Method 2A Application: Life Cycle Analysis Report

This document (**POET Life Cycle Analysis Report.pdf**) encompass the POET's Method 2A Application "Life Cycle Analysis Report." This document includes a series of 12 tables that appear at end this report.

The Life Cycle Analysis (LCA) Report documents the analysis of the POET facility data for dry mill ethanol production (with natural gas as the primary process fuel) and corresponding calculation of carbon intensity (CI) values following CARB methods. The calculation of CI was completed in conjunction with the CARB version of the GREET1.8b model (in spreadsheet format). The interaction and use of GREET1.8b in this analysis is summarized as follows.

(A) The key modeling parameters used as input by GREET1.8b were calculated as shown in this report.
(B) The sub-pathway modeling parameters were input into GREET1.8b, and the values of CI as estimated by GREET1.8b are then copied back into this report.
(C) The report analysis made further adjustments to the value for CI (for parameters and impacts that cannot be modeled in GREET) and then reported the final estimate for CI for each application sub-pathway.
(D) This report compares the final sub-pathway CI value estimated against the nearest, existing CARB pathway estimate for CI. The CARB application process requires that the difference in CI values (sub-pathway versus existing CARB pathway) be at least 5 g CO_2e/MJ. This criterion for difference in CI is met for all sub-pathways evaluated.

The analysis generally utilizes GREET1.8b default assumptions, with the meaningful exception that historical POET facility data are used to establish the value of key modeling parameters related to the ethanol production process. Specific modeling parameters based on POET-specific plant data were ethanol yield, total energy consumption, energy consumption by fuel type and DGS yield.

The remainder of this document describes the contents of the LCA Report and is organized by the 12 individual tables that appear at the end of this document.

Table 1 (100% Dry DGS Results)

These tabulated data present the summary of facility-based modeling inputs for 100% Dry DGS carbon intensity (CI, units = g CO_2e/MJ, the CI values estimated by the GREET model (Version 1.8b) using these inputs, and the final CI values reported with all adjustments included. This table summarizes the input parameters used to define CI as defined from confidential historical POET facility data. Because sub-pathway 6 (RSH with biogas as process fuel) is not yet supported by historical facility data, the results of sub-pathway 1 (RSH with natural gas as process fuel) are converted over to sub-pathway 6 by making changes to reflect the change in process fuels.

The key modeling parameters of ethanol yield, energy consumption and DDGS are reported here, which in turn are those estimated directly from the POET supplied facility data for years 2009 and 2010 (covering the 18 month period). All reported modeling parameters values are denominator-weighted averages. For example, the volumetric energy consumption in the units of BTU per gallon of ethanol produced is estimated by the sum of the energy consumption (BTU) divided by the sum of the ethanol produced (gallon) across all similar facilities.

Modeling parameters are expressed in units/conditions as used by GREET. This means energy is reported as a lower heating value (LHV) and DGS mass is reported for dry mass only (0% moisture). For sub-pathways utilizing the fractionation process, the distribution of DGS mass co-product into the following, specific co-products were estimated (1) bran, (2) syrup, (3) full-fat germ, (4) high-protein DDG and (5) other DDG. .

Conventional cook process with CARB defaults (from GREET 1.8b) are shown in the shaded right-hand column (for comparative purposes). GREET 1.8b extracted values for CI and total energy requirements from the sub-pathways are presented in the shaded data towards the bottom of the table with the "GREET1.8b" label. Note that these GREET1.8b values reported here **do not yet include** the 0.8 increment in CI due to the denaturant impact. Note that the default LCFS pathway for conventional cook process of 67.9 reported here differs from the February 2009 CARB documented value of 67.6 due to a different GREET model used for the CARB document (the current GREET1.8b model is dated December 2009, which is after the creation of the CARB's corn pathway document).

The "final" CI and energy requirements are contained in the final 2 rows of shaded data (values reported in these rows now **do include** the 0.8 increment in CI due to the denaturant impact). The final CI values include adjustments for sub-pathway effects not handled by the GREET model: (A) use of landfill gas as a process fuel, (B) use of thin stillage as a process fuel and (C) use of biogas as a process fuel.

Key observations on these results are as follows.

(A) The tradeoff (in mass) between ethanol yield and DGS production in these results follows expectation. As yield goes up, the mass of DGS co-products go down.
(B) The combined heat and power (CHP) boilers reduce grid-purchased electricity consumption significantly for a given facility. Results shown here report grid electricity consumption only (CHP generated electricity is excluded) as the CHP generated power's emissions are already counted from burning the process fuel. The estimation of CHP generated electricity is discussed further in subsequent tabulated data , and this power is subtracted from the total electricity consumption reported for the POET facilities at this point in the analysis to identify the grid-purchased electricity.
(C) For sub-pathway 4, fractionalization results in multiple co-products (e.g., DGS, bran cake, etc.). These co-products are all treated without distinction as "DGS" in the calculations based on a review of the nutritive information.

Table 2 (100% Wet DGS Results)

These tabulated data present the summary of modeling inputs for 100% Wet DGS CI evaluation (by sub-pathway) as well as the CI values estimated by the GREET model (Version 1.8b). This table summarizes the input parameters as defined from POET facility data provided. There are effectively no differences between these tabulated results and those of Table 1 above – except for the energy requirement for DGS drying is excluded from the energy consumption estimate.

Each facility produces both dry and wet DGS products and the analysis keeps the CI estimates separate for proper accounting of both CI values of a facility.

Table 3 (Baseline CI Comparison)

These tabulated data present the difference between each sub-pathway's CI and that of the closest match CARB CI. The closest CARB pathway for sub-pathways 3 and 6 is "Mid-West Dry Mill, 80% NG 20% Biomass" and for the remaining it is "Mid-West Dry Mill, 100% NG." All newly defined sub-pathways result in a reduction in CI of at least 5 gCO2e/MJ without exception.

All sub-pathway values for CI are those developed by Sierra using the GREET1.8b model. Nearest baseline values are those reported by CARB in their lookup tables. Values reported include the denaturant impact on CI.

Tables 3 and 4 (DGS Nutrition)

A summary of the nutritive information of the POET DGS product line is included in these tabulated data. POET nutritive pamphlets on each co-product are also included in the reference file ***Nutritive Information.zip***.

Table 5 (CHP Generation)

The POET-facility CHP generation was estimated with the pertinent information reported here. Direct data were not available that separated grid electricity and CHP generation, and CHP generation is based on scaling (in proportion to the total process fuel consumed) from the "UIC FEB2009" reference used for this study and is contained in the reference file ***EthanolPlantTechnologyReport.pdf***.

Tables 7 and 8 (Land Fill Gas as Fuel)

The use of landfill gas as a process fuel for ethanol production could not be directly handled by GREET1.8B. The data and values used for our evaluation are summarized here and were extracted from the LCFS CARB pathway report for CNG from landfill gas (report release date of February 28, 2009, see reference file ***CARB landfill gas.pdf***). Table 7 contains the unmodified data from the CARB reference. Table 8 contains the data modified for the POET sub-pathway case. The high compression energy required for refueling of on-road motor vehicles is omitted from the POET-pathway analysis as not applicable to the stationary use of this fuel. The pipeline distance between landfill gas recovery and use at POET facilities was corrected for prior to use in this evaluation (from 50 miles assumed by CARB to 11 miles for the POET facility, which is the specific distance between the POET facility and the municipally operated landfill).

Tables 9 and 10 (Biogas As Fuel)

The use of biogas as a process fuel for ethanol production could not be directly handled by GREET1.8b. The data and values used for our evaluation are summarized here and were extracted from the LCFS CARB pathway report for CNG from biogas (report release date of July 20, 2009, see reference file ***CARB biogas.pdf***.). Table 9 contains the unmodified data from the CARB reference. Table 10 contains the data modified for the POET sub-pathway case. The high compression energy required for refueling of on-road motor vehicles is omitted as not applicable to the stationary use of this fuel. The pipeline distance between biogas recovery and use at POET facilities was corrected for prior to use in this evaluation (from 50 miles assumed by CARB to "1 mile" for the POET facility – the biogas recovery occurs at an adjacent property).

Tables 11 and 12 (Drying Energy)

The energy requirements for drying DGS are summarized in these tabulated data.

The results in dekatherms (Dths) per ton equaled 4.3. These are the underlying CA-GREET1.8b-based values, and were carried forward into the energy estimates supporting the CI analysis. Utilizing the GREET-based values here would also mean these sub-pathway results and the differences between dry and wet DGS would be fully consistent with the existing CARB corn pathway estimates.

Table 1. Sub-Pathway Average Modeling Parameters, Results Based on Extracted 2009-2010 POET Data, 100% Dry DGS

Modeling Parameter	Units		1	2	3	4	5	6	Default GREET V1.8b Values for Conventional Cook Process, Mid-West Dry Mill, 100% NG
		Sub-Pathway Name:	**Raw Starch Hydrolysis**	**Raw Starch Hydrolysis, Combined Heat and Power**	**Raw Starch Hydrolysis, Biomass & Landgas Fuels**	**Raw Starch Hydrolysis, Corn Fractionation**	**Conventional Cook, Combined Heat and Power**	**Raw Starch Hydrolysis, Biogas Fuel**	
Ethanol Yield	gal/bu		2.81	2.79	2.81	2.59	2.69	2.81	**2.72**
Total Energy Consumption (LHV, Excludes Liquid CO2 Production)	BTU/gal		29,289	30,899	30,262	28,132	34,102	29,289	**36,000**
Grid Electricity Share	*% of BTU*		*11.9%*	*3.0%*	*12.5%*	*12.9%*	*2.5%*	*11.9%*	***10.2%***
Natural Gas Share	*% of BTU*		*88.1%*	*97.0%*	*61.2%*	*87.1%*	*97.5%*		***89.8%***
Landfill Gas Share	*% of BTU*				*10.5%*				
Waste Wood Share	*% of BTU*				*12.2%*				
Field Waste Share	*% of BTU*				*2.6%*				
Thin Stillage Share	*% of BTU*				*0.9%*				
Biogas Share	*% of BTU*							*88.1%*	
Grid Electricity for Ethanol Production	kWhr/gal		1.02	0.28	1.11	1.06	0.25	1.02	**1.08**
DDGS Yield	lb DDGS/gal		4.89	4.75	4.78	6.39	5.63	4.89	**5.34**
Bran Share	*% of mass*					*24.9%*			
Syrup Share	*% of mass*					*3.1%*			
Full-Fat Germ Share	*% of mass*					*32.2%*			
High Protein DDG Share	*% of mass*					*1.1%*			
DGS Share	*% of mass*					*38.7%*			
Adjustment: Landfill Gas GHG	gCO2e/gal				29.36				
Adjustment: Landfill Gas Energy	BTU/gal				451.21				
Adjustment: Thin Stillage GHG	gCO2e/gal				0.00				
Adjustment: Thin Stillage Energy	BTU/gal				264.72				
Adjustment: Biogas GHG	gCO2e/gal							295.71	
Adjustment: Biogas Energy	BTU/gal							4000.08	
GREET V1.8b GHG Emissions	**gCO2e/MJ**	***includes loss factor***	61.64	57.69	57.33	60.86	59.72	40.23	**67.89**
GREET V1.8b Energy Required	**BTU/mmBTU**	***includes loss factor***	1,561,865	1,524,624	1,537,137	1,548,233	1,564,271	1,200,265	**1,662,585**
GREET V1.8b Loss Factor	Unitless		1.0005	1.0005	1.0005	1.0005	1.0005	1.0005	1.0005
Final GHG Emissions w/ Adjustments	**gCO2e/MJ**	***includes denaturant factor***	**62.44**	**58.49**	**58.50**	**61.66**	**60.52**	**44.70**	**68.69**
Final Energy Required w/ Adjustments	**BTU/mmBTU**		**1,561,865**	**1,524,624**	**1,546,521**	**1,548,233**	**1,564,271**	**1,252,696**	

Table 2. Sub-Pathway Average Modeling Parameters, Results Based on Extracted 2009-2010 POET Data, 100% Wet DGS

Modeling Parameter	Units	Sub-Pathway: / Sub-Pathway Name:	1 Raw Starch Hydrolysis	2 Raw Starch Hydrolysis, Combined Heat and Power	3 Raw Starch Hydrolysis, Biomass & Landgas Fuels	4 Raw Starch Hydrolysis, Corn Fractionation	5 Conventional Cook, Combined Heat and Power	6 Raw Starch Hydrolysis, Biogas Fuel	Default GREET V1.8b Values for Conventional Cook Process, Mid-West Dry Mill, 100% NG
Ethanol Yield	gal/bu		2.81	2.79		2.59	2.69	2.81	**2.72**
Total Energy Consumption (LHV, Excludes Liquid CO2 Production)	BTU/gal		18,769	20,696		14,412	22,017	18,769	**25,502**
Grid Electricity Share	*% of BTU*		*18.5%*	*4.5%*		*25.1%*	*3.9%*	*18.5%*	***14.4%***
Natural Gas Share	*% of BTU*		*81.5%*	*95.5%*		*74.9%*	*96.1%*		***85.6%***
Landfill Gas Share	*% of BTU*								
Waste Wood Share	*% of BTU*								
Field Waste Share	*% of BTU*								
Thin Stillage Share	*% of BTU*								
Biogas Share	*% of BTU*							*81.5%*	
Grid Electricity for Ethanol Production	kWhr/gal		1.02	0.28		1.06	0.25	1.02	**1.08**
Wet DGS Yield (Mass of Dry Matter Only)	lb DGS/gal		4.89	4.75		6.39	5.63	4.89	**5.34**
Bran Share	*% of mass*					*24.9%*			
Syrup Share	*% of mass*					*3.1%*			
Full-Fat Germ Share	*% of mass*					*32.2%*			
High Protein DDG Share	*% of mass*					*1.1%*			
DGS Share	*% of mass*					*38.7%*			
Adjustment: Landfill Gas GHG	gCO2e/gal								
Adjustment: Landfill Gas Energy	BTU/gal								
Adjustment: Thin Stillage GHG	gCO2e/gal								
Adjustment: Thin Stillage Energy	BTU/gal								
Adjustment: Biogas GHG	gCO2e/gal							175.19	
Adjustment: Biogas Energy	BTU/gal							2369.80	
GREET V1.8b GHG Emissions	**gCO2e/MJ**	***includes loss factor***	52.89	49.21		49.46	49.67	40.23	**59.16**
GREET V1.8b Energy Required	**BTU/mmBTU**	***includes loss factor***	1,414,242	1,381,447		1,355,690	1,394,679	1,200,265	**1,515,241**
GREET V1.8b Loss Factor	Unitless		1.0005	1.0005		1.0005	1.0005	1.0005	1.0005
Final GHG Emissions w/ Adjustments	**gCO2e/MJ**	***includes denaturant factor***	**53.69**	**50.01**		**50.26**	**50.47**	**43.21**	**59.96**
Final Energy Required w/ Adjustments	**BTU/mmBTU**		**1,414,242**	**1,381,447**		**1,355,690**	**1,394,679**	**1,231,327**	

Table 3. Direct Emission Carbon Intensity by Sub-Pathway Compared to Existing Reference Pathway
(Sub-pathway Determined by GREET1.8b , Nearest Reference Pathway Determined by CARB)

Sub-Pathway:	Sub-Pathway Name:	Nearest Reference Pathway	Sub-Pathway CI (gCO2e/MJ)		Reference Pathway CI (gCO2e/MJ)		CI Difference from Reference (gCO2e/MJ)	
			100% Dry DGS	100% Wet DGS	100% Dry DGS	100% Wet DGS	100% Dry DGS	100% Wet DGS
1	Raw Starch Hydrolysis	Mid-West Dry Mill, 100% NG	62.44	53.69	68.40	60.10	-5.96	-6.41
2	Raw Starch Hydrolysis/Combined Heat and Power	Mid-West Dry Mill, 100% NG	58.49	50.01	68.40	60.10	-9.91	-10.09
3	Raw Starch Hydrolysis/Biomass & Landfill Gas Fuels	Mid-West Dry Mill, 80% NG 20% Biomass	58.50		63.60		-5.10	
4	Raw Starch Hydrolysis/Corn Fractionation	Mid-West Dry Mill, 100% NG	61.66	50.26	68.40	60.10	-6.74	-9.84
5	Conventional Cook/Combined Heat and Power	Mid-West Dry Mill, 100% NG	60.52	50.47	68.40	60.10	-7.88	-9.63
6	Raw Starch Hydrolysis/Biogas Process Fuel	Mid-West Dry Mill, 80% NG 20% Biomass	44.70	43.21	63.60	56.80	-18.90	-13.59

CI values reported include the 0.8 gCO2e/MJ denaturant impact.

Table 4. Co-Product Nutrition Information

Nutritive Parameter	Dakota Gold® BPX™			Dakota Gold® HP™			Dakota Germ™			Dakota Gold® Corn Condensed Distillers Solubles			Dakota Bran™		
	DGS Nutritive Content	Comparitive Corn Value	Ratio	HP DGS Nutritive Content	Comparitive Corn Value	Ratio	Germ Nutritive Content	Comparitive Corn Value	Ratio	Syrup Nutritive Content	Comparitive Corn Value	Ratio	Bran Nutritive Content	Comparitive Corn Value	Ratio
Dry Matter, %	**91.1%**			**92.1%**			**91.5%**			**34.2%**			**Variable**		
Crude Protein, % (Fed Basis)	**25.6%**			**38.6%**			**14.5%**								
Crude Protein, % (Dry Basis)	**28.1%**	9.8%	**2.87**	**41.9%**	9.8%	**4.28**	**15.8%**	9.8%	**1.62**	**20.3%**	9.8%	**2.07**	**14.0%**	9.8%	**1.43**
Metabolizable Energy – Swine, Kcal/lb	**1614**	1505	**1.07**	**1687**	1505	**1.12**	**1828**	1505	**1.21**		1505			1505	
Metabolizable Energy – Poultry, Kcal/lb	**1272**	1522	**0.84**	**1216**	1522	**0.80**	**1760**	1522	**1.16**		1522			1522	
Net Energy$_L$, Mcal/cwt		78			78			78		**126**	78	**1.62**	**103**	78	**1.32**
Net Energy$_M$, Mcal/cwt		84			84			84		**126**	84	**1.50**	**100**	84	**1.19**
Net Energy$_G$, Mcal/cwt		56			56			56		**89**	56	**1.59**	**68**	56	**1.21**

Corn energy content values are POET reported data for 2010; corn crude protein from University of Missouri reported in 2010.

Table 5. Co-Product Distribution and Average Crude Protein (Dry Basis)

Co-Product	Undifferentiated DGS	Fractionation Process Co-Products
Dakota Gold® BPX™	100.0%	38.7%
Dakota Gold® HP™	0.0%	1.1%
Dakota Germ™	0.0%	32.2%
Dakota Gold® Corn Condensed Distillers Solubles	0.0%	3.1%
Dakota Bran™	0.0%	24.9%
Mass Average Crude Protein (Dry Basis, %):	28.1%	20.6%

Table 6. Calculation of Electricity Generation from CHP Boilers, Based on "UIC, FEB2009" Reference Report

Facility/Reference	Total Energy, LHV (BTU/gal, Includes Grid & CHP Electricity)	Total Energy, LHV (BTU/gal, Includes Grid Electricity Only)	Process Fuel Energy, LHV (BTU/gal, Electricity Omitted)	Total Electricity (kWhr/gal)	CHP Generation (kWhr/gal)	Grid Electricity (kWhr/gal)
UIC, FEB2009: Literature Value for CHP Facility	26,321	24,343	23,899	0.71	0.58	0.13
Sub-pathway #2: Raw Starch Hydrolysis/Combined Heat and Power	30,721	28,458	27,328	0.99	0.66	0.33
Sub-pathway #5: Conventional Cook Process/Combined Heat and Power	36,855	34,102	33,253	1.06	0.81	0.25

"UIC, FEB2009" report included in References to the Method 2A Application.

Table 7. Summary of Energy Consumption and GHG Emissions per mmBtu of CNG Produced from Landfill Gas. ARB Pathway Documents Estimates.

Pathway Element	Energy Required (BTU/mmBTU)	GHG Emissions (gCO2e/MJ)
Landfill Gas Recovery and Transport	9,262	0.49
Landfill Gas Processing	-867,520	-49.56
Transport & Distribution	1,350	0.45
Compression at Station	40,748	2.15
Total WTT	**-816,160**	**-46.47**
Carbon in Fuel	1,000,000	55.20
Vehicle CH_4 and N_2O		2.53
Total TTW	**1,000,000**	**57.73**
Total WTW	**183,840**	**11.26**

Table 8. Pathway Total as It applies to POET Facility Case

Pathway Element	Energy Required (BTU/mmBTU)	GHG Emissions (gCO2e/MJ)	GHG Emissions (gCO2e/mmBTU)
Landfill Gas Recovery and Transport	9,262	0.49	
Landfill Gas Processing	-867,520	-49.56	
Transport & Distribution	297	0.10	
Compression at Vehicle Refueling Station	0	0.00	
Total Indirect	**-857,961**	**-48.97**	
Carbon in Fuel	1,000,000	55.20	
Estimated CH_4 and N_2O		2.53	
Total Direct	**1,000,000**	**57.73**	
Total Pathway	**142,039**	**8.76**	**9241.23**

Table 9. Summary of Energy Consumption and GHG Emissions per mmBtu of CNG Produced from Biogas Gas (i.e., Digester Gas). ARB Pathway Documents Estimates.

Pathway Element	Energy Required (BTU/mmBTU)	GHG Emissions (gCO2e/MJ)
Digester Gas Recovery and Transport	22,209	1.17
Digester Gas Processing	-867,258	-48.02
Transport & Distribution	1,350	0.45
Compression at Vehicle Refueling Statior	40,746	2.15
Total WTT	**-802,953**	**-44.25**
Carbon in Fuel	1,000,000	55.18
Vehicle CH_4 and N_2O		2.52
Total TTW	**1,000,000**	**57.70**
Total WTW	**197,047**	**13.45**

Table 10. Pathway Total as It applies to POET Facility Case

Pathway Element	Energy Required (BTU/mmBTU)	GHG Emissions (gCO2e/MJ)	GHG Emissions (gCO2e/mmBTU)
Digester Gas Recovery and Transport	22,209	1.17	
Digester Gas Processing	-867,258	-48.02	
Transport & Distribution	27	0.01	
Compression at Vehicle Refueling Station	0	0.00	
Total Indirect	**-845,022**	**-46.84**	
Carbon in Fuel	1,000,000	55.18	
Estimated CH_4 and N_2O		2.52	
Total Direct	**1,000,000**	**57.70**	
Total Pathway	**154,978**	**10.86**	**11456.85**

Table 11.

Incremental Drying Energy for DDGS

BTU/ton value used in subsequent calculations:	**4,295,880**
Dths/ton value used in subsequent calculations:	**4.30**

Table 12.

Calculations for Incremental Drying Energy for DDGS (BTU/lb or Dths/ton)

Parameter	Units	Notes	GREET1.8b
DDGS	lb/gal	100% dry	5.34
Drying Energy	BTU/gal, LHV	100% DDGS	11,470
Drying Energy	BTU/lb, LHV	100% DDGS	2,148
Drying Energy	Dths/ton, LHV	100% DDGS	4.30