Life Cycle Associates

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

April 11, 2014

California Air Resources Board
Katrina Sideco
(916) 323-1082
ksideco@arb.ca.gov

Reference: **Comments on ARB LCFS Workshop, March 11, 2014**

Dear Ms. Sideco,

Life Cycle Associates is pleased to provide on ARB's presentations and concept paper for the LCFS March 11 LCFS workshop. The ARB has performed extensive analyses with both CA_GREET and GTAP and the work has come a long way over the past six years. ARB has presented some information that should be addressed; so, I am providing these comments with the aim of improving the efficiency, transparency, and accuracy of the LCFS GHG analysis.

Biofuel Bins

ARB proposes to establish bins for Tier 1 biofuels. The stated objective is to reduce staff time on fuels that are well known and be able to focus more time on emerging fuels. ARB proposed several options.

Initial Suggestion: Establish bins for biofuels with declining bin size from 10 to 3 g CO_2e/MJ
Alternatives: Establish look up table or formula to establish carbon intensities (CI) with a full range of Method 1 pathways.

ARB's efforts to streamline the pathway process are commendable. However, the proposed approaches have some issues discussed below. Let us first reflect on the challenges in achieving a fuel pathway certification.

- Two years of operating data, backed up with transaction receipts.
    - Converting transaction receipts to GREET inputs is challenging due to overlap in inventory and multiple uses of inputs for various processes.
    - Some fuel production facilities share electric utilities or produce no fuel products; so, transaction receipts can be of limited value.
    - Commercial fuel producers have inventory and process measurement systems; so, collection of transaction data provides a valuable but frustrating cross check.
    - Fuel providers selling under Method 1 presumably also need to maintain transaction records tied to their GREET inputs to prepare for audit. Since many Method 2A applications are surprised by the rigor or collecting transaction data, I suspect that Method 1 fuel providers may not know or have all of the records needed to verify their CI.
- Proof of energy savings for wet and modified DGS
    - ARB requires operating data, not model predictions.
    - In the past, ARB has allowed model predictions for prospective corn ethanol pathways for multiple process configurations but ARB requires very detailed information on dry, wet, and modified DGS energy savings.
    - Energy savings associated with moisture removal in DGS is well understood. The heat of vaporization associated with removal of 50% moisture to 10% moisture is 16,000 Btu/gal of ethanol. The realized savings to the ethanol plant is about 11,000 Btu/gal based on Argonne National Laboratory's estimates[1] and our observations of the distribution of fired heaters at ethanol plants.

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

  - Experiments to measure wet and dry DGS energy inputs are costly. Wet DGS sells at a reduced price and ethanol plants do not operate in 100% wet DGS mode normally.
  - The uncertainty in the energy savings associated with DGS drying is one of the smaller uncertainties in the corn ethanol pathway and ARB could allow the use of a default value.
  - Under all circumstances the sum of the natural gas used for producing wet DGS and dry DGS should correspond to the annual natural gas usage for and ethanol plant.
- Uncertainty over energy savings from the corn ethanol pathway assigned to corn oil biodiesel.
- Difficulty in executing CA GREET model
  - Inputs are in various places throughout the model
  - Fuel_Prod_TS sheet results in small interpolation error
  - Disaggregation of results requires external calculation
  - Users must use different regional LCI data for corn production and ethanol plant operation phases in Regional Lookup tab
- Documentation of CA_GREET calculations
  - Considerable effort has gone into explaining CA_GREET calculations. This effort was a requirement of the LCFS regulations. After 5 years, ARB staff are comfortable with the CA_GREET calculations and the need to detangle every calculation for a linear model should no longer be necessary.
- Ethanol plants have invested over $10,000 each to develop Method 2B pathways. Some have supported investment decisions in efficiency upgrades based on lower CIs. These investments should not be made worthless.

Issues with Bins

- Large bin size as well as a 5 g CO_2e/MJ substantiality requirement is not an incentive for investment and are unfair. Innovations may not be rewarded. A typical dry mill corn ethanol plant consumes about 27,000 Btu/gal, LHV of natural gas.[2] Energy savings on the order of 2,000 Btu per gallon are possible with improvements in controls and motivation to operate at high capacity. The impact on CI is ± 2 g/MJ. With bins, the LCFS will only provide motivation for a 2 g/MJ improvement if it jumps a fuel producer into a lower bin. Therefore, bins will incent gaming the system with an initial screening to determine what bin a facility falls into and then what levels of improvements will allow a drop into a lower bin. Large bins will assure that ethanol plants producing at the upper range of the bins sell fuel to California.
- Large bins do not actually save ARB staff time unless they discourage Method 1 applications. I believe that each facility should know its CI and be responsible for record keeping to prove its CI upon audit. With this understanding, fuel producers could participate in Method 1 pathways with small bin (0.5 g/MJ for example) with no less effort than large bin sizes.
- Declining bin sizes are unfair and do not incent energy savings for corn ethanol or soy biodiesel facilities. Their greater than 70 g/MJ CI is largely due to ILUC and not due to anything within the control of the fuel producer. High bin widths for high CI fuels when the ILUC is under debate add unnecessary uncertainty to the LCFS.
- ARB's proposals on bin size do not address the challenges with Method 2A applications.

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

Life Cycle Associates Proposal on Bins and Method 1 Calculations

Several approaches will eliminate staff and applicant time in performing CA_GREET calculations. These options include variations of external GREET calculations that follow the formulae in CA_GREET but are simpler to execute.

- Look up table

ARB staff could simply generate a look up table that is comparable to the tax tables generated by the IRS. The inputs would be

  - Corn yield (gal/bu)
  - DGS yield (bone dry lb/bu)
  - Natural gas (Btu/gal, LHV)
  - Electric power, (kWh/gal)
  - Electric power region
  - Transport distance by rail and truck

This set of inputs could be reduced in complexity. Showing discrete CI bins for every combination of inputs would become challenging and ARB would be need to simplify the look up table.

- Reduced form formula

Fuel pathways could be reduced to a formula based on the six inputs shown above. The coefficients would be calculated by ARB in CA GREET and fuel producers could determine their CI. Since producers could determine their CI to a high degree of precision, ARB would need to set criteria on the variability of inputs. Constraining all of the inputs (for example ethanol yield > 2.73 gal/bu, natural gas usage < 26,000 Btu/gal, etc.) would be overly restrictive. ARB could set limits on the uncertainty of the CI (for example < 74 g CO_2e/MJ. This reasoning suggests that bins with small widths (0.5 g CO_2e/MJ) would be appropriate for fuel producers to calculate their own Method 1 CI. ARB could encourage a third party review of the CI under Method 1 applications.

- External GREET calculation

An external GREET calculation could be implemented in Excel and contain a reduced form formula or the array structure in CA_GREET. The calculation would include the LCI data for corn, natural gas, power, transport, as well as the fugitive loss factors and vehicle emissions. This approach would be easier to use and potentially modify than the GREET model in its entirety. An external calculation could also be implemented in a web interface tool.

These suggestions eliminate most of the labor in calculating fuel pathways. The focus of the effort then involved data collection and verification.

Treatment of Corn Oil Biodiesel

Processes for the extraction of corn oil from distillers' grains with solubles (DGS) can be integrated into corn ethanol production facilities with little modification to the plant and energy savings for the ethanol production.[2] ARB has estimated that the installation of corn oil extraction at pre-existing ethanol plants could reduce the energy use at a typical production plant by approximately 5.4%.[3]

The corn oil can be used in several applications, each with different GHG implications. The primary uses of corn oil include animal feed, return corn oil to DGS (to raise fat content and benefit from energy savings at ethanol plant, and biodiesel).

When corn oil is used for animal feed, it displaces oil seeds such as soy and canola as a source of fat in animal feed. Since the productivity per acre is lower than that for corn, the indirect land use changes (ILUC) per kg of oil is much higher than the ILUC per kg of corn. Therefore, when

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

corn oil is used as an animal feed, the avoided ILUC credit is about 2.5 times higher than that for grain corn.

Corn oil can also be used to produce biodiesel. The extracted oil is sent to biodiesel production plants where the corn oil is converted to fatty acid methyl esters (FAME) biodiesel using a transesterification process. Several approaches are possible for the co-product treatment. With the displacement method, corn oil biodiesel would receive a credit for the diesel fuel it displaces. In 2011 ARB staff developed a pathway for corn oil biodiesel (COB).[3] The pathway assigned energy savings for corn ethanol to corn oil resulting in the CI of 6 g CO_2e/MJ for corn oil biodiesel. This method leveraged the energy savings for the corn ethanol plant onto the biodiesel. On February 22, 2011, I provided comments pointing out the challenges to this approach.[4] These include:

- All of the emissions in the COB pathway are accounted for but the system is fair only if all of the ethanol and corn oil are shipped to California as fuels. Otherwise, the value of the LCFS credits are concentrated in the corn oil
- Corn oil biodiesel is a carbon derivative, which creates a “golden gallon” which over values the contribution of corn oil biodiesel
- If energy savings are assigned to COB, then the LCA for corn ethanol will not include these energy savings. This creates a situation where ARB may require burdensome accounting of the GHG savings associated with corn oil biodiesel and tracking of corn oil sales to feed or biodiesel
- Corn oil alternatively would be used as an animal feed supplement. It would displace soybean oil and its corresponding upstream emissions, agricultural N_2O, and indirect land use.

As it turns out, all of my predictions have manifested themselves as problems. The corn oil biodiesel pathway has created a gold rush to corn oil with a inaccurate rating of the benefits to the environment. Corn oil is diverted from feed applications, where it has a high calorific value, and corn ethanol producers have an additional challenge in assessing their carbon intensity. Corn ethanol plants have been asked to claw back the energy savings associated with corn oil biodiesel even thought these facilities don’t have control of marketing of their corn oil. Finally, the value of LCFS credits is not even passed on to the producers of corn oil because corn oil used as feed is priced the same as corn oil used as fuel feedstock.

I recommend a harmonized treatment of all secondary products/ feedstocks. The corn oil biodiesel pathway should reflect its incremental emissions associated with processing the corn oil to biodiesel. A CI lower than that of the transesterifiation is not appropriate. My comments from 2011 outline a more appropriate approach.

Migration to New GREET

The migration to a new GREET model is appropriate because newer versions of GREET support additional fuel pathways. The model also includes user navigation improvements. ARB should take into account the differences between CA_GREET1.8b and GREET1_2013.

CA_GREET Configuration

The CA_GREET model is a California-specific version of Argonne National Laboratory’s GREET life cycle model and performs life cycle analyses of fuels used under California’s Low Carbon Fuel Standard (LCFS) regulations. Life Cycle Associates developed the model for the California Air Resources Board (ARB) based on GREET version 1.8b.

Key differences between CA_GREET and the default GREET model include:

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

- CA_GREET is configured with criteria pollutant emission factors that reflect California emission standards and emission policies.
- CA_GREET has a regional lookup table that allows a user to select from eight regions in a pull-down menu, representing feedstock and fuel regions involved in the production of California fuels, and California-specific input parameters rather than U.S. average parameters.
- Transport distances reflect average distances to California for crude oil, natural gas, and ethanol.
- The urban shares inputs are configured to reflect marginal fuel production for use in California.
- Calculation components have been added; new fuel pathways have also been added using the existing GREET structure. The model is configured for CNG and LNG from dairy digester gas and landfill gas, respectively. The model is also configured for waste cooking oil and tallow pathways. The model is not populated with all of the inputs for numerous sub-pathways such as corn and sugar cane ethanol. Developing additional sub-pathway inputs still require user modifications.
- The GREET1_2013 model can be challenging to modify. For example, changes made on the Fuel_Prod_TS tab can result in division by zero errors in the individual fuel pathway worksheets when customizing the model for a specific pathway.

The primary data inputs that affect CA_GREET include:

- Natural gas fugitive emissions (affects all fuel pathways).
- Natural gas based marginal power for crude oil production and co-generation export power.
- Gasoline, diesel, LPG refinery efficiency.
- Regionally specific power.
- Urban shares inputs that reflect the distribution of regionally specific criteria pollutant emissions in California.

These inputs should not be modified without substantiation and stakeholder review.

Biofuel-Specific Inputs

The default values for biofuels have little or no recursive impact on the GREET model results. For example changing the CA_GREET default energy input for dry mill corn ethanol plants from 36,000 Btu/gal to a different value has no impact on other fuel pathways.

<u>Changes to Corn Ethanol Pathway</u>

Several aspects of the corn ethanol pathway should be re-examined with the shift to the new CA_GREET. Many of these model features have been accepted in the GREET1 model for several years. The following modifications should be re-examined.

- DGS displaces corn, DGS, and urea as feed.
    - CA_GREET uses a 1:1 displacement ratio of DGS to corn.
    - DGS is sold for its protein content and displaces some soy.
    - ARB should examine the co-product options evaluated in the co-products working group discussed below.
- Soybean farming should include N_2O emissions from soybeans.
    - Soy produces as much N_2O per acre as corn but GREET only counts the contribution of chemical fertilizer.
    - The co-product credit for soybean meal for DGS will be affected by the N_2O from soy bean production.

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

    - Some corn producers use corn stover as feed. The co-product credit and LUC impact of feeding stover should be allowed as an innovative pathway.
- ARB should examine the co-product credit for avoided enteric fermentation.
    - DGS contains a higher N content than other feed. The higher protein content results in shorter time on feed lot, and therefore lower enteric fermentation emissions. The overall protein content consumed by cattle is probably the same and the significant factor in enteric fermentation is time required to gain weight.

Consistent LCI Data

ARB suggested that other sources of LCI data such as NREL and Eco Invent could be acceptable for fuel pathways. A basic requirement of the LCFS has been the consistent use of one model. In some instances, calculations are performed external to GREET; however, CA_GREET LCI data are appropriate for the LCFS. At the March 11 workshop, ARB proposed using the NREL LCI data based on the Western US Region to be the basis for avoided power for innovative crude technologies. This source of LCI data is inappropriate as the CI for power can be calculated within the GREET model or with GREET LCI data for the fuel inputs.

Innovative Technologies and Renewable Power

Renewable energy credits should be available for all fuels distributed by common carrier. ARB has allowed for LCFS credits to be generated for renewable biogas, transmitted by pipeline. The same credits should be allowed for solar and biomass based power. We recognize that renewable power could be used to meet renewable power obligations, but the ARB should not decide for power producers what markets are available for renewable power. Similarly, ARB should allow the use of low carbon gas and power as inputs for biorefineries. This incentive will drive innovation in the expansion of low carbon energy feedstocks and ARB can place appropriate limits on double counting of environmental benefits.

ARB proposed using a Western Regional mix to determine the avoided power for innovative crude technologies. This resource mix is inappropriate considering that the export power from co-generation in CA_GREET is based on a marginal natural gas mix. Furthermore, biorefineries operating in California use the marginal California mix to assess their CI. Counting a low CI for power going into biorefineries and a high CI for power leaving oil refineries is not appropriate. The issue of diverse regions for crude oil production and shuffling remains and ARB may need to select uniform power resource mix. ARB should first establish principles on regional detail before selecting resource mixes for individual fuel pathways.

Methodology for accounting for Co-Products

Many processes produce not only fuels but also other streams or co-products. Two primary methods are used for accounting for the co-products:

- Allocation: All energy and emissions generated by the process are allocated to the main or desired product of that process, either by mass, energy, economic value, sucrose content, or other suitable metrics.

- Substitution: The co-product generates an energy and emission credit equal to the energy and emissions saved by not producing the material that the co-product is most likely to displace.

How GHG emissions are distributed among fuel and co-products differs on which allocation approach is employed. When energy allocation is employed, the emissions per MJ are the same for fuels and all products. With substitution, all of the emissions for feedstock and processing are

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

assigned to fuels and the co-products are accounted for by displacement. This latter approach results in higher emissions for the feedstock and fuel phase, which are offset by the co-product displacement credit (if any), thereby more accurately representing the impact of the co-products.

The choice of allocation method becomes challenging when a processes like those described above generates a mix of both fuels and co-products.

The substitution approach is largely followed by the fuel pathways approved under the EPA RFS2 and California LCFS. The GREET model provides the flexibility for both allocation and substation methods and is configured with displacement credits for many fuel pathways such as distiller's grains from corn ethanol and electric power from FT diesel, cellulosic ethanol, and sugarcane ethanol.[5] The treatment of co-products such as many chemicals is not available in the CA_GREET model and these are best addressed with external calculations.

The co-product accounting methods used by ARB vary widely across fuel pathways. For direct emissions, corn ethanol uses displacement, soy biodiesel uses allocation by mass as well as allocation by energy, and gasoline and diesel use allocation by process energy. For indirect emissions, displacement is generally used, but that displacement is based on economic inputs in the GTAP model and not physical displacement.

In reality, the possible products and their downstream applications accessible from the many processes are more complex than what is currently represented in the GREET model. A more consistent approach for co-products accounting is necessary, particularly for fuels with similar pathways. To the extent possible, the displacement approach should be used to account for co-products as that is most reflective of real-world conditions.

Co-product Displacement Factors and Ratios

Animal feeding and nutrition is a complex issue. Estimating appropriate displacement ratios to properly account for the co-product credit of DGS in a life-cycle assessment is further complicated by limited real-world data on feed rations, which are highly dependent on locally available feed ingredients and economics. There is significant variability to co-product displacement ratios for corn DGS depending upon feed markets. The GTAP model treats DGS as a substitute for corn because prices in DGS have not tracked prices in soybeans.[6] However, experience with DGS marketing has shown that the material is a valuable feed for swine in China. DGS prices may lower than expected due to the cost of transport to China.

The current CA_GREET model uses a DGS: feed corn displacement ratio of, 1:1 (which assumes no significant improvement in animal performance with DGS) but excludes the co-displacement of both SBM and Urea. This interpretation of co-product displacement uses simplified diet formulations and does not reflect the real world practices.[7]

The GREET1 model is configured to reflect the fact that DGS displaces both feed corn, SBM and Urea. In the case of Corn Stover, several recent publications have highlighted the increasing alternative uses of stover as an animal feed.[9,10,11,12]

The following recommendations would improve the accuracy of co-product treatments:

- ARB should adopt either the methodology or co-product displacement ratios used in GREET1 to more accurately reflect the conditions in practice.
- ARB could develop a modified Method 1 procedure that would be more dynamic and would allow biofuel producers to suggest alternative co-product credits estimates that are more applicable to their region and how their co-products are used in the animal feed market.

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

- ARB should develop consistent procedures for the treatment of co-product power, chemicals, and other products from fuel production facilities.

Table 1 shows the Co-product Displacement Factors and Ratios used by the LCFS and GREET1_2013. ARB should also examine co-product impacts for corn replacement feed (CRF) for corn stover that is associated with corn for ethanol production.

Table 1. Co-product Displacement Factors and Ratios

Displacement Factors	Displacement Ratio				
	Corn	SBM	Urea	Corn	Hay
	(lb/lb bone dry DGS)			(lb/lb bone dry CRF)	
CA LCFS Assumptions	1	0	0	0	0
GREET1_2013				0	0
Beef	1.203	0	0.068	0	0
Dairy	0.445	0.545	0	0	0
Swine	0.577	0.419	0	0	0
Poultry	0.552	0.483	0	0	0
Stover (CRF)[a]	0	0	0	0.50	0.50

[a] Corn Replacement Feed (CRF) is a rapidly emerging agricultural practice where corn stover is removed from the fields in addition to the grain and substituted for corn grain and hay in cattle feed. [8,9] The displacement credit for CRF is based on a substitution ratio of 0.5 lb corn and 0.5 lb hay equating to 1.0 lb of CRF on a dry matter basis.[10,11,12]

Petroleum GHG Emissions

ARB has examined the emissions from crude oil sources using the OPGEE model.[13] The model provides a more accurate assessment of crude oil production based on oil field parameters. This approach is one of the best available options because emission inventories are not reported for oil production in most oil fields in the world and it follows the approach used in recent petroleum LCA studies.[14,Error! Bookmark not defined.] The crude oil analysis could be improved with the following actions.

Use CA_GREET LCI Data. OPGEE appears to be configured with GREET 1.8d LCI data for natural gas and electric power. The modeling effort is intended to be a life cycle analysis with consistent accounting throughout the fuel cycle. Mixing and matching LCI data is not appropriate. In addition, the fuel specifications which correspond to carbon factors for natural gas combustion should also be consistent with CA_GREET. Of course the OPGEE results should also be implemented into CA_GREET. An aggregate energy input by fuel type and aggregate fugitive emission factors could be represented as CA_GREET inputs using the GREET model input parameters.

Include effect of crude oil upstream emissions on refinery emissions in CA_GREET. GREET assigns 1 mmBtu of crude oil to 1 mmBtu of gasoline or diesel fuel. The refining emissions in CA_GREET also include a component of the upstream emissions associated with crude oil production.

The energy inputs for crude oil refining (E_{RFGRef}) are based on the refinery efficiency input. The portion of these emissions based on crude oil (which reflects refinery fuel gas) is reflected by the fuel shares input, S_{stgas}. GREET also models fluid catalytic cracker coke emissions as coal (E_{coal}), although the CA_GREET assumption shows zero coke combustion. The total energy used in refining is represented by the following formula. The parameter E_C refers to the upstream fuel

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

cycle energy for crude oil production which is calculated in GREET or OPGEE. The parameter S refers to the fuel shares or energy resource mix within the oil refinery.

- $E_{RFGRef} = S_{CRef} \times (1 + E_C) +$
  $S_{ResRef} \times (1 + E_C \times LF_{Res} + E_{Res}) +$
  $S_{NGRef} \times (1 + E_{NG}) + S_{CoalRef} \times (1 + E_{Coal}) +$
  $S_e \times (E_{efuel} + E_{efeedstock}) + S_{stgas} \times (1 + E_C)$

Therefore, the refinery emissions associated with crude oil correspond to the term $S_{stgas} \times (1 + EC)$. The crude oil term for FCC coke should actually be $S_{Coke} \times (1 + E_c)$.

For a still gas fuel shares of 50%, the contribution toward refining is 91,716 Btu/mmBtu of gasoline as shown in Figure 1. Therefore the CI associated with refining should be 9.2% higher for the still gas component. For a CI change in crude oil from 96 to 99 g CO_2e/MJ, the refinery component should be an additional 9.2% x 3 g CO_2e/MJ = 0.27 g CO_2e/MJ. Of course this refining contribution should be propagated throughout GREET. The energy contribution of FCC coke should also be addressed. The percentage of coke combustion would also result in additional upstream crude oil emissions.

	A	X	Y	AB	AC
31	**3) Calculations of Energy Consumption and Emissions fo**				
32		**Reformulated Gasoline**			
33		**CARFG Gasoline Blendstock Refining**	**CARFG Gasoline Blendstock Refining: Non-Combustion Emissions**	**CA RFG Transportation and Distribution**	**CA RFG Storage**
34	**Energy efficiency**	84.5%			
35	**Urban emission share**	0.0%		100.0%	100.0%
36	**Loss factor**	1.000		1.000	1.000
37	**Shares of process fuels**				
38	Crude oil	0.0%			
39	Residual oil	6.0%			
40	Diesel fuel	0.0%			
41	Gasoline	0.0%			
42	Natural gas	40.0%			
43	Coal	0.0%			
44	Electricity	4.0%			
45	Refinery still gas	50.0%			
46	Feed loss	0.0%			
47	**Energy use: Btu/mmBtu of fuel throughput**				
48	Crude oil	0			
49	Residual oil	11,006			
50	Diesel fuel	0			
51	Gasoline	0			
52	Natural gas	73,373			
53	Coal	0			
54	Electricity	7,337			
55	Feed loss	0		201	0
56	Refinery still gas	91,716			
57	Natural gas flared				
58	Total energy	202,436		4,128	0

Figure 1. CA_GREET calculations converting refinery emissions into energy inputs by fuel type. (from Petroleum Tab)

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

Develop refined method for co-product treatment. Crude oil refining produces sulfur, asphalt, petroleum coke, residual oil and other products that are not the primary product of refining. The GREET refinery efficiency inputs reflect the energy content of asphalt. Other methods of treating co-products provide a more nuanced assessment of co-product impacts and environmental effects.[14] ARB's use of the Nelson index is innovative but this method requires more review and comparison with other allocation and attribution methods. These alternative methods can provide the basis for GREET model inputs.

In summary, issues with crude oil calculations are highlighted below:

- The higher CI for crude oil is not reflected in the refining phase in GREET. [14]
- ARB prooses no bins for innovative crude oil. Does this mean that every solar panel attached to an oil refinery or oil field will receive LCFS credits? This opportunity should be expanded to all fuels including electric vehicles and home charging as well as biorefineries purchasing renewable power and biogas.
- Refinery efficiency inputs for the new CA_GREET should reviewed. If no consensus is established, the existing CA_GREET parameters should be reimplemented in CA version of GREET1. The mix of fuel shares based on still gas, natural gas, and FCC coke combustion could be readily recalculated with little effort.
- The new California model should be named CA_GREET1_2013. CA_GREET2 is misleading because GREET2 refers to a vehicle life cycle model.

Land Use Conversion

ARB's analysis of LUC reflects an update to the GTAP model, new carbon stock factors, and a sensitivity analysis centered around elasticity factors. Several efforts will improve the LUC modeling.

ARB should report the LUC per tonne of feedstock and per acre. Extracting these values from the GTAP runs will verify that crops are treated consistently. On the margin, soybeans are competing with corn land and the LUC per acre of land should be the same even though removing soy oil and corn from feed markets result in different agro economic effects. If ARB would report these LUC parameters, stakeholders could better judge the effectiveness of LUC modeling. The current LUC estimates for corn ethanol and soy biodiesel reflect different shocks. However, the impacts are occurring on the same land so the LUC per acre of Midwestern farmland use for corn ethanol or soy biodiesel should be the same per acre of farmland, once co-products are taken into account.

Sensitivity analysis should include more than elasticity factors. The nesting structure in GTAP is a key variable in the LUC calculations. Nesting determines the substitution between DGS and other co-products as well as soy bean meal and other co-products. Changing nesting structure would involve configuring multiple versions of the GTAP model, which would be a difficult task. However, the effect of co-products could readily be calculated if ARB would report the LUC results per acre and tonne for corn, soybeans, soybean meal, soy oil, and palm oil. ARB could then perform a sensitivity analysis based on the effect of co-products.

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

Thank you for taking into account these comments. I look forward to discussing these comments with you in more detail.

Best Regards,

Stefan Unnasch
Managing Director
Life Cycle Associates, LLC

References

[1] Wang, M. et al. Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types, Environ. Res. Lett. (2) 02. **2007**.

[2] Boland. S. and Unnasch. S. Carbon Intensity of Marginal Petroleum and Corn Ethanol Fuels. Life Cycle Associates Report LCA.6075.83.2014, Prepared for Renewable Fuels Association. **2014**

[3] California Air Resources Board (2012) Final Statement of reasons for Rulemaking, Addition of New Fuel Pathways to the California Low Carbon Fuel Standard Lookup Table, Available at: http://www.arb.ca.gov/regact/2011/lcfs11/fsor.pdf.

[4] California Air Resources Board (2011) Proceedings of the Executive officer Hearing, Available at: http://www.arb.ca.gov/board/mt/2011/mt022411eo.pdf

[5] Wang, M., et al., Methods of dealing with co-products of biofuels in life-cycle analysis and consequent results within the U.S. context. *Energy Policy.* **2011**, *39*, 5726-5736.

[6] Heirigs, P.; Hodson, P.; Kaffka, S.; O'Connor, D.; Stowers, M.; Vessia, O. Issues Related to Accounting for Co-Product Credits in the California Low Carbon Fuel Standard. Expert Workgroup Investigating Indirect Effects of Transportation Fuels Subgroup on Issues Related to Co-Product Credits. California Air Resources Board, **2010**.

[7] Klasing, K.; Hazzledine, M.; Baral, A.; Malins, C. Improving estimates of displacement ratios of co-products for calculating GHG credits in life cycle analysis of biofuels. The International Council of Clean Transportation, LCAXII, Tachoma, WA. **2012.**

[8] Oak Ridge National Laboratory, U.S. Billion Ton Update. Biomass Supply for a Bioenergy and Bioproducts Industry. *United States Department of Energy*

[9] Shreck, A. L.; Nuttelman, B. L.; Griffin, W. A.; Erickson, G. E.; Klopfenstein, T. J. Chemical Treatment of Low-Quality Forages to Replace Corn in Cattle Finishing Diets. *Nebraska Beef Report* **2012**, 106-107.

[10] Nelson, R. G. Resource Assessment and Removal Analysis for Corn Stover and Wheat Straw in the Eastern and Midwestern United States - Rainfall and Wind-Iinduced Soil Erosion Methodology. *Biomass & Bioenergy* **2002**, *22*, 349-363.

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

[11] Wilhelm, W. W.; Hess, J. R.; Karlen, D. L.; Johnson, J. M. F.; Muth, D. J.; Baker, J. M. Review: Balancing Limiting Factors & Economic Drivers for Sustainable Midwestern U.S. Agricultural Residue Feedstock Supplies. *Industrial Biotecnhology* **2010**, *6*, 271-287.

[12] Muth, D.; Bryden, K. M. An Integrated Model for Assessment of Sustainable Agricultural Residue Removal Limits for Bioenergy Systems; accepted with revision. *Environmental Modelling and Software* **2012**, *104* (4), 970-981.

[13] El-Houjeiri, H. M. and Brandt, A. R. (2013) Oil Production Greenhouse Gas Emissions Estimator User guide & Technical documentation Department of Energy Resources Engineering Stanford University.

[14] Keesom, W. H.; Blieszner, J. and Unnasch, S. EU Pathway Study: Life Cycle Assessment of Crude Oils in a European Context. Prepared by Jacobs Engineering and Life Cycle Associates for Alberta Petroleum Marketing Commission (APMC). **2012**