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23 February 2011

Mr. John Courtis
Manager, Alternative Fuels Section
California Air Resources Board
P.O. Box 2815
Sacramento, CA 95812

By email:

Open Letter

Dear John,

Life Cycle Associates and several individuals knowledgeable of the LCFS are writing to provide comments on the draft document "Detailed California-Modified GREET pathway for Corn Oil Biodiesel (COB)," which was posted on the ARB Low Carbon Fuel Standard (LCFS) website on Dec. 14th, 2010.

1. Introduction

The ARB has developed a new Low Carbon Fuel Standard LCFS pathway for COB. ARB treats back end corn oil extraction as an incremental technology and assigns all of the energy inputs for oil extraction and energy savings in ethanol production resulting from the oil extraction to COB (COB). This approach assigns no emissions for corn farming, for making the corn oil available for extraction via the ethanol production process, or land use conversion (LUC) to COB and leaves the emissions for ethanol production unchanged. The direct carbon intensity (CI) calculated for COB with this approach is 5.9 g CO_2e/MJ with no additional LUC emissions.

ARB's approach for COB is inconsistent with both International Organization for Standardization (ISO) standards as well as the approach used for other fuels under the LCFS for life cycle assessment and creates potentially undesirable incentives. Allocation schemes consistent with ISO standards are possible for this pathway.

Our comments will first address ARB's approach to the COB pathway. Secondly, we will examine the options for allocating energy inputs and emissions to COB that would be more consistent with other pathways approved by ARB. Then we review the CI for COB, comparing ARB's calculation to our recommended allocation procedures for both well to wheels (WTW) fuel cycle and land use impacts. Finally, we examine the technical issues and policy implications of ARB's approaches to corn oil extraction.

2. Allocating Energy Inputs

Several energy and emission allocation approaches could be applied to COB, because the process produces both energy products (ethanol and COB) as well as feed product distillers dried grains and glycerin. The additional production of COB is similar to other fuel pathways examined by ARB, such as soybean based renewable diesel. The soy oil renewable diesel pathway also results in the production of feed, fuel, and a co-product fuel.

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The ISO 14040 standards for life cycle assessment require a consistent treatment of products and co-products and these principles have been embraced by ARB[1]. Substitution is the preferred method to distribute emissions among products and co-products. In situations where the impact of the co-product is uncertain, the allocation method is appropriate. Four methods for treating co-products are examined here[2]:

i. Treat both ethanol and COB as primary fuel products and allocate farming, corn mill, and distillers dried grains with solubles (DDGS) to both ethanol and biodiesel based on energy content of products[3].
ii. Treat both ethanol and COB as primary fuel products and allocate farming, corn transport, fuel plant, and DDGS results to both ethanol and biodiesel based on process energy use.
iii. Treat ethanol as the primary product and provide co-product credit for DDGS and COB based on the co-product substitute value.
iv. Treat COB as an incremental product. Assign additional energy inputs and emissions to COB.

i. Allocation based on energy content of products

Corn is the feedstock for the production of ethanol and corn oil. DDGS is a co-product. Since both ethanol and corn oil used to produce biodiesel are energy products, the energy inputs and emissions as well as DDGS co-products are assigned to both energy products. Corn oil is further processed to biodiesel with glycerin as a co-product, and the glycerin is treated with the energy allocation method. The treatment of inputs and products receive the treatment shown in Table 1.

Table 1. Energy Allocation Approach for Corn Ethanol with COB

Process Input/Step	Allocation Method
Farming inputs and emissions	Energy allocation based on LHV of ethanol, biodiesel, and glycerin
Land use conversion	Energy allocation based on LHV of ethanol, biodiesel, and glycerin
Biorefinery natural gas and electricity	Energy allocation based on LHV of ethanol, biodiesel, and glycerin
DDGS co-product	Substitution credit, distributed based on LHV of ethanol, biodiesel, and glycerin
Fuel transport	Assigned to each product based on distance
Corn oil transesterification	Energy allocation based on LHV of biodiesel and glycerin
Biodiesel fuel	Count fossil carbon from methanol towards biodiesel, since inputs to produce biodiesel were allocated to glycerin

LHV = lower heating value

[1] California Air Resources Board, Staff presentation to LCA Working Group 1 Meeting, November 16, 2007.
[2] The methods discussed here are ranked in order of our interpretation of consistency with ISO 14040 standards as well as consistency with other LCFS fuel pathways.
[3] Using a combination of substitution and allocation methods to assign co-product credits has already been applied to several fuel pathways under the LCFS, including biodiesel and renewable diesel where soybean meal receives mass allocation (essentially a substitution credit) and glycerin is treated with energy allocation. Synthetic fuel pathways also utilize energy allocation to allocate results among multiple fuel products and substitution to determine a credit for excess electricity generated that displaces the grid mix.

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The production of both corn ethanol and COB is represented by the system boundary diagram shown in Figure 1. This allocation system is consistent with ARB's pathway for corn ethanol as well as the pathway for soy oil biodiesel and renewable diesel. Note that all of the energy inputs and emissions for feedstock production, feedstock transport and fuel production receive the same allocation treatment. The DDGS co-product is treated by substitution because it is used as feed and ARB has decided to assume 1:1 substitution (mass basis) of feed corn by DDGS. The remaining products are treated by energy allocation.

The transesterification of corn oil produces biodiesel, which contains fossil carbon derived from methanol. Since the emissions associated with biodiesel are distributed by allocation, a credit for glycerin production is taken into account[4]. The allocation factors for each of the inputs and products are shown in Table 2. The allocation factors indicate the fraction of inputs for each step that are assigned to the final products. Note that the total product energy indicated in the far right column includes the ethanol, biodiesel and glycerin energy; corn oil is converted to biodiesel and the oil energy yield is only shown for reference.

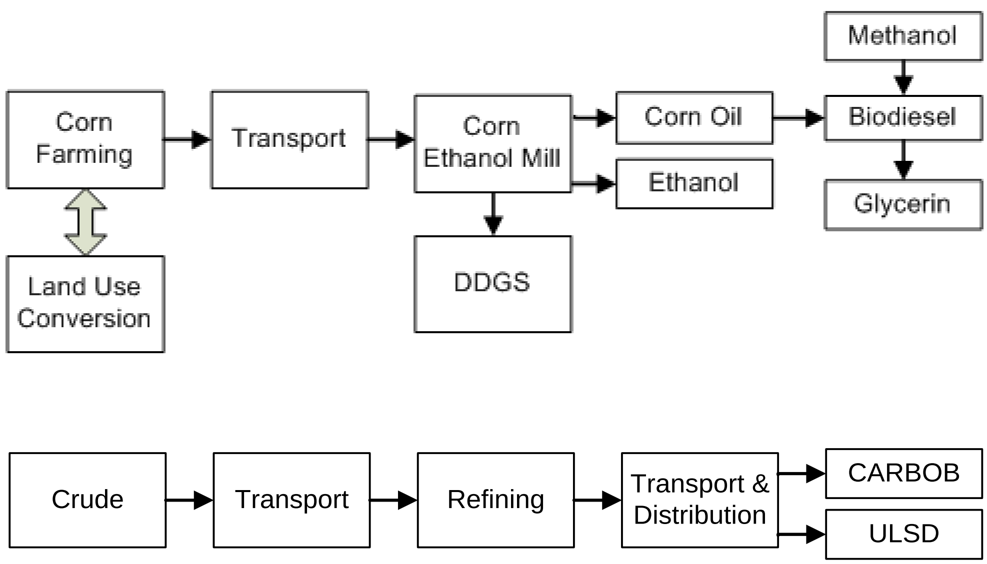

Figure 1. System Boundary Diagram for Corn Ethanol with COB and Petroleum Reference System.

Note that for the allocation method, the corn ethanol and COB are assigned 91.1% and 8.9% respectively of the emissions expressed per bushel of corn. The results when expressed per MJ of ethanol or biodiesel feedstock are equivalent. The biodiesel emission results for feedstock production through fuel production are further allocated between biodiesel and glycerin based on the biodiesel energy share (95.1%). The calculation details are described in Section 3.

[4] Other analysis approaches assign no GHG emissions from fossil carbon in methanol to biodiesel. This approach provides both a substitution and allocation credit.

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Table 2. Allocation Factors for Corn Ethanol and COB Pathway

Input/Product	Feedstock	Corn Mill Biorefinery	Corn Oil	Biodiesel	Glycerin	Total Products
Input (lb)	56					
GHG Emissions (g CO_2e)						
Feedstock Emissions(g/bu)	8,319	7,580		7,205	374	
LUC Emissions (g/bu)	6,571	5,987		5,692	296	
Fuel Plant (g/bu)		6,856		6,517	338	
Feedstock Emissions (g/MJ)		34.60		32.89	1.71	
LUC Emissions (g/MJ)	30.00	27.33		25.98	1.35	
Fuel Plant (g/MJ)		31.30		29.75	1.55	
Product Streams						
Product (lb/bu)		17.92	1.31	1.26	0.13	20.61
Product (gal/bu)		2.72	0.18	0.17		3.07
Lower Heating Value (Btu/gal)		76,330	119,341	119,550	7,979/lb	
Product Energy (Btu/bu)		207,618	21,100	20,255	1,052	228,924
Allocation Factors based on Energy Shares						
Corn Mill Fuel Products		91.1%		8.9%		100.0%
Corn Oil Transesterification				95.1%	4.9%	100.0%

ii. Allocation based on process energy requirements

The energy inputs and emissions for the corn mill biorefinery could also be assigned in proportion to the unit operation for the production of each fuel. For example, corn would be assigned to both ethanol and biodiesel, distillation would be assigned to ethanol, and corn oil separation would be assigned to corn oil. The distribution of energy for DDGS drying could be assigned to the DDGS credit, which is then assigned to each fuel product. Such an allocation approach would reflect the energy inputs for each fuel. However, this method is not used for other fuel pathways under the LCFS (for example soy oil renewable diesel). Furthermore, defining the energy inputs among different unit operations would be subjective and could not be verified without revealing complete details about the operation of the process. For these reasons, the process energy allocation method is not preferred for the COB pathway.

iii. Treat corn DDGS, COB and glycerin through substitution

DDGS, COB and glycerin could be treated as co-products using the substitution method with the credit applied to corn ethanol. This method assumes that DDGS displaces feed corn and that COB and glycerin displace analogous petroleum-derived products (petroleum ultra-low sulfur diesel and petro-glycerin). This approach is consistent with the treatment of DDGS within the corn ethanol pathway and is examined in Section 3. Except for electric power, energy products are not typically treated by substitution in fuel LCA and displacement of petroleum products yields large credits that often overwhelm fuel cycle emissions. Therefore, this approach would not be a preferred method for this pathway.

iv. Treat corn oil extraction as an incremental technology

ARB treats corn oil extraction as an incremental technology. This approach assigns the electrical energy for corn oil extraction to the corn oil and provides a credit to the biodiesel for energy

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savings realized by integrating oil extraction into the fuel plant. The advantage in this approach is that it partially assigns the energy inputs based on the processing energy. However, the ARB's approach selectively defines COB as an incremental technology. The system boundary diagram for this approach is shown in Figure 2. ARB's treatment of the incremental biodiesel production is inappropriate because corn ethanol is also a fuel under the LCFS. The calculations for this approach are also reviewed in Section 3.

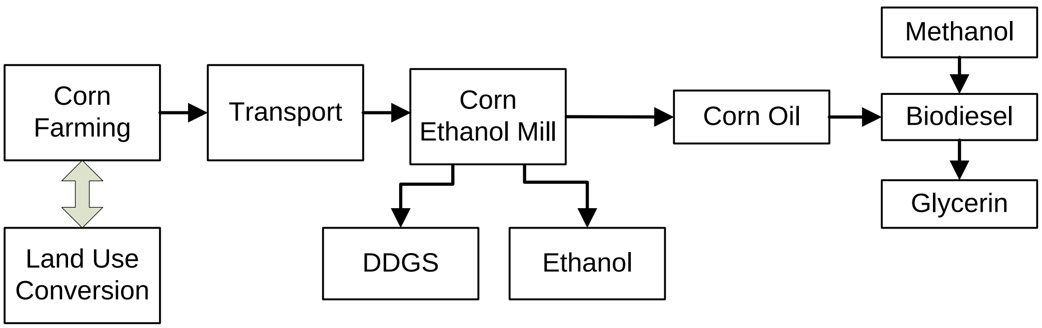

Figure 2. System Boundary Diagram for Corn Ethanol Mill Producing Incremental COB.

3. Carbon Intensity Calculations

The calculations for the four methods of distributing energy inputs and emissions are examined here in detail. The emphasis is on Method i, which provides the most appropriate treatment of COB, and on Method iv as chosen by ARB. Our analysis shows that the total GHG emissions from the corn mill are about the same with Methods i and iv (see Figure 3).

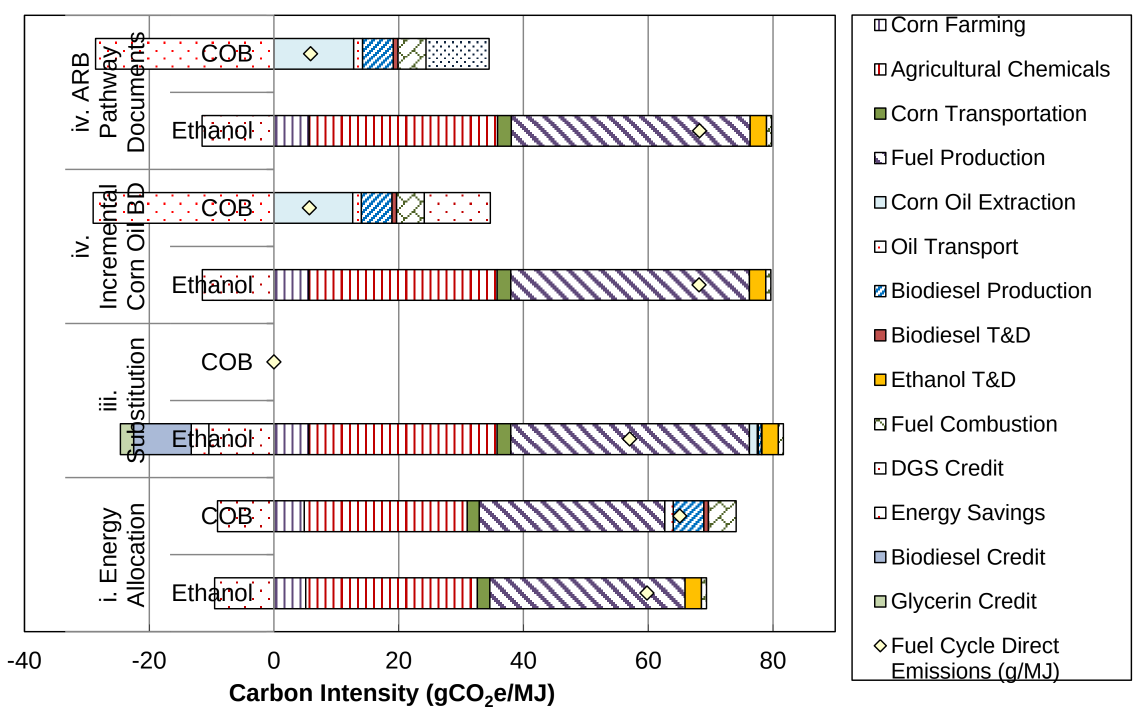

Figure 3. Carbon Intensity (g CO_2e/MJ) for corn ethanol co-produced with COB.

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The CI for COB varies by a factor of 10 across methods. Attachment I provides the detailed breakdown of the CI for corn ethanol and COB based on Methods i, iii, and iv, as well as ARB's calculations for Method iv; results were not calculated for Method ii. Method i results in lower emissions for corn ethanol and higher emissions for COB when compared with Method iv; although the total emissions assigned to the fuels is relatively close. The CI for COB using Method i is 65 g CO_2e/MJ without LUC compared to 5.7 g CO_2e/MJ for Method iv (note several small errors in ARB's pathway document account for the difference).

Emissions are disaggregated by processing step and the allocation factors from Table 2 are applied to each processing step. Since the calculation of intensive (g CO_2e/MJ) emissions can produce confusion, the extensive or total emissions per bushel are also shown for each calculation method. Total emissions for Methods i and iv are 21,113 and 21,655 g CO_2e/bushel, respectively. The difference in overall emissions is due to some of the agricultural inputs being assigned to glycerin in Method i.

i. Method i

In this method, the corn farming, feedstock transport and fuel plant energy emissions are calculated per MJ of ethanol produced and then converted to denominator units of MJ ethanol plus biodiesel by multiplying by 91.1%. This yields the corn ethanol results for those pathway steps. The biodiesel results for farming, feedstock transport and the fuel plant are further allocated to account for glycerin by multiplying by 95.1%. This allocation factor is the same used by ARB in the soybean biodiesel pathway to allocate results between biodiesel and glycerin. The corn ethanol transport and distribution and fuel combustion results are then added to the ethanol fuel cycle results without applying any allocation factors; the biodiesel results for fuel transport and combustion are treated similarly. The glycerin production rate is assumed to be the same as assumed by ARB for soy oil biodiesel production (0.105 lbs glycerin/lb biodiesel produced). The equations used are as follows:

$$A_F = \frac{207{,}618 \text{ Btu EtOH/bu}}{207{,}618 \text{ Btu EtOH/bu} + 20{,}255 \text{ Btu BD/bu}} = 91.1\%$$

$$A_T = \frac{20{,}255 \text{ Btu BD/bu}}{20{,}255 \text{ Btu BD/bu} + 1{,}052 \text{ Btu glycerin/bu}} = 95.1\%$$

$$EM_E = A_F \times (F_C + T_C + P) + T_{Ethanol} + C_{Ethanol}$$

$$EM_{BD} = A_F \times A_T \times (F_C + T_C + P) + T_{BD} + C_{BD}$$

Where:

A_F = corn ethanol energy share, between ethanol and biodiesel
A_T = biodiesel energy share, between biodiesel and glycerin
EM_E = Fuel cycle emissions allocated to ethanol
EM_{BD} = Fuel cycle emissions allocated to biodiesel
F_C = Corn farming emissions
T_C = Corn transport emissions
P = Total fuel production emissions
$T_{Ethanol}$ = Ethanol transport and distribution emissions
T_{BD} = Biodiesel transport and distribution emissions
$C_{Ethanol}$ = Ethanol net combustion emissions
C_{BD} = Biodiesel net combustion emissions

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ii. Method ii

The CI was not estimated for this method since the selection of process data would be very subjective. In addition, no publicly available data on the distribution of energy for unit operations for corn ethanol and corn oil extraction were readily available.

iii. Method iii

In this method, corn ethanol is treated as the primary fuel and all other co-products are treated with the substitution method. All emissions throughout the fuel pathway are allocated to ethanol. Fuel production emissions are calculated for corn ethanol using the same method used for baseline corn ethanol without oil extraction. Although the fuel plant emissions could be calculated as a single energy and emission result, the results were calculated based on the same categories as the ARB COB fuel pathway to show the contribution of each component. Ethanol transport and distribution is the same as in the baseline ethanol pathway.

The corn oil is assumed to be converted to biodiesel using the same conversion factor assumed for soy oil transesterification (1.04 lb oil/lb biodiesel) and the resulting biodiesel displaces petroleum diesel on an energy basis. This credit includes the WTT emissions for diesel plus the fossil carbon in fuel expressed as carbon dioxide. The equation for the biodiesel credit is as follows:

Biodiesel Credit =(0.48 lbs oil/gal ethanol)/(1.04 lbs oil/lb BD) × (16,149 Btu/lb BD) × (99,968 g CO_2e/mmBtu diesel)/(76,330 Btu/gal ethanol) = -9,726 g CO_2e/mmBtu ethanol (-9.22 g/MJ)

The corn oil could also be assigned a credit for the displacement of soybean oil on a mass or energy basis. This substitution assumption results in a smaller credit for corn oil (-2.0 g CO_2e/MJ using mass allocation) because the corn oil is not displacing fossil carbon in this case.

The glycerin produced during transesterification displaces petro-glycerin, and a co-product credit is granted based on the glycerin emissions in GREET, plus the fossil carbon in glycerin. The glycerin production rate is assumed to be the same as that used by ARB for soy oil biodiesel production (0.105 lbs glycerin/lb biodiesel produced). The glycerin credit is calculated as follows:

Glycerin Credit =(0.48 lbs oil/gal ethanol)/(1.04 lbs oil/lb BD) × (0.105 lb glycerin/lb BD) × (3,420 g CO_2e/lb glycerin)/(76,330 Btu/gal ethanol) × (10^6 Btu/mmBtu) = -2,258 g CO_2e/mmBtu ethanol (-2.14 g/MJ)

iv. Method iv

In this method, COB is treated as the primary product. Corn ethanol is part of the existing plant operation. Corn oil extraction energy as well as the energy savings from the corn ethanol plant are assigned to biodiesel. Inputs associated with transesterification are also assigned to the biodiesel. Agricultural inputs and emissions, baseline corn ethanol plant emissions, and LUC emissions are all assigned to corn ethanol. Ethanol transport and distribution is the same as in the baseline ethanol pathway.

The results for Method iv are compared to ARB's pathway document in Attachment 1. The comparison reveals three errors in ARB's calculations: (1) omission of upstream natural gas emissions of CH_4 and N_2O, (2) corn oil to biodiesel yield, and (3) allocation of emissions to glycerin.

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4. Technical Issues and Policy Implications

ARB's proposed approach to defining a CI for COB presents several technical and policy challenges detailed below.

A. Biofuel LCAs should be performed using consistent methodology. We believe that fuel LCA calculations should be performed in a consistent manner. A consistent approach promotes equity among fuel pathways and inspires confidence in the LCFS process. ARB's treatment of back end corn oil extraction as an incremental technology with the energy saving from the ethanol plant applied to the corn oil is too subjective. What other technologies could be defined as incremental[5]?

B. Biofuel LCAs should not create lopsided incentives. ARB's proposed treatment of COB results in a very low CI for the fuel. The incentive to build back end corn oil extraction facilities will therefore be much higher than the incentive for technologies such as front end extraction for food grade corn oil, improving corn ethanol plant efficiency, or operating wet mill corn ethanol plants producing food grade corn oil. Plants currently selling corn oil into the animal feed markets, produced via the same process, will be motivated to instead convert their oil to biodiesel. ARB's approach creates a "golden gallon" that will be very valuable under the LCFS because a very small volume blended with conventional diesel achieves LCFS targets. The golden gallon approach allows a blender to easily meet both their diesel and gasoline CI reductions for multiple years by utilizing very small volumes of back end COB. This carbon derivative provides an opportunity for unintended consequences.

C. Biofuel LCAs should not arbitrarily assign low carbon intensities to selective gallons coming from the same refinery. The golden gallon approach sets a bad precedent because it is inconsistent with the treatment of other fuel LCA pathways and opens the door for similar treatment with other fuel pathways. Would ARB also apply the incremental technology approach to a corn ethanol plant that reduced its energy input by 3000 Btu/gallon while improving its yield from 2.7 to 2.8 gallon/bushel[6]? The golden gallon will be the most valuable product from a fuel production facility thereby creating a distorted incentive.

D. Biofuel LCAs should be consistent with ISO Standards. ARB's golden gallon treatment is inconsistent with standard methods of life cycle assessment identified under ISO 14040. These standards require the identification of a system boundary for the biofuel and the definition of a reference system. Energy inputs and emissions are then to be assigned to products and co-products through a consistent method such as substitution or allocation. Under the LCFS, the reference system is petroleum gasoline and diesel production and the biofuel fuel system is assigned a CI. ARB defines the analysis only around COB, which leads to an incomplete definition of the system boundary. The fate of the ethanol is

[5] Many technologies could be defined as incremental. Consider an example where a coal fired power plant is retrofitted with new boiler tubes and the generation capacity is increased. An argument could be made that the additional power should be treated as incremental capacity.

[6] The CI for the incremental gallon for corn ethanol with a 3000 Btu/gallon energy savings and a yield change of 2.7 to 2.8 gal/bu would be

-2.8 MJ natural gas x 66 g/MJ/(0.1 gal/2.7 gal)/80.5 MJ/gal + 68 g/MJ = 4 g/MJ

Similarly, an oil refinery that purchases renewable power could ask to assign the power to the incremental production of diesel

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not addressed. Unfortunately, the incremental biodiesel approach is inconsistent with the ISO standards and should not be applied under the LCFS.

E. Biofuel LCAs should not unfairly penalize competing technologies. Several other corn oil extraction technologies could also be implemented in corn ethanol plants. These include front end extraction to produce food grade corn oil production, as well as back end extraction where the corn oil is used for animal feed or as boiler fuel. In these circumstances, no additional vehicle fuel is produced and the LCA would need to reflect both the changes in food or feed production as well as impacts on the ethanol plant with an adjustment to the CI for the ethanol fuel. Since these technologies do not produce additional fuel, the improvements in energy efficiency would be reflected in the CI of the ethanol. We do not see the case of corn oil extraction with biodiesel production to be sufficiently unique to warrant a treatment that is different from other technologies.

F. Biofuel LCAs should be based upon actual instead of predicted performance. The ARB staff based the CI of COB on process data from GreenShift technologies. ARB's analysis could serve as a default fuel pathway as long as fuel producers save a total of 3,070 Btu of energy (natural gas plus electricity) per gallon of ethanol produced. This intermediate calculation does not provide an appropriate constraint on the CI because it combines natural gas and electric energy without a linkage to the corn oil volume. A more straightforward approach would be to specify the net Btu of natural gas and the kWh of electric power and the corn oil volumes separately.

G. Biofuel LCAs should take into account distribution logistics. Treating COB as an incremental product provides an incentive that is realized only through the sale of COB in California. Ethanol plants would need to store sufficient corn oil to warrant a shipment to California. Since corn oil would represent a smaller fraction or output compared to ethanol, the storage of corn oil provides cost and fuel quality challenges. Consider a 50 million gallon/year corn ethanol plant. This facility would consume 1 billion lb/year of corn and potentially could produce 20 million lb/year of corn oil. This fuel volume corresponds to about 8,200 gal/day of biodiesel which would require 4 days of production to fill one rail car. The corn oil would then need to be processed to biodiesel. Instead of this biodiesel being used in local proximity to the ethanol plant, where transport emissions and fuel use would be minimized, the low CI value assigned by ARB motivates the transport of this biodiesel from the Midwest to California.

H. Biofuel LCAs should be technology neutral. The lopsided incentive for COB could make this technology the preferred method for corn oil extraction with no obvious improvement in GHG emission compared to other corn oil extraction methods or uses. It also promotes the production of biodiesel over food grade corn oil and detracts resources from other technologies such as biorefinery efficiency improvements or separation of corn oil from the DDGS for use as a separate animal feed.

I. Biofuel LCAs need to recognize both food and fuel impacts. The extraction of corn oil reduces the oil content of DDGS and the overall food output from corn ethanol. High oil content DDGS is considered a high quality feed, especially for swine and poultry. In order to provide the same feed energy, another source of oil will need to be added to the animal diet. Providing an incentive to turn this corn oil into fuel ignores the other vegetable oil that will likely be added to the food system[7]. Providing a very low CI for the

[7] For example, the logical market response from food processers would buy soy oil to supplement the fat content of the low oil DGS. The alternative use of the soy oil to produce biodiesel would achieve a CI of 67

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biodiesel with zero adjustment to the ethanol provides an incentive that detracts from the integrated production of food and fuel that is achieved with corn ethanol.

5. Recommendations

Due to the issues identified with ARB's approach to COB, we recommend the more straightforward and conventional allocation method based upon energy content of products for determining the CI for corn ethanol plants with co-produced biodiesel.

Energy inputs for farming and land use conversion should be assigned to the ethanol and biodiesel. Corn mill energy inputs should be assigned in proportion to the energy content of the fuel that is produced. The steps would be the following:

- Draw system boundary diagram showing corn dry mill with ethanol and corn oil products and downstream processing to biodiesel
- Allocate energy inputs and emissions for farming and LUC to both energy products
- Allocate energy inputs for the corn mill to both ethanol and COB
- Calculate energy inputs for biodiesel transesterification and allocate emissions to biodiesel and glycerin
- Add transport and non-biogenic vehicle emissions

g/MJ (subject to revision by ARB); so the soy oil would be less valuable as a fuel than the corn oil. The effect of ARB's allocation approach would be to promote shuffling of vegetable oils in the feed market.

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Attachment 1. Corn Ethanol and COB Emission Summary

Case:	i. Energy Allocation		iii. Substitution		iv. Incremental Corn Oil BD		iv. ARB Pathway Documents	
Fuel:	Ethanol	COB	Ethanol	COB	Ethanol	COB	Ethanol	COB
DGS Treatment:	Displacement Credit Allocated Among Liquid		Displacement Credit	No Credit	Displacement Credit	Displacement Emissions	Displacement Credit	Displacement Emissions
DGS Credit (lb/gal):	5.34		4.86	0	5.34	-0.48	5.34	-0.48
Corn Oil Treatment:	Allocation		Displacement Credit		No Upstream Emissions		No Upstream Emissions	
Glycerin Treatment:	Energy Allocation		Displacement	No Credit	Energy Allocation		Energy Allocation	
Pathway Step	g CO_2e/ MJ Ethanol	g CO_2e/ MJ COB	g CO_2e/ MJ Ethanol	g CO_2e/ MJ COB	g CO_2e/ MJ Ethanol	g CO_2e/ MJ COB	g CO_2e/ MJ Ethanol	g CO_2e/ MJ COB
Corn Farming	5.09	4.84	5.59	0.00	5.59	0.00	5.65	0.00
Agricultural Chemicals	27.51	26.15	30.19	0.00	30.19	0.00	30.20	0.00
Corn Transportation	2.00	1.90	2.19	0.00	2.19	0.00	2.19	0.00
Fuel Production	31.30	29.75	38.24	0.00	38.24	0.00	38.30	0.00
Corn Oil Extraction	0.00	0.00	1.30	0.00	0.00	12.64	0.00	12.80
Oil Transport	0.00	1.37	0.14	0.00	0.00	1.37	0.00	1.40
Biodiesel Production	0.00	4.89	0.50	0.00	0.00	4.89	0.00	4.90
Biodiesel T&D	0.00	0.76	0.07	0.00	0.00	0.76	0.00	0.80
Ethanol T&D	2.63	0.00	2.63	0.00	2.63	0.00	2.63	0.00
Fuel Combustion	0.80	4.45	0.80	0.00	0.80	4.45	0.80	4.50
DGS Credit	-9.52	-9.05	-10.45	0.00	-11.48	10.58	-11.51	10.10
Energy Savings	0.00	0.00	-2.83	0.00	0.00	-29.01	0.00	-28.60
Biodiesel Credit	0.00	0.00	-9.22	0.00	0.00	0.00	0.00	0.00
Glycerin Credit	0.00	0.00	-2.14	0.00	0.00	0.00	0.00	0.00
Fuel Cycle Direct Emissions (g/MJ)	59.81	65.07	57.03	0.00	68.17	5.69	68.26	5.90
LUC Emissions (g/MJ)	27.33	25.98	30.00	0.00	30.00	0.00	30.00	0.00
Total Fuel Cycle Emissions (g/MJ)	**87.15**	**91.05**	**87.03**	**0.00**	**98.17**	**5.69**	**98.26**	**5.90**
Total Fuel Cycle Emissions (g/bu)	19,089	2,024	19,063	0	21,504	126	21,524	131

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Life Cycle Associates	**University of Illinois at Chicago**
__Stefan Unnasch________	__Steffen Mueller_________
Printed Name	Printed name
_______________________	_______________________
Signature	Signature
_______________________	_______________________
Title	Title
_______________________	_______________________
Date	Date