Stefan Unnasch
1. 650.461.9048 direct
1.484.313.9504 facsímile
unnasch@LifeCycleAssociates.com
884 Portola Road, Suite A11
Portola Valley, CA 94028 USA

August 14, 2017

California Air Resources Board
Anil Prabhu
aprabhu@arb.ca.gov
LCFSWorkshop@arb.ca.gov

Reference: **Comments on Corn Oil Biodiesel Carbon Intensity**

Dear Anil,

Life Cycle Associates would like to take this opportunity to provide comments on the calculation of the carbon intensity (CI) ethanol production with DGS with corn oil co-products. Many ethanol plants produce distiller's corn oil (DOC) for use as animal feed or as a feedstock for corn oil biodiesel (COB) production. The pathways for the combination of corn ethanol and corn oil biodiesel require alignment to support a more equitable distribution of emissions between ethanol and biodiesel. For example, the current pathway does not include ILUC from corn and double counts the corn oil extraction energy for both the COB and corn ethanol pathways. An appropriate system boundary diagram for corn ethanol is shown in Figure 1. Here corn oil is either a feed co-product or an energy product for biodiesel feed. If it is a biodiesel feed, the emissions for the ethanol pathway should be allocated between the two products.

We are attaching a copy of my prior comments to this pathway for reference. However, the current CA_GREET model has a very significant inconsistency between the corn ethanol and COB pathways which lead to inaccurate accounting or carbon intensity of both corn ethanol (EtOH) and COB. We recommend making the following changes to the corn ethanol pathway.

- Provide substitution credit for corn oil used as animal feed based on soy bean oil\
  - Corn oil is a substitute for soy oil in animal feed and the same upstream and ILUC emissions should be the basis for the co-product credit.
- Allocate energy inputs and emissions between ethanol and corn oil used for biodiesel based on energy content of product
  - Both ethanol and corn oil for COB are energy products and the burden of the emissions should be distributed to both products based on energy.
- Allocate ILUC to ethanol and corn oil for COB based on energy content of products
- Track carbon intensity in g/kg or g/lb of corn oil
  - Allows for GREET-type inputs for COB pathway

Stefan Unnasch
1. 650.461.9048 direct
1.484.313.9504 facsímile
unnasch@LifeCycleAssociates.com
884 Portola Road, Suite A11
Portola Valley, CA 94028 USA

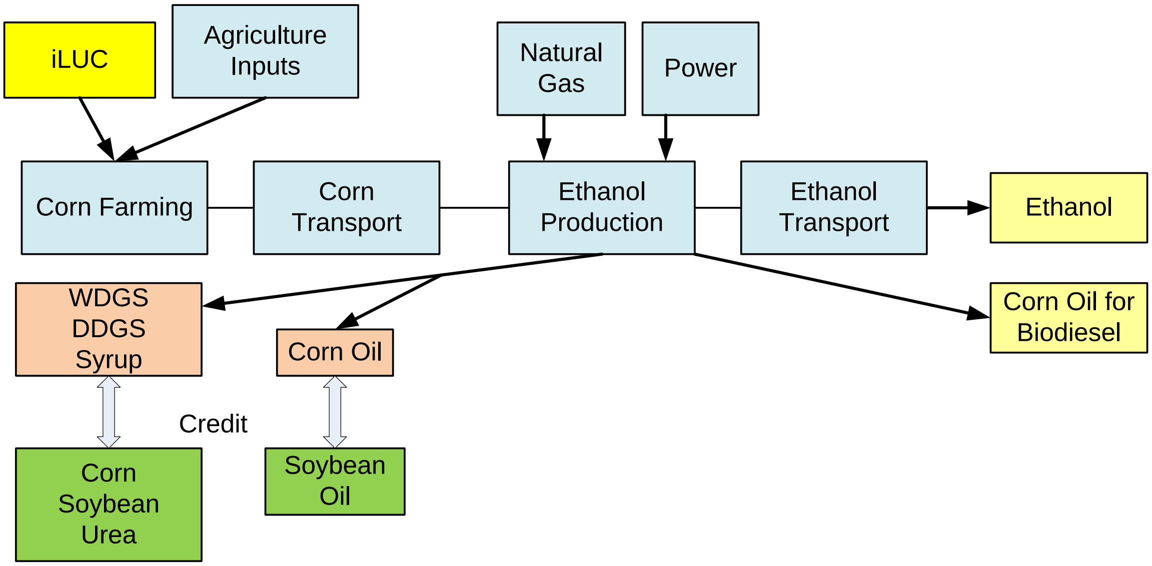

Figure 1. Corn Ethanol System Boundary Diagram

For the corn oil biodiesel pathway

- Update energy and emission allocation to corn oil. Provide a default value based on average of ethanol plants.
- Include ILUC for corn ethanol allocated to corn oil

The analysis here addresses only the indirect land use change associated with the corn ethanol pathway. Comments regarding ILUC for displaced soy oil are the subject of a subsequent comment.

The current corn ethanol pathway assigns all of the corn oil (CO) production as a part of DGS and gives credit based on the same displacement ratios as DGS. CO is used in animal feed as a direct substitute for soy oil and hence should be provided with a 1:1 displacement credit for soy oil. This implies that the amount of corn oil produced will no longer be included in the DGS amount, slightly reducing the DGS credit but increasing the amount of credit for CO.

Additionally, the corn oil used for BD production should be treated like an energy product. Therefore, similar to other pathways in CA_GREET, CO, as energy co-product, should be allocated all the energy inputs and the corresponding emissions based on the energy allocation method. Per the energy allocation method, the emissions are allocated to various products proportional to the total energy content of each of the respective co-product produced. This approach also implies that the corn oil does not receive a displacement credit. The CI of this CO is also associated with it and is carried over to the BD producer who essentially buys this CO along with its associated CI burden. ARB may choose to assign an average CI value for this to every COB producers for accounting simplicity.

To illustrate the proposed methodology, we calculated the CI for each scenarios using CA_GREET defaults and few assumptions. As per the default COB pathway, 0.03 gal of CO is produced per gal of ethanol. With a density of 7.6 lb/gal for CO, this results in 0.23 lb CO /gal EtOH. We also assumed the default EtOH yield, energy inputs, and chemical inputs for the corn ethanol pathway for calculation. The 3-CAMX region was selected in this example.

Stefan Unnasch
1. 650.461.9048 direct
1.484.313.9504 facsímile
unnasch@LifeCycleAssociates.com
884 Portola Road, Suite A11
Portola Valley, CA 94028 USA

Table 1 below shows the CI calculation following the three different methods: the current method, soy displacement method for CO as feed, and energy allocation for CO as COB feedstock. It should be noted that the CI values are in terms of MJ of the fuel in the respective columns. Note that the corn oil in Table 1 is only the feedstock phase and subsequent processing to FAME is required for the BD pathway.

Table 1. Comparison of CI in g CO2e/MJ Fuel Calculation using Various Methods.

Parameter/Method	**Current**	**Soy Displacement**	***Energy Allocation***	
DGS lb/gal	5.64	5.41	5.41	
CO to feel lb/gal	0.00	0.23	0.00	
CO to BD lb/gal	0.00	0.00	0.23	
CI (g CO2e/MJ fuel)	Ethanol	Ethanol	Ethanol	Corn Oil
Feed	24.17	22.70	21.36	21.36
Fuel	31.97	31.97	30.08	30.08
T&D	3.90	3.90	3.90	3.90
Denaturant, g/MJ	0.69	0.75	0.91	0.00
ILUC	19.80	19.80	18.63	18.63
TTW	**80.54**	**79.12**	**74.87**	**73.97**

The table indicates a reduction in CI for ethanol using soy displacement method (79.12 g CO_2e/MJ) and an even greater reduction using the energy allocation method (73.97 g CO_2e/MJ) in comparison to the current method (80.52 CO_2e/MJ). By implication of energy allocation, the CO has a very similar CI as ethanol on per MJ of respective fuel basis.

The implication on the COB pathway analysis is also examined here. The inputs for the CA_GREET2.0 model are shown in Table 2. These values should be replaced with the allocated emission from the corn ethanol pathway.

Table 2. CA_GREET2.0. Default CO Extraction and DGS Debit.

511	**Corn Oil to Biodiesel (From DGS of a Dry Mill Corn Ethanol)**		
512	Corn oil yield, gal/gal EtOH	0.03	
513	Biodiesel yield, lb biodiesel/lb oil	1.10	
514			
515	**Corn Oil Extraction**		**CI, g/MJ**
516	Extraction energy, Btu/lb oil	924.29	4.82
554			
555	**Corn Ethanol DGS Debit**		9.95
556	DGS reduction due to Corn Oil extraction	4.30%	

As previously mentioned, the CI associated with the CO is carried forward along with it to the COB pathway where it adds the corresponding burden. These calculations are shown in the following Table 3. The TTW for ethanol and CO calculated above is first converted into g CO_2e/gal of EtOH. (the same result is achieved if total tons of emissions are tracked). For the CO, this value is then converted to emissions per lb of CO using the CO yield in lb/gal EtOH (256 g/gal ethanol/0.23 lb CO per gal EtOH). Subsequently, this value is converted to the g CO_2e/MJ of biodiesel using the CO to BD yield and BD LHV. These feedstock production emissions are equivalent to the current "Corn oil extraction" phase in COB (Table 2) but reflects the correct distribution of emissions. This approach also makes obsolete the DGS reduction debit phase as the corn oil upstream emissions reflect a share of the ethanol pathway.

Stefan Unnasch
1. 650.461.9048 direct
1.484.313.9504 facsímile
unnasch@LifeCycleAssociates.com
884 Portola Road, Suite A11
Portola Valley, CA 94028 USA

Table 3. CI implications for Corn Oil Biodiesel Feedstock Phase

Method	**Current**	**Soy Displacement**	***Energy Allocation***	
CI\Fuel	Ethanol	Ethanol	Ethanol	Corn Oil
Emissions g CO_2e/gal of EtOH	5,827	5,724	5,417	256
Emissions g/lb CO				1,121
CO extraction in COB g/MJ BD	4.1			76.0
DGS reduction debit g/MJ BD	10.9			0
Total CO burden on COB g/MJ BD	15.0			76.0

In summary, this wet DGS pathway in CA_GREET2.0 is an improvement over the COB 007 pathway but it should be brought further in alignment of emission allocation. ARB should add LUC emissions for corn oil removed from DGS. Furthermore, the above approach is appropriate for all types of ethanol production including ethanol with front end corn oil extraction.

ARB should revise both the corn ethanol and the COB pathway in the new version of CA_GREET.

Please refer to my comments of September 18, 2014. Many of these comments are still relevant and are easily addressed.

Thank you for considering my comments.

Best Regards,

Stefan Unnasch

Stefan Unnasch
Managing Director
Life Cycle Associates, LLC