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

October 24, 2014

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

Reference: **Comments on CA_GREET2, October 2014**

Dear Ms. Sideco,

Life Cycle Associates would like to take this opportunity to provide comments on CA_GREET2.0-v180. These comments address a number of issues in the recent release. We expect to find additional items and hope to comment on these in the future. The comments address issues with specific pathways and the CA_GREET2.0-v180 model.

Pathway Comments

Petroleum Pathways

Please refer to my letter of September 15 for more detailed comments, attached. Briefly, CA_GREET2 does not address the following in the petroleum pathway:

- Pointing error for US petroleum to CA refining
- OPGEE results for CA not in GREET
- Upstream for crude oil not taken into account (partially addressed in GREET1_2014)

Crude oil to Product Yield

The new CA_GREET2 includes changes to the emissions from crude oil refining based on the GREET1_2013 model. The GREET1_2013 model (which was the basis for CA_GREET_2 uses inputs for oil refining based on the recent papers from ANL. GREET1_2013 models all petroleum fuels with a 1:1 conversion of crude oil to refined product. This assumption under counts the upstream fuel cycle emissions from crude oil refining because it does not take into account the yield from crude oil to refined product. This has been corrected in the latest GREET model, GREET1_2014.

GREET1_2014 has modified the energy inputs for crude oil refinery emissions. First, the fuel share for each refined produce are different with insight based on recent refinery modeling studies. The model now includes a crude oil to refined product yield factor, Y (for example Y = 0.863 for gasoline).
The energy inputs for oil refining, E based on the refinery efficiency, η become

$$E = (1/\eta - Y)$$

This modification to GREET serves as a proxy to reflect the yield from crude oil to refined product and should be viewed as a more accurate representation of the GHG emissions from oil refining. The merits of this approach require further comparison with other approaches. The term Y, increases the natural gas and other fuel use in the oil refinery when combined with the fuel shares input. The emissions associated with petroleum coke and refinery still gas combustion are not affected by the Y term, even though these fuels are derived from crude oil. The upstream fuel cycle emissions from these fuels should also be included in the GREET calculations. These fuel sources are derived from crude oil; so the emissions should include the upstream fuel cycle component.

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

NG and RNG Pathways

The following observations were made on the CA_GREET2 results. The results may vary with region.

The CI for LFG to LNG is 0 g/MJ feed and -28 g/MJ fuel. The credit is due to co-produced power. Diverting LFG from a flare or from power generation will not result in new power production. This credit is inappropriate as it does not follow ISO procedures in that the system boundary diagram for the RNG system and the reference system would not show an increase in power production. While California law does require the treatment of LFG through flaring, this fact does not justify the attribution of electric power to LFG. At best, the LFG is diverted from flaring.

The CI for LNG includes 34.8 and 174.3 g CH4 per mmBtu of LNG. Does ARB intend to make this level of methane capture a condition of all LCFS applications? Could a LNG producer operate under a total limit of boil off emissions or do the methane emissions from each category need to be met?

The CI for CNG from WWT is -81 g/MJ. This credit is associated with avoided methane emissions. If WWT facilities are processing additional feedstock such as food waste, a version of the methane credit is appropriate. However, if existing WWT facilities are diverting biogas from a flare or power production, the CI should be comparable to that of flared LFG to LNG. ARB needs to assure that fuel pathways that receive this CI represent new sources of food waste that otherwise would be sent to landfills. The credit for power should be examined closely. Could a WWT operator not burn half of their biogas to produce more power and drive their CI to -200 g/MJ?

The CI for Animal Waste to CNG and LNG are -85 and -56 g/MJ respectively. The negative number reflects a credit for avoided methane from the processing of manure. The spread between CNG and LNG appears large. Could methane not be liquefied to produce LNG for less than 30 g CO_2e/MJ.

Finally, these RNG routes in GREET are suitable as fuels and feedstocks for other fuel pathways. Natural gas, through pipeline injection is a feedstock for di-methyl ether, Fischer Tropsch diesel, hydrogen, and a fuel for biodiesel, ethanol, and numerous other fuel pathways. The GHG savings associated with RNG are the same if used in the vehicle or if used to as a feedstock for other fuel. Allowing RNG as a feedstock for only CNG and LNG is only fair for on-site production. However, when the pathway is used RNG via pipeline injection the benefits of RNG can be realized with any number of fuel pathways. As long as the pathway supports new RNG production and does not divert the gas from power production, this energy resource should be considered for other fuels. The options should be debated openly and discussed in a workshop.

Biodiesel Pathways

Vegetable Oil Biodiesel

The CI for biodiesel production for the various vegetable oils ranges from 11 to 16 g/MJ. The energy input for the biodiesel production is the same for all of the pathways but the upstream co-product is affecting the downstream biodiesel. This treatment is due to one of the system/subsystem allocation procedures that are available in GREET. CA_GREET1.8b was corrected to allocate emissions between biodiesel and glycerin, by energy. ARB has changed the allocation procedure to a method that does not reflect the environmental impact of biodiesel production. The CI of biodiesel, which includes primarily methanol and natural gas should not be reduced because the upstream feedstock generated a co-product credit. This allocation method

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

is inappropriate and should be changed to either energy allocation between biodiesel and glycerin or the displacement method, if the applicant can prove the use of the co-product.

Waste Oil Biodiesel

The CI for tallow and UCO is based on the energy inputs for recovering these wastes. This method is reasonable and should be applied to other residues.

Ethanol Pathways

Co-Product Credits

The T1 tool and ARB's supporting documentation indicate that a 1:1 displacement ratio is used for DGS co-product credits. A displacement ratio based on current practices which result in the displacement of soy and urea is more appropriate. This subject has been part of expert working group topics, CRC meetings, and other venues for many years. Please refer to my letter of September 16 for more detailed comments, attached.

ARB appears to intend to use the 1:1 displacement ratio for DGS, however, the T1 input calculator values for DGS displacement do not agree with the active calculations on the EtOH sheet, which use displacement ratios of 0.96, 0.07, and 0.01 for feed corn, soybean meal, and urea respectively. ARB should consider the GREET defaults for DGS displacement and also adjust the GTAP modeling to reflect the displacement of soybean meal with DGS.

Biogenic VOC Calculations

ARB modified the biogenic VOC emissions from ethanol. The VOC emissions were set to zero. This erroneously sets the loss factor to 1.000000000000. The correct calculation should include:

- Calculate VOC from fugitives as before
- Apply biogenic uptake credit for fully oxidized VOC or use a GWP of zero for biogenic -VOC
- Apply treatment to both distribution fugitives and ethanol plant emissions as well as all other biofuel pathways.

Enteric Fermentation

ARB's justification of not including the credit for enteric fermentation is inappropriate. The declaration that the feeding of animals is not in the system boundary is not consistent with other co-product credits based on animal feed in GREET.

The DGS contains a higher nitrogen content than other feed. The overall protein content consumed by cattle is higher than with feeds such as hay. The significant factor with enteric fermentation is the time required to gain weight. The DGS higher protein content results in shorter time on feedlot, and therefore lower enteric fermentation emissions from ruminant digestion.

ARB's rationale for excluding enteric fermentation does not justify its exclusion from the pathway calculations.

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 Model Comments

Possible Hysteresis Errors

The T1 tool with in CA_GREET2 could result in a hysteresis error where the pathway result differs if various GREET inputs are changes and then changed back to their original settings. Prior attempts to use calculators within GREET have resulted in results that are not repeatable because the macros in GREET may be incompatible with tools that use macros. ARB should test the T1 calculator to make sure that it generates the same results if different regions are selected and if the Results sheet macros are initiated.

We recommend that ARB verify all fuel pathways using an external disaggregated calculator, see appendix for more details. An example disaggregated calculator is attached.

Reduced form Calculations

Please refer to my letter from A September 16, 2014. ARB could simply provide an equation for the pathway results for many fuel pathways. However, the T1 tool provides the flexibility to change the region, thus, a published equation would only help about one third of pathways published to date.

The comments address important aspects of the CA_GEET2.0-v180 tool. Please review these and the attached appendix carefully and do not hesitate to contact us if you have any queries. I look forward to discussing these comments with you in more detail.

Best Regards,

Stefan Unnasch
Managing Director
Life Cycle Associates, LLC

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

Appendix

Disaggregation of GREET for External Calculations

Life Cycle Associates developed a pathway specific, stand-alone sub-module to perform the fuel pathway calculations in a simple, linear and transparent manner. The modules are 100% compatible and consistent with CA_GREET2 without the complexities of interlinking dependencies and allow for regionally specific LCI data. The calculation sub-module provide the flexibility to address the nuances and intricate details of the pathway involved, without compromising the model integrity.

The major advantages of using an external GREET model for life cycle analysis includes modeling flexibility, transparency, and efficiency. An external GREET framework allows any level of disaggregation of inputs, calculations, and results, easily models high-level aggregated pathway components and low-level unit processes. The calculation methodology is transparent, as all LCI data, input parameters, calculations and disaggregated results are clearly organized, labeled, and documented for review. An external GREET approach is also very efficient at assessing multiple sub-pathway scenarios and conducting sensitivity analysis of key parameters.

Table 1 provides an overview of the disaggregated calculations and results and provides exact agreement with the GREET model. You can see the contribution of each step in the fuel 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 1. Disaggregated result for CA_GREET2.0-v180 for corn ethanol.

Pathway Group	**Farming and Transport**										
Emission Source	**Feedstock Farming**	**CO_2 emissions from land use change**	**Nitrogen Fertilizer**	**Field Emissions**	**P_2O_5**	**K_2O**	**$CaCO_3$**	**Field CO_2 from $CaCO_3$ and Urea**	**Herbicide**	**Insecticide**	**Feedstock Transport (Btu/bu, g/bu**
Loss Factor	**Energy, Emissions/bu**										
Total energy **(Btu/unit)**	12,138		25,215		3,680	1,533	199		1,275	128	24,318
Fossil fuels	11,922		24,894		3,534	1,411	198		1,213	121	24,191
Coal	1,150		1,702		769	642	10		330	34	683
Natural gas	3,443		20,813		1,942	292	17		290	29	2,169
Petroleum	7,329		2,379		823	477	170		593	58	21,338
VOC **Emissions (g/unit)**	0.651		2.617		0.231	0.024	0.007		0.013	0.002	1.080
CO	3.218		3.046		0.450	0.130	0.027		0.074	0.009	3.678
NOx	6.185		3.890	9.428	1.150	0.350	0.081		0.172	0.018	17.110
PM10	0.417		0.627		0.224	0.037	0.008		0.038	0.003	0.626
PM2.5	0.360		0.504		0.173	0.027	0.005		0.026	0.003	0.556
SOx	0.415		8.460		11.988	0.190	0.006		0.143	0.009	0.508
CH_4	1.865		4.251		0.539	0.188	0.019		0.152	0.015	2.386
N_2O	0.023		1.670	11.596	0.006	0.002	0.000		0.001	0.000	0.040
CO_2	916.274	377.760	1350.255		260.848	120.836	15.907	505.943	100.362	9.896	1933.854
CO_2 including VOC & CO	923.4	377.8	1,363.2	0.0	262.3	121.1	16.0	505.9	100.5	9.9	1,943.0
Total GHG (g CO_2e/unit)	**977**	**378**	**1,967**	**3,456**	**277**	**126**	**17**	**506**	**105**	**10**	**2,015**
(g CO_2/mmBtu)	**4,570**	**1,768**	**9,204**	**16,169**	**1,298**	**592**	**77**	**2,367**	**490**	**48**	**9,427**
(g CO_2e/MJ)	**4.3**	**1.7**	**8.7**	**15.3**	**1.2**	**0.6**	**0.1**	**2.2**	**0.5**	**0.0**	**8.9**
Variables	E_{farm}	$E_{landuse}$	$E_{nitrogen}$	$E_{NO,\ N2O\ field}$	E_{P2O5}	E_{K2O}	E_{CaCO3}	$E_{CO2\ urea,\ Ca(}$	E_{herb}	E_{insect}	$E_{T\&D}$
Equations		$E_{fert/chem} = \Sigma(E_{landuse}, E_{nitrogen}, E_{NO,\ N2O\ field}, E_{P2O5}, E_{K2O}, E_{CaCO3}, E_{CO2\ urea,\ CaCO3}, E_{herb}, E_{insect})$									
Sum by group	$E_{feed} = E_{farm} + E_{fert/chem} + E_{cp}$										
WTT sum	$E_{EtOH,\ WTT} = E_{feed} \times L$										
RT Lookup Region	MW										

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 ctd. Disaggregated result for Corn Ethanol with GREET1_2013 input data.

Pathway Group			**Co-Product Credits**					**Total Feed Phase**		
Emission Source	**Corn Feedstock (Btu/bu, g/bu)**	**Corn Feedstock (g/MMBtu)**	**Displaced Corn (Btu/gal, g/gal)**	**Soybean Meal (Btu/gal, g/gal)**	**Displaced Urea (Btu/gal, g/gal)**	**Enteric CO_2 (Btu/gal, g/gal)**	**Total Credits (Btu/MMBtu, g/MMBtu)**	**Total corn feedstock**	**NG Boiler (Btu/gal, g/gal)**	**Electric Power (Btu/gal, g/gal)**
Loss Factor										
Total energy **(Btu/unit)**	68,485	320,438	-6,630	-1,373	-390		-109,960	210,478	21,899	2,246
Fossil fuels	67,483	315,749	-6,533	-1,348	-385		-108,304	207,445	21,873	1,907
Coal	5,320	24,893	-515	-224	-22		-9,974	14,919	137	1,788
Natural gas	28,996	135,671	-2,807	-328	-341		-45,534	90,137	21,650	80
Petroleum	33,167	155,185	-3,211	-797	-22		-52,796	102,389	85	40
VOC **Emissions (g/unit)**	4.626	21.6	-0.448	-0.171	-0.039		-8.6	13.021	0.234	0.017
CO	10.632	49.7	-1.029	-0.226	-0.044		-17.0	32.724	0.878	0.192
NOx	38.384	179.6	-3.716	-0.367	-0.044		-54.1	125.523	1.726	0.229
PM10	1.981	9.3	-0.192	-0.052	-0.004		-3.2	6.027	0.073	0.035
PM2.5	1.653	7.7	-0.160	-0.038	-0.003		-2.6	5.101	0.070	0.012
SOx	21.719	101.6	-2.103	-0.179	-0.013		-30.1	71.554	0.251	0.422
CH_4	9.416	44.1	-0.912	-0.165	-0.067		-15.0	29.066	3.987	0.279
N_2O	13.339	62.4	-1.291	-0.041	-0.001		-17.5	44.944	0.046	0.003
CO_2	5,592	26,164	-541.364	-107.285	-14.969	0	-8,694.1	17,470.218	1319.788	186.580
CO_2 including VOC & CO	5,623.1	26,309.9	-544.4	-108.2	-15.2	0.0	-8,747.7	17,562.2	1,321.9	186.9
Total GHG (g CO_2e/unit)	**9,833**	**46,010**	**-12,472**	**-1,633**	**-223**	**0**	**-14,328**	**31,682**	**1,435**	**195**
(g CO_2/mmBtu)	**46,010**						**-2,543**		18,804	2,551
(g CO_2e/MJ)	**43.609**	**43.6**	**-11.8**	**-1.5**	**-0.2**	**0.0**	**-13.6**	30.03	**17.8230**	**2.4**
Variables	E_{feed}		E_{DGS}	E_{SBM}			E_{CP}	E_{corn}	E_{NG}	E_{elec}
Equations	$\Sigma(E_{farm}, E_{fert/chem}, E_{T\&D})$			$E_{CP} = SUM(E_{DGS}, E_{SBM}, E_{urea})$					$E_{plant} = \Sigma(E_{NG}, E_{elec}, E_{fe}$	
Sum by group										
WTT sum										
RT Lookup Region			MW							

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 ctd. Disaggregated result for Corn Ethanol with GREET1_2013 input data.

Pathway Group	Ethanol Production							Ethanol T&D			Total Fuel Phase	WTT Total
Emission Source	Coal Power (Btu/gal, g/gal)	Energy Loss (Btu/gal)	Fermentation Enzymes (g/gal)	"Ethanol Production" (g/gal)	Ethanol Production, Non-Combustion (Btu/gal, g/gal)	Ethanol Plant (Btu/gal, g/gal)	Ethanol Plant (Btu/MMBtu, g/MMBtu)	Ethanol T&D (Btu/mmBtu, g/mmBtu)	Distribution Fugitives (g/mmBtu)	Ethanol Storage (g/mmBtu)		Total WTT (Btu/mmBtu, g/mmBtu)
Loss Factor								1.0000	1.0000	1.0000		
Total energy (Btu/unit)	0	59,870	741	84,755		84,755	1,110,375	35,583			1,145,958	1,356,436
Fossil fuels	0		646	24,427		24,427	320,013	35,415			355,428	562,873
Coal	0		410	2,335		2,335	30,593	898			31,490	46,409
Natural gas	0		221	21,951		21,951	287,577	3,031			290,608	380,745
Petroleum	0		15	141		141	1,844	31,486			33,330	135,719
VOC Emissions (g/unit)	0.000		0.007	0.259	2.239	2.498	32.722	1.613	0.000		34.3	47.4
CO	0.000		0.054	1.124		1.124	14.728	5.444			20.2	52.9
NOx	0.000		0.072	2.027		2.027	26.558	25.981			52.5	178.1
PM10	0.000		0.009	0.117	0.856	0.973	12.741	0.935			13.7	19.7
PM2.5	0.000		0.004	0.086	0.14552	0.232	3.038	0.837			3.9	9.0
SOx	0.000		0.105	0.778		0.778	10.192	0.752			10.9	82.5
CH_4	0.000		0.102	4.368		4.368	57.227	3.548			60.8	89.8
N_2O	0.000		0.002	0.050		0.050	0.660	0.059			0.7	45.7
CO_2	0.000		55.237	1562		1,561.606	20,459	2834			23,292.9	40,763.2
CO_2 including VOC & CO	0.0	0.0	55.3	1,564	7.0	1,571.2	20,583.7	2,847.9	0.0	0.0	23,431.6	40,993.9
Total GHG (g CO_2e/unit)			**58**	**1,688**	**7**	**1,695**	**22,211**	**2,954**	**0**		**25,165**	**56,848**
(g CO_2/mmBtu)	**1,509**			22,120	91	22,211						
(g CO_2e/MJ)			**0.055**	**20.965**	**0.1**	**21.1**	**21.1**	**2.8**	**0.0**		**23.852**	**53.9**
Variables		$E_{ferment}$		E_{prod}	E_{vent}		$E_{plant} \times LF_D$	$E_{T\&D}$				$E_{EtOH, WTT}$
Equations												
Sum by group					$E_{fuel} = E_{plant} + E_{T\&D}$			$E_{T\&D}$				
WTT sum												
RT Lookup Region					MW							