Lifecycle Emissions of White Energy's Hereford Corn/Sorghum to Ethanol Plant

Revised: January 13, 2011

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1.0 Summary

White Energy's Hereford dry mill plant in Texas produces ethanol from corn and sorghum feedstocks. The corn is procured from the Midwest and the sorghum is obtained locally. All of the distillers' grains (DGs) are currently provided to livestock in the "wet" stage. About 84% of the feedstock is corn and 16% is sorghum, but historically the plant is operated between 5% and 30% sorghum.

AIR estimated the direct carbon intensity of the Hereford plant with wet DGs by estimating the carbon intensity of corn and sorghum separately, and weighting the two together by feedstock volume. We also estimated the carbon intensity of the plant with dry DGs and a modified DGs with moisture content of 50%. For corn farming and chemical emissions, we used CARB's Corn Ethanol report, and for sorghum farming and chemical emissions, we used the GREET model and local data on sorghum yields and fertilizer/pesticide inputs. Corn feedstock transport emissions were estimated with GREET, and sorghum transport emissions were assumed to be the same as CARB's corn ethanol feedstock transport emissions. Ethanol plant emissions for the wet DGs were estimated using GREET and the plant's energy inputs to estimate emissions for the plant. For dry and modified DGs, emission increases to the base wet DG plan were estimated from the CARB lookup table difference between wet and dry DGs for a Midwest ethanol plant, and the expected moisture content of the modified and dry DGs relative to the wet DGs. Ethanol transport and delivery emissions were assumed to be the same as the transport and delivery emissions for corn ethanol from the Midwest. Distillers grains credits for corn were assumed to be the same as the CARB Corn Ethanol report, and distillers grains credits for sorghum were assumed to be the same as the corn credits, because the DGs that come from the plant to local feedlots mainly replace corn (rather than sorghum) in animal diets. Denaturant emissions were assumed to be the same as in the CARB Corn Ethanol report, or 0.8 g/MJ.

The results of this analysis are summarized in Tables ES-1 and ES-2. Table ES-1 shows the emissions by process for both sorghum and corn. Table ES-2 shows the emissions at 1% sorghum, 10% sorghum, 20% sorghum, and 30% sorghum. Table ES-2 also shows our estimate for the plant operated with dry DGs and modified DGs.

CARB will be estimating the indirect land use value of sorghum. However, since 84% of the feedstock of this plant is corn, the ILUC for the plant will be dominated by the current corn value of 30 g/MJ.

ES-1. GHG Lifecycle Emissions for the Hereford Plant		
Well-to-Tank Ethanol Cycle Components	Sorghum GHG (gCO2e/MJ)	Corn GHG (gCO2e/MJ)
Farming	20.11	5.65
Ag Chemical Production	24.64	30.20
Transport	2.22	3.76
Ethanol Production	23.12	23.12
Ethanol Transport and Delivery	2.70	2.70
Co-Products	-11.51	-11.51
Denaturant	0.80	0.80
Total	62.08	54.72

Table ES-2. GHG Lifecycle Direct Emissions for the Hereford Plant (g/MJ)				
Well-to-Tank Ethanol Cycle Components	1% Sorghum Fraction	10% Sorghum Fraction	20% Sorghum Fraction	30% Sorghum Fraction
Wet Distillers Grains				
Farming	5.79	7.10	8.54	9.99
Ag Chemical Production	30.14	29.64	29.09	28.53
Transport	3.74	3.61	3.45	3.30
Ethanol Production	23.12	23.12	23.12	23.12
Ethanol Transport and Delivery	2.70	2.70	2.70	2.7
Co-Products	-11.51	-11.51	-11.51	-11.51
Denaturant	0.80	0.8	0.8	0.8
Total	54.79	55.46	56.19	56.93
Dry Distillers Grains (Wet + 8.3 g/MJ)				
Total	63.09	63.76	64.49	65.23
Modified Distillers Grains (Wet + 2.3 g/MJ)				
Total	57.09	57.76	58.49	59.23

2.0 Introduction

White Energy produces ethanol from a plant in Hereford, Texas. The primary feedstock for this plant is corn from the Midwest, but a secondary feedstock is sorghum obtained locally mostly from Texas. Over the past two years, the percent of sorghum in the feedstock has varied between 7% and 24%. Historically, the plant has been operated between 5% sorghum and 30% sorghum. All of the distillers' grains are currently provided as wet DGS with 65% moisture content (by weight). Much of the ethanol from this plant is sold into the California market. The purpose of this study is to estimate lifecycle emissions for the Hereford plant.

Our method for estimating the CI of the Hereford plant is as follows:

- Use CARB's emissions for corn farming and chemical use for the volume proportion of feedstock that is corn, since this feedstock is from the Midwest
- Use the GREET model to estimate transport emissions for corn from the Midwest to Texas (740 mi), and use the CARB corn ethanol transport emissions for transport of sorghum feedstock to the plant (50 miles), and for transport of ethanol to California
- Develop sorghum farming and chemical use emissions for the volume proportion of feedstock that is sorghum
- Estimate ethanol plant emissions from plant-specific inputs
- Estimate the co-product credit from the CARB Corn Ethanol report, since, DDGs from this plant mainly go to replace corn, and not sorghum
- Compute a volume-weighted average emissions for the combined feedstocks

In addition to estimating the carbon intensity of the plant as a wet DGS plant, we also are estimating the plant's CI with dry DGs (12% moisture content by weight) and with modified DGs (50% moisture content). The modified DGs are produced with the same dryers as the dry DGs, except that they are operated for a shorter period of time.

This study does not evaluate any land use changes for sorghum ethanol, as CARB has indicated they would be evaluating that component of the lifecycle emissions.

This report is divided into the following sections:

- Hereford Plant
- Sorghum Farming GHG Emissions
- Ethanol Plant GHG Emissions
- Results

3.0 Hereford Plant

A flow chart of the Hereford plant is provided in Appendix 1, including a list of combustion equipment. Hereford is permitted with a maximum capacity of 120 million gallons per year. The air quality permit is provided in the Support Documentation. Table 1 shows the feedstock usage, ethanol production, distillers' grains production, and energy usage at the Hereford facility. We show the DG production on a wet and dry basis. To convert wet DGs to dry, we use a factor of 0.35, and to convert the dry DGs to a dry basis, we use a factor of 0.88.[1]

Table 1. Feedstock and Energy Use at the Hereford Plant

Ethanol Plant	Units	2008	2009	Average
Feedstock Input, Ethanol Output and DG Output				
Grain usage, corn	Bu	[redacted]	[redacted]	[redacted]
Grain usage, sorghum	Bu	[redacted]	[redacted]	[redacted]
Sorghum percent of total grain		[redacted]	[redacted]	[redacted]
Ethanol production	Gal	[redacted]	[redacted]	[redacted]
Wet DGs Production	Tons	[redacted]	[redacted]	[redacted]
Dry DGs Production	Tons	[redacted]	[redacted]	[redacted]
Wet DG Production (dry basis)	Tons	[redacted]	[redacted]	[redacted]
Dry DG Production (dry basis)	Tons	[redacted]	[redacted]	[redacted]
Total DG Production (dry basis)	Tons	[redacted]	[redacted]	[redacted]
Percent DG wet		[redacted]	[redacted]	[redacted]
Energy Usage				
Natural Gas	Dth[2]	[redacted]	[redacted]	[redacted]
Electricity	kWh	[redacted]	[redacted]	[redacted]

Ethanol and distillers' grains yields from this plant are shown in Table 2. Ethanol yields per bushel of sorghum plus corn are [redacted]. Distillers' grains yields (dry basis) were 13.9 lbs per bu of corn and sorghum in 2009.

[1] Wet DGS at the Hereford plant are provided to local feed markets with a moisture content of 65%. Testing is conducted bi-hourly to ensure accuracy within plus or minus 1%. Thus, to convert wet DGs to dry matter, we multiply by (1-0.65) = 0.35. Dry DGs are provided at 12% moisture content, thus to convert dry DGs to dry matter we multiply by (1-0.12)=0.88.

[2] A decatherm (Dth) is 1 million BTU, according to the dictionary published by EnergyVortex.com, http://www.energyvortex.com/energydictionary/therm__decatherm html

Table 2. Ethanol and Distillers' Grain Yields			
Parameter	2008	2009	2-Year Average
Ethanol yield per bu sorghum + corn	[redacted]	[redacted]	[redacted]
Distillers' grain yield, dry, lbs per bu corn + sorghum	[redacted]	[redacted]	[redacted]
Distiller grain yield, dry, per gallon ethanol	[redacted]	[redacted]	[redacted]

GREET requires some of these values in somewhat different units, for example, it requires energy use in kWh/gal. The converted values are shown in Table 3. For ethanol yields in g/bu, we are utilizing the yields that were estimated by dividing the total ethanol from the plant by the sum of the sorghum and corn bushels.

Table 3. CA-GREET Plant and Ethanol Production Parameters			
Parameter & Units	2008	2009	Average
Share of Sorghum Ethanol Plant that is Dry Mill	[redacted]	[redacted]	[redacted]
Ethanol yield, gallons/bushel	[redacted]	[redacted]	[redacted]
Energy Use: NG, Coal, and Biomass, Btu/gallon	[redacted]	[redacted]	[redacted]
Share: NG	[redacted]	[redacted]	[redacted]
Share: Coal	[redacted]	[redacted]	[redacted]
Share: Biomass	[redacted]	[redacted]	[redacted]
Electricity Demand, kWh/gallon	[redacted]	[redacted]	[redacted]
Total Ethanol Production Energy: Btu/gallon	[redacted]	[redacted]	[redacted]
Electricity Share of Total Ethanol Production	[redacted]	[redacted]	[redacted]

4.0 Farming and Chemical Emissions

This section discusses corn and sorghum farming and chemical emissions.

4.1 Corn

Corn farming and chemical emissions utilize the emissions develop by CARB for corn from the GREET model. These are shown in Table 4.

Table 4. GHG Emissions Summary for Dry Mill Corn Ethanol	
Corn Ethanol Fuel Cycle Components	Emissions (g/MJ), Dry Mill
Corn Farming	5.65
Ag Chemicals Production	30.20

Source: "Detailed California-Modified GREET Pathway for Corn Ethanol", February 27, 2009, Version 2.1

4.2 Sorghum

This section discusses sorghum farming and chemical use emissions. The following sections are included.

- Sorghum yields
- Energy use during farming
- Chemical use

4.2.1 Sorghum Yields

The state of Texas is divided into agricultural districts (see Appendix 2), and the Hereford plant is located in District 11, Northern High Plains. Nearly all of the sorghum that comes into the plant is derived from this district, although some also comes from District 12 and 21, and Oklahoma (letter from grain supplier to this effect in Support Documentation). The sorghum yield for Texas District 11 from 2004 to 2009 is shown in Table 5. [2]

Table 5. Sorghum Yields in District 11 of Texas	
Year	Yield (bu/acre)
2004	55.1
2005	66
2006	51
2007	70
2008	54
2009	67
Average, 2004-2009	60.5
Average, last 3 years (2007-2009)	63.7

The results show yields to be 60.5 bu/ acre for the last 6 years, and 63.7 bu/acre for the last 3 years. Since the majority of the sorghum is coming from District 11, we propose to use the yields in the last 3 years for District 11 for developing lifecycle emissions.

4.2.2 Fuel/Energy Use

The GREET model requires that the residual oil, diesel, gasoline, liquefied petroleum gas (LPG), electricity, coal, and natural gas consumed in farming be quantified. There are several sources of farm energy use for sorghum in Texas, as follows:

- U.S. Department of Agriculture Surveys
- FASOM Model
- Congressional Research Service (CRS) Report for Congress

In this section, estimates from these sources will be compared, and final estimates will be determined for use in GREET modeling.

4.2.2.1 U.S. Department of Agriculture

Diesel and gasoline are generally used to power equipment in order to prepare fields, plant, fertilize, and harvest sorghum. Natural gas is generally used for irrigation (where used), and electricity is used in drying sorghum. Although sorghum can tolerate a drier climate than corn, irrigation results in much higher yields. Therefore, our expectation is that the electricity and natural gas used would be higher than used for corn.

The most recent survey that included sorghum is a relatively old survey conducted in 1995. The USDA-ERS 1995 sorghum farming survey reported the values as shown in Table 6 for the Central Plains (Kansas-Nebraska-Missouri), Southern Plains (Oklahoma, Arkansas, Texas) and all U.S. areas. [3]

Table 6. Sorghum Farming Energy Use, 1995 USDA Survey

Energy Source & Units	Central Plains	Southern Plains (Includes Texas)	U.S. Average
Diesel (gallons/acre)	4.53	6.88	5.39
Gasoline (gallons/acre)	3.06	3.16	3.09
Electricity (kWh/acre)	0.15	Too variable to report	0.46
Liquefied Petroleum Gas (LPG) (gallons/acre)	Not reported	Not reported	Not reported
Natural Gas (cubic feet/acre)	Too variable to report	2240	900

Diesel and gasoline use in Texas is somewhat higher than their U.S. averages, while natural gas use is considerably higher. The survey shows that the amount of electricity used for sorghum in the southern plains was too variable to report during the time of this

survey. Both the high natural gas usage and electricity variability are likely due to the varying amounts of irrigation and drying needed for the crop.

4.2.2.2 FASOM Model

The FASOM model was utilized by the EPA in determining the net change in total agriculture emissions due to the renewable fuel standard. [3,4] The model contains estimates of energy use by crop type.

Table 7 shows values that were derived from the FASOM model, as given in the EPA RFS2 report. [4] These values represent the U.S. average energy consumption for sorghum farming, and not necessarily the values in Texas or District 11 of Texas, where the plant is located.

Table 7. Farming Energy Use, FASOM Model

Energy Source & Units	Sorghum (U.S. Average)
Diesel (gallons/acre)	9.07
Gasoline (gallons/acre)	3.56
LPG (gallons/acre)	Not Available
Electricity (kWh/acre)	5.79
Natural Gas (cubic feet/acre)	Not Available

FASOM shows much higher diesel and somewhat higher gasoline use than the 1995 USDA survey for sorghum.

4.2.2.3 CRS Report for Congress

In November 2004, the Congressional Research Service (CRS) prepared a report entitled "Energy Use in Agriculture: Background and Issues". [5] In this report, detailed analyses of farming energy use costs were prepared for each of the ten USDA Production Expenditure Regions of the country. Texas is part of the Southern Plains Region, which also includes Oklahoma. Although the study covers all crop types, sorghum is a major crop for this region. Therefore, the values given in Table 8 should still be representative for sorghum in District 11 of Texas. The CRS Report for Congress is provided in the Support Documentation. The methodology for developing the values in Table 8 from the CRS report is described in Appendix 4.

Table 8. Farming Energy Use, CRS Report	
Energy Source & Units	Southern Plains USDA Production Expenditure Region (All Crops: OK, TX)
Diesel (gallons/acre)	6.50
Gasoline (gallons/acre)	3.07
LPG (gallons/acre)	0.68
Electricity (kWh/acre)	Not Available
Natural Gas (cubic feet/acre)	2372

A comparison between the CRS and USDA Survey estimates for diesel, gasoline, and natural gas use shows excellent agreement. In addition, the CRS report provides an estimate for LPG consumption.

Based on the data in Tables 11-13, it appears that the USDA values for sorghum are still reasonable. The values used in further GREET modeling are summarized in Table 9.

Table 9. Sorghum Farming Energy Use, Modified CA-GREET Model		
Energy Source & Units	Sorghum	Source
Diesel (gallons/acre)	6.88	1995 USDA
Gasoline (gallons/acre)	3.16	1995 USDA
LPG (gallons/acre)	0.68	CRS Report
Electricity (kWh/acre)	5.79	FASOM
Natural Gas (cubic feet/acre)	2240	1995 USDA

4.2.3 Fertilizer Use

The amounts and types of fertilizer applied for sorghum farming depends on a wide range of factors, including desired yield, tillage method, and crop rotation. AIR obtained farming survey data from the USDA-ERS for Texas sorghum. These application rates are summarized in Table 10. [6]

Table 10. USDA-ERS Texas Sorghum Fertilizer Application Rates			
Fertilizer	Percent Treated	Application Rate	Final Rate
Nitrogen (N)	63.830	89.347 pounds/acre	57.03 pounds/acre
Phosphate (P2O5)	42.966	33.572 pounds/acre	14.42 pounds/acre
Potash (K20)	14.498	11.831 pounds/acre	1.72 pounds/acre
Lime (CaCO3)	0	0 pounds/acre	0 pounds/acre

Lime is not used in District 11 due to the natural composition and acidity of the soil. [3]
The final fertilizer rates used in the modified CA-GREET model are given in Table 11.

[3] See communication from Dr. Trostle on this subject in Appendix 3.

Table 11. Sorghum Farming Fertilizer Rates, Modified CA-GREET Model		
Fertilizer	Application Rate, lbs/acre	Application Rate, g/bu @ 63.7 bu/acre
Nitrogen (N)	57.03	406.1
Phosphate (P2O5)	14.42	102.7
Potash (K20)	1.72	12.2
Lime (CaCO3)	0.0	0.0

4.2.4 Pesticide Use

The amounts and types of herbicide, pesticide, and insecticide used in Texas sorghum farming were obtained from the USDA-ERS. They are summarized in Table 12 below. [6]

Table 12. Sorghum Farming Pesticides Rates, Modified CA-GREET Model				
Type	Percent Treated	Rate Per Application	Number of Applications	Final Application Rate
Herbicide	77.478	1.232 pounds/acre	1.644	1.57 pounds/acre
Pesticide	81.258	1.280 pounds/acre	1.909	1.99 pounds/acre
Insecticide	17.471	0.491 pounds/acre	1.586	0.14 pounds/acre

The GREET model determines the herbicide energy use based on the following four products: Atrazine, Metolachlor, Acetochlor, and Cyanazine. AIR was not able to determine the product makeup of the herbicide amounts listed in Table 12. Therefore, it was assumed that the GREET default weighting of 25% for each product was applicable to sorghum. The final pesticide values used in the modified CA-GREET model are found in Table 13.

Table 13. Sorghum Pesticide Application Rates, CA-GREET		
Type	Application Rate, lbs/acre	Application Rate, g/bu @ 63.7 bu/acre
Herbicide	1.57	11.17
Pesticide	1.99	14.14
Insecticide	0.14	0.97

4.2.4 Other Assumptions

The CA-GREET model requires several additional farming-related inputs:

- The nitrogen content of the above and below ground biomass
- Vehicle type and distances for harvesting and delivery grain to the ethanol plant
- CO2 emissions from direct land use changes
- Urban shares of transportation mode activities
- Co-product credits

AIR discussed these aspects with USDA personnel. Although no corroborating data could be cited, they believed that these parameters should be similar to corn farming. As a result, the values in Table 14 were used in the modified CA-GREET model.

Table 14. Miscellaneous Sorghum Farming Parameters, CA-GREET

Parameter	Value
Nitrogen content of the above and below ground biomass	141.6 grams/bushel (assumed to be same as corn)
Vehicle type and distances for harvesting and delivery of sorghum to the ethanol plant	MHDT, 10 miles from field to stack MHDT, 40 miles from stack to plant
Vehicle type and distance for corn transport to Texas from Midwest	Rail, 740 miles
CO2 emissions from direct land use changes	None, as long as land is always used for farming
Urban shares of transportation mode activities	0% for all transportation modes
Co-product credit	Equivalent to corn ethanol displacement method

5.0 Results

In order to compute the sorghum emissions via GREET, numerous modifications were made to the model. New sorghum-specific calculations and/or data sections were installed in the following spreadsheet tabs: Inputs, T&D_Flowcharts, T&D, Urban_Shares, Fuel_Prod_TS, Ag_Inputs, and EtOH. A list of changes made to the GREET model for this analysis is shown in Appendix 5.

5.1 Farm Emissions

The CARB report on corn ethanol contains three key summaries in Tables 1.01 (Farm Operation Energy Use), 1.09 (Farming GHG Emissions), and B (Ethanol Fuel Cycle GHG Emissions). Comparable tables were created for the sorghum ethanol production using the modified CA-GREET model and the inputs described in this report. These three tables, showing both the corn and sorghum results, are given below in Table 15.

Table 15. Farm Operation Energy Use for Sorghum and Corn

	Sorghum		Corn (Dry Mill)	
Fuel Type	Fuel Share	Primary Energy Input (Btu/bu)	Fuel Share	Primary Energy Input (Btu/bu)
Residual Oil	0.00%	0	0.00%	0
Diesel Fuel	25.91%	13,876	45.23%	5,715
Gasoline	10.75%	5,757	18.19%	2,298
Natural Gas	61.07%	32,705	14.53%	1,835
Coal	0.00%	0	0.00%	0
LPG	1.69%	905	16.77%	2,119
Electricity	0.58%	311	5.28%	667
Total Direct Energy Use for Cultivation		53,553		12,635

Table 15 shows that the sorghum farming energy use, on a per bushel basis, is about 4.2 times that for corn. This is primarily due to the natural gas used to pump water for irrigation. Table 16 shows the GHG emissions for the total farming component, as estimated with the modified GREET model based on the fuel types in Table 16.

Table 16. Farming GHG Emissions (from modified GREET)				
	Sorghum		Corn (Dry Mill)	
Emissions Species	Emissions (g/bu)	GHG (gCO2e/mmBtu)	Emissions (g/bu)	GHG (gCO2eq/mmBtu)
VOC	6.34	93.31	2.05	31
CO	111.35	826.41	40.688	308
CH4	18.75	2,213.31	2.250	271
N2O	0.08	115.91	0.025	36
CO2	3,803.50	17,963.40	1,103	5,315
Total GHG (g CO2e/mmBtu)		21,212.34		5,960
Total GHG (g CO2e/MJ)		20.11		5.65

5.2 Agriculture Chemical Emissions

Agriculture chemical emissions are summarized in Tables 17, 18, and 19. These are similar to Table 2.05, 2.06, and 2.07 in the CARB Corn Ethanol report. GHG emissions for the chemicals alone are shown in Table 17. Table 18 shows a summary of N_2O emissions conversion. Table 19 shows the summary of these two sources of emissions by fertilizer type. Total chemical input emissions are 24.64 g/MJ.

Table 17. Calculated GHG Emissions from Production of Agricultural Chemicals for Sorghum							
GHG Type	Nitrogen	P2O5	K2O	Ca CO3	Herbicide	Insecticide	Total
	g/bu						
CH4	0.881	0.153	0.012	0.000	0.308	0.494	1.848
N2O	0.659	0.002	0.000	0.000	0.002	0.004	0.668
CO2	986	104	9	0	238	375	1,713
Total	1,205	109	9	0	247	389	1,958
Total GHG Dry Mill (g/mmbtu)	5,689	513	42	0	1,165	1,837	9,246
Total GHG Dry Mill (g/MJ)	5.39	0.49	0.04	0.00	1.10	1.74	8.76

Similar to Table 2.05 in CARB Corn Ethanol Report

Table 18. Inputs and Calculated Emissions for Soil N2O from Sorghum Cultivation	
Component	Value
Fertilizer N input (g/bu)	406.3
Above and Below Biomass (g/bu)	141.7
Total (g/bu)	548.0
Percent conversion to N2O-N	1.325%
N2O formed/N2O-N (g/g)	1.57
N2O Emissions (g/bu)	11.41
GHG Emissions (gCO2e/mmBtu)	16,058
GHG Emissions (gCO2e/MJ)	15.22

Similar to Table 2.06 in CARB Corn Ethanol Report

Table 19. Chemical Input Emissions (g/MJ)	
Component	Emissions
Fertilizer	5.92
Herbicide	1.10
Pesticide + Insecticide	1.74
Soil N2O	15.22
CO2 from CaCO3	0.00
CO2 from Urea	0.60
VOC and CO	0.06
Total	24.64

Similar to Table 2.07 in CARB Corn Ethanol Report

5.3 Ethanol Production Emissions

5.3.1 Wet Distillers Grains

This analysis examined the difference in ethanol production emissions between 2008 and 2009, to determine if a relationship could be determined between the % sorghum and the ethanol production emissions. The two White plants in Texas, Hereford and Plainview, are identical plants in terms of their operating equipment. Both have a maximum production of just above 100 million gallons per year, and both utilize a mixture of corn and sorghum.

Table 20 shows the corn and sorghum inputs for 2008 and 2009 for both plants, as well as the sorghum fraction. The table also shows the GREET emissions estimated using all of the energy inputs for these plants. Detailed tables of emissions for both plants are shown in Appendix 6.

Table 20. Hereford and Plainview Ethanol Production Emissions for 2008 and 2009				
	Hereford		Plainview	
	2008	2009	2008	2009
Corn (million bu)	[redacted]	[redacted]	[redacted]	[redacted]
Sorghum (million bu)	[redacted]	[redacted]	[redacted]	[redacted]
Total (million bu)	[redacted]	[redacted]	[redacted]	[redacted]
Sorghum Fraction	[redacted]	[redacted]	[redacted]	[redacted]
Ethanol Production (mgy)	[redacted]	[redacted]	[redacted]	[redacted]
GREET Ethanol Production Emissions g/MJ	[redacted]	[redacted]	[redacted]	[redacted]

Table 20 shows that the emissions of Hereford and Plainview are indeed very similar when ethanol production is 55 mgy or higher. For Plainview in 2009, however, where the production was significantly lower, ethanol production emissions were a few g/Mj higher than for the other volumes. In that year, this plant was shut down in March, and then restarted in October at ½ capacity. When the plant was restarted, the boilers were operated at full. So, not only was some energy being consumed to keep the plant in readiness between March and October, the plant was operated (necessarily) in a less than maximum efficiency mode when it was started up. This explains the higher energy per MJ in that year. [4] We do see a trend toward somewhat lower emissions with higher sorghum fraction, when the volumes are higher. But the emissions for Hereford for 2008 and 2009 are very similar, so we will use an average of 22.96 g/MJ for both years for this plant.

5.3.2 Dry and Modified Distillers Grains

The Hereford plant may produce both dry and modified distillers grains in the future. The dry distillers grains would be produced with a moisture content of 12%, and the modified product would be provided with a moisture content of 50%. These products would be produced by operating the dryers for a longer period of time, and this would consume more natural gas, causing the plant's carbon intensity to be higher. Ideally, if we had energy values for when the plant was being operated exclusively to produce dry and modified distillers grains, the impact could be developed from these plant energy values. However, this has not been done at the plant, so we do not have these values, and have to develop an alternative method of making these estimates. Our proposal is to develop the difference in carbon intensity from the CARB Corn Ethanol values for wet and dry DGs, and add these to the value we have for the Hereford plant as a wet DGS plant.

[4] Also, the Plainview plant was still under construction in January through April of 2008, so there was no energy usage for the first four months of 2008.

5.3.2.1 Dry DGs from CARB's Corn Ethanol Values

Table 22 shows CARB's corn ethanol values for a Midwest, NG corn ethanol plant with both wet and dry DGs. [3] When dry DGs are provided, the direct CI is 8.3 g/MJ higher than when provided in the wet condition. For Hereford, we propose to add 8.3 g/MJ to the CI of the plant for estimating the plant emissions for dry DGs.

Table 22. CI Values for CARB Corn Ethanol NG Plant in the Midwest	
DGs	CI (g/MJ), without LUC
Dry	68.4
Wet	60.1
Difference, Dry-Wet	8.3

5.3.2.2 Modified Distillers Grains

Dry distillers grains typically have a moister content of 12%, while wet distillers grains have a moisture content of 65%. White intends to offer a modified distillers grains product with a moisture content of 50%. This product would be produced from dryers that are fueled with natural gas. The carbon intensity of the modified product can be interpolated from the moisture content of the modified product and the CARB carbon intensities of the wet and dry distillers grains shown in Table 23. We propose to add 2.3 g/MJ to the wet DG carbon intensity to estimate the CI of the plant operated producing modified DGS.

Table 23. CI Values for CARB Corn Ethanol NG Plant in the Midwest	
DGs	CI (g/MJ), without LUC
Dry (12%)	68.4
Modified (50%)	62.4
Wet (65%)	60.1

5.4 Co-product Credits

Wet distillers grains from the Hereford plant are provided to local Texas feedlots. Our investigation into what these DGs are replacing indicates that it is replacing corn, and not sorghum. As a result, we propose to use the corn distillers' grains co-product credit of 11.51. The estimated co-product credit of sorghum using GREET is higher than this due to the higher farming plus fertilizer emissions of sorghum vs corn, thus, using the corn value is more conservative.

5.6 Summary of Results

The summary of results for the Hereford plant is shown in Table 24. Each section assumes that the plant only uses the corresponding grain. Interestingly, even with irrigation, the sorghum GHG emissions are only about 14 percent higher than those for the Illinois corn used at the plant.

Table 24. GHG Lifecycle Emissions for the Hereford Plant		
Well-to-Tank Ethanol Cycle Components	Sorghum GHG (gCO2e/MJ)	Corn GHG (gCO2e/MJ)
Farming	20.11	5.65
Ag Chemical Production	24.64	30.20
Transport	2.20	3.76
Ethanol Production	23.12	23.12
Ethanol Transport and Delivery	2.70	2.70
Co-Products	-11.51	-11.51
Denaturant	0.80	0.80
Total	62.08	54.72

Farming emissions are higher for sorghum than for a corn due to the impact of irrigation. Agriculture chemical emissions for sorghum are lower than for corn, mainly because lime is not needed. Transport emissions of the sorghum feedstock are lower than corn because sorghum is obtained locally, while the corn used at the plant is shipped about 740 miles by rail from farms in Illinois. Ethanol production emissions and ethanol transport and delivery are nearly the same. The co-product credits are the assumed to be the same for sorghum and corn because DGs produced at the plant are replacing corn rather than sorghum in cattle diets.

White anticipates operating the plant with a sorghum fraction between 5% and 30%, but generally, in the 15-20% range. Since the sorghum emissions are slightly higher than the corn emissions the highest emissions for the plant would be at a sorghum fraction of 30%. The levels for 1%, 10%, 20% and 30% are shown in Table 26. We also show the levels with dry and modified DGs.

Table 25. GHG Lifecycle Emissions for the Hereford Plant (g/MJ)				
Well-to-Tank Ethanol Cycle Components	1% Sorghum Fraction	10% Sorghum Fraction	20% Sorghum Fraction	30% Sorghum Fraction
Wet Distillers Grains				
Farming	5.79	7.10	8.54	9.99
Ag Chemical Production	30.14	29.64	29.09	28.53
Transport	3.74	3.61	3.45	3.30
Ethanol Production	23.12	23.12	23.12	23.12
Ethanol Transport and Delivery	2.70	2.70	2.70	2.7
Co-Products	-11.51	-11.51	-11.51	-11.51
Denaturant	0.80	0.8	0.8	0.8
Total	54.79	55.46	56.19	56.93
Dry Distillers Grains (Wet + 8.3 g/MJ)				
Total	63.09	63.76	64.49	65.23
Modified Distillers Grains (Wet + 2.3 g/MJ)				
Total	57.09	57.76	58.49	59.23

References

1. "Detailed California-Modified GREET Pathway for Corn Ethanol", February 27, 2009, Version 2.1.

2. National Agricultural Statistics Service, U.S. Department of Agriculture, http://quickstats.nass.usda.gov/.

3. Economic Research Service, U.S. Department of Agriculture, February 1997, FBE97-1, contacts: Nora Brooks and Robert McElroy

4. "Renewable Fuel Standard (RFS2) Regulatory Impact Analysis", EPA-420-R-10-006, February 2010, Figures 2.4-3, 2.4-4, 2.4-5, and 2.4-6.

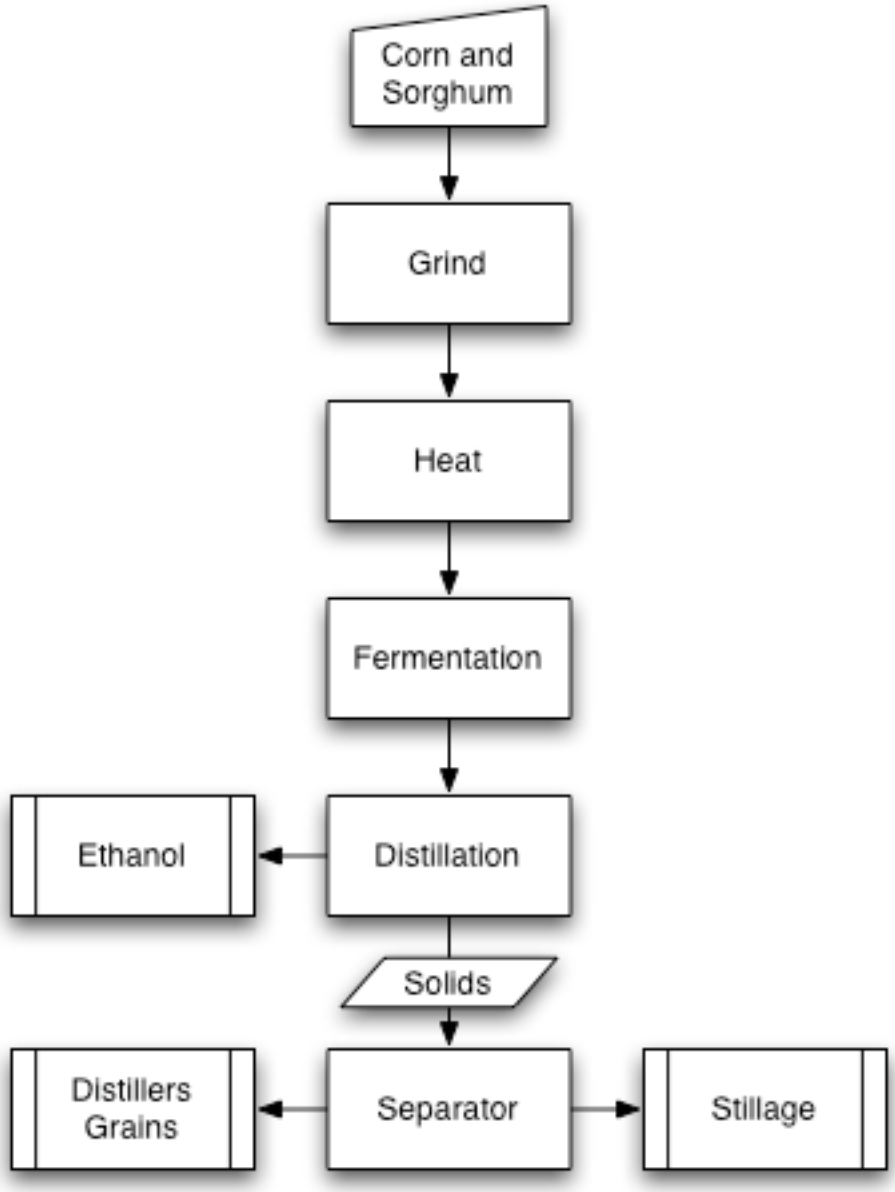
5. CRS Report for Congress, "Energy Use in Agriculture: Background and Issues", Congressional Research Service, The Library of Congress, Order Code RL32677, November 19, 2004.

6. Economic Research Service, U.S. Department of Agriculture, http://www.ers.usda.gov/data/arms/cropoverview.htm.

7. "Energy Dictionary", by Energy Vortex, http://www.energyvortex.com/energydictionary/therm__decatherm.html

Appendix 1

Flow Chart of Plant and List of Combustion Equipment



Hereford Combustion Equipment

1. 2 gas fired package boilers - maximum heat input 120 mmbtu/hr per unit. These provide steam for heating the grain/water mixture.

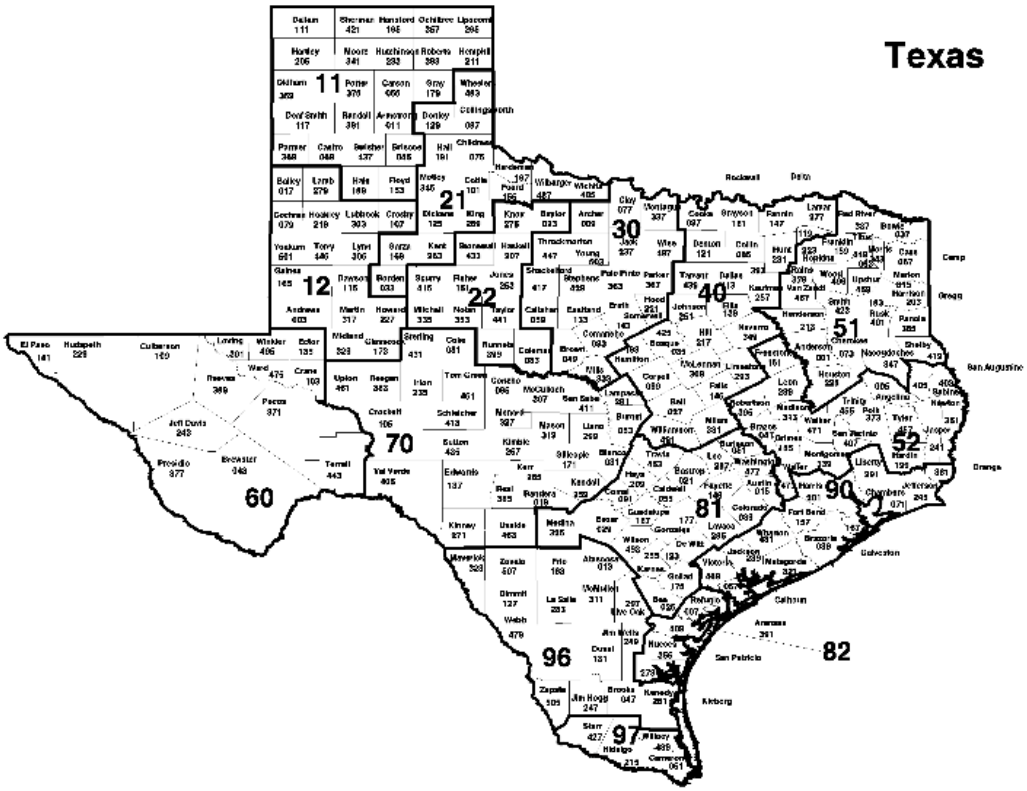
2. 2 dryers - max heat input 45 mmbtu/hr per unit. These provide for drying of the DGs when operated.

3. 1 regenerative thermal oxidizer - max heat input 10 mmbtu/hr. This unit is the air pollution control unit for the plant.

4. 2 load out flares to control emissions when loading truck or rail units with ethanol

Appendix 2

Texas Agricultural Districts



Appendix 3

Communication from Dr. Trostle on Lime Applications

Subject: West Texas Trostle Followup/Lime Use
From: "Calvin L Trostle" <c-trostle@tamu.edu>
Date: Mon, 21 Jun 2010 14:25:27 -0500
To: <kbomb@umich.edu>

Dennis,

Thanks for your inquiry. I found the D-11 that you are referring to as it used to be called D-1N, and what is now D-12 to the south was D-1S. I can pretty much vouch for there being no agricultural limestone use in what is now D-12.

Ag. statistics for the region, at least what is readily available, is found at http://www.nass.usda.gov/Statistics_by_State/Texas/index.asp#.html, where among other things you can access the data either on a county level or a district level.

The Plainview and Hereford ethanol plants are in D-11, and the Levelland plant is in D-12.

As I noted on the phone, soil pH here is largely all 7.2 or above, and some is up to 8.3 where geologic calcium carbonate (caliche) is highest. Liming is to increase acid soil pH, so that is not needed here. There is some limited use of agricultural gypsum, or calcium sulfate, south of Lubbock where salts, which accumulate from saline irrigation waters, begin to affect soils especially if there is sodium. Peanut farmers are most likely to use it. The gypsum, however, lowers pH.

Finally, depending on how your modeling is conducted, does it matter where the grain used in the ethanol plants comes from? 90%+ of the corn in the Plainview & Hereford ethanol plants is hauled in my rail, usually from the Midwest. Most of those plant's grain sorghum is likely from the region, and nearly all of the grain sorghum at the Levelland plant west of Lubbock is derived from this region. I believe the ethanol plant at Levelland, however, has CO2 capture equipment, and then that would be marketed back to the region's oil & gas industry. At least they planned to do this. I don't know if the other two plants, owned by White Energy, do the same.

I would speculate that the GHG emissions are potentially far higher from the massive cattle feedlot operations in the region than they would be from ethanol production.

I could guess at other resource data you might need, but I'll let you tell me if there is something else you might need.

Calvin

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Subject: Re: Fwd: West Texas Trostle Followup/Lime Use
From: "Calvin L Trostle" <c-trostle@tamu.edu>
Date: Tue, 22 Jun 2010 07:52:18 -0500
To: <kbomb@umich.edu>

Dennis, my colleague in Amarillo reports no agricultural lime use in the TX Panhandle.

Calvin

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>>> Brent Bean 6/22/2010 7:45 AM >>>

No

>>> Calvin L Trostle 6/21/2010 2:31 PM >>>

{Brent, are you aware of any agricultural lime applications anywhere in Extension district D-1? That for the most part is USDA's D-11, which is Lipscomb, Hemphill, Gray, Armstrong, Briscoe, Floyd and all counties to the west. This is in response to Univ. of Michigan research inquiry. CLT}

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Appendix 4

Derivation of Table 8

In November 2004, the Congressional Research Service (CRS) prepared a report entitled "Energy Use in Agriculture: Background and Issues" [see reference below]. This report contains national fuel costs and detailed farming energy use costs for each of the ten USDA Production Expenditure Regions of the country. The Southern Plains Region consists of Texas and Oklahoma. Although the study covers all crop types, sorghum is a major crop for this region. Therefore, the analysis below should still be representative for sorghum in District 11 of Texas.

The GREET model calculations require that the farming energy use units be in the form of Volume per Acre. Since the energy use costs in the CRS report were not in this format, the following method was used to obtain the proper units.

The first step in this process was to determine the average cost of the fuels used in farming (gasoline, diesel, natural gas (NG), and liquefied petroleum gas (LPG)). The CRS report contains the required information in Table A1, a portion of which is reproduced in Table 1 below.

Table 1
Derivation of Fuel Price per Unit

From Table A1, CRS Report					
Fuel	**Units**	**GEG***	**Cost/GEG**	**Average Cost/GEG**	**Price per Unit**
Gasoline	Gallon	1.00	$1.99	1.990	1.990
Diesel	Gallon	1.11	$1.54	1.540	1.709
Natural Gas	1,000 CuFt	0.88	$1.16-$1.75	1.455	1.280
LP Gas	Gallon	0.73	$1.92-$3.08	2.500	1.825

* GEG: Gasoline Equivalent Gallon

The first four columns of the table are taken directly from the CRS Table A1. The GEG (Gasoline Equivalent Gallon) gives the relative amount of energy each fuel contains, as compared to gasoline. In some cases, a range of values is given for the amount each fuel costs per GEG (Cost/GEG). As a result, a simple average was computed from this range. The average price per fuel unit is computed by multiplying the Average Cost/GEG by the GEG value. The results are listed in the rightmost column of the Table 1.

The next step is to convert the CRS fuel use values, given in total cost over the total area planted, to the units required by GREET. Table 2 below is based on Table A5 from the CRS report.

Table 2
Derivation of Table 8, Farm Energy Use, CRS Report

From Table A5: So. Plains (OK,TX), Area Planted: 34,904,000 Acres						
Fuel	**Cost ($Million)**	**Cost per Acre**	**Price per Unit**	**Price Unit**	**Use per Acre**	**Unit per Acre**
Gasoline	213	6.102	1.990	Gallons	3.07	Gallons
Diesel	388	11.116	1.709	Gallons	6.50	Gallons
Other Fuels (Mainly Natural Gas)	106	3.037	1.280	1000 CuFt	2,372	CuFt
LP Gas	43	1.232	1.825	Gallons	0.68	Gallons

As the table shows, the Southern Plains region planted over 34.9 million acres of crops during the period analyzed by the report (2003-2004). The total fuel cost values, in millions of dollars, are taken directly from the CRS Table A5. By dividing each fuel cost by the total acres planted, the Cost per Acre values are computed. In turn, by dividing the Cost per Acre values by the corresponding Price per Unit values (computed in Table 1), the amount of fuel used per acre is determined. These values, in the correct units required by GREET, are given in the two rightmost column of Table 2. They are also given in Table 8 in the main body of this report.

Reference:

CRS Report for Congress, “Energy Use in Agriculture: Background and Issues”, Congressional Research Service, The Library of Congress, Order Code RL32677, November 19, 2004.

Appendix 5

GREET Model Changes for Hereford

Modifications Made to CA-GREET Model for Hereford Sorghum Analysis			
Worksheet	Type	Cell(s)	Purpose
Ag_Inputs	Insertion	J91:Q126	Insert Sorghum and Wheat Calculations to "Herbicides: Average for Crop Type" in Section 4) Summary of Energy Use and Emissions of Agricultural Chemicals: per gram
Ag_Inputs	Addition	L277:P301	Add "Sorghum Farming" calculations to Section 5.4) Summary of Energy Use and Emissions of Farming Machinery
Ag_Inputs	Insertion	Y91:Z126	Insert Sorghum and Wheat Calculations to "Insecticides: Average for Crop Type" in Section 4) Summary of Energy Use and Emissions of Agricultural Chemicals: per gram
EtOH	Insertion	A92:E125	Insert input and calculation Section "1.2d) Key Assumptions Regarding Sorghum-Ethanol"
EtOH	Addition	AE133:AJ158	Add "Calculations of Co-Product Credits for Sorghum Ethanol" to Section 1.3) The Types of Electricity Displaced by Co-Produced Electricity in Biomass-based EtOH Plants for Export
EtOH	Addition	AO230:AP254	Add complete "Dry Milling Sorghum Ethanol " calculations and summary to Section 4) Summary of Energy Consumption and Emissions: Btu or Grams per mmBtu of Fuel Throughput at Each Stage; Subsection 4.1) Energy Consumption and Total Emissions
EtOH	Addition	AQ230:AR254	Add complete "Wet Milling Sorghum Ethanol " calculations and summary to Section 4) Summary of Energy Consumption and Emissions: Btu or Grams per mmBtu of Fuel Throughput at Each Stage; Subsection 4.1) Energy Consumption and Total Emissions

EtOH	Addition	AS230:AT254	Add complete "Sorghum Ethanol: Combined Dry and Wet Milling Ethanol " calculations and summary to Section 4) Summary of Energy Consumption and Emissions: Btu or Grams per mmBtu of Fuel Throughput at Each Stage; Subsection 4.1) Energy Consumption and Total Emissions
EtOH	Addition	CY177:DG266	Add complete "Sorghum Farming: calculations and display to Section 3) Calculations of Energy Consumption and Emissions for Each Stage
EtOH	Addition	DH177:DK266	Add complete "Sorghum Ethanol Production" calculations and display to Section 3) Calculations of Energy Consumption and Emissions for Each Stage
EtOH	Addition	DL177:DO266	Add complete "Co-Product Credits of Sorghum Ethanol: Market Value Method" calculations and display to Section 3) Calculations of Energy Consumption and Emissions for Each Stage
EtOH	Addition	DP177:DV266	Add complete "Co-Product Credits of Sorghum Ethanol: Displacement Method" calculations and display to Section 3) Calculations of Energy Consumption and Emissions for Each Stage
EtOH	Addition	DW177:DX266	Add complete "Sorghum Ethanol and Cellulosic Ethanol T&D" calculations and display to Section 3) Calculations of Energy Consumption and Emissions for Each Stage
EtOH	Addition	H10:I11	Add Sorghum and Wheat "N content of above and below ground biomass: grams/bushel for corn, grams/ton for cellulosic biomass, and grams/tonne for sugar cane" to Section 1.1) Feedstock Farming
EtOH	Addition	H13:I14	Add Sorghum and Wheat "N2O Emissions: N in N2O as % of N in N fertilizer and biomass" to Section 1.1) Feedstock Farming
EtOH	Addition	I16:J22	Add Sorghum and Wheat "Farming Energy Use and Fertilizer Use" to Section 1.1) Feedstock Farming

EtOH	Addition	I24:J25	Add Sorghum and Wheat "CO2 Emissions from Land Use Change" to Section 1.1) Feedstock Farming
EtOH	Addition	I5:J6	Add Sorghum and Wheat "Shares of Feedstocks for Ethanol Production" to Section 1) Scenario Control and Key Input Parameters
EtOH	Addition	P161:S174	Add Sorghum and Wheat calculations to Section 2) Shares of Combustion Processes for Each Stage
Fuel_Prod_TS	Addition	AA285:AC293	Add data table to Shares of Ethanol Production Section for "Share of Sorghum EtOH to Total EtOH Production"
Fuel_Prod_TS	Addition	AE285:AG293	Add placeholder data table to Shares of Ethanol Production Section for "Share of Wheat EtOH to Total EtOH Production"
Fuel_Prod_TS	Addition	AI285:AK293	Add data table to Shares of Ethanol Production Section for "Share of Dry Mill Sorghum EtOH Production Between Dry and Wet Sorghum EtOH Production"
Fuel_Prod_TS	Addition	AM285:AO293	Add placeholder data table to Shares of Ethanol Production Section for "Share of Dry Mill Wheat EtOH Production Between Dry and Wet Sorghum EtOH Production"
Fuel_Prod_TS	Addition	CU269:CW279	Add data table to Ethanol Production Section for "EtOH Yield of Sorghum EtOH Plant: Dry Mill, gal/bushel"
Fuel_Prod_TS	Addition	CY269:DA279	Add data table to Ethanol Production Section for "EtOH Yield of Sorghum EtOH Plant: Wet Mill, gal/bushel"
Fuel_Prod_TS	Addition	DC255:DE265	Add data table to Corn and Biomass Farming Section for "Sorghum Farming Energy Use: Btu/bushel of Sorghum"
Fuel_Prod_TS	Addition	DC269:DE279	Add data table to Ethanol Production Section for "Sorghum EtOH Plant Energy Use: Dry Mill, Btu/gal"
Fuel_Prod_TS	Addition	DG255:DI265	Add data table to Corn and Biomass Farming Section for "N Fertilizer Use for Sorghum Farming: N grams/bushel"
Fuel_Prod_TS	Addition	DG269:DI279	Add data table to Ethanol Production Section for "Sorghum EtOH Plant Energy Use: Wet Mill, Btu/gal"

Fuel_Prod_TS	Addition	DK255:DM265	Add data table to Corn and Biomass Farming Section for "P2O5 Fertilizer Use for Sorghum Farming: P2O5 grams/bushel"
Fuel_Prod_TS	Addition	DK271:DM279	Add data table to Ethanol Production Section for "Share of Coal in Total Process Fuels of Sorghum Ethanol Plant: Dry Milling"
Fuel_Prod_TS	Addition	DO255:DQ265	Add data table to Corn and Biomass Farming Section for "K2O Fertilizer Use for Sorghum Farming: K2O grams/bushel"
Fuel_Prod_TS	Addition	DO271:DQ279	Add data table to Ethanol Production Section for "Share of Coal in Total Process Fuels of Sorghum Ethanol Plant: Wet Milling"
Fuel_Prod_TS	Addition	DS255:DU265	Add data table to Corn and Biomass Farming Section for "CaCO3 Fertilizer Use for Sorghum Farming: CaCO3 grams/bushel"
Fuel_Prod_TS	Addition	DW257:DY265	Add data table to Corn and Biomass Farming Section for "Herbicide Use for Sorghum Farming: grams/bushel"
Fuel_Prod_TS	Addition	EA255:EC265	Add data table to Corn and Biomass Farming Section for "Insecticide Use for Sorghum Farming: grams/bushel"
Fuel_Prod_TS	Addition	EE255:EG265	Add placeholder data table to Corn and Biomass Farming Section for "Wheat Farming Energy Use: Btu/bushel of Wheat"
Fuel_Prod_TS	Addition	EI255:EK265	Add placeholder data table to Corn and Biomass Farming Section for "N Fertilizer Use for Wheat Farming: N grams/bushel"
Fuel_Prod_TS	Addition	EM255:EO265	Add placeholder data table to Corn and Biomass Farming Section for "P2O5 Fertilizer Use for Wheat Farming: P2O5 grams/bushel"
Fuel_Prod_TS	Addition	EQ255:ES265	Add placeholder data table to Corn and Biomass Farming Section for "K2O Fertilizer Use for Wheat Farming: K2O grams/bushel"
Fuel_Prod_TS	Addition	EU257:EW265	Add placeholder data table to Corn and Biomass Farming Section for "CaCO3 Fertilizer Use for Wheat Farming: CaCO3 grams/bushel"

Fuel_Prod_TS	Addition	EY257:FA265	Add placeholder data table to Corn and Biomass Farming Section for "Herbicide Use for Wheat Farming: grams/bushel"
Fuel_Prod_TS	Addition	FC255:FE265	Add placeholder data table to Corn and Biomass Farming Section for "Insecticide Use for Wheat Farming: grams/bushel"
Fuel_Prod_TS	Addition	FG255:FI265	Add data table to Corn and Biomass Farming Section for "CO2 Emissions from Landuse Change: Sorghum Farm, grams/bushel"
Fuel_Prod_TS	Addition	FK255:FM265	Add data table to Corn and Biomass Farming Section for "CO2 Emissions from Landuse Change: Wheat Farm, grams/bushel"
Fuel_Prod_TS	Addition	FO257:FQ265	Add data table to Corn and Biomass Farming Section for "Sorghum Yield, bu/harvest acre"
Fuel_Prod_TS	Addition	FS257:FU265	Add placeholder data table to Corn and Biomass Farming Section for "Wheat Yield, bu/harvest acre"
Inputs	Insertion	A272:D313	Insert Section 7.9) "Key Assumptions for Simulating Sorghum-Based Ethanol Production" (includes Sections 7.9.a, 7.9.b, 7.9.c, 7.9.c.1, 7.9.c.2, and 7.9.c.3). All appropriate data transfers from other worksheets and calculations also included.
Inputs	Addition	F206:G207	Add Sorghum and Wheat inputs for Section 7.4a) "N content of above and below ground biomass…"
Inputs	Addition	F209:G210	Add Sorghum and Wheat inputs for Section 7.4b) "N2O emissions…"
Inputs	Addition	I184:J185	Add Sorghum and Wheat inputs for Section 7.1) "Share of Each Beedstock"
Inputs	Addition	I187:J197	Add Sorghum and Wheat inputs for Section 7.2) "Farming Energy Use and Fertilizer Use" Section
Inputs	Addition	I200:J201	Add Sorghum and Wheat inputs for Section 7.3) "CO2 Emissions from Potential Land Use Changes of Farming: grams/bushel for corn, grams/dry ton for cellulosic biomass, and grams/tonne for sugar cane"
T&D	Addition	DQ135:DR165	Add Sorghum "Farm to Collection Stack" and "Stack to Ethanol Plant" calculations to Section 10

T&D	Addition	DS135:DT165	Add Wheat "Farm to Collection Stack" and "Stack to Ethanol Plant" calculation to Section 10
T&D	Addition	II90:IL132	Add Sorghum "Truck, Barge, Rail, Truck" calculations to Section 9
T&D	Addition	IM90:IP132	Add Wheat "Truck, Barge, Rail, Truck" calculations to Section 9
T&D Flowcharts	Addition	B1519:AE1531	Add Sorghum transportation and distribution inputs, unnecessary graphics omitted
T&D Flowcharts	Addition	B1534:AE1546	Add Wheat transportation and distribution inputs, unnecessary graphics omitted
Urban Shares	Insertion	B80:H81	Add Sorghum and Wheat Inputs to Section 3: "Urban Shares of Transportation Mode Activities"
Urban Shares	Addition	I151:J152	Add Sorghum and Wheat Inputs for Section 7: "Urban Shares of Ethanol Activities; Farming"
Urban Shares	Addition	O153:P154	Add Sorghum Inputs for Section 7: "Urban Shares of Ethanol Activities; Ethanol Production"

Appendix 6

Detailed Emission Results for Hereford and Plainview Based on GREET Model
(2008, 2009, and Average)

Calculated CO2 Emissions (g/gal Anhydrous) for Dry Mill Ethanol Production, Hereford, 2008

	CO2 in g/gal	CO2 in g/mmBtu
Natural Gas		
Large Industrial Boiler	[redacted]	
Small Industrial Boiler	[redacted]	
WTT NG	[redacted]	
Total	[redacted]	[redacted]
Electricity		
As Feedstock	[redacted]	
As Fuel	[redacted]	
Total	[redacted]	[redacted]
VOC	[redacted]	[redacted]
CO	[redacted]	[redacted]
CH4	[redacted]	[redacted]
N2O	[redacted]	[redacted]
Total GHGs (gCO2e/mmBtu)		[redacted]
Total GHGs (gCO2e/MJ)		[redacted]

Calculated CO2 Emissions (g/gal Anhydrous) for Dry Mill Ethanol Production, Hereford, 2009

	CO2 in g/gal	CO2 in g/mmBtu
Natural Gas		
Large Industrial Boiler	[redacted]	
Small Industrial Boiler	[redacted]	
WTT NG	[redacted]	
Total	[redacted]	[redacted]6
Electricity		
As Feedstock	[redacted]	
As Fuel	[redacted]	
Total	[redacted]	[redacted]
VOC	[redacted]	[redacted]
CO	[redacted]	[redacted]
CH4	[redacted]	[redacted]
N2O	[redacted]	[redacted]
Total GHGs (gCO2e/mmBtu)		[redacted]
Total GHGs (gCO2e/MJ)		[redacted]

Calculated CO2 Emissions (g/gal Anhydrous) for Dry Mill Ethanol Production, Hereford

	CO2 in g/gal	CO2 in g/mmBtu
Natural Gas		
Large Industrial Boiler	[redacted]	
Small Industrial Boiler	[redacted]	
WTT NG	[redacted]	
Total	[redacted]	[redacted]
Electricity		
As Feedstock	[redacted]	
As Fuel	[redacted]	
Total	[redacted]	[redacted]
VOC	[redacted]	[redacted]
CO	[redacted]	[redacted]
CH4	[redacted]	[redacted]
N2O	[redacted]	[redacted]
Total GHGs (gCO2e/mmBtu)		[redacted]
Total GHGs (gCO2e/MJ)		[redacted]

Calculated CO2 Emissions (g/gal Anhydrous) for Dry Mill Ethanol Production, Plainview, 2008

	CO2 in g/gal	CO2 in g/mmBtu
Natural Gas		
Large Industrial Boiler	[redacted]	
Small Industrial Boiler	[redacted]	
WTT NG	[redacted]	
Total	[redacted]	[redacted]
Electricity		
As Feedstock	[redacted]	
As Fuel	[redacted]	
Total	[redacted]	[redacted]
VOC	[redacted]	[redacted]
CO	[redacted]	[redacted]
CH4	[redacted]	[redacted]
N2O	[redacted]	[redacted]
Total GHGs (gCO2e/mmBtu)		[redacted]
Total GHGs (gCO2e/MJ)		[redacted]

Calculated CO2 Emissions (g/gal Anhydrous) for Dry Mill Ethanol Production, Plainview, 2009

	CO2 in g/gal	CO2 in g/mmBtu
Natural Gas		
Large Industrial Boiler	[redacted]	
Small Industrial Boiler	[redacted]	
WTT NG	[redacted]	
Total	[redacted]	[redacted]
Electricity		
As Feedstock	[redacted]	
As Fuel	[redacted]	
Total	[redacted]	[redacted]
VOC	[redacted]	[redacted]
CO	[redacted]	[redacted]
CH4	[redacted]	[redacted]
N2O	[redacted]	[redacted]
Total GHGs (gCO2e/mmBtu)		[redacted]
Total GHGs (gCO2e/MJ)		[redacted]

Calculated CO2 Emissions (g/gal Anhydrous) for Dry Mill Ethanol Production, Plainview

	CO2 in g/gal	CO2 in g/mmBtu
Natural Gas		
Large Industrial Boiler	[redacted]	
Small Industrial Boiler	[redacted]	
WTT NG	[redacted]	
Total	[redacted]	[redacted]
Electricity		
As Feedstock	[redacted]	
As Fuel	[redacted]	
Total	[redacted]	[redacted]
VOC	[redacted]	[redacted]
CO	[redacted]	[redacted]
CH4	[redacted]	[redacted]
N2O	[redacted]	[redacted]
Total GHGs (gCO2e/mmBtu)		[redacted]
Total GHGs (gCO2e/MJ)		[redacted]