</u>

The GTAP model used to estimate land use changes has a land use credit of about 33% for distillers grains (DG). This is based on an assumption that DGs replace only corn meal, and that they replace corn meal only on a pound-for-pound basis. The ARB presentation reflects this assumption as well. However, carefully conducted research has recently indicated that these assumptions are far from correct. Because DGs have a much higher protein and fat content, they are currently substituted for the base feed on greater than a pound for pound basis. In addition, the base feed that DGs are replacing includes some soy meal as well as corn meal. Since soy yields are lower per acre than corn yields, any soy meal that DGs replace has a greater land use credit than the corn meal it replaces.

DGs are a co-product of producing ethanol from corn. DGs are a protein- and fat-rich feed source that is used to feed livestock and poultry. In the corn ethanol lifecycle, production of DGs fulfills two purposes. First, the energy of these co-products can be subtracted from the total energy used to produce ethanol, resulting in a lifecycle “energy credit.” Second, they significantly reduce the land-use impact of ethanol made from corn by displacing some of the corn and other feed ingredients in livestock diets.

The GREET model uses the displacement method to estimate the DG energy credit. The energy credit is estimated as the energy required to produce a product that would be a suitable substitute for the DGs.

DGs can be provided from the ethanol plant in the “wet” or “dry” form. If they are dried, then the ethanol plant uses more energy (typically natural gas to fuel dryers). Conversely, energy use by the ethanol plant is much lower if DGs can be provided in the wet form.

However, in the wet form they must be fed to livestock relatively quickly before they degrade.

With regard to land use, DGs are important in reducing the land requirement of ethanol from corn. Most corn in the U.S. is used to feed livestock, so when DGs from an ethanol plant are used to feed livestock, they supplant some raw corn products. As a result, somewhat less corn needs to be planted to feed livestock, and less land is used than if DGs were not fed to livestock. In addition, the U.S. exports a significant amount of DGs (approximately 4.5 million metric tons in 2008). This displaces some amount of demand for corn and soybean meal exports for animal feed.

The amount of land credit applied to DGs is a function of two factors. One is the mass ratio of raw corn and soy products that DGs replaces in the livestock diet. Recent research by Argonne National Laboratory indicates that 1 pound of DGs replaces about 1.28 pounds of conventional corn- and soy-based feed in aggregated rations. [2] This greater-than-one-to-one replacement ratio is due to the fact that DGs are generally higher in protein and fat than the diet they are replacing. The second item that affects the land use credit is the amount of soy meal in the base diet that is being replaced. Because the yield on soybeans per hectare is much lower than corn on a volume basis, the more soybean meal in the base diet that DGs are replacing, the greater the land-use credit. The recent Argonne analysis found that 24% of the 1.28 lbs of base diet (or 0.303 lbs) replaced by 1 lb of DGs was soybean meal. The following paragraphs summarize the Argonne research as it pertains to land use credits.

Argonne estimates displacement ratios for DGs, which are used to estimate the energy used to produce alternatives to DGs, and these energy values are credited to ethanol production. The displacement ratios are mass ratio of displaced product per pound of co-product. For example, previous analysis by Argonne indicated that 1 lb of DGs replaced 1.077 lbs of corn meal and 0.823 lbs of soybean meal. Thus, the displacement ratio of corn was 1.077 and for soybean meal was 0.823.

DGs have a much higher protein and fat content than corn grain, as shown in Table 2, taken from the Argonne study.

Table 2. Major Components of Corn and DDGS

Item	Corn grain	DDGs
Dry matter (%)	85.5	89.3
Crude protein (%)	8.3	30.8
Fat (%)	3.9	11.1

As shown in the table, the crude protein levels in DDGS are more than three times the protein levels in corn grain, and nearly three times the fat content.

Argonne goes on to estimate the percent of DGs used by animal type. Dairy cattle consume 44.2%, beef cattle consume 44.2%, and swine consume 11.6% of the DDGs, The estimated inclusion rates were 20% for beef cattle, 10% for dairy cattle, and 10% for swine. For WDGS

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[2] "Update of Distillers Grains Displacement Ratios for Corn Ethanol Life-Cycle Analysis", Arora, Wu, and Wang, Argonne National Laboratory, September 2008.

(wet distillers grains), a 40% inclusion rate was estimated for beef cattle, and 10% for dairy cattle.

The base feed for beef cattle contains little or no soybean meal, but the base feed for dairy cattle contains a significant amount of soybean meal. For example, for 10% DDGS replacement over a dairy cow's lifetime, the cow consumes 1864 kg of DDGS, and this replaces 1266 lbs of corn and 1152 kg of soybean meal. The displacement ratios for the different animal types and different meal types are shown in Table 3.

Table 3. Displacement Ratios by Animal Type and Feed Component Type (kg/kg of DGs)

Parameter	Beef Cattle	Dairy Cattle	Swine
Corn Displacement	1.196	0.731	0.890
SBM Displacement	-	0.633	0.095
Urea Displacement	0.056	-	-

The table shows that for each kg of distillers grains consumed by dairy cattle, this replaces 0.731 kg of corn and 0.633 kg of soybean meal. When the results from Table 3 are multiplied by the market shares of DGs supplied to the three animal groups, the overall displacement ratios are 0.955 kg/kg DGs for corn, 0.291 kg/kg DGs for soybean meal, and 0.025 kg/kg DGs for urea. Argonne also estimated the impacts of the 2007 Energy independence and Security Act on the volume of DDGs and these ratios. Argonne found with the 2007 EISA volume of 15 bgy ethanol, the displacement ratios would be as follows:

Corn:	0.947 kg/kg DGs
Soybean meal:	0.303 kg/kg DGs
Urea:	0.025 kg/kg DGs
Total:	1.275 kg/kg DGs

These ratios are only slightly different than the current ratios of 0.955, 0.291, and 0.025.

We estimated the impacts of the Argonne work on land use changes using inputs from the California GREET report for corn ethanol, and information from USDA. [3] The California GREET report for corn ethanol indicates that the DG yield per gallon of anhydrous ethanol is 6.4 lbs. Assuming 151 bu/acre (USDA value for 2007), and 2.6 gal/bu (GREET input) this results in 2513 lbs DGs per acre. The Argonne co-products report indicates that this will replace 3217 lbs of feed, consisting of 2445 lbs of corn meal and 772 lbs of soy meal. Again using USDA's corn and soy yields for 2007 of 8456 lbs/acre (151 bu/acre * 56 lbs/bu) and 2502 lbs per acre (42 bu/acre and 60 lbs/bu), the corn acres replaced are 0.29 acres, and the soy acres replaced are 0.42 acres, for a total of 0.71 acres replaced by the DGs produced from making ethanol. [4] Thus, 71% of the acres devoted to corn ethanol are replaced by DGs resulting from the corn ethanol production process.

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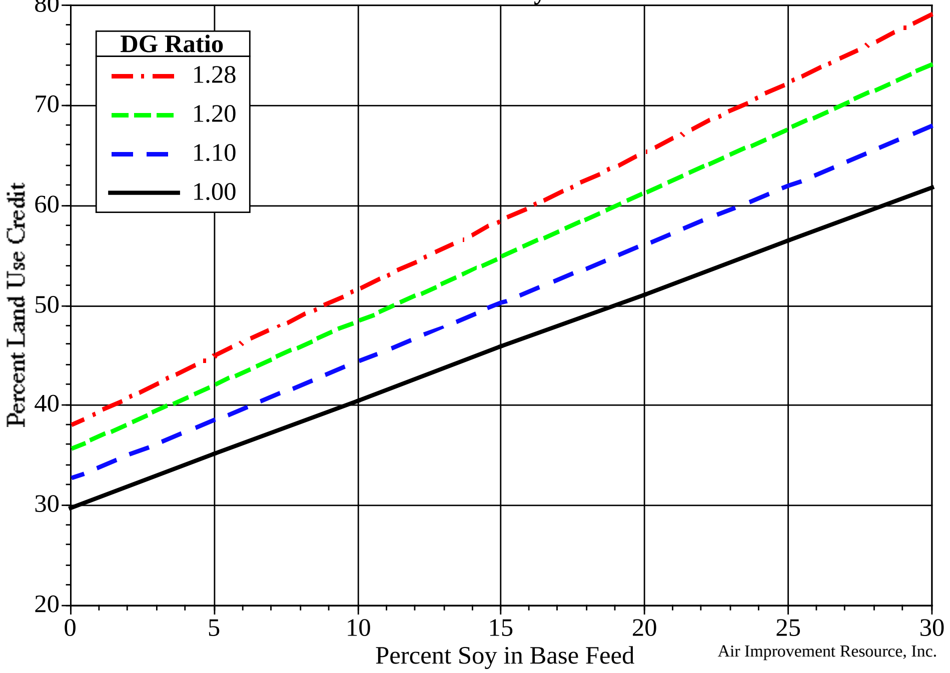
[3] "Detailed California-Modified GREET Pathway for Denatured Corn Ethanol", Stationary Sources Division, ARB, April 21, 2008, and "Agriculture Statistics 2007", U.S. Department of Agriculture.

[4] Note that in this estimate, we have estimated that 100% of the corn is converted to corn meal, but 73% of the soybean bushel of 60 lbs is converted to soy meal because 26% of the mass has been extracted in the form of soy oil. (Source: CBOT Soybean Crush Reference Guide). Also, the ethanol yield of 2.6 gal/bu may be low – two recent studies of ethanol plants indicate that the yield may be between 2.7 and 2.8 gal/bushel. This would increase the DG land credit from 71% to 77%. (Sources: "Analysis of the Efficiency

The sensitivity of the DG land use credit to assumptions on mass replacement of base feed and percent of soy meal replaced is further illustrated in Figure 1, where we have plotted the land use credit in percent vs. the soy percent in base feed replaced by DGs, and also the DG total replacement ratio (i.e., the 1.275 kg/kg DGs above).

Figure 1

Land Use Credit versus Percent Soy in Base Feed and DG Ratio



The percent of soy in the base feed based on the Argonne research is 24% (0.303/1.275). The total replacement ratio is 1.28/1. Thus, the figure shows that at 25%, and on the line of 1.28, the land use credit is near 71-72%, and not 33% as us being utilized in GTAP and by ARB. This figure can be used if different total replacement ratios, or percent of soy in base feed values are determined. If DGs are assumed to replace only corn, the DG ratio in Figure 1 would be 1.00. This equates to a DG land use credit of 30%. Of course, slightly different estimates of yields of corn and soybeans per unit area could result in slightly different estimates than the above.

Another conclusion from the above is that as corn and soy yields increase in the future, the DG land use credit increases. The above values were based on 2007 yields. In 2015, if corn yields increase by 23.4% and soy yields increase by 4%, then the land use credit would be 78% for the 1.28 total replacement ratio line. Thus, the land use credit increases as yields increase, due to increased production of DGs on the same area.

Some critics of this displacement ratio approach for estimating land use credits of DGs have pointed out that the use of DGs fluctuates with its price relative to corn meal, and therefore, at different times, feedlots may utilize different levels of DGs with the base feed. While this may be true, it does not detract at all from the basic validity of the displacement ratio

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of the U.S. Ethanol Industry in 2007”, May Wu, Argonne, March 27, 2008, and “U.S. Ethanol Industry Efficiency Improvements, 2004 through 2007”, Christianson and Associates, August 5, 2008) approach, because in the end, *all DGs are consumed by livestock*. The only relevant question, then, is what the composition of the feed is that they are replacing.

If we take the 26.6 g/MJ developed from the 23.4% yield improvement developed in the previous section, and back out the 33% land use credit for DGs assumed by GTAP, we obtain 26.6/0.67 = 39.7 g/MJ. If we then apply the 71% updated DG credit, we obtain 11.5 g/MJ. ***Thus, accounting for both the 2015 yield and the 71% DG credit brings us to 11.5 g/MJ.***

III. Emissions from the Conversion of Forest

The January 30 CARB presentation shows that CARB currently estimates 0.9 mha of forest will be converted to cropland around the world as a result of a 15 bgy U.S. corn ethanol volume. CARB also estimates that 0.6 mha, or 66% of the forest, is in the U.S.

In estimating the CO2 emissions from the conversion of this forest, ARB assumes that all of the above-ground mass and 25% of the below-ground root mass is immediately converted to CO2. This is the same as assuming that all of the above-ground mass and 25% of the below ground mass of every tree on the 0.9 mha of converted forest is burned, releasing all of the CO2 to the atmosphere. The argument has been made by researchers from UC Berkeley that any wood products used in building, paper, or other products have a relatively short life (less than 100 years?), and that therefore, assuming all the mass is released as CO2 is a reasonable assumption. However, no sources have been cited by ARB or other researchers involved in estimating land use emissions for ARB in utilizing this assumption.

It is important to keep in mind that the forestland in GTAP is primarily commercial forestland that is harvested for lumber, paper, and fuel for producing electricity, as well as many other products. Thus, if commercial forest is converted to cropland, then it stands to reason that it would be harvested first to take advantage of its existing value. The questions of relevance are then:

1. What is the allocation of above-ground mass to various products, such as wood for building, paper, and so on?

2. What are the estimated lives of these products before they are decomposed, and what are the mechanisms of this decomposition?

3. Ultimately, how much of the above ground mass that is harvested and used for products remains as stored carbon in a landfill for a long time, and is not converted to CO2?

None of these significant questions have been addressed by either ARB or their researchers to date, and the answers to these questions are of critical importance, because it is the conversion of forest to CO2 that drives the land use emission estimates that ARB has proposed using. For example, in its October 2008 estimate of 35 g CO2 eq/MJ for land use conversion, 71%, or 25 g of the emission estimate, is from conversion of forest.[5] We do not

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[5] This was determined by AIR by running Scenario A from October 16 with GTAPBIO-AEZ. Scenario A has an LUC of 37 g CO2 eq/MJ.

know how much of the current 30 g CO2 eq/MJ estimate is from forest, but assuming the same ratio as in the October 2008 workshop, the estimate would be 21 g CO2 eq/MJ. Thus, determining some reasonable answers to the questions above could have a very large potential impact on the land use emissions attributed to ethanol. At least two reports are of relevance to this issue, and there are likely others.

A paper by Skog and Nicholson estimates carbon sequestration in wood and paper products in the U.S. [6] The authors find that both wood and paper spend a long time in landfills without decaying:

> "The length of time wood, as opposed to paper, remains in end uses may have only a minor effect on the net amount of carbon sequestered in the long run. If, when taken out of use, products are disposed of in a modern landfill, the literature indicates that they will stay there almost indefinitely with almost no decay (Micales and Skog, 1997)."

A study by Fabiano Ximenes regarding the fate of carbon in Radiata Pine trees shows that in the above-ground mass, 37% of the carbon is in harvest residues (limbs, etc.) and 63% is used in sawlogs. [7] Further, of the 67% of carbon in sawlogs, 24% is used in dressed timber products, 5% in composite building products, and 2.5% in paper. All of this 31.5% of carbon in these products is assumed to eventually end up in a landfill, although when they enter a landfill can vary greatly. The remaining 33% of carbon is divided between horticulture products (13%) and energy (20% - wood used in boilers to produce electricity). This information is summarized in Attachment 1, which was from the Ximines report. We would expect these allocations to vary somewhat depending on the types of trees that are being harvested. Overall, in the Ximines report, 32% of the carbon above ground mass is estimated to be eventually stored in landfills.

If we conservatively estimate that 25% of the carbon of the above-ground mass of trees is used in products for a time and eventually ends up in landfills, where little or no decay takes place, then we can estimate what effect this has on the 11.5 g/MJ estimated after correcting for exogenous yields and updated DGs. If 71% of the 11.5 is from conversion of forest, that is 8.2 g/MJ. According to an ARB spreadsheet used to generate the October 16 results, in the U.S. approximately 18% of the total carbon mass assumed by ARB to convert to CO2 is contained in the roots (the total mass is estimated as all of the above ground mass and 25% of the root mass). [8] Thus, 1.5 g/MJ is in the roots, and would not be sequestered in landfills. That leaves 8.2 - 1.5 = 6.7 g/MJ above ground. Applying the 25% figure (% carbon in above-ground mass that is used productively) to 6.7 results in 1.8 g/MJ.

So, if we account for the mass of carbon that is stored in landfills in the U.S. and does not react to form CO2, then we obtain 11.5 - 1.8 = 9.7 g CO2eq./MJ for total corn ethanol LUC emissions. Of course, if CARB does not make the previous two adjustments (yield and DG credit) and does for this factor, this adjustment has a greater impact.

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[6] "Carbon Sequestration in Wood and Paper Products", Skog (USDA Forest Service) and Nicholson (Maryland Energy Administration), USDA Forest Service General Technical Report, RMRS-GTR-59.2000

[7] "Carbon Storage in Forest Products", Fabiano Ximines, New South Wales Department of Primary Industries.

[8] See ARB spreadsheet "draft_luc_ucb.xls", provided to T. Darlington by M.O'Hare.

Our recommendation is to reduce the LUC of corn ethanol using this method, until more detailed work on this issue can be performed. We note that Purdue has also reduced forest carbon by 25% to account for storage in products and landfills in preliminary work performed for Argonne National Laboratory. [9]

IV. Effects of Reduced Enteric Fermentation

The Argonne National Laboratory report on distillers grains also indicates that the use of DGs as livestock feed reduces enteric fermentation from livestock, because of shorter life cycles. [10] Table 16 of the report shows the GHG savings due to reduced enteric fermentation by type of livestock. Over the 3 types of livestock, the average savings is 3,381 g/million BTU of ethanol. This converts to 3.2 g/MJ ethanol.

This can be subtracted directly from the 9.7 g/MJ established in the previous section, to obtain 6.5 g/MJ for total LUC emissions for corn ethanol.

V. Summary of Effects

The effects of the four adjustments discussed in these comments on CARB's LUC estimate of 30 g/MJ are shown in Table 4 below. Taking into account the four factors, LUC emissions for corn ethanol are reduced from 32.8 g/MJ (before any exogenous yield improvement) to 6.5 g/MJ.

Table 4. Summary of the Effects of Four Adjustments on LUC for Corn Ethanol

Adjustment	Amount of Adjustment (g CO2eq/MJ)	Cumulative (starting point 32.8 g/CO2 eq/MJ)
Consistent Yields	6.2	26.6
Updated DG Credit	15.1	11.5
Carbon in Landfills	1.8	9.7
Reduced enteric fermentation	3.2	**6.5**

VI. CA-GREET Model Issues

In addition to the CA-GREET concerns outlined in the letter submitted by RFA to CARB on Feb. 13, 2009, we would like to raise the issues outlined below. Our primary concern is that CARB is being inconsistent in its allocation approach for ethanol and biodiesel co-products.

DG Allocation Approach

We are concerned with the allocation treatment of distillers grains for corn ethanol in California GREET 1.8B. There are two issues with how CA-GREET1.8B estimates the energy credit of distillers grains. First, the CA-GREET 1.8b model assumes that DGs replace only corn. This has been shown to be faulty assumption based on the detailed research by Argonne referenced earlier in these comments. Further, this parameter varies from the

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[9] "Land Use Change Carbon Emissions die to US Ethanol Production", Tyner, Taheripour and Baldos, Purdue University, Revision 3 Draft, January 2009.

[10] See reference 1

default Argonne GREET 1.8b assumptions. DGs replace both corn and soybean meal. Second, CARB is utilizing the displacement approach for allocating energy to ethanol and DGs. However, CARB should use the BTU-based allocation method instead, and for two reasons:

1. CARB is using the BTU-based method for the soybean meal co-product produced at a biodiesel plant.

2. DGs produced at an ethanol plant have higher energy content than the corn used in the plant to produce ethanol. This is clearly shown in Table 2 of the Argonne report, and demonstrated by the fact that 1 lb of DGs replaces 1.28 lbs of feed. Therefore, some of the energy used in the plant to produce both ethanol and DGs, which is now all being allocated only to ethanol, should be allocated to DGs as well. And, the best method of doing this is to utilize the BTU-based allocation method.

The impacts of utilizing the BTU-based approach are significant. With the current displacement method, the GHGs associated with ethanol production from a natural gas dry mill are 69 g CO2eq/MJ (excluding land use change emissions). With the BTU-based approach, where the energy used in farming and at the plant is allocated to the products on the basis of their final energy content (consistent with the CARB biodiesel approach), the GHGs associated with ethanol production from the same plant are 47 g CO2eq/MJ, according to our modeling with CA-GREET1.8B. This represents a 32% decrease from the carbon intensity value derived from using the displacement method.

Lime Application Rates

In our previous comments on CA-GREET (dated June 27, 2008), we noted that the lime application rate assumed in the model of 1202 g/bu/year is far too high, and a better estimate of lime application rates was about 87.4 g/bu/year, based on the recent work by Kim and Dale. The latest CA-GREET model still assumes 1202 g/bu. What is the basis for maintaining this assumption when better data exists to guide the parameter?

VII. ARB's Baseline Gasoline Change

We believe ARB should make the LUC emission and CA-GREET adjustments discussed above. When these adjustments are made, corn ethanol will have a significantly lower overall carbon intensity value than baseline gasoline. Because of this, we encourage ARB to revisit its decision to use 2010 E10 as the baseline gasoline. Inclusion of 10% corn ethanol in the baseline gasoline formulation forces corn ethanol to compete against itself, rather than petroleum fuels with higher carbon intensity.

Several months ago, when ARB anticipated that the LUC emissions value for corn ethanol could be very high, it changed baseline gasoline (from which the 10% LCFS carbon intensity reduction is estimated) from 2006 (with 5.7% ethanol) to 2010 (with 10% corn ethanol). We assume the purpose behind this change in the baseline year and gasoline formulation was to prevent penalizing oil companies for the possibility of increasing carbon intensity values between 2006 to 2010 due to the implementation of E10 in 2010. The transition to E10 in 2010 is largely expected because of changes in the Predictive Model. However, if ARB finds that the carbon intensity of corn ethanol is less than gasoline (due to justifiable adjustments to LUC and GREET analyses), this change in baseline date is not justified or desired, because increasing ethanol content from E5.7 to E10 would actually reduce overall blend carbon intensity.

Therefore, commensurate with ARB making reasonable changes to the LUC emissions estimate for corn ethanol, we request that the baseline return to 2006 and E5.7. The impetus for this change is further supported by the Governor's Executive Order S-01-07, which suggested the 10% reduction in carbon intensity should be relative to 2006 carbon intensity levels.

Appendix B

Analysis of Current Feeding Practices of Distiller's Grains with Solubles in Livestock and Poultry Feed Relative to Land Use Credits Associated with Determining the Low Carbon Fuel Standard for Ethanol

Dr. Jerry Shurson
Professor
Department of Animal Science
University of Minnesota
March 25, 2009

Analysis of Current Feeding Practices of Distiller's Grains with Solubles in Livestock and Poultry Feed Relative to Land Use Credits Associated with Determining the Low Carbon Fuel Standard for Ethanol

Dr. Jerry Shurson
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Department of Animal Science
University of Minnesota
March 25, 2009

Introduction

The purpose of this report is to provide an independent, scientific evaluation of the information contained in two reports being used as references regarding the land use credit associated with the primary co-product, distiller's grains with solubles (DGS), generated from corn ethanol production. The information reviewed in this report was obtained from two sources: "Update of Distillers Grains Displacement Ratios for Corn Ethanol Life-Cycle Analysis" by Arora, Wu and Wang (2008) and Appendix C11 "Co-product Credit Analysis when Using Distiller's Grains Derived from Corn Ethanol Production" by the California Air Resources Board. It is critical that accurate, science-based information be used for government policy decisions. Therefore, the following report is a critique of the scientific validity of the information contained in these two references in order to provide the "current state of knowledge" relative to the use of ethanol co-products in livestock and poultry feeds. The intended use of this report is to provide a third-party evaluation of these issues for the Renewable Fuels Association as it prepares comments that will be submitted to the California Air Resources Board on the Low Carbon Fuel Standard.

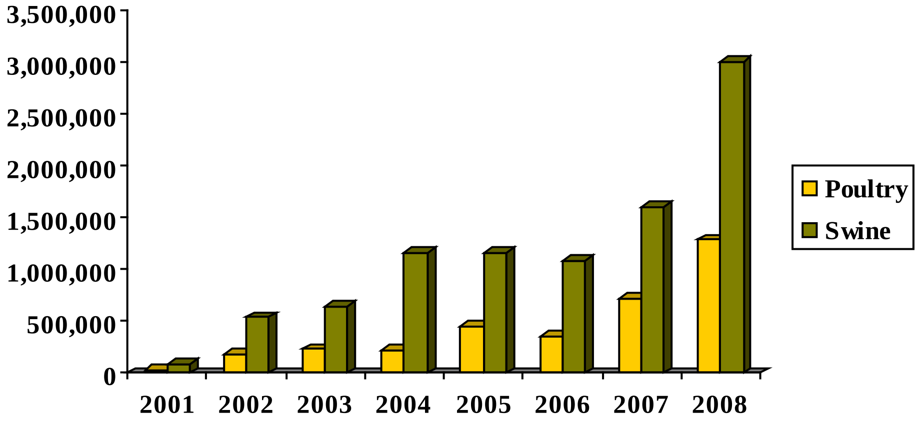
Review of Argonne National Laboratory Analysis (Arora et al., 2008)

The authors of this report correctly acknowledge that the addition of distillers grains with solubles to dairy, beef, and swine feeds has different effects on the amount of corn, soybean meal, and urea (which applies to dairy and beef diets only) that it partially replaces. Although dairy and beef cattle have historically been, and continue to be, the predominant consumers (80%) of DGS in animal agriculture, the amount being used in swine and poultry diets has been increasing over the past several years (Figure 1). In 2001, total annual estimated consumption of DGS was 89,000 MT for swine and 35,000 MT for poultry whereas in 2008, swine and poultry DGS consumption was about 3.0 and 1.3 million MT, respectively. This is a tremendous increase in DGS use over only an 8-year period and represents only 35 and 22% of the potential use in swine and poultry feed in the U.S., respectively (Cooper, 2006).

The percentage estimates of DGS consumed by various livestock and poultry species in 2008 are shown in Table 1. Dairy cattle consumed the greatest amount of DGS (9.0 million MT), followed by beef cattle (8.2 million MT), swine (3.0 million MT), and poultry (1.3 million MT), with the remaining 4.5 million MT being exported. As the amount of DGS production has increased, the estimated quantities of DGS consumed by all livestock and poultry sectors have also increased, and the estimated percentages of distribution of total DGS consumption have changed to include a higher percentage of total production in swine and poultry diets. Three primary factors that will affect further future market penetration in the various food animal sectors, and the percentage use of total DGS production are:

1. The price relationship between DGS and the ingredients it competes with in livestock and poultry diets (e.g. corn and soybean meal [all species], urea [cattle], and inorganic phosphate, fat, and synthetic amino acids [swine and poultry].
2. Availability of supply of the co-product as a feed ingredient.
3. Research focused on developing solutions for overcoming the barriers to increase DGS use in the livestock and poultry industries.

Figure 1. Estimated use of DGS in U.S. poultry and swine diets from 2001- 2008 (Metric Tonnes).



Source: S. Markham, CHS, Inc. (personal communication).

Therefore, when calculating land use credits due to DGS production and consumption, the usage in the swine and poultry sectors needs to be accurately estimated. Although the Arora et al (2008) report was the most comprehensive and objective analysis of the impact of DGS displacement ratios, the results are somewhat biased because it did not provide a thorough and accurate evaluation of the impact of DGS consumption in the swine and poultry industries.

Table 1. Estimated North American DGS usage rate by species (2008).

Species	% of total non-export[1]	Metric Tonnes
Dairy Cattle	42	9,025,800
Beef Cattle	38	8,166,200
Swine	14	3,008,600
Poultry	6	1,289,400
Exports	-	4,510,000[2]
Total	100	26,000,000[3]

[1] Source: S. Markham, CHS, Inc. (personal communication).

[2] Source: D. Keefe, U.S. Grains Council

[3] Source: Renewable Fuels Association www.ethanolrfa.org

In addition, the calculations for displacement ratios for DGS in the Arora et al. (2008) report only accounted for the amount of corn, soybean meal and urea replaced. While this is valid for calculating displacement ratios for cattle feeds, it does not fully account for partial replacement of other common ingredients used in swine and poultry diets such as inorganic phosphate, fat, synthetic amino acids, and salt.

2.1.1.2 DGS Inclusion in Feed and Animal Performance

Beef cattle

Arora et al. (2008) chose an excellent source of data and information for beef cattle using the review and meta-analysis by Klopfenstein et al. (2008) involving nine experiments to measure growth performance at DGS dietary inclusion levels up to 40%. Using these data for calculating feed ingredient displacement ratios for DGS in beef feedlot cattle diets is very appropriate.

Dairy cattle

Data from a recent study by Anderson et al. (2006) were used in the calculation of displacement ratios for DGS in lactating dairy cattle diets. The dietary inclusion rates of DGS in the Anderson et al. (2006) study represent the current range in feeding levels in the dairy industry, and the milk production and composition responses are consistent with other published studies. Although a more thorough review and summary of results from multiple studies should have been done, the data and assumptions used in their calculations are scientifically valid and representative of diet composition changes, as well as milk production levels and composition when feeding DGS diets to lactating dairy cows.

Swine

The analysis of DGS use in swine feeds was inadequately described by Arora et al. (2008) and was based on results from only a few select studies. It is more appropriate to use information from all of the published scientific studies to accurately characterize growth responses of growing swine fed diets containing DGS at levels of 10 to 30% of the diet. Stein and Shurson (2008) recently conducted a comprehensive literature review of results from all published studies and summarized growth performance responses for weanling pigs (Table 2) and grower-finisher pigs (Table 3). The majority of the studies conducted have shown no change in weanling pig and growing-finishing pig performance when DGS is included in the diet at levels up to 30% compared to feeding typical corn-soybean meal based diets. Although feed conversion (G:F) was improved in 50% of the weanling pig studies and 16% of the growing-finishing pig studies, indicating improved utilization of DGS diets compared to conventional corn-soybean meal diets, I chose to be conservative by assuming that feeding DGS diets results in no change in growth rate or efficiency of feed utilization. Therefore, when calculating displacement ratios for DGS, I did not give any credit for improvements in performance but rather focused on the amounts of common feed ingredients that DGS partially replaces (Table 4).

Currently, the industry average dietary inclusion rate of DGS in growing swine diets is 20%, which is double the assumption used in the Argonne report, and it has been as high as 40% for growing-finishing pigs when it has been priced substantially lower than the feeding value of corn, soybean meal, and inorganic phosphate. At a 20% dietary DGS inclusion rate, 400 lbs of DGS plus 6.4 lbs of calcium carbonate, and 2.8 lbs of synthetic amino acids replace 279.6 lbs of corn, 118 lbs of soybean meal, and 11.6 lbs of dicalcium phosphate per ton (2000 lbs) of complete feed (Table 4), resulting in a displacement ratio of 0.699 for corn, 0.295 for soybean meal, and 0.029 for dicalcium phosphate (Table 5). At the 30% dietary DGS inclusion rate the displacement ratios are 0.688 for corn, 0.307 for soybean meal, and 0.027 for dicalcium phosphate (Table 5).

Table 2. Effects of including corn distillers dried grains with solubles (DGS) in diets fed to weanling pigs[1]

Item	N	Response to dietary corn DGS		
		Increased	Reduced	Not changed
ADG	10	0	0	10
ADFI	10	0	2	8
G:F	10	5	0	5

[1] Data calculated from experiments by Whitney and Shurson (2004), Gaines et al. (2006), Linneen et al. (2006), Spencer et al. (2007), Barbosa et al. (2008), and Burkey et al. (2008).

Table 3. Effects of including corn distillers dried grains with solubles (DGS) in diets fed to growing-finishing pigs[1, 2]

Item	N	Response to dietary corn DGS		
		Increased	Reduced	Not changed
ADG	25	1	6	18
ADFI	23	2	6	15
G:F	25	4	5	16

[1] Data based on experiments published after 2000 and where a maximum of 30% DDGS was included in the diets.

[2] Data calculated from experiments by Gralapp et al. (2002), Fu et al. (2004), Cook et al. (2005), DeDecker et al. (2005), Whitney et al. (2006), McEwen (2006, 2008), Gaines et al. (2007ab); Gowans et al.(2007), Hinson et al. (2007), Jenkin et al. (2007), White et al. (2007), Widyaratne and Zijlstra (2007), Xu et al. (2007ab, 2008ab), Augspurger et al. (2008), Drescher et al. (2008), Duttlinger et al. (2008), Hill et al. (2008), Linneen et al. (2008), Stender and Honeyman (2008), Weimer et al. (2008), and Widmer et al. (2008).

Table 4. Partial replacement amounts of common feed ingredients with 20 or 30% DGS in typical swine grower diets.

Ingredient, %	**0% DGS**	**20% DGS**	**Difference**	**30% DGS**	**Difference**
Corn	81.30	67.32	-13.98	60.65	-20.65
Soybean meal, 46% CP	16.50	10.60	-5.90	7.30	-9.20
DGS	0.00	20.00	+20.00	30.00	+30.00
Dicalcium phosphate	0.82	0.24	-0.58	0.00	-0.82
Calcium carbonate	0.68	1.00	+0.32	1.13	+0.45
Salt	0.30	0.30	0.00	0.30	0.00
Synthetic amino acids	0.15	0.29	+0.14	0.37	+0.22
Vitamins and trace minerals	0.25	0.25	0.00	0.25	0.00
Total	100.00	100.00		100.00	

Table 5. Summary of co-product displacement ratios for swine when DGS is added at 20 and 30% dietary inclusion rates.

Dietary DGS Inclusion Rate	**Corn**	**Soybean meal**	**Dicalcium phosphate**
20%	0.699	0.295	0.029
30%	0.688	0.307	0.027

Poultry

Use of DGS in broiler, layer, and turkey diets was omitted from the analysis in the Argonne report (Arora et al., 2008). The authors cited that “poultry consumption was excluded because feed composition and performance data available for poultry were insufficient”. While the

NASS-USDA (2007) survey did not include poultry data, other sources could have been used as a reference. Therefore, I elected to provide the following summary of DGS usage in broiler, layer, and turkey diets and calculate displacement ratios for common ingredients partially replaced in these diets, and include this information in the final composite displacement ratios for all food animal species.

Current dietary inclusion rates of DGS in broiler diets range from 3 to 15%, with an average of 5% (Dr. Amy Batal, 2009, personal communication). Commercial layer diets contain between 3 to 12% DGS, with an average dietary inclusion rate of 7% (Dr. Amy Batal, personal communication). For turkeys, typical dietary DGS use levels are 10%, but in 2008, levels of 20 to 30% DGS were used when feed prices were extremely high (Dr. Sally Noll, personal communication). Tables 6, 7, and 8 summarize the partial replacement rates of corn, soybean meal, and inorganic phosphate with DGS in broiler, layer, and turkey diets, respectively. The ranges in dietary DGS inclusion rates for broiler, layer, and turkeys used in this analysis result in no change in growth performance compared to feeding conventional corn-soybean meal based diets.

Table 6. Partial replacement amounts of common feed ingredients with 5 or 10% DGS in typical broiler grower diets.

Ingredient, %	0% DGS	5% DGS	Difference	10% DGS	Difference
Corn	64.87	61.81	-3.06	58.75	-6.12
Soybean meal, 49% CP	27.19	24.99	-2.20	22.79	-4.40
DGS	0.00	5.00	+5.00	10.00	+10.00
Poultry by-product	3.00	3.00	0.00	3.00	0.00
Defluorinated phos.	1.05	0.95	-0.10	0.85	-0.20
Calcium carbonate	0.59	0.68	+0.09	0.77	+0.18
Salt	0.39	0.38	-0.01	0.37	-0.02
Synthetic amino acids	0.32	0.36	+0.04	0.42	+0.10
Fat A-V Blend	2.26	2.49	+0.23	2.72	+0.46
Vitamins, trace minerals, and additives	0.33	0.34	+0.01	0.33	0.00
Total	100.00	100.00	100.00	100.00	100.00

At a 5% dietary DGS inclusion rate, 100 lbs of DGS plus 1.8 lbs of calcium carbonate, 0.80 lbs of synthetic amino acids, and 4.6 lbs of animal-vegetable blend fat replaces 61.2 lbs of corn, 44 lbs of soybean meal, and 2 lbs of defluorinated phosphate in one ton (2000 lbs) of complete feed, resulting in a displacement ratio of 0.612 for corn, 0.440 for soybean meal, and 0.020 for defluorinated phosphate. At the 10% dietary DGS inclusion rate the displacement ratios for corn, soybean meal, and defluorinated phosphate are the same as those at the 5% dietary inclusion level.

Table 7. Partial replacement amounts of common feed ingredients with 5 or 10% DGS in typical layer diets (peak egg production).

Ingredient, %	0% DGS	5% DGS	Difference	10% DGS	Difference
Corn	58.64	55.60	-3.04	52.56	-6.08
Soybean meal, 49% CP	26.53	24.34	-2.19	22.14	-4.39
DGS	0.00	5.00	+5.00	10.00	+10.00
Defluorinated phos.	2.26	2.16	-0.10	2.06	-0.20
Calcium carbonate	8.92	9.01	+0.09	9.10	+0.18
Salt	0.19	0.18	-0.01	0.17	-0.02
Synthetic amino acids	0.22	0.26	+0.04	0.30	+0.08
Fat A-V Blend	2.90	3.12	+0.22	3.34	+0.44
Vitamins, trace minerals, and additives	0.34	0.33	-0.01	0.33	-0.01
Total	100.00	100.00		100.00	

Similar to broiler diets, at a 5% dietary DDGS inclusion rate in layer diets, 100 lbs of DDGS plus 1.8 lbs of calcium carbonate, 0.80 lbs of synthetic amino acids, and 4.4 lbs of animal-vegetable blend fat replaces 60.8 lbs of corn, 43.8 lbs of soybean meal, and 2 lbs of defluorinated phosphate per ton (2000 lbs) of complete feed, resulting in a displacement ratio of 0.608 for corn, 0.438 for soybean meal, and 0.020 for defluorinated phosphate. At the 10% dietary DDGS inclusion rate, the displacement ratios for corn, soybean meal, and defluorinated phosphate are the same as those for the 5% dietary inclusion level.

Table 8. Partial replacement amounts of common feed ingredients with 10 or 20% DDGS in typical turkey grower diets (11-14 week old tom, or 8-11 week old hen).

Ingredient, %	0% DGS	10% DGS	Difference	20% DGS	Difference
Corn	59.57	54.10	-5.47	48.62	-10.95
Soybean meal, 46% CP	28.68	24.08	-4.60	19.47	-9.21
DGS	0.00	10.00	+10.00	20.00	+20.00
Dicalcium phosphate	0.95	0.69	-0.26	0.43	-0.41
Calcium carbonate	0.72	0.91	+0.19	1.09	+0.37
Salt	0.23	0.19	-0.04	0.15	-0.08
Synthetic amino acids	0.31	0.37	+0.06	0.39	+0.08
Animal fat	5.03	5.22	+0.19	5.41	+0.38
Vitamins, trace minerals, and additives	4.51	4.44		4.44	
Total	100.00	100.00		100.00	

In turkey diets, a 10% dietary DGS inclusion rate results in adding 200 lbs of DGS plus 3.8 lbs of calcium carbonate, 1.20 lbs of synthetic amino acids, and 3.8 lbs of animal fat to replace 109.4 lbs of corn, 92 lbs of soybean meal, 5.2 lbs of defluorinated phosphate, and 0.80 lbs of salt per ton (2000 lbs) of complete feed, resulting in a displacement ratio of 0.547 for corn, 0.460 for soybean meal, 0.026 for dicalcium phosphate, and 0.004 for salt. At the 20% dietary DGS inclusion rate, the displacement ratios for all of these ingredients are the same as the 10% DGS dietary level.

Table 9 shows a summary of DGS displacement ratios for broilers, layers, and turkeys. Since these values are similar, I chose to average them to obtain a composite ratio for corn, soybean meal, and phosphate for the overall displacement ratio calculations for poultry shown in Table 10. These values are the same at DGS inclusion rates up to 20% which exceeds current average dietary inclusion rates of 5% for broilers, 7% for layers, and 10% for turkeys.

Table 9. Summary of DGS displacement ratios for poultry.

Species	**Corn**	**Soybean meal**	**Phosphate**
Broilers	0.612	0.440	0.020
Layers	0.608	0.438	0.020
Turkeys	0.547	0.460	0.026
Average	**0.589**	**0.446**	**0.022**

2.1.2 Step 2: Characterize U.S. Distillers Grains Consumption by Animal Type

The Argonne report referred to the NASS-USDA survey published in 2007 as a source of DGS consumption data by species. However, this survey was conducted before the record high corn and soybean meal prices occurred in 2008, and therefore, the dietary inclusion rates for various species reported in this survey are conservative, especially for swine based on current diet usage rates in 2008-2009. Usage estimates of DGS in poultry diets was not included in this survey.

2.1.3 Step 3: Characterize Life Cycle of Animals

The information provided in the Argonne report for beef and dairy cattle is valid and adequately accounts for improved growth performance of feedlot beef cattle and improvements in milk production in lactating dairy cattle. Because growth performance of swine, broilers, layers, and turkeys are unchanged with typical dietary inclusion rates of DGS as previously described, no adjustments in displacement ratios for DGS are needed like those for cattle. This was accurately represented for swine in the Argonne report, although the authors used a 10% dietary DGS inclusion rate where I have used displacement ratios assuming a 20% DGS dietary inclusion rate for swine. The Argonne report did not include calculations for displacement ratios for poultry, however, they will be used in the final displacement ratio calculations presented here.

2.1.4 Step 4: Results - Displacement Ratio of Distillers Grains

The final composite DGS ratio results are presented in Table 10. By adding the proportional amounts of each ingredient that is decreased or increased as a result of using DGS in the diets, while accounting for market share for each species, 1 kg or 1 lb of DGS can displace 1.244 kg or lbs of other dietary ingredients to achieve the same level of performance (or improved performance as with cattle). This displacement ratio is slightly lower, but similar to the value of 1.271 kg obtained in the Arora et al. (2008) report which had limited information on swine dietary DGS usage and expected growth performance results, and DGS usage in poultry diets was not included.

In my analysis, the overall displacement ratio for corn and soybean meal was 1.229 compared to the Argonne calculation of 1.28. The reason for this slightly lower value was that the corn displacement value (0.895) was slightly lower in my analysis compared to the value (0.955) calculated in the Arora et al. (2008) report. However, the soybean meal displacement ratio was higher (0.334 vs. 0.291) value in Argonne report. This indicates that 27% of the corn and soybean meal displacement value is soybean meal compared to 24% in the Argonne report. Most of this change can be explained by the greater proportion of soybean meal displaced (and less corn) in swine and poultry diets, with the remaining contribution coming mostly from savings in phosphate supplementation.

Table 10. Summary of DGS displacement ratio by species and overall DGS displacement ratio[1].

Parameter	**Dairy**	**Beef**	**Swine (20%)**	**Poultry**	**Overall Ratio (kg/kg DGS)**
Market share, %	42	38	14	6	100
Corn	0.731	1.196	0.699	0.589	0.895
Soybean meal	0.633	-	0.295	0.446	0.334
Urea	-	0.056	-	-	0.021
Synthetic amino acids	-	-	+0.140	+0.073	(0.024)
Fat	-	-	-	+0.363	(0.022)
Inorganic phosphate	-	-	0.580	0.220	0.094
Calcium carbonate	-	-	+0.320	+0.183	(0.056)
Salt	-	-	-	0.027	0.002
Total	**1.364**	**1.252**	**1.114**	**0.663**	**1.244**

[1] Values designated with + indicate additions to maintain equivalent dietary nutrient levels when DGS is added to diets for swine and poultry and values in ( ) indicate subtractions from the overall composite ratio.

Review and Critique of Appendix C11 Co-product Credit Analysis when Using Distiller's Grains Derived from Corn Ethanol Production (CARB)

The authors of this Appendix acknowledge that when DGS displaces traditional feed ingredients such as corn and soybean meal, it reduces green house gas emissions and becomes a life-cycle carbon intensity credit for corn ethanol. However, they criticize the Argonne National Laboratory report (Arora et al., 2008) as having insufficient justification for adopting the DGS displacement value in this report. I strongly disagree. In the preceding analysis of this report, I have noted the areas of insufficient information and have made calculations to be more reflective of actual DGS use among the major livestock and poultry species that consume it. Although this Appendix of the CARB report attempts to describe some of the challenges of using DGS in livestock and poultry feeds, it does not accurately represent factual information for making informed decisions on the impact of feeding DGS on land use credits. The following is a summary of critical evaluation of the incorrect information and improper context of statements in this Appendix.

In this Appendix, the California Air Resources Board (CARB) indicated that their staff conducted an extensive literature review to determine the likelihood that significant quantities of traditional feed ingredients will be replaced by DGS. The accuracy of this statement is highly questionable because they vaguely reference a limited number of sources of information, and no list of publications or other sources of information are provided at the end of the Appendix. Furthermore, the most striking point of the information in this Appendix is that they question whether the barriers to DGS use will be overcome to allow it to be used in livestock and poultry feeds in a significant way. **The fact is, ALL of the growing supply of DGS has been, and continues to be used in livestock and poultry feeds both domestically and in the export market**. Although the barriers they have identified are realistic, their impact is more on further market penetration and use in the various livestock and poultry sectors than on the ethanol industry's ability to market the quantities of DGS currently being produced. Variability in nutrient content along with handling, storage and transportation are challenges that have, to some degree, limited market penetration of DGS use for some species. However, under competitive market price conditions, DGS will continue to be fully utilized in livestock and poultry feeds.

There are several additional technical errors in the CARB Appendix C11.

1. In Table C-11-1, they do not reference the source of the information in the table, generalize ranges in digestibility and availability across species, and do not define "availability". Data in this table are being used to argue that variability in nutrient content will determine the **feasibility** of displacing traditional feeds with DGS. It is not a

question of feasibility, but rather a question of managing variability and appropriately valuing and determining nutrient loading values of the source of DGS being fed.

2. Livestock **ARE** able to digest a much higher percentage of the protein (amino acid fraction) than the 16.8 to 28.8% that was indicated. Wet and dry DGS contains about 55% ruminally undegradable protein, and the crude protein digestibility of DGS for swine ranges from 58 to 71%. If protein digestibility were as low as indicated in this Appendix, there would be much lower levels of soybean meal or urea replaced in animal feeds by DGS than is currently done.

3. Yes, DGS is low in lysine content relative to the nutrient requirements of pigs and poultry. That is why **diets for swine and poultry** are supplemented with synthetic lysine and other amino acids to make up for low levels of lysine and a few other amino acids. Supplemental synthetic amino acids are generally not used in cattle diets.

4. High sulfur content of DGS can be a concern in cattle diets in geographic areas where sulfur content of water, forages and other feed ingredients are also high, and a high dietary inclusion rate (40%) of DGS with high sulfur content is fed. However, this has not limited DGS use in cattle feeds (38% of total DGS production is fed to beef feedlot cattle). Historically, there have been a few cases of polioencephalamalacia that have occurred in beef feedlots when high amounts of DGS containing high levels of sulfur have been fed along with high sulfur content of other feed ingredients.

5. The phosphorus content and digestibility in DGS is high (65 to 90%) for all species. This provides a significant nutritional advantage for DGS in swine and poultry diets because it allows for a significant reduction in the need for supplemental inorganic phosphate to meet the animals phosphorus requirement while substantially reducing diet cost. Furthermore, using DGS to displace corn and soybean meal, which have much lower phosphorus content and digestibility, can substantially reduce the amount of phosphorus excreted in manure.

6. Hogs do not get urinary calculi, but it can occur in ruminants. It is essential to add supplemental calcium to diets containing DGS because it is very low in calcium compared to phosphorus, and the proper calcium:phosphorus ratio must be maintained to insure optimal health and growth performance of all food animal species.

7. Lactating dairy cow diets high in fat do not cause milk to contain an unacceptably high fat content. Feeding high fat diets to lactating dairy cows actually can depress milk fat content. That is why dairy cattle feeds should not contain more than about 20% DGS to avoid potential milk fat depression.

8. While it is true that fine particle size of complete feeds can increase the incidence of gastric ulcers in swine, particle size of DGS often exceeds 700-800 microns and only represents a maximum of 20 to 30% of the diet. Particle size of corn and soybean meal has a greater effect on overall diet particle size than most sources of DGS.

9. DDGS is a preferred energy and protein source for cattle because the fermentable carbohydrate (fiber) in DDGS reduces the risk of rumen acidosis compared to feeding corn which has a very rapidly fermentable carbohydrate (starch) that can increase the risk of acidosis.

10. Handling of some sources of dried DGS and transportation costs of wet DGS are challenges but they have not prevented widespread use of DGS in livestock and poultry feeds domestically or in the export market.

11. Livestock producers depend on their nutritionists to help them use diets containing DGS to obtain the best performance at the lowest cost. The majority of animal nutritionists in the feed industry have extensive knowledge of the benefits and limitations of feeding DGS to various livestock and poultry species. Lack of knowledge may have limited DGS use several years ago, but not today.

12. Exports of DGS increased 91% in 2008 from 2.36 million MT to 4.51 MT. There is no doubt that the efforts of U.S. Grains Council have been extremely effective in increasing the export market for DGS.

13. The conclusions in this Appendix are not realistic or valid. The staff who compiled and wrote this Appendix have demonstrated great incompetence in their understanding of the use of DGS in animal feeds.

In summary, the Arora et al. (2008) report slightly overestimated the DGS displacement ratio by not accurately accounting for the contributions consumed by swine and poultry. Based on current estimates for market share for each species and a revised composite DGS displacement ratio, 1 kg or 1 lb of DGS can displace 1.244 kg or lbs of other dietary ingredients to achieve the same level of performance (or improved as with cattle), which is slightly lower, but similar to the value of 1.271 kg obtained in the Arora et al. (2008) report. The information contained in the CARB Appendix does not appear to acknowledge that **all** of the 26 million tonnes of DGS produced in 2008 **was** consumed by livestock and poultry, and inaccurately describes the nature of the challenges for increased use of DGS in livestock and poultry feeding in the future. The information contained in the CARB Appendix C11 is misleading and has no value in establishing land use credits for current DGS production and use.

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Appendix C

Memorandum Re: Comments on the Use of the GTAP Model for the California Air Resources Board

Informa Economics, LLC

informa economics
an AGRA informa company

Memorandum

To: Tom Darlington, Air Improvement Resource
From: Scott Richman
CC: Geoff Cooper, Renewable Fuels Association; Don Frahm, Informa Economics
Date: April 15, 2009
Re: Comments on the Use of the GTAP Model for the California Air Resources Board

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Informa Economics ("Informa") has had an opportunity to conduct an initial review of the California Air Resources Board ("ARB") *Proposed Regulation to Implement the Low Carbon Fuel Standard*. Specifically, Informa has reviewed sections of the report and the appendices that pertain to the use of the Global Trade Analysis Project ("GTAP") model, as well as a brief summary that was provided to Informa separately regarding the model's results pertaining to crop area. The following are Informa's three key comments regarding the use and results of the model:

1. There is an incorrect assertion in Appendix C10 (pp. C-44 and C-47) that yield increases have been the same across countries and major crops since 2001; therefore, ARB incorrectly assumes a simple adjustment external to the GTAP model is appropriate to account for the significant increase in U.S. corn yields since 2001. Per Table 1 below, growth rates in corn yields have differed between the U.S. and the rest of the world (ROW); moreover, there has been a particularly notable difference in the growth rate of other crop yields versus U.S. corn. From 2001 through 2007, U.S. corn yields increased at an annual average rate of 1.5%, whereas ROW corn yields increased at a 2.0% rate; thus the ROW growth rate was 1.4 times that of the U.S. Including preliminary yield estimates for 2008, ROW corn yields increased 2.2% annually from the 2001 base year to the average for the period 2006-2008, or 1.5 times the increase in U.S. corn yields. As acknowledged by the authors of the appendix, "If U.S. corn yield grows slower than ROW yield, then we will overestimate the net change in cropland due to increase in ethanol production" (C-49).

   The differential in growth rates versus yields of other commodities, specifically soybeans, is of particular importance in determining real-world crop area allocation in response to a demand shock. From 2001 to 2007, soybean yields increased at an average annual rate of 0.9% in the U.S. and 1.2% in the ROW; these rates were only 0.6 and 0.8 times the U.S. corn yield growth rate, respectively. (Data for Table 1 were obtained from the USDA's Production, Supply & Distribution database;

though it is recognized that the GTAP model utilizes data from the U.N. Food and Agriculture Organization, it is doubtful there would be a significant difference.)

Table 1: Annualized Crop Yield Growth Rates

	Growth Rate 2001-2007	Ratio to U.S. Corn Growth	Growth Rate 2001A-2008P	Ratio to U.S. Corn Growth	Growth Rate 2001 to 2006-2008P Avg.	Ratio to U.S. Corn Growth	Growth Rate 1999-2001 Avg. to 2006-2008P Avg.	Ratio to U.S. Corn Growth
U.S. Corn	1.5%		1.6%		1.5%		1.5%	
Non-U.S. Corn	2.0%	1.4	2.3%	1.5	2.2%	1.5	2.0%	1.3
U.S. Soybeans	0.9%	0.6	0.0%	0.0	0.7%	0.5	1.2%	0.8
Non-U.S. Soybeans	1.2%	0.8	-0.1%	-0.1	0.9%	0.6	0.8%	0.5
U.S. Wheat	0.0%	0.0	1.6%	1.0	0.4%	0.3	-0.1%	-0.1
Non-U.S. Wheat	0.6%	0.4	1.6%	1.1	1.1%	0.7	1.0%	0.7

Note: 2008P indicates preliminary non-U.S. and world estimates

In Appendix C10 (p. C-47), the authors provide an example in order to:

> "demonstrate that post GTAP adjustment to the net change in cropland due to increased biofuel production is sufficient and no further adjustments are necessarily to reflect higher current yields.
>
> In 2001, US corn yield is 335 bu/ha and ROW corn yield is 109 bu/ha. In US cultivated area is 36.34 Mha. In the ROW cultivated area is 252.04 Mha …
>
> To produce 13.25 billion gallons of corn ethanol, we would need 5096 Mbu of corn. …
>
> Land required for this production is:
>
> 5096Mbu / 109bu = 47 Mha in the ROW. So, in this simple calculation, the net change in cropland is 47 Mha.
>
> If we compare average corn yield over 2006-2008 and our base year (2001) corn yield for U.S., we find that U.S. corn yield had grown by 9.5%. …
>
> What is the net change in cropland due to increased ethanol production at higher yields? Again, to produce 13.25 billion gallons of corn ethanol, we would need 5096 Mbu of corn. …
>
> Land required for this production is:
>
> 5096 Mbu / 119 bu/ha = 43 Mha in the ROW. At higher yields, the net change in cropland is 43 Mha.

> Now, compare 47 Mha and 43 Mha. One could obtain 43 Mha by simply adjusting 47 Mha to reflect higher current corn yields:
>
> 47/(1+0.095) = 43 Mha.
>
> This idea is behind the post GTAP adjustment applied to the net change in cropland obtained at 2001 yields. So, to know the net change in cropland at higher current yields, it is sufficient to apply factor 1/(1+percent change in corn yield/100) to the GTAP net change in cropland due to increased ethanol expansion obtained at 2001 yields."

In reality, while U.S. corn yields did increase by 9.5% during this time period, ROW corn yields increased by 14.2% (refer again to Table 1). Using the factor 1/(1+percent change in corn yield/100), the amount of land required would be:

47/(1+0.142) = 41 Mha

Thus, the reduction in land required due to yield improvements should have been 6 million hectares (47 Mha - 41 Mha), which is a 50% greater reduction than the 4 million hectares (47 Mha - 43 Mha) from the GTAP authors' example. This indicates that the land use adjustment that was performed outside the GTAP model might have been inadequate; that is, the adjusted results from the model might still have overstated the amount of land use change associated with an increase in ethanol production.

2. The elasticities of crop yields with respect to certain factors as discussed in Appendix C5 are questionable. This is particularly true for the elasticity of crop yields with respect to area expansion. As stated on page C-29, "Although this is a critical input parameter, little empirical evidence exists to guide the modelers in selecting the most appropriate value." This is unfortunate since, depending on the parameters used, there was a "77% variation in the GHG emission estimate." Additionally, "professional judgment" was used to set the parameter; however, the amount of error that could be introduced by this variable suggests that the elasticity should be determined empirically or it should be excluded from the model. The parameter was judgmentally set at a value of 0.5, indicating that yields on new land are far less than those on land previously planted to the crop. A brief examination of the data indicates that the empirical evidence for such a low value is lacking.

   The best example of this can be seen by examining the area and yields of soybeans. As shown in Table 2, soybean area outside the U.S. almost exactly doubled between the 1989-1991 period and the 2006-2008 period, from 33 million hectares to 65 million hectares. (Much of the increase occurred in South America.) During the same timeframe, yields increased by 38%. This was significantly higher than the 23% yield increase that occurred in the U.S. on a 23% increase in soybean area. If new land were far less productive than previously planted land, the large increase in non-U.S. yields would have been logically suspect, and at a minimum the increase would have been expected to have been lower than that of the U.S., where the percentage area increase was only one-fourth as large.

The results for corn are not as dramatic as those for soybeans, since the expansion in area has not been as large in percentage terms, but area and yield patterns for corn point in the same direction as those for soybeans. Both U.S. and non-U.S. corn area grew by roughly one-fifth between the 1989-1991 period and the 2006-2008 period. Over that timeframe, yields increased by approximately one-third. Additionally, the increases outside the U.S. have been slightly higher than those for the U.S.: non-U.S. yields increased 34% on an area increase of 22%, while U.S. yields rose by 32% on an area expansion of 18%.

Table 2: Long-Term Growth in Crop Area and Yields

	Area (000 Hectares)					**Yields (Quintals/Ha)**				
	Avg. 1989-1991	**Avg. 1999-2001**	**Avg. 2006-2008P**	**Change 1989-91 to 2006-08P**	**% Change 1989-91 to 2006-08P**	**Avg. 1989-1991**	**Avg. 1999-2001**	**Avg. 2006-2008P**	**Change 1989-91 to 2006-08P**	**% Change 1989-91 to 2006-08P**
U.S. Corn	27,054	28,633	31,809	4,754	18%	72	85	95	23	32%
Non-U.S. Corn	101,971	110,029	124,094	22,123	22%	28	32	37	9	34%
World Corn	129,025	138,662	155,902	26,877	21%	37	43	49	12	32%
U.S. Soybeans	23,480	29,384	28,786	5,305	23%	23	26	28	5	23%
Non-U.S. Soybeans	32,566	46,163	64,784	32,219	99%	16	21	23	6	38%
World Soybeans	56,046	75,547	93,570	37,524	67%	19	23	24	5	28%

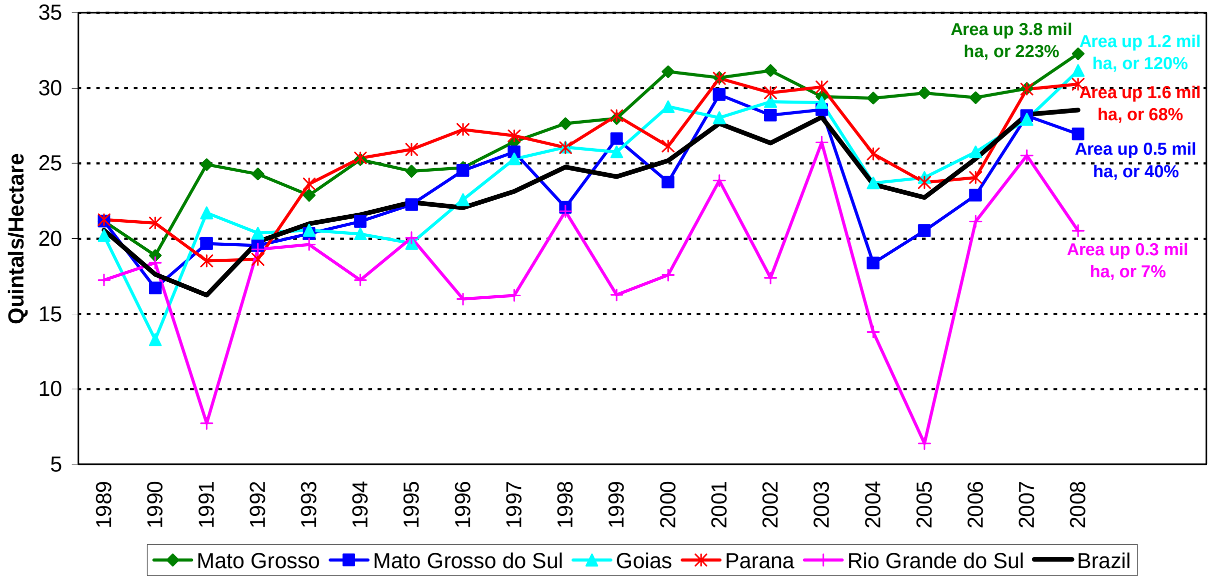
Note: 2008P indicates preliminary non-U.S. and world estimates

In Appendix C-5, the first comment about the elasticity of crop yields with respect to area expansion is, “Because almost all of the land that is well-suited to crop production has already been converted to agricultural uses, yields on newly converted lands are almost always lower than corresponding yields on existing crop lands.” (C-29) One of the main areas of the world where a substantial amount of new land has been brought into crop production during the last couple of decades is Brazil. From 1989 to 1998, major crop area in Brazil increased by 9 million hectares, virtually all accounted for by an increase in soybean area. A review of Brazilian soybean yields by state produces results that are contrary to the assertion that “yields on newly converted lands are almost always lower than corresponding yields on existing crop lands.”

In fact, as shown in Figure 1, the Brazilian states where soybean area expansion has been the greatest over the last two decades have tended to have higher yields than those where less expansion has taken place. In recent years, yields have been highest in Mato Grosso, where soybean area expanded by 3.8 million hectares between 1989 and 2008, an increase of 223%. The second-highest yield in 2008 among states reflected in Figure 1 (the top five states by soybean area) was in Goias, where soybean area has increased by 1.2 million hectares since 1989, or

120%. Both states experienced yields that were higher than the Brazilian average, and yields in Mato Grosso have been consistently above the national average.

Figure 1: Brazilian Soybean Yields by State



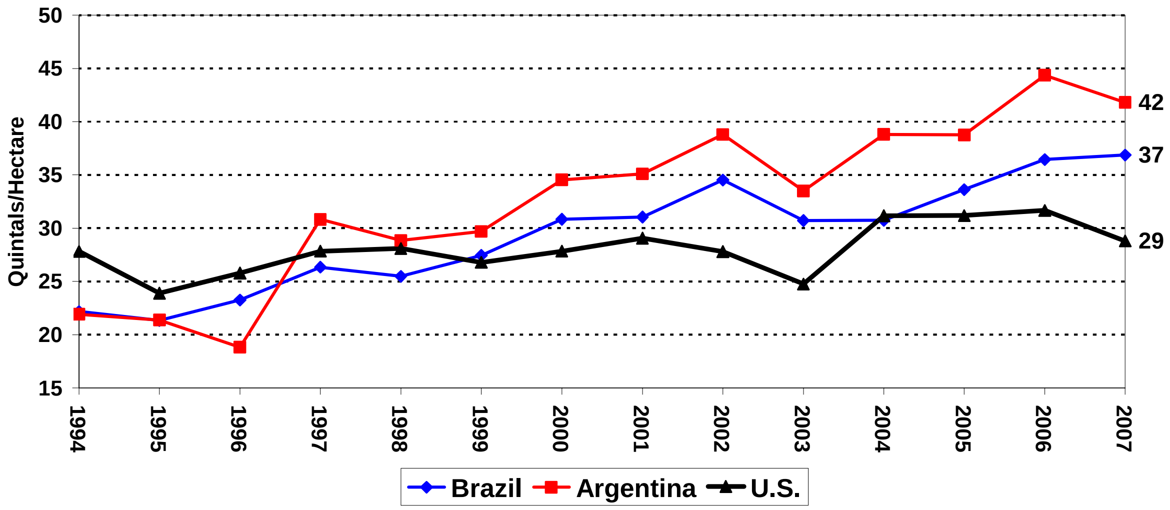
Parana is a more traditional soybean-producing state, and its yields have been consistently above the national average. However, there has been considerable expansion in Parana as well, with 1.6 million hectares more planted in 2008 than 1989, an increase of 68%.

Back in 1989, Rio Grande do Sul was the largest soybean-producing state in Brazil, accounting for 30% of the country's planted area. However, there has been little soybean area expansion in the state, and yields significantly lag the national average and are more variable than in the other major states.

In summary, yields in the "new" soybean states of Mato Grosso, Mato Grosso do Sul and Goias were 31 quintals per hectare (3.1 metric tons per hectare) in 2008, compared to an average 25 quintals per hectare in the more established soybean-growing states of Parana and Rio Grange do Sul. Averaged over the last three years (2006-2008), the yield differential was slightly smaller, with the "new" states averaging 29 quintals per hectare and the established states averaging 25 quintals per hectare.

Looked at another way, the combination of substantial soybean area growth and increasing yields in Brazil and Argentina demonstrate that it is mathematically unlikely that the assignment (based on judgment) of a value of 0.5 to the elasticity of crop yields with respect to area expansion is correct. Given actual national average soybean yields that have occurred in the U.S., Brazil and Argentina since 1994, Figure 2 shows soybean yields that would have had to be achieved on the land on which soybeans were grown in 1994, if the yield elasticity for new land were 0.5. By 2007, the yield on existing land would need to have been 42 quintals per hectare (62 bushels per acre) in Argentina and 37 quintals per hectare (55 bu/ac) in Brazil, which is far higher than the 29 quintal-per-hectare (43 bu/ac) yield implied for existing land in the U.S. It is also roughly double the 22 quintal-per-hectare (33 bu/ac) yield that occurred on the same land in Brazil in Argentina in 1994. Actual national average yields in 2007 were roughly 28 quintals per hectare (42 bu/ac) in all three countries in 2007 (across all area planted).

Figure 2: Implied Soybean Yields on Previously Existing Land, Assuming an Area Expansion Elasticity of 0.5



In conclusion, regarding the elasticity of crop yields with respect to area expansion, the given the findings provided above, it cannot be determined that yields on new area have been meaningfully different than yields on area previously planted to crops (i.e., that the elasticity is less than 1). It appears that "judgment" was used to set the value for the elasticity parameter at an unrealistically low level; ARB should correct this by obtaining empirical data regarding actual yields on existing crop land versus newly planted land.

3. It is likely problematic that the GTAP model takes cross-commodity effects into account, but the subsequent adjustment outside the model does not. In a manner related to the previous two comments, the assumptions (stated or implicit) in Appendices C5 and C10 that all yield increases have been similar, which allows an adjustment to be made outside the model rather than having all acreage allocation and impact estimates made inside the model, are problematic. In particular, the extent to which corn versus soybean area is assumed to increase in the ROW in response to a shock to U.S. corn demand is important. On average over the last three years, U.S. corn yields have been approximately 2.55 times ROW corn yields, whereas U.S. soybean yields have been a lesser 1.25 times ROW soybean yields (i.e., half the magnitude of the corn differential). Thus, if corn area increases in the

U.S. at the expense of soybean acres, and additional soybean acres in the ROW are needed to make up for a loss of U.S. soybean acres, the land-use impact will be less than if corn were to account for a large share of the ROW area change. Given the comments above regarding the elasticities discussed in Appendix C5, it is not clear that the model "handled" this issue appropriately.

Appendix D

Report by NERA:

Accounting for Differences in the Timing of Emissions in Calculating Carbon Intensity for the California Low Carbon Fuels Standard

April 2009

Accounting for Differences in the Timing of Emissions in Calculating Carbon Intensity for the California Low Carbon Fuels Standard

Prepared for the
Renewable Fuels Association

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Contents

List of Figures

List of Tables

Executive Summary

The California Air Resources Board (CARB) has proposed regulations to implement a Low Carbon Fuels Standard (LCFS). In developing the LCFS, CARB must consider indirect emissions (in this case, increases in emissions due to land use changes) as well as direct emissions associated with different fuels. One of the issues addressed by CARB staff in the Initial Statement of Reasons (ISOR) is how to account for the fact that the emission profiles of the various fuels differ widely over time. In particular, the CARB staff estimates that land use changes associated with increased use of corn-based ethanol would generate substantial indirect CO_2 emissions in the early years of a project. In contrast, the reductions in direct emissions due to the use of ethanol rather than gasoline would be spread relatively evenly over many years. What formula is used to aggregate these various streams across time has a major effect on the potential credits given to corn-based ethanol as a substitute for gasoline in meeting a LCFS.

A. CARB Considers Four Alternative Timing Approaches in the Initial Statement of Reasons

In the ISOR, the CARB staff reviews four different methods for comparing uneven streams of emissions over time:

1. The *Annualized* method averages emissions over the life of the project and compares those averages.

2. The *Net Present Value* (NPV) method compares the present value of discounted emissions.

3. The *Fuel Warming Potential* (FWP) projects the impacts of emissions on the stock of CO_2 in the atmosphere over a fixed Impact Horizon and sums those impacts for comparison.

4. *The Economic Fuel Warming Potential* (FWPe) uses the same projections as the FWP, but discounts the stock impacts.

Note that the Annualized method is a special case of the NPV method with a discount rate of zero. Similarly, the FWP method is a special case of the FWPe method, again with a discount rate of zero.

These methods vary significantly in the relative weights they give CO_2 emissions in different years. The Annualized method weights emissions equally for all years in which they occur. At the other extreme, the FWPe gives relatively little weight to emissions in later years both because it discounts their impacts on the stock of CO_2 and because it tracks those emissions' effects on the atmospheric stock for fewer years, as we discuss below.

B. The Two Fuel Warming Potential Approaches are Arbitrary and Should Not be Used to Compute Carbon Intensity for Land Use Changes

The two FWP and FWPe methods, while claiming to provide a proxy measure of relative damages, in fact reflect an arbitrary choice of a fixed Impact Horizon over which effects are evaluated. This fixed Impact Horizon leads to calculating the effects of emissions in later years over fewer years, thus arbitrarily decreasing the relative importance of later-year emissions. With a 30-year Impact Horizon, for example, the atmospheric impacts of a unit emitted in year 1 are tracked over the full 30 years. However, a unit emitted in year 30 is tracked over only 1 year.

This truncation of the analysis for emissions in later years gives undue weight to emissions in the early years, when those for corn-based ethanol are greatest. We show that eliminating this differential truncation, so that the atmospheric effects of all emissions are tracked for the same length of time from the time they are emitted, makes the FWP equivalent to the Annualized method and the FWPe equivalent to the NPV approach. This equivalence holds true regardless of the length of time over which emissions are tracked following their release. In light of the arbitrary nature of the Impact Horizon and its uneven impacts, we recommend that CARB not rely on either of the two FWP approaches.

C. Calculations of Carbon Intensity Should Account for the Expectation that the Social Cost of Carbon Will Increase over Time

Discounting is normally applied to monetary measures of costs and benefits. If it is to be applied to emissions or other physical measures, it is not appropriate to apply the same discount rate used for dollars unless the dollar value per unit of the physical measure is constant over time. In the case of CO_2 emissions, there is a wide consensus among researchers who have studied the issue that the “Social Cost of Carbon” (SCC) is growing over time. This growth reflects several different factors, including growth in populations and income and rising atmospheric concentrations of CO_2 and other greenhouse gases. An IPCC report published in 2007, after reviewing the literature, concluded that “current knowledge suggests a 2.4 percent rate of growth.”

In practice, adjusting for value means that whatever discount rate CARB finds is appropriate for monetary measures should be reduced by the estimated growth rate of the SCC. The ISOR provides estimates of carbon intensity using discount rates of 2 percent and 3 percent. Using the IPCC estimate of 2.4 percent, if the monetary discount rate is 2 percent, for example, the discount rate that should be applied is -0.4; i.e., later emissions should receive *more* weight than early emissions because of the greater damage they cause. If the monetary discount rate is 3 percent, the discount rate applied to emissions should be only 0.6 percent.

D. Illustrative Comparisons of Impacts of Alternative Methods on the Estimated Carbon Intensity of Land-Use Changes

For illustrative purposes, we use the various time-accounting methods to compute alternative estimates of ethanol's indirect emissions—the "Land Use Change Carbon Intensity" (LUC CI) for corn-based ethanol—using the ISOR's estimated profile of the LUC emissions. For each of three different general methods we computed the LUC CI's for discount rates in the range 0 to 3 percent—the range that bounds the values provided in the ISOR—as shown in Table E-1:

1. The "Annualized/NPV" method corresponds to the ISOR's Annualized method for a discount rate of 0 and to its NPV method for positive discount rates.

2. The Value-Adjusted method adjusts the discount rate to reflect a 2.4 percent annual growth in the SCC.

3. The FWP(e)-30 method corresponds to the ISOR's FWP method for a discount rate of 0 percent and to its FWPe method for positive discount rates with an Impact Horizon of 30 years.

For any given discount rate, the FWP(e) methods gives the highest estimates and the Value-Adjusted method the lowest.

Table E-1. LUC CIs with Alternative Methods for Accounting for Emission Timing (CO2e/MJ)

Discount Rate	Annualized/NPV	Value-Adjusted	FWP(e)-30
0%	29.9	22.9	47.5
1%	33.3	25.7	49.8
2%	36.9	28.7	52.2
3%	40.7	31.9	54.7

Note: Assumes 30-year project horizon and SCC growth of 2.4 percent for Value-Adjusted method.
Annualized/NPV values are ISOR's Annualized Method for r=0 and its NPV method for r>0.
FWP(e)-30 values are the FWP method for r=0 and FWPe for r>0, assuming 30-year Impact Horizon
Source: NERA calculations based on CARB (2009) and O'Hare et al. 2009.

Note that the Value-Adjusted approach yields values of 28.7 and 31.0 for discount rates of 2 and 3 percent, respectively. These values are similar to the value of 29.9 achieved using the Annualized/NPV approach with a discount rate of 0 (i.e., no discounting), the approach apparently preferred by CARB staff.

I. Introduction and Overview

The California Air Resources Board (CARB) has proposed regulations to implement a Low Carbon Fuel Standard (LCFS) pursuant to Executive Order S-01-07 and Assembly Bill 32 (AB 32). In developing the LCFS, CARB is required to consider indirect as well as direct emissions associated with different fuels. Estimating the direct and indirect emissions of different fuels is a complex task that depends on numerous assumptions and assessments. The task is made more complicated by the fact that calculating the carbon intensity of various fuels involves comparing emissions profiles that differ in their timing. In this paper we focus on how emission profiles that vary over time can be aggregated to allow meaningful comparisons across fuels.

A. CARB's Estimated Profiles and Aggregation Methods

CARB staff has produced an Initial Statement of Reasons (ISOR) that provides an overview of the regulations and their implementation as well as analyses in support of the proposed rule. A principal component of the ISOR is an analysis of the Carbon Intensity (CI) of "alternative fuel pathways" that might be used in order to comply with the rule. These calculated CI values have implications for the level of credit that will be granted for use of the alternative fuel pathways under the rule, and ultimately how long a given alternative fuel pathway will remain a viable compliance option. For crop-based biofuels, calculations reported in the ISOR include the impact of indirect emissions, based on projections of increased land clearing and conversion (and the consequent release of CO_2 emissions) resulting from increased demand for ethanol. The ISOR refers to these indirect emissions from land clearing as Land Use Change (LUC) emissions.

These emissions have a very different temporal pattern than the reductions in direct emissions from substituting ethanol for gasoline. As estimated by CARB staff, the indirect emissions tend to be significant in early years and gradually fall to zero over about 20 years. In contrast, the direct emissions benefits per unit of fuel are smaller but constant over time. As a result, the calculation of carbon intensity requires a method for comparing emission streams that differ over time.

For any given profile of indirect emissions over time, the ISOR presents four different methods of calculating the indirect CI for comparison with the direct reductions in emissions achieved compared to gasoline:

1. *Annualize*. This approach averages emissions over the project life. It is the CARB staff's currently preferred approach.
2. *NPV* ("net present value"). This approach compares the discounted sums of emissions.
3. *FWP* ("Fuel Warming Potential"). This approach projects how emissions will influence the abundance of CO_2 in the atmosphere over time, based on the Bern model of the carbon cycle. It then sums those values over an "Impact Horizon."
4. *FWPe* ("economic FWP"). This approach uses the projections made with the FWP, but instead of summing the contributions to CO_2 in the atmosphere, it computes their discounted values.

B. Project Objectives and Organization of the Report

The objective of this project is to compare alternative methods for accounting for the different timing of indirect and direct emissions. The remainder of this report is organized into three major sections:

- Section II provides an overview of the methods presented in the ISOR for aggregating emissions over time and shows graphically the implicit weights they give to emissions in different years. It also shows how the FWP methods give disproportionate weight to earlier emissions because they account for their atmospheric impacts over more years than they do for later years. Correcting that imbalance makes the FWP method equivalent to the Annualized method and the FWPe method equivalent to the NPV method.

- Section III shows how taking account of the wide consensus that the marginal damages caused by CO_2 emissions (the “Social Cost of Carbon) will continue to increase for many decades affects the relative weights given to different years. For any given monetary discount rate (including zero), the appropriate discount rate for emissions is reduced substantially and in some cases even becomes negative, increasing the relative weight given to emissions in later years.

- Section IV use the methods developed in the previous two sections to compute alternative estimates of the Land Use Change Carbon Intensity (LUC CI) for corn-based ethanol based on the CARB staff’s estimated emissions profile using “representative” parameter values. It also offers brief concluding remarks.

II. Overview of the CARB Staff Analysis

This section provides an overview of the CARB analyses of timing considerations in calculating carbon intensity. We begin by presenting the CARB staff's estimated time profile of emissions from land use changes. Then we explain in more detail the alternative methods for aggregating emissions over time that the ISOR presents.

A. Summary of Indirect Emissions Analysis

CARB staff use life-cycle analysis to estimate the CI of ethanol and other fuel pathways that might be used under the LCFS. Complete life-cycle analysis requires the development of carbon intensity estimates for both "direct" emissions (resulting from fuel production, transport, storage, and use) and "indirect" emissions (resulting from market interactions associated with changes in fuel demand). CARB staff has developed estimates of indirect emissions only for land use changes for crop-based biofuels, asserting that this is the "one indirect effect that generates significant quantities of GHGs" (p. IV-17). We focus only on CARB staff's assessment of indirect emissions from corn-based ethanol. CARB staff used a computable general equilibrium (CGE) model to estimate the amount and types of land that would be converted as a result of increased ethanol demand, and then estimated the CO_2 emissions that would result.

The profile of emissions from land use changes depends heavily on a large number of assumptions. Because our focus is on alternative methods for weighting emissions over time, not the emissions themselves, we rely on the CARB staff's "representative" emissions profile from land-use changes that may be associated with corn-based ethanol. We understand, however, that the profile is subject to substantial uncertainty and is very sensitive to various assumptions, in particular how much land would be converted per unit of ethanol and the type of land converted.

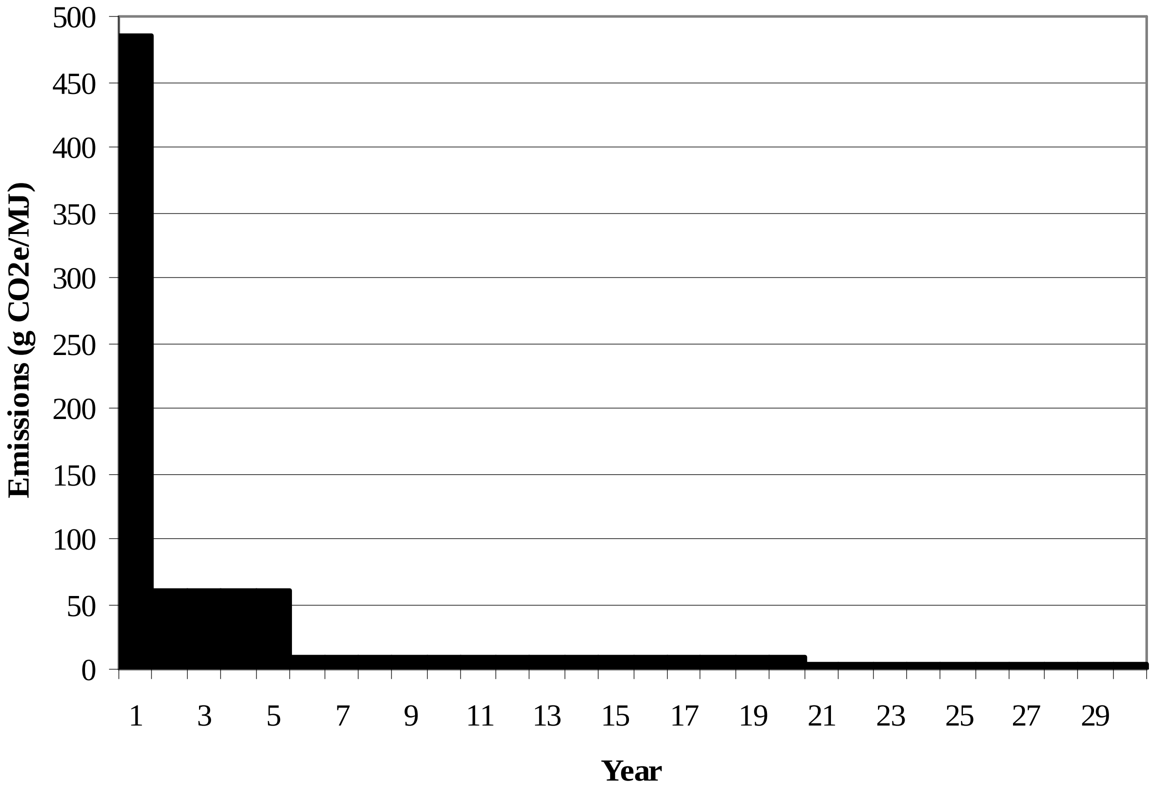
As shown in Figure 1, the CARB staff's "representative" emission profile has the following characteristics:

§ a large initial flux in emissions due to the release of carbon from vegetation cleared from the land and assumed to be burned or left to decay;

§ release of carbon sequestered in the soil, with relatively high emissions over the first five years and then a lower rate of emissions over the next 15 years; and

§ forgone sequestration occurring over the entire Project Horizon (the period from initial production until corn-based ethanol is assumed to be displaced by other biofuels become more cost-effective).

Throughout this report we refer to "gasoline" and "corn-based ethanol," but the same metrics apply to diesel and other fossil motor fuels and to other biofuels.



Note: Emissions are in gCO2e/MJ
Source: CARB 2009

Figure 1. CARB's Estimates of CO_2 Emissions from Land-Use Changes Associated with the Production of Corn-Based Ethanol

B. Aggregating Emissions Over Time

Because the time profile of indirect emissions is different than that for direct emissions, it is necessary to find a way of aggregating emissions over time so that the different streams associated with different fuels can be compared meaningfully in terms of their CIs. As noted above, the ISOR presents four different methods of aggregation. Application of each accounting method requires the choice of a “Project Horizon.” The Project Horizon represents the number of years over which the analyst expects the production of the corn-based ethanol to continue. CARB staff argues that corn-based ethanol will not be competitive with other biofuels in the long run because of relative costs and direct emissions. The ISOR considers project horizons of 20 and 30 years, with 30 years as the preferred horizon. As discussed above, the ISOR examines four different aggregation methods: (1) Annualized (averaged emissions), (2) NPV (discounted emissions); (3) FWP (carbon-cycle model); and (4) FWPe (FWP with discounting).

In addition to the Project Horizon, the two FWP methods require specifying an Impact Horizon, which is the period of time over which the global warming impacts of ethanol and the gasoline reference fuel are aggregated for comparison. The ISOR evaluates Impact Horizons ranging from 10 to 100 years, but focuses on results from 30 and 50 years. It does not make sense to use an Impact Horizon that is shorter than the Project Horizon and in general the impact horizon should extend well beyond the project horizon in light of the long residence of CO_2 in the atmosphere. The two methods that involve discounting (NPV and FWPe) require specifying a discount rate.

We now discuss the four methods in detail. We focus on the relative weight that each method gives to emissions in different years (w_t = emissions in year t), where the first year's weight is defined as $w_1 = 1.0$.

1. Annualized Method

The Annualized method simply averages LUC emissions over the Project Horizon; i.e., it takes the sum of the indirect emissions and divides them by the length of the Project Horizon. Thus, emissions in all years receive equal weight for any given Project Horizon; $w_t = 1$ for all t. However, annualized indirect emissions fall as the Project Horizon increases and the relatively high early indirect emissions are spread over more years.

2. Net Present Value of Emissions

Taking the NPV of emissions assigns declining weights to emissions the farther in the future they occur. The relative weight for emissions in year t is simply $w_t = (1+r)^{-(t-1)}$, where r is the discount rate. Thus, the early sequestration losses assumed from land-use changes get more weight than the net emission reductions achieved in later years. The emissions in year 1, when CARB assumes land would be cleared, receive a weight of 1.0. At the 2 percent discount rate used by CARB in the main body of the ISOR, however, emissions in year 20 receive a relative weight of only 0.69 and those in year 30 receive a weight of 0.56. Thus, to offset each ton of emissions released in year 1, with a discount rate of 2 percent, emissions in year 20 would have to fall by more than 1.4 tons or emissions in year 30 would have to fall by almost 1.8 tons. Higher discount rates would lead to much more rapidly declining weights. With a rate of 3 percent, the discount rate used in Appendix C-4 of the ISOR for illustrative purposes, the weight for year 20 falls to 0.57 and that for year 30 falls to 0.42. The NPV approach also is sensitive to the project horizon, though less so than the averaging method. As with the averaging method, however, it does not vary with the Impact Horizon.[1]

The NPV approach is equivalent to annualizing LUC emissions with a positive interest rate. To calculate the annualized value of an uneven stream, one first takes the NPV of that stream. The annualized value is then the level stream over a specified number of years that yields the NPV of the original uneven stream. Mortgage payments are calculated in this way; monthly payments are set so that their NPV (discounted at the mortgage's interest rate) over the life of the loan is equal to the amount borrowed. If the annualized value is calculated using a discount rate

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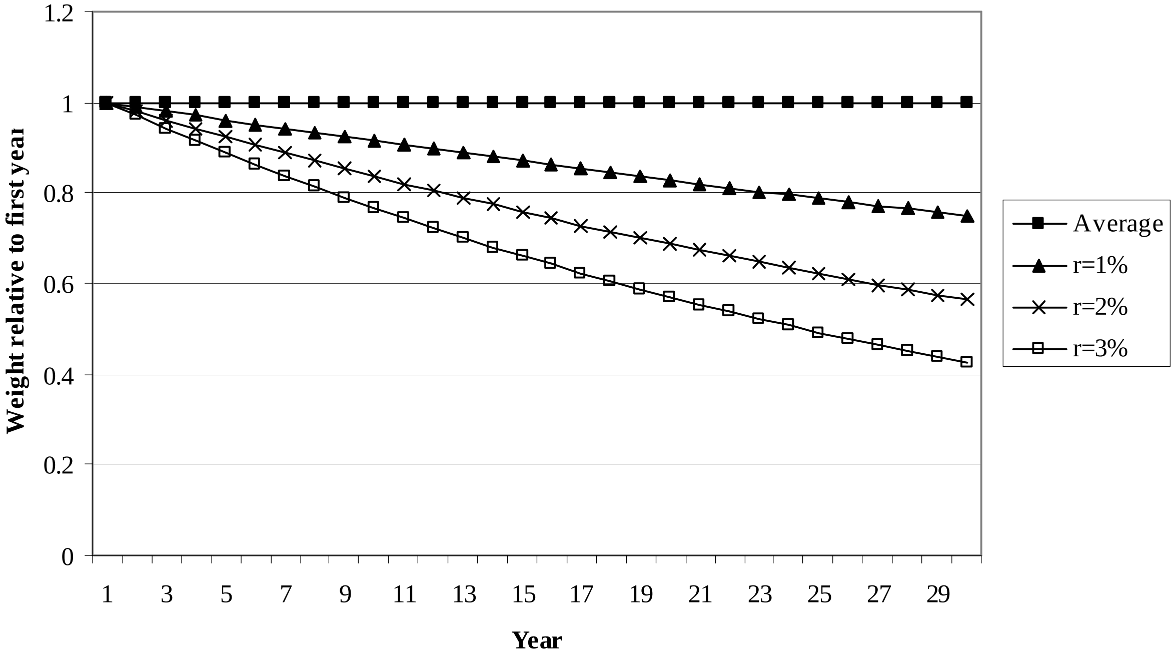
[1] The NPV approach would vary with the impact horizon only for impact horizons shorter than the project horizon, which, as we noted earlier, generally would not make sense.

of zero, it is the same as the CARB staff's "Annualized" approach, which is a simple average. For positive discount rates, however, the annualized value will be larger than the simple average.

Figure 2 plots the relative weights for the Annualized and the NPV methods, showing values for the NPV for discount rates of 1 and 3 percent in addition to the 2 percent rate used in the ISOR.



Source: NERA Calculations based on CARB (2009).

Figure 2. Relative Weights Given Emissions in Different Years: Averaging and NPV Methods

3. Fuel Warming Potential

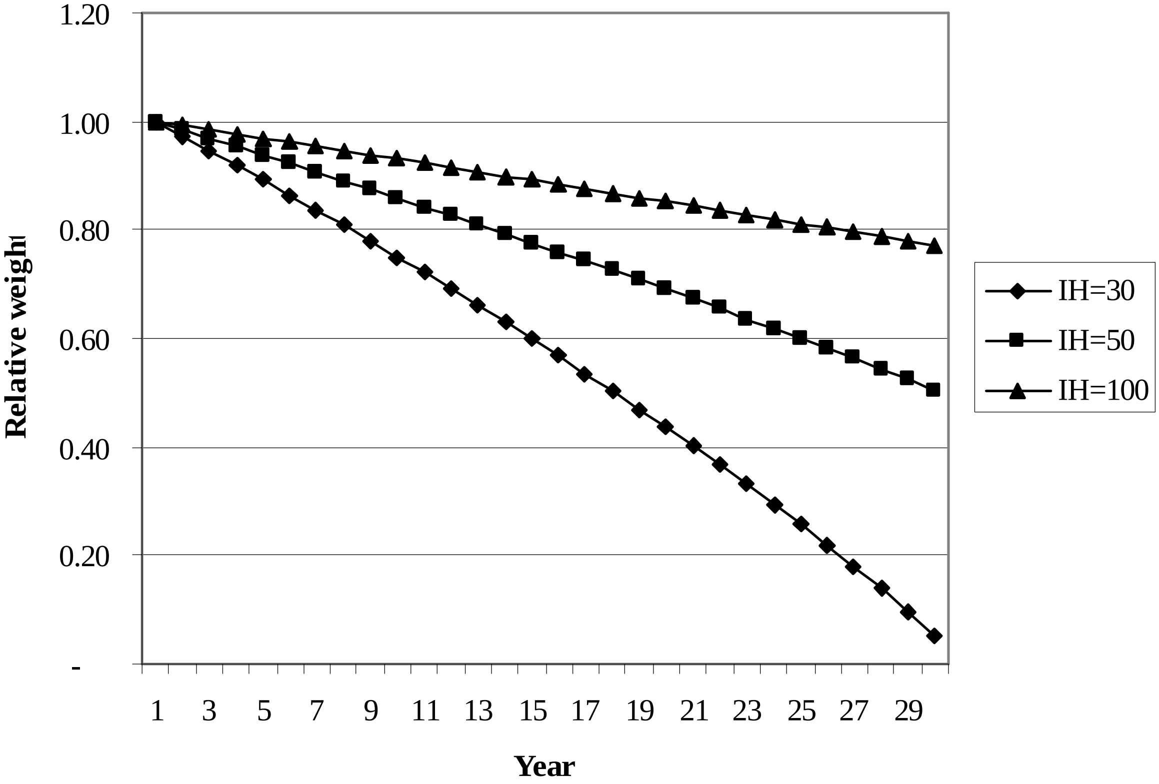
The FWP measure, developed by O'Hare et al. (2009) and presented in the ISOR, is substantially more complicated to compute. For a unit of CO_2 emitted in a given year, this model uses the Bern carbon-cycle model to project how much CO_2 will remain in the atmospheric stock over time; the farther one goes into the future from the year in which the emission occurred, the smaller the fraction of the original emission that remains in the atmosphere. The Bern model in essence yields a decay function, D(*i*), which is the fraction of a unit of CO_2 remaining in the atmosphere *i* years after the unit is emitted. The FWP method totals the projected stock impacts from the year in which the emission occurs to the end of the Impact Horizon (H_I). We can then compute the relative weight for a given year by dividing the sum for that year by the sum for the first year:

$$w_t = \frac{\sum_{i=t}^{H_I} D(i-t+1)}{\sum_{i=1}^{H_I} D(i)}. \tag{1}$$

This expression may be rewritten in the following form:

$$w_t = \frac{\sum_{i=1}^{H_I-t+1} D(i)}{\sum_{i=1}^{H_I} D(i)}. \tag{2}$$

Note that because the FWP uses a fixed impact horizon, the impacts of later emissions are summed over fewer years. For example, consider Project and Impact horizons that are both equal to 30 years. For emissions that occur in the first year, their impact will be summed over the full 30 years of the Impact Horizon. For emissions that occur in year 30, however, their impact will be summed over only one year. Thus, later tons get less weight than early ones, with especially rapid fall-off as the year of the emission approaches the Impact Horizon. The relative weights are highly sensitive to the Impact Horizon, as shown in Figure 4, which plots the relative weights given to emissions in different years for alternative Impact Horizons ranging from 30 to 100 years and a Project Horizon of 30 years. The shorter the Impact Horizon, the less relative weight emissions in later years receive. As the Impact Horizon grows longer, all of the weights approach 1.0; with an infinite impact horizon, the FWP would be the same as the averaging method.



Source: NERA calculations based on CARB (2009).

Figure 3. Relative Weights under FWP Measure with Alternative Impact Horizons

4. “Economic” Fuel Warming Potential

Appendix C of the ISOR also presents a measure that it calls the “Economic Fuel Warming Potential,” which it abbreviates as FWPe. It is simply the FWP with contributions discounted back to a common starting year:

$$w_t = \frac{\sum_{i=t}^{H_I} D(i-t+1)(1+r)^{-i}}{\sum_{i=1}^{H_I} D(i)(1+r)^{-i}} = (1+r)^{-(t-1)} \frac{\sum_{i=1}^{H_I - t+1} D(i)(1+r)^{-i}}{\sum_{i=1}^{H_I} D(i)(1+r)^{-i}}. \qquad \textbf{(3)}$$

On the right-hand side, the term $(1+r)^{-(t-1)}$ is the discount factor reflecting the fact that a unit emitted in year *t* does not start affecting atmospheric concentrations until *t*-1 years after a unit emitted in year 1 does. The ratio of the sums is similar to the ratio with the FWP, but with discounting applied.

With the FWPe approach, emissions in later years receive less weight relative to those in early years both because their implicit impacts are summed over fewer years (as with the FWP) and because they are discounted more heavily. As with the pure FWP, the FWPe is sensitive to the Impact Horizon, although the effect of the Impact Horizon is smaller on a proportional basis than with the FWP.[2] Figure 4 compares the weights assigned by the FWP and FWPe (with a discount rate of 2 percent) approaches for two different Impact Horizons, 30 and 50 years. The longer the Impact Horizon, the more slowly the weights decline over time. Conversely, the higher the discount rate, the more rapidly they decline. As we show in Appendix A, for any given discount rate, the longer the impact horizon, the closer the weights come to those obtained with the NPV method; in the limit, as the impact horizon approaches infinity, the FWP method approaches the Annualized method and the FWPe approaches the NPV method.

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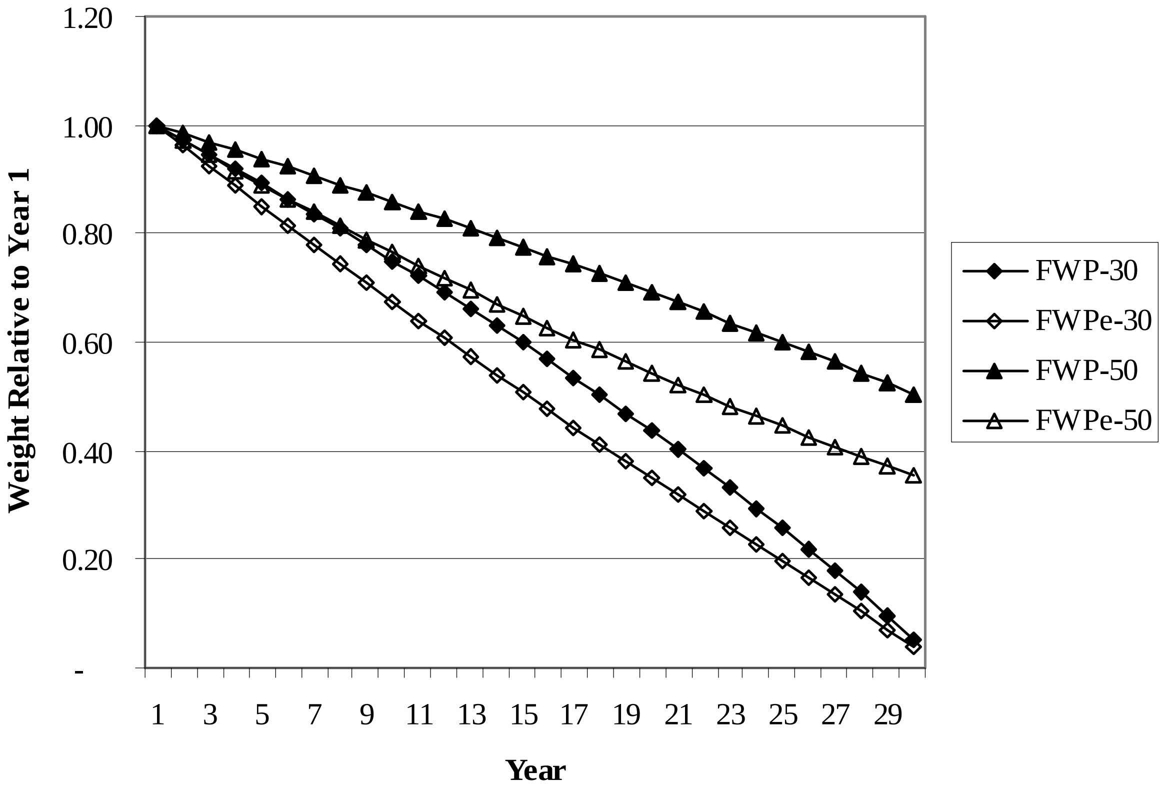
[2] That is because the $H_I - t+1$ extra years counted for year 1 but not year t are discounted and thus receive less weight.



Note: FWPe weights reflect a 2 percent discount rate.
"-n" in legend means an Impact Horizon of n years.
Source: NERA computations based on methods in O'Hare et al. (2009)

Figure 4. Comparison of Relative Weights for FWP and for FWPe with Impact Horizons of 30 and 50 Years and a Discount Rate of 2 Percent for FWPe

C. Modified Fuel Warming Potential and "Economic" Fuel Warming Potential

As discussed above, the FWP and FWPe give lesser weight to emissions in later years simply because those methods evaluate the effects of those emissions in the atmosphere for fewer years. Here we consider a modified version of the FWP(e), one that does not require using a very long Impact Horizon. We propose that instead of using a fixed Impact Horizon, the number of years over which emissions are evaluated after they occur should be constant, to avoid uneven truncation effects. We call this period the Evaluation Horizon. That is, if the evaluation horizon is 25 years, impacts of year 1 emissions are tracked (using the Bern equation) over 25 years, from year 1 through year 25 and the impacts of year 21 emissions also are tracked over 25 years, from year 21 through year 45. Similarly, if the Evaluation Horizon is 100 years, year 1 emissions are tracked over years 1-100 and year 21 emissions are tracked over years 21-120.

If one evaluates the FWP in this way, using a consistent evaluation period after a given emission occurs, it turns out that the length of the evaluation horizon does not affect the relative weights given emissions in different years; i.e., it does not matter whether one follows emissions in the atmosphere for 1 year after they are emitted or for 1000 years, so long as the Evaluation Horizon is the same for emissions in all years. Appendix A provides a formal proof of this fact.

With the modified FWP, all years receive equal weight: $w_t = 1$ for all t. Thus, if the FWP is modified to evaluate each unit of emissions for the same number of years following its release, the FWP is no different than the Annualized approach. Similarly, if one modifies the FWP_e in the same manner, applying a uniform Evaluation Horizon after emissions occur, it yields the same weights as the NPV method, regardless of how long the Evaluation Horizon is. Thus, although the FWP and FWPe approaches may *appear* to be more sophisticated approaches than their emission-based counterparts, in fact they are no different once one equalizes the times over which the impacts of emissions are tracked after they occur. The temporal patterns of weights given by the original FWP and FWPe approaches are distorted by the uneven evaluation periods applied to emissions in different years because of an arbitrarily chosen Impact Horizon.

III. Accounting for Changing Marginal Damages

The methods presented in the previous section implicitly assume that the marginal value of controlling a unit of emissions is constant over time; i.e., they assume a ton emitted in 2029 causes the same marginal climate change damage as a ton emitted today, when those damages are valued at the time of the emissions. Discounting emissions accounts for the fact that we value a dollar received today more than one received in 20 years. However, as O'Hare et al. (2009) point out, discounting emissions (or other physical measures) using an economic discount rate intended for monetized costs and benefits is not appropriate if the dollar value of emissions is changing. In this section we analyze the impact on relative weights of accounting for projected changes in the marginal damages caused by emissions at different times. Although there is considerable uncertainty about the dollar value of damages caused by CO_2 emissions, commonly called the Social Cost of Carbon (SCC), there is a broad consensus in the literature that the SCC is growing and that the growth rate is significant relative to the discount rates commonly applied to long-term effects of climate change. As a result, taking account of these changes in the value of controlling a ton of CO_2 emissions can have a substantial effect on weights given to emissions over time.

A. Social Cost of Carbon is Likely to Rise over Time

Estimating the marginal damages caused by a ton of emissions in any year is a difficult task subject to many uncertainties. Integrated assessment modeling studies, however, have consistently found that the SCC will rise over time for decades to come. These models take account of the residence time of carbon in the atmosphere, as the FWP and FWPe do, but they also account for the fact that the underlying atmospheric concentrations to which emissions contribute at the margin will change, thus affecting marginal impacts on climate change, and that the impacts of climate change will vary over time with changes in population, income, and other factors.

The SCC in year *t* is the present value of the stream of marginal damages caused by a ton of emissions in that year during the period it resides in the atmosphere. This SCC reflects many factors: how that ton of emissions will affect the atmospheric stock of GHGs in subsequent years, how those changes in the stock will translate into changes in climate, and finally the marginal damages caused by those changes in climate. Finally, the present value in year *t* of that stream of marginal damages resulting from a ton of emissions must be computed. That present value represents the SCC for year *t*.

There are several reasons why one would expect the SCC to increase over time. First, even with substantial cuts in emissions—especially if they are limited to a subset of developed nations—the atmospheric concentration is likely to continue to grow for many decades, if not a century or more, before a steady-state concentration is reached.[3] This will be the case regardless of what LCFS regulation CARB imposes. Second, within broad limits, the later a ton is emitted, the more it will contribute to higher concentrations because a smaller fraction will have been removed from the atmosphere. Third marginal damages from climate change are likely to increase with the level of climate change. Fourth, marginal damages are likely to increase over time due to growth in population and income (Pearce 2003). As population increases, more individuals are exposed to any negative ecological, health, or economic effects associated with climate change. Similarly, as average worldwide incomes increase, the costs associated with economic disruptions become larger. Thus, it seems likely that the SCC will increase for many decades, well beyond the project horizons assumed in the analyses presented in the ISOR.

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[3] See, for example, Webster et al. (2003).

B. Estimates of the Social Cost of Carbon from the Literature

Numerous studies report estimates of the SCC, but relatively few address the rate at which the SCC will grow over time. In addition, to the extent to which studies report an expected growth rate over time (or point estimates of the SCC in multiple years), the varied assumptions and methodologies used in different studies make it challenging to reconcile estimates made by different groups. Studies vary in the emissions scenarios assumed (generally either business as usual or optimal control of emissions), the time horizon evaluated, the discount rate, whether equity weights are used (which give greater weight to impacts in less-developed regions), and the scope of damages considered, among other factors.

For all of their differences, however, those studies that have estimated the SCC for different years consistently have produced estimates of the SCC that increase over time. Clarkson and Deyes (2002) provide a survey of studies that develop point estimates for the SCC, including five that estimate the SCC in multiple time periods and find that it increases over time.[4] Pearce (2003) builds upon the research in Clarkson and Deyes, focusing on estimates developed without equity weights and incorporating three additional studies that also find that point estimates of the SCC increase over time.[5] Finally, the Final Report of the UK Government's *Social Costs of Carbon Review* (Watkiss et al. 2006) commissioned additional analyses of the SCC over time using two different integrated assessment models, and likewise

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[4] The time periods range from 1991-2000 to 2021-2030. The relevant studies are Cline (1992), Maddison (1994), Nordhaus (1994), Fankhauser (1995), and Tol (1999).

[5] Pearce considers the same time periods and many of the same studies as Clarkson and Deyes. The additional studies considered include Peck and Teisberg (1992), Roughgarden and Schneider (1999) and Nordhaus and Boyer (2000).

finds that the SCC increases over time, though the rate at which this occurs varies over time and between models.[6]

In interpreting the wide range of findings outlined above, the IPCC Fourth Assessment Report notes that "current knowledge suggests a 2.4% rate of growth." (Yohe et al. 2007, p. 822). We use this number for illustrative purposes.

C. Applying the Growth Rate of the Social Cost of Carbon

Discounting normally is applied to monetized costs and benefits (or damages), and it is not appropriate to apply a monetary discount rate to physical quantities unless the economic marginal value of the physical measure remains the same over time. If the marginal value of the physical unit is growing at a constant rate over time, however, there is a simple relationship between the financial discount rate and the rate that should be applied to the underlying physical measure.

Let SCC_t be the marginal damages from a unit emitted in year t, reflecting the discounted sum of its damages over its residence in the atmosphere. The present value of one unit of emissions in year t is then $SCC_t/(1+r)^t$. If SCC_t is growing at the rate s, then we can rewrite its present value as $SCC_0 \cdot (1+s)^t/(1+r)^t$, or $SCC_0[(1+s)/(1+r)]^t$. In computing relative weights for different years, the SCC_0 term drops out because it appears in all years; i.e., in developing relative weights, the absolute value of SCC_0 is not needed. The weight given to a unit emitted in year t relative to a unit emitted in year 0 is $[(1+s)/(1+r)]^t$. We obtain the same result if we use a discount rate for emissions that is equal to $(r-s)/(1+s)$, which is approximately the same as $r-s$ for small values of s. Thus, for example, if the monetary discount rate is 3 percent and the growth rate of the SCC is $s = 2.4$ percent, the equivalent discount rate for emissions is about 0.6

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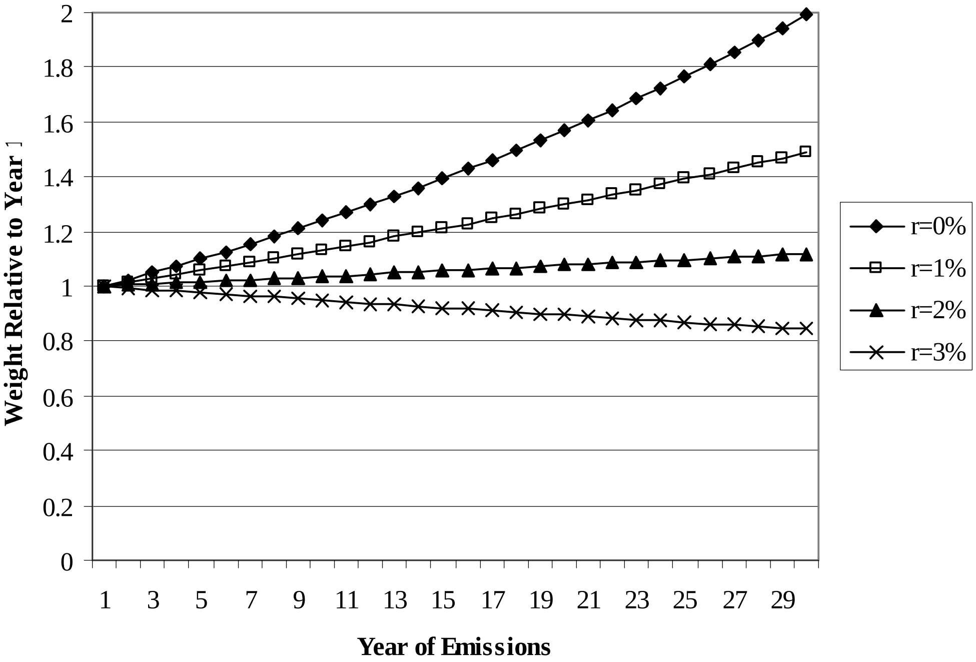
[6] The analyses commissioned by the UK DEFRA evaluate SCC estimates over a time horizon of 60 years.

percent.[7] If the monetary discount rate is 2 percent, the rate used in the ISOR, the equivalent discount rate for emissions is -0.4 percent; i.e., later emissions receive *more* weight than current emissions because the SCC is rising faster than the discount rate.

Figure 5 plots relative weights for a range of monetary discount rates assuming 2.4 percent annual growth in the SCC. If the growth rate exceeds the discount rate, the weights rise over time. If the discount rate exceeds the growth rate of the SCC, the weights fall with time, but at a significantly slower rate than if the growth in the SCC was not incorporated in the calculation.



Note: Assumes that the SCC is growing at 2.4% per year, so the effective discount rate applied to emissions is (*r*-2.4%)/(1.024).
Source: NERA calculations

Figure 5. Relative Weights for Value-Adjusted Emissions and Alternative Monetary Discount Rates

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[7] More precisely, it is (*r*-*s*)/(1+*s*), or (0.03-0.024)/(1.024) = 5.86 percent for *r*=3 percent and *s*=2.4 percent.

IV. Illustrative Comparisons of Land Use Change Carbon Intensity Values and Concluding Comments

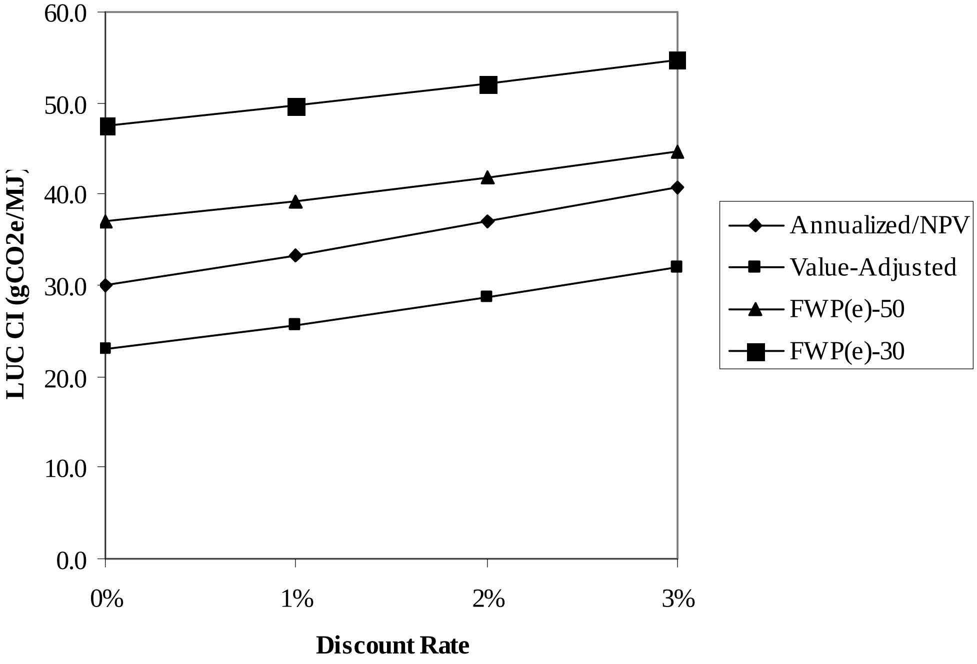
In this section we compute LUC CIs based on the CARB staff "representative" LUC emissions using the alternative methods of accounting for the timing of emissions discussed in Sections II and III. We also offer some brief concluding remarks.

A. Comparison of Land Use Change Carbon Intensity Values Using CARB Staff's Emission Estimates and Different Methods for Accounting for the Timing of Emissions

In computing the LUC CIs for the CARB staff's LUC emission estimates, we consider three general methods of accounting for the timing of emissions:

1. Annualized/NPV: Weights based on the discounted sum of emissions. This is the ISOR's Annualized method for r=0 percent and its NPV method for r>0 percent.
2. FWP(e): Weights based on FWP method (when r=0 percent) or FWPe method (when r>0 percent). We consider two Impact Horizons, 30 (FWP(e)-30) and 50 (FWP(e)-50) years.
3. Value-adjusted method: Weights based on discounted sums of emissions with discount rate adjusted for growth rate of SCC (2.4 percent for illustrative purposes).

Figure 6 plots the results, varying the discount rate over the range considered in the ISOR, from 0 to 3 percent. As the figure shows, for any given discount rate, the FWPe yields the highest LUC CI and the Value-adjusted method yields the lowest value. The emissions-only method yields intermediate values. For any given method, the LUC CI is lowest with a discount rate of zero and rises as the discount rate increases. The FWP(e) values are substantially higher with a shorter Impact Horizon.



Note: Assumes 30-year project horizon and SCC growth of 2.4% for Value-Adjusted method.
Annualized/NPV line is ISOR's Annualized Method for r=0 and its NPV method for r>0.
FWP(e) lines are FWP method for r=0 and FWPe for r>0.
Line labeled FWP(e)-50 assumes a 50-year impact horizon and FWP(e)-30 assumes a 30-year impact horizon

Source: NERA calculations based on CARB (2009) and O'Hare et al. 2009.

Figure 6. Impact of Discount Rate on Alternative Methods of Computing LUC CI

Table 1 reports the same information as Figure 6, but in tabular form.

Table 1. LUC CIs with Alternative Methods for Accounting for Emission Timing

Discount Rate	Annualized/NPV	Value-Adjusted	FWP(e)-50	FWP(e)-30
0%	29.9	22.9	37.0	47.5
1%	33.3	25.7	39.3	49.8
2%	36.9	28.7	41.8	52.2
3%	40.7	31.9	44.7	54.7

Note: Assumes 30-year project horizon and SCC growth of 2.4% for Value-Adjusted method.
Annualized/NPV line is ISOR's Annualized Method for r=0 and its NPV method for r>0.
FWP(e) lines are FWP method for r=0 and FWPe for r>0.
FWP(e)-50 assumes a 50-year impact horizon and FWP(e)-30 assumes a 30-year impact horizon

Source: NERA calculations based on CARB (2009) and O'Hare et al. 2009..

B. Concluding Remarks

The method used to aggregate emissions across time can have a large impact on the estimated indirect emissions due to land use changes associated with corn-based ethanol. We recommend that CARB staff reject the use of the FWP and the FWPe methods because they reflect an arbitrary truncation effect. Early emissions can receive dramatically more weight than later ones because their impacts in the atmosphere are tracked and accumulated by the method for more years after they are released. The magnitude of this effect depends on the arbitrarily chosen length of an Impact Horizon. Correcting for the truncation effect with the FWP and FWPe makes them equivalent to the simpler Annualized and NPV approaches, respectively, that are based on emissions.

The Annualized and NPV approaches are superior to the FWP and FWPe, respectively, but like those methods they fail to account for the fact that there is a broad consensus that the marginal damages caused by a ton of CO_2 emissions will grow over time, so that, for example, it will be worth more in 20 years to reduce emissions by a ton in that year than it is worth to control a ton today. This means that in aggregating emissions that occur in different future years, the weights should reflect those higher relative values, as well as whatever discount rate CARB determines is appropriate for monetized benefits.

The practical effect of accounting for changes over time in the SCC is to reduce the monetary discount rate by the growth rate in marginal damages to arrive at a discount rate appropriate for physical emissions. If one uses either of the two discount rates for benefits highlighted in the ISOR (2 or 3 percent) and the growth rate in the SCC suggested in a recent IPPC report (2.4 percent), this approach yields emission discount rates of between -0.6 percent (with r=2 percent) and +0.4 percent (with r=3 percent), bracketing the emission discount rate of zero implicit in the CARB staff's preferred Annualized or averaging approach. This means that the indirect emissions values for ethanol calculated taking into account increasing marginal damages and the ISOR discount rates of 2 and 3 percent bracket the value obtained using the CARB staff's preferred Annualized (averaging) approach.

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Appendix A. Impact of Constant Evaluation Horizon on FWP(e)

This appendix shows how the FWP(e) approach is affected by the Impact Horizon and how the approach would be modified through use of a common Evaluation Horizon.

A. The FWP(e) Weights and the Impact Horizon

The FWP and FWPe methods defined by CARB have a fixed Impact Horizon. The FWP is simply a special case of the FWPe with a discount rate of zero. Under the FWPe, the weight given emissions in year t relative to year 1 is given by:

$$w_t = \frac{\sum_{i=t}^{H_I} D(i-t+1)(1+r)^{-(i-1)}}{\sum_{i=1}^{H_I} D(i)(1+r)^{-(i-1)}},$$

where D(i) is the fraction of CO_2 remaining in the atmosphere t years after it is emitted and H_I is the Impact Horizon. Note that D(i) depends only on the number of years since an emission occurred, and not when the emission occurred within the Project Horizon. Rearranging terms yields:

$$w_t = (1+r)^{-(t-1)} \frac{\sum_{i=1}^{H_I-t+1} D(i)(1+r)^{-i}}{\sum_{i=1}^{H_I} D(i)(1+r)^{-i}}.$$

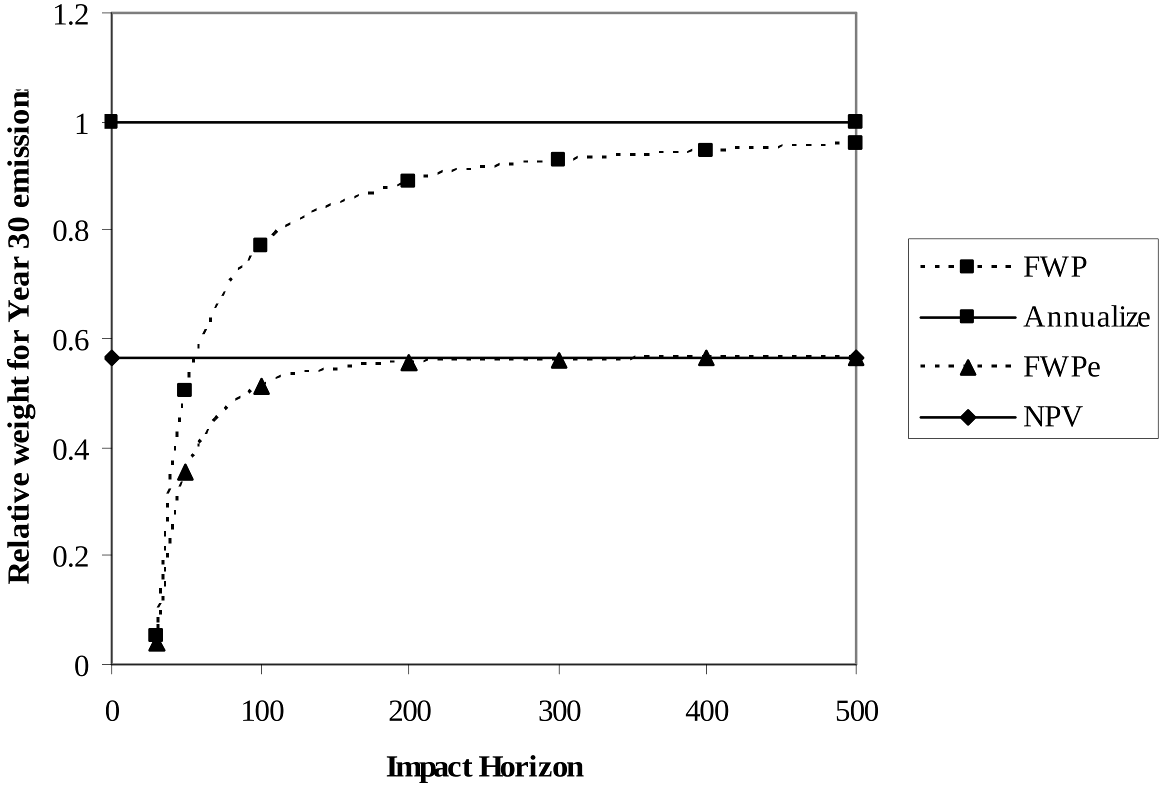
Note that in addition to the discount factor, the two summations in the ratio have the same first (H_I –t+1) terms, the numerator lacks the last t terms that are in the denominator. This difference reflects the fact the method tracks the fate of emissions in the atmosphere for a longer time with early emissions than later ones.

To see how w_t changes as the Impact Horizon lengthens, we can rewrite w_t in the following form:

$$w_t = (1+r)^{-(t-1)} \left\{ 1-(1+r)^{-(H_I-t)} \left[\frac{\sum_{i=1}^{t-1} D(H_I+i-t)(1+r)^{-i}}{\sum_{i=1}^{H_I} D(i)(1+r)^{-i}} \right] \right\}$$

As H_I approaches infinity, the term in square brackets approaches 0, because the number of terms in the summation in the numerator remains constant at t-1, but each terms gets smaller because the t-1 years of atmospheric concentrations not included in the FWPe are increasingly far away from the time of emissions, and hence will have decayed more. In contrast, the sum in the denominator continues to grow with H_I. Moreover, if the discount rate is positive, the ratio shrinks even faster and it is multiplied by a discount factor, $(1+r)^{-(H_I-t)}$, that approaches zero as H_I grows. As a result, as H_I approaches infinity, w_t approaches $(1+r)^{-(t-1)}$, which is the same weight given by the NPV method. If r=0 (i.e., with the FWP), w_t approaches 1 as H_I approaches infinity, the same as the Annualized method.

Figure A-1 compares the relative weights for emissions in year 30 for alternative Impact Horizons. The FWP weight converges slowly to the Annualized weight. With an Impact Horizon of 100 years, it is 77 percent as large as the Annualized weight. With an impact horizon of 500 years, it is 96 percent as large. The FWPe converges more rapidly to the NPV weight as the Impact Horizon lengthens, reaching 91 percent of the NPV value with a horizon of 100 years and 99 percent of the NPV value with a horizon of 200 years or more.



Note: FWPe and NPV weights computed using a discount rate of 2 percent.
Source: NERA calculations

Figure A-1. Weights for Year-30 Emissions with Alternative Impact Horizons

B. Applying a Constant Evaluation Horizon to the FWP(e) Method

If we modify the method to evaluate CO_2 in the atmosphere for a constant number of years (H_E) after they occur, the ratio is:

$$w_t = \frac{\sum_{i=t}^{t+H_E-1} D(i-t+1)(1+r)^{-(i-1)}}{\sum_{i=1}^{H_E} D(i)(1+r)^{-(i-1)}}$$

Rearranging terms yields:

$$w_t = \frac{(1+r)^{-(t-1)} \sum_{i=1}^{H_E} D(i)(1+r)^{-i}}{\sum_{i=1}^{H_E} D(i)(1+r)^{-i}} = (1+r)^{-(t-1)} .$$

Note that this weight does not vary with the length of the Evaluation Horizon (H_E) and that it is the same as the NPV method.