Method 2A Sub-Pathway Life-Cycle Analysis Report

Western Plains Energy, LLC

Summary of CA-GREET Model Inputs, Structure Changes, and Carbon Intensity Results

SUMMARY

This pathway report summarizes details on four (4) proposed sub-pathways, two (2) sorghum ethanol and two (2) for corn ethanol under the Low Carbon Fuel Standard (LCFS). The CA-GREET model (version 1.8b, December 2009) was used to assess the life-cycle emissions of greenhouse gases for these pathways which represent different operating scenarios for the Western Plains Energy, LLC (WPE) Oakley, Kansas ethanol plant. This report supports the proposed modifications to the existing pathways. These pathways represent net reductions in life cycle GHG emissions ranging of 11.72 and 13.29 gCO_2e/MJ for the 10% and 30% biogas cases, respectively, versus the reference sorghum pathway. Both Well-to-Tank direct emissions results, indirect effects from denaturant combustion and ILUC impacts are included in the sub-pathways proposed for ethanol from corn. These pathways represent net reductions in life cycle GHG emissions ranging of 13.19 and 14.73 gCO_2e/MJ for the 10% and 30% biogas cases, respectively, versus the reference corn pathway.

WESTERN PLAINS ENERGY PRODUCTION PROCESS

WPE is proposing a set of new dry grind sorghum ethanol sub-pathways and dry grind corn ethanol sub-pathways under the LCFS to reflect the particular processes employed at its ethanol production facility in Oakley, Kansas. WPE's Oakley plant is a 40 million gallon per year (MMGPY) nameplate ethanol plant, which is permitted to produce 52 MMGPY. The plant converts locally sourced sorghum and corn grain to ethanol using ICM's dry grind process.

The plant is most similar to the following existing pathway entitled "Midwest Sorghum, Dry Mill, Wet DGS, NG" and "Midwest, Dry Mill, Wet DGS, NG. However there are a number of important process changes that afford WPE's product with lower carbon intensity. Technically, the plant uses the same standard dry mill ethanol process. However, some of the process heat load for the boiler will be satisfied with biogas which will be produced onsite via anaerobic digestion. WPE has constructed a set of digesters to process feedlot cattle manure and produce biogas. With WPE combusting biogas in the boilers and producing only WDGS; the consumption of natural gas as a process fuel is substantially lower than the rate used in both of the reference pathways, and the development of new plant-specific sub-pathways are warranted.

Table 1 presents the high level process energy inputs and yields for Western Plains Ethanol based on 2010 through 2011 operating data. These are compared to both reference pathways. These normalized metrics are supported with plant operating data submitted along with this application.

Table 1: Process Energy and Yield Summary ("gallon" refers to an anhydrous gallon of ethanol, BTUs of thermal energy usage shown on LHV)

	Historical 2-yr Average Western Plains Energy, LLC – Oakley, KS	*Midwest Sorghum; Dry Mill; Wet DGS, NG*	*Midwest Corn; Dry Mill; Wet DGS, NG*
Yield (gallon / bushel)	[redacted]	2.72	2.72
Natural Gas Consumption for DGS Dryer (Btu / gallon)		N/A	N/A
Natural Gas Consumption for Steam (Btu / gallon)		85.9% * 26,100 = 22,430	85.9% * 26,100 = 22,430
Grid Electricity Consumption (Btu / gallon)		(100% - 85.9%) * 26,100 = 3,670	(100% - 85.9%) * 26,100 = 3,670

PROPOSED PATHWAY DESCRIPTIONS

Biogas will be produced onsite via anaerobic digestion. This process converts feedstock, such as cattle feedlot manure (from an estimated ## head of cattle), food waste, thin stillage, grain dust, livestock slaughter waste, or other biomass products, into biogas. The gas is then cleaned onsite and piped to the WPE Ethanol Plant. The anaerobic digester was constructed during 2012 and was commissioned in December 2012; WPE expects the anaerobic digester to be fully operational by the end of 2013.

Ethanol Plant

The plant will produce a mixture of DDGS and WDGS, but only WDGS is being considered due to current plant operations that would utilize the proposed sub-pathways. The proposed pathways are illustrated in Table 2.

Table 2: Pathway Descriptions

Sub-Pathway Descriptions
WPE; Midwest Sorghum, Dry Mill, 100% WDGS, 10% Biogas, 90% NG
WPE; Midwest Sorghum, Dry Mill, 100% WDGS, 30% Biogas, 70% NG
WPE; Midwest; Corn; Dry Mill, 100% WDGS, 10% Biogas, 90% NG
WPE; Midwest; Corn; Dry Mill, 100% WDGS, 30% Biogas, 70% NG

Actual plant data from the 2010 and 2011 operating years and estimated data related to the anaerobic digester has been used to develop the proposed sub-pathways. During the 2010 and 2011 operating period, the plant produced an average of [redacted]% DDGS and [redacted]% WDGS on a dry matter-equivalent basis.

As the plant's thermal energy load is highly dependent on the amount of co-product drying that occurs, it is necessary to understand the dryer's energy load in order to extrapolate total plant energy consumption at the [redacted]% (historical two year average) and [redacted]% DDGS proposed cases. Data from the plant's process designer, ICM, Inc., has been provided to support this and show that dryer gas consumption is [redacted] Btu/gal (HHV) for 100% DDGS and 0 Btu/gal (HHV) for 100% WDGS. These are converted to LHV and used to estimate the current dryer gas load at the 2010/2011 average co-product shares. For, example, the two year average DDG production share was only [redacted]%, so the average dry load is [redacted] * [redacted] Btu/gal (HHV). This result is subtracted from the plant total gas use and is equal to the gas consumption required for process steam production and TO operation, which is held constant. The plant thermal energy loads for the other two cases are then computed by adding the process load to known dryer gas loads, as discussed above.

The second column of Table 3 shows the two year average actual co-product production rates (both DDGS and WDGS) and production rates normalized as dry matter co-product output, equal to [redacted]b d.m./gal. The two year average plant energy use for the period is also shown. The next two columns present the allocated energy use when the plant is producing 100% WDGS or 100% DDGS. NOTE: only the WDGS pathway is being proposed in this application, the DDGS pathway is shown only for context.

Table 3 Co-product production rate and plant thermal energy load for 2010/11 Average, 100% Wet DGS and 100% Dry DGS cases

	2010/2011 WPE Average	*Proposed for 100% WDGS*	*Theoretical 100% DGS (NOT PROPOSED)*
DDGS (lb/gal) @ 11% m.c. **WDGS Production (lb/gal) @ 65% m.c.**	[redacted]	[redacted]	[redacted]
Dry Matter DGS equivalent (lb/gal) **Natural Gas Consumption (Btu/gal)** **Electricity Consumption (Btu/gal)**	[redacted]	[redacted]	[redacted]

Table 4 presents the inputs from Column 3 above and re-cast for the case where 10% and 30% of the plant's thermal energy is supplied by biogas. These are the proposed inputs for this application. The value of [redacted] lb WDGS per gallon is equivalent to [redacted] lb dry matter DGS per gallon which is used in the GREET model.

Table 4: Ethanol plant thermal energy load for 100% WDGS (BTUs shown on LHV)

	100% WDGS (Corn & Sorghum) 10% Biogas	*100% WDGS (Corn & Sorghum) 30% Biogas*
DDGS Production (lb/gal) **WDGS Production (lb/gal)** **Electricity Consumption (Btu/gal)** **Natural Gas Consumption (Btu/gal)** **Biogas Consumption (Btu/gal)**	[redacted]	[redacted]

Digester Plant

The digester plant is expected to produce approximately [redacted] MMBtu per year, or [redacted] Btu (LHV) per gallon when fully operational. The biogas will be treated to remove hydrogen sulfide and water before being piped to the ethanol process. The digesters will circulate hot glycol supplied by two 12.6 MMBtu/hr boilers which will be fired by natural gas. The energy required to produce biogas is shown in the table below and are used in the CA-GREET model as inputs to the biogas production pathway. These values apply to all four proposed sub-pathways.

Table 5: Projected rates of energy consumption for digester plant

Energy Source	*Input (Btu/gal)*	*Share of Total Input*
Biogas for glycol boilers	[redacted]	0%
Natural gas for glycol boilers		81.27%
Electricity for pumps		18.73%
Total Energy Inputs		100.00%

INPUTS & MODIFICATIONS to CA-GREET 1.8b

This section summarizes the specific input values which have been used to run the CA-GREET model to develop carbon intensity results for the proposed sub-pathways. While the scope of the analysis is well-to-wheels, modifications from the CA-GREET default sorghum and corn ethanol pathways are only necessary for the biorefinery operations, and the biogas production and sorghum farming practices.

BIOREFINERY

Table 6 presents the specific modifications that have been made to the CA-GREET model pertaining to the biorefinery efficiency, while

Table 7 shows a comprehensive list of all the modifications which have been needed to modify the process and the biogas production in this proposed pathway. The data below has been derived from annual aggregate data provided by WPE. Cumulative energy usage data has been provided and is normalized by gallon in the model. A structural change to the model was made so that biogas could be used as a process fuel at the biorefinery. The upstream emissions from biogas production are estimated using the existing dairy biogas to CNG pathway included in GREET. Plant energy use values, ethanol and DDG yield have all been updated to reflect WPE's process efficiency.

Table 6: Biorefinery Operations Input Modifications

Modified Parameter	***CA-GREET Cell Reference (Corn or Sorghum model)***	***WPE 10% Biogas, 100% Wet DGS***	***WPE 30% Biogas, 100% Wet DGS,***	***Midwest Sorghum; Dry Mill; Wet DGS, NG***	***Midwest, Dry Mill, Wet DGS, NG***
Yield (gallon/bushel)	Fuel_Prod_TS!D277	[redacted]	[redacted]	2.72	2.72
Total Plant Energy Use (Btu/gallon)	Inputs!C253 or Inputs!E253			26,100	26,100
Thermal Energy Use (Btu/gallon)	Inputs!C254 or Inputs!E254			22,430	22,430
Natural Gas Use (% fuels, Btu/gallon)	Inputs!C255 or Inputs!E255			85.9% * 26,100 = 22,430	85.9% * 26,100 = 322,430
DDG production rate (bone dry lb/gallon)	EtOH!C101 or EtOH!AF101			5.34	5.34
Grid Electricity Use (kWh/gallon)	Inputs!C258 or Inputs!E258			(100% - 92.7%) * 36,000 = 2,628	(100% - 92.7%) * 36,000 = 2,628

Table 7: Comprehensive list of modifications needed

Modified Cell in CA-GREET (corn or sorghum)	***New Value or Cell Reference***	***Comments***
Inputs!C253 or Inputs!E253	=WPE_Inputs!B24	B24, F24, or J24 depending on the DDG scenario evaluated
Inputs!C254 or Inputs!E254	=WPE_Inputs!B25	B25, F25, or J25 depending on the DDG scenario evaluated
Inputs!C255 or Inputs!E255	=WPE_Inputs!E22	E22, I22, or M22 depending on the DDG scenario evaluated
Inputs!C258 or Inputs!E258	Added formula = (C253-C254)/3412	To compute electric input
EtOH!C101 or EtOH!AF101	=5.90	See reference calculations
Fuel_Prod_TS!D277	=2.75	See reference calculations

Modified Cell in CA-GREET (corn or sorghum)	New Value or Cell Reference	Comments
NG!AA66	100%	Remove energy use for gas compression
NG!FO66	78%	Digester efficiency
NG!FO75	81.27%	Share of digester plant energy input at natural gas
NG!FO76	0.00%	Share of digester plant energy input as biogas
NG!FO79	18.7%	Share of digester plant energy input as electricity
NG!FO88	=10^6/(1/78%-1)*44.35%	Calculated biogas energy use for digester
NG!FP88	Modified formula	Include biogas use by digester plant in biogenic storage calculation
EtOH!DH172:DH180	Modified formulas	Delete calculations for emissions from solid biomass combustion
EtOH!L178 or EtOH!DH178	Modified formula	Added biogas CH4 combustion emission factor L164*(EF!C12+NG!H135*NG!$I$123+NG!I135)/1000000
EtOH!L180 or EtOH!DH180	Modified formula	Added biogas CO2 combustion emission factor L164*(EF!C14+(NG!H137*NG!$I$123+NG!I137))/1000000

BIOGAS PRODUCTION

To compute the emissions from production of biogas to the ethanol plant, these pathways assume the default dairy biogas to CNG pathway already developed in GREET is used. This pathway contains additional energy for treatment (CO2, H2O removal) compression and liquefaction that are not required for transportation to Western Plains from the digester plant. The energy needed for compression of the gas is included in the energy loads detailed above and is reflected in the digester efficiency. The WPE estimate includes additional thermal energy needed to heat the digester using a boiler that circulates glycol through heat exchangers in the digesters. Two glycol boilers will each consume 12.6 MMBtu (HHV) per hour of natural gas and have the ability to use the remaining biogas after the process steam load is served. The digesters will also require an estimated ## kW of electrical power to run pumps, mixing and compression equipment. This estimate is made using the total installed motor capacity of ##kW and a diversity factor of 0.75 which characterizes the fraction of the total motor capacity which is expected to be operational at any given moment. Thus the expected nominal electrical load at the plant will be 1,537 kW. A digester “efficiency” value of ##% is computed as the net biogas production divided by the net biogas production plus the energy inputs to the process. This efficiency value is used in the dairy biogas to CNG pathway.

FARMING PRACTICES

Changes were made to the default chemical input for sorghum farming practices. WPE obtains sorghum (and corn) from areas surrounding the facility. Based on farming practices in the area, lime is not applied to the ground as the soil does not require lime for pH adjustment. This change is summarized in Table 6.

Table 6: Modification Made to Sorghum Farming Practices

Parameter	GREET Cell Reference	Default Value (g/bu)	Updated Value (g/bu)
Lime application in sorghum farming	Fuel_Prod_TS!DS257	357.6	0

CARBON INTENSITY RESULTS

The carbon intensity values for each of the four (4) proposed sub-pathways are summarized in Table 7. Direct emissions summarize Well-to-Tank direct emissions results, indirect land use change (ILUC) and indirect effects from denaturant and combustion are added in for the Total Carbon Intensity. These pathways represent net reductions in life cycle GHG emissions ranging of 11.72 and 13.29 gCO_2e/MJ for the 10% and 30% biogas cases, respectively, versus the reference sorghum pathway. Both Well-to-Tank direct emissions results, indirect effects from denaturant combustion and ILUC impacts are included in the sub-pathways proposed for ethanol from corn. These pathways represent net reductions in life cycle GHG emissions ranging of 13.19 and 14.73 gCO_2e/MJ for the 10% and 30% biogas cases, respectively, versus the reference corn pathway.

Table 7: Proposed Sub-Pathways for Western Plains Energy, LLC

Sub-Pathway Description	***Direct Emissions including denaturant & combustion (gCO_2e/MJ)***	***Total Carbon Intensity Including ILUC (gCO_2e/MJ)***	***Reduction from Reference Pathway (gCO_2e/MJ)***
WPE; Midwest Sorghum, Dry Mill, 100% WDGS, 10% Biogas, 90% NG	44.88	74.88	86.61 – 74.88 = 11.72
WPE; Midwest Sorghum, Dry Mill, 100% WDGS, 30% Biogas, 70% NG	43.31	73.31	86.61 – 73.31 = 13.29
WPE; Midwest; Corn; Dry Mill, 100% WDGS, 10% Biogas, 90% NG	46.91	76.91	90.10 – 76.91 = 13.19
WPE; Midwest; Corn; Dry Mill, 100% WDGS, 30% Biogas, 70% NG	45.37	75.37	90.10 – 75.37= 14.73

SUPPORTING DOCUMENTATION

The following documents have been provided along with this application package and support the process yields and energy consumption inputs used in the CA-GREET model for the sub-pathways.

- ***WPE Construction Permit –** Issued December 27, 2011.
- ***WPE Operating Permit –** Issued December 27, 2011.
- ***Anaerobic Digester Process Flow Diagram** The document contains information that Western Plains Energy, LLC deems confidential.
- ***WPE Ethanol Plant Process Flow Diagram**
- ***Carbon Inputs** – shows totals for production volumes and inputs into the model. The document contains information that Western Plains Energy, LLC deems confidential.
- ***WPE Electric Bills–** Utility invoices which shows usage of electricity. The document contains information that Western Plains Energy, LLC deems confidential.
- ***US Energy Natural Gas Usage Reports -** Natural gas invoices which shows usage of natural gas. The document contains information that Western Plains Energy, LLC deems confidential.
- ***WPE Biogas Samples** – shows heat input data for biogas. The document contains information that Western Plains Energy, LLC deems confidential.
- ***WPE RFS2 Engineering Review** The document contains information that Western Plains Energy, LLC deems confidential.
- ***WPE 2010 Operating Year Data –** Includes co-product amounts for the 2010 operating year. The document contains information that Western Plains Energy, LLC deems confidential.
- **2 Year WPE GREET Model Input Data 09-25-2013 –**This document contains information that Western Plains Energy, LLC deems confidential.
- **WPE_Corn_10%biogas_0%DDG_ca_greet1.8b_dec09_Confidential –** CA-GREET model containing inputs and results for sub-pathways producing *0% DDGS of total co-products by dry matter* corn ethanol*.* The document contains information that Western Plains Energy, LLC deems confidential.
- **WPE_Corn_30%biogas_0%DDG_ca_greet1.8b_dec09_Confidential –** CA-GREET model containing inputs and results for sub-pathways producing *4% DDGS of total co-products by dry matter for* corn ethanol*.* The document contains information that Western Plains Energy, LLC deems confidential.
- **WPE_Sorghum_10%biogas_0%DDG_ca_greet1.8b_dec09_Confidential –** CA-GREET model containing inputs and results for sub-pathways producing *0% DDGS of total co-products by dry matter* sorghum ethanol*.* The document contains information that Western Plains Energy, LLC deems confidential.
- **WPE_Sorghum_30%biogas_0%DDG_ca_greet1.8b_dec09_Confidential –** CA-GREET model containing inputs and results for sub-pathways producing *4% DDGS of total co-products by dry matter* sorghum ethanol*.* The document contains information that Western Plains Energy, LLC deems confidential.

*Indicates documents that were provided during the December 2011 initial application submittal that support the data contained within this report.