Lifecycle GHG Emissions from Poet-DSM Project Liberty Cellulosic Ethanol Plant

December 10, 2015

Air Improvement Resource, Inc.
2240 Maksaba Trail
Macatawa, Michigan 49434
616-335-8922
airimprovement.com

Lifecycle GHG Emissions from
Poet-DSM Project Liberty Cellulosic Ethanol Plant

1.0 Summary

The POET-DSM Project Liberty plant is a 25 million gallon per year (mgy) facility (starting up with an estimated 13.3 mgy) utilizing corn stover as a feedstock. The plant commenced operations in September 2014. POET-DSM Liberty is seeking CARB approval for cellulosic ethanol utilizing its process under the current Low Carbon Fuel Standard requirements. This document discusses the estimated lifecycle emissions of the process.

Estimated major inputs and outputs are shown in Table 1. Farmers sending stover to POET-DSM Liberty utilize a 25% removal rate of stover from fields. The plant also outputs steam and biogas, which are utilized at the co-located POET Emmetsburg Biorefinery corn ethanol facility.

	[redacted]		
	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
	[redacted]	[redacted]	
	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
	[redacted]	[redacted]	
	[redacted]	[redacted]	

This study evaluated the carbon intensity of the plant utilizing the California CaGREET2.0 model. Results of the CI analysis are shown in Table 2. The total CI for the plant with a yield of [redacted] is 21.58 gCO2e/MJ.

Table 2. GHG Emissions from POET-DSM Liberty (gCO2e/MJ)	
Source	[redacted]
Agricultural Chemicals	12.81
Feedstock Collection	4.34
Feedstock Transport	2.31
Ethanol Production:	
Cellulosic Chemicals Lifecycle Emissions Plus Polypropylene Net Lifecycle and Combustion	15.19
Natural Gas Used for Process	4.90
Grid-Based Electricity	74.72
Biomass fines, filter cake, syrup, and net wrap biomass combustion	4.16
Fugitive Methane	1.63
Boiler Ash and Sulfur Cake Disposal	1.12
Ethanol Transport and distribution	2.76
Denaturant	2.94
Well-To-Tank Emissions Before Co-Product Credits	126.89
Less Biogas and Steam Export to POET Emmetsburg Corn Ethanol Plant	-105.30
Total Well-To Tank	21.58
Carbon in Fuel (Tank to Wheels)	0.00
Indirect Land Use Change Emissions	0.00
Total Well-to-Wheels Estimate	21.58

2.0 Introduction

The POET-DSM Liberty plant, which is undergoing startup and is producing ethanol, is a 25 million gallon per year ethanol plant (starting up with an estimated 13.3 mgy) utilizing corn stover as a feedstock. The plant not only produces ethanol, but also produces enough steam and biogas to provide the process fuel for both the POET-DSM Liberty plant and the co-located POET Emmetsburg corn ethanol facility.

This document develops the lifecycle GHG emissions for the POET-DSM Liberty plant. In this analysis, we have utilized the California GREET model to make these estimates. This report is divided into the following sections:

- Process Description
- Material Flows and Energy Balance
- GREET Modeling
- Chemicals
- Results

3.0 Process Description

A detailed process description is contained in "CONFIDENTIAL_Liberty_ProcessDescription.pdf."

4.0 Material Flows and Energy Balance

A detailed material flow and energy balance is contained in "CONFIDENTIAL Liberty_Energy.Flow_Image.pdf." Many of the values in this material and energy balance were used in the GREET modeling. A summary of this information is shown in Table 3. The values in Table 3 reflect direct energy uses, and not indirect or upstream results for the different fuels. Approximately 80% of the energy used to process biomass comes from the biomass itself, 17% is from electricity. After the energy that is exported to POET Emmetsburg is subtracted, the net energy used to produce ethanol is just over 45,000 BTU/gallon.

[redacted]		
[redacted]	[redacted]	
	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]	[redacted]	
[redacted]		[redacted]

5.0 GREET Modeling

AIR modified the CaGREET2.0 model to include the input spreadsheet assembled by POET-DSM (Attachment 1). This section discusses the GREET inputs. A separate file "CONFIDENTIAL_Liberty_CA GREET Inputs" details these changes.

5.1 Feedstock Collection

In the POET-DSM Liberty operation, a single pass is used after grain harvesting to bale; windrows are not used. POET-DSM strongly urges the producers to NOT rake and form a windrow. The preferred method is to shut the chaff spreaders off at the back of the grain harvester and let the biomass fall to the ground – collecting and baling the stover as-is on the second pass.

In this analysis we are assuming that the CaGREET2.0 feedstock collection energy use is correct. In the future, we may develop an updated estimate based on POET-DSM's recommended collection process.

5.2 Nutrient Replacement

[redacted]

[redacted]

In this analysis we are basing the nutrient replacement rates on CaGREET2.0. [redacted]

5.3 Feedstock Transport

POET-DSM estimates an average transport distance of 35 miles. The feedstock is transported with heavy-heavy-duty diesel trucks (HDDVs). We use the CaGREET2.0 2% biomass loss rate for feedstock transport.

5.4 Yield

[redacted]

---

[1] *2008-2012 Project Report, Emmetsburg Soil Study: Evaluation of corn cob and stover removal levels on crop production, soil quality and nutrient levels,* Birrell and Karlen, ISU, 2012.

[2] POET/DSM report, *Biomass Collection, Nutrient Replacement Requirements.*

5.5 Biomass Percent Moisture

The percent moisture is used by GREET to estimate biomass transport emissions. CaGREET2.0 assumes 12% moisture content for biomass coming into the plant. POET-DSM has test results indicating 30% moisture is to be expected in this area, so the default CaGREET2.0 value for the biomass was modified to 30%. [3] The higher moisture content makes feedstock transport emissions slightly higher than if the default value of 12% were used.

5.6 POET-DSM Liberty Plant Emissions

Process fuels used by the POET-DSM Liberty plant include the following:

- Electricity from the grid
- Biogas produced from the anaerobic digester
- Some natural gas from the grid
- Biomass fines, filter cake, syrup, and polypropylene net

However, in addition to using some natural gas and electricity from the grid, the plant also produces excess steam, which is used at the co-located POET Emmetsburg corn ethanol plant, and produces excess biogas, which is also used by the POET Emmetsburg facility.

The solid fuel boiler (SFB) uses the natural gas, the biomass fines, filter cake, syrup, and netting. There is also the option of using biogas in the SFB that is not utilized at POET Emmetsburg, but in this lifecycle analysis, we are assuming all biogas is used by POET Emmetsburg.

5.6.1 Electricity

Electricity use is estimated at [redacted] per year. We are using region 7 in the CaGREET model (MROW). For oil, we use the U.S. Average in CaGREET2.0.

5.6.2 Biogas, Natural Gas, Steam

The biogas is estimated to be 60% methane and 40% CO_2. Grid–sourced natural gas use by the SFB is estimated at [redacted] per year, but the biogas output from the POET-DSM Liberty process is estimated at [redacted] Because of the flammability hazard, the biogas concentrations are carefully monitored at the compressor and storage tank head space. POET-DSM Liberty has estimated that these losses at the maximum can be no more than 0.08% of the total biogas produced. Analysis of fugitive

[3] The biomass is 30% moisture, the fines are estimated at 30% moisture, and the net wrap is 0% moisture. Weighted together by mass input rates (85.55% biomass, 13.36% biomass fines, 1.02% net wrap fines, and 0.08% net wrap), the weighted average moisture input for estimating feedstock transport is (still) 30%.

emissions from other locations outside the plant are no more than 0.3%. Therefore, for this analysis we estimate a total biogas loss of no more than 0.5%. Biogas losses in the plant are and will be continuously monitored.
In GREET we assume this biogas production by POET-DSM Liberty replaces natural gas that would otherwise be used by POET Emmetsburg. Consequently, it is estimated as a credit to the POET-DSM Liberty lifecycle GHG emissions.

Steam is also exported to POET Emmetsburg. The amount provided to POET Emmetsburg is [redacted]. We estimate no more than a 1% loss in steam energy provided to POET Emmetsburg during transmission, and this is expected to replace [redacted] of natural gas used at POET Emmetsburg, using POET Emmetsburg 85% boiler efficiency.

5.6.3 Biomass Fines, Net Wrap Biomass, Net Wrap (plastic), Filter Cake, Syrup Combusted in Solid Fuel Boiler

As the stover is de-baled at the plant, the biomass fines, net wrap biomass, and net wrap are sent to the solid fuel boiler. The remainder of the biomass enters processing. The filter cake and syrup that come from stover processing are also sent to the solid fuel boiler.

Table 4 shows the mass flow rates and annual energy of each of these components, based on 350 days of operation per year. Approximately [redacted] of the energy content to the SFB is from the filter cake, followed by the biomass fines and the syrup. The heat contents of the fines, filter cake, and syrup have been determined by POET-DSM from pilot program test data. [redacted] The emissions of the PP net are developed in Attachment 2. [redacted]

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]			[redacted]	[redacted]

GREET2.0 estimates biomass emissions from the fraction of biomass used for energy versus the fraction used for ethanol (the input in GREET is the fraction used for ethanol).

This fraction is computed at [redacted] on a BTU basis and is in the POET-DSM Liberty CaGREET2.0 model.

5.7 Polypropylene Net

The polypropylene net is also burned in the SFB. Since it is not biomass, we have to account for the GHG to produce the net. We also have to account for the GHG emissions involved in burning the net.

Attachment 2 outlines the sources used to estimate the emissions to produce and burn the net. Total lifecycle emissions of the net are estimated at 0.33 gCO2e/MJ of ethanol. This spreadsheet was imported into the GREET POET-DSM Liberty model so that GREET does all calculations.

5.8 Chemical Emissions

POET-DSM conducted a detailed analysis of projected chemical use at the plant. This was conducted in two stages – major chemicals and minor chemicals. The major chemicals are those with annual usage over 500,000 lbs., and are shown in Table 5. All emission rates are from GREET2.0. Enzyme emissions include transport emissions assuming a distance [redacted] and are estimated using GREET2.0. The enzyme is transported on a non-refrigerated tanker truck. Major chemical use emissions are 14.74 gCO2e/MJ.

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

POET-DSM also estimated emissions from minor chemical use. A number of sources were located for these, mainly from the Ecoinvent database and chemical suppliers. Results are shown in Table 6.

[redacted]		
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

5.9 Ethanol Transport Distance

To estimate the ethanol transport distance, we input "Emmetsburg, IA" and "Los Angeles, CA" into Google Maps. Since the resulting road route parallels the Union Pacific railroad route, this was assumed to be a reasonable surrogate for the rail distance. We obtained 1,790 miles. Table 7 shows transportation and delivery modes and distances.

Table 7. Transport Modes and Distances		
Transport Type	Mode	One-Way Distance
Feedstock to Plant	HHDT	35 miles
Ash and Sulfur Cake to Landfill	HHDT	150 miles
Ethanol to CA	Rail	1,790 miles
Ethanol to Bulk Terminal	HHDT	40 miles
Ethanol to Refueling Station	HHDT	50 miles

5.10 Ash and Sulfur Cake Transport

Initially Ash and sulfur cake are transported to a landfill 150 miles from POET-DSM Liberty. The plant will produce approximately 30,000 tons per year of ash and sulfur cake. The material will be hauled to the landfill in heavy-duty diesel trucks with a 20-ton capacity. A separate section in the POET-DSM Liberty model estimates these transport emissions. Alternative beneficial uses are being evaluated for these products.

6.0 Results

6.1 Emissions for the Plant

GREET emission results for the POET-DSM Liberty ethanol plant are shown in Table 8.

Table 8. GHG from Process Fuels from POET-DSM Liberty Plant (gCO2e/MJ)	
Source	[redacted]
Corn Stover (filter cake, biomass fines, syrup, net wrap fines)	3.79
Net natural gas (NG use + steam credit + biogas credit)	-100.31
Grid electricity	74.72
Plastic lifecycle and combustion	0.33
Total	-21.47

6.2 Overall GHG Emissions by Source

Overall lifecycle GHG results are shown in Table 9. The total CI is 21.58 g CO2e/MJ.

Table 9. GHG Emissions from POET-DSM Liberty (gCO2e/MJ)	
Source	[redacted]
Agricultural Chemicals	12.81
Feedstock Collection	4.34
Feedstock Transport	2.31
Ethanol Production:	
Cellulosic Chemicals Lifecycle Emissions Plus Polypropylene Net Lifecycle and Combustion	15.19
Natural Gas Used for Process	4.90
Grid-Based Electricity	74.72
Biomass fines, filter cake, syrup, and net wrap biomass combustion	4.16
Fugitive Methane	1.63
Boiler Ash and Sulfur Cake Disposal	1.12
Ethanol Transport and distribution	2.76
Denaturant	2.94
Well-To-Tank Emissions Before Co-Product Credits	126.89
Less Biogas and Steam Export to POET Emmetsburg Corn Ethanol Plant	-105.30
Total Well-To Tank	21.58
Carbon in Fuel (Tank to Wheels)	0.00
Indirect Land Use Change Emissions	0.00
Total Well-to-Wheels Estimate	21.58

Attachment 1

Spreadsheet of Material and Energy Flows

[redacted]

Attachment 2

Polypropylene Emission Factors

The data in the table below are taken from LCI data for polypropylene obtained from Franklin and Associates. [4] Lifecycle emissions of polypropylene are 0.31 g/MJ.

[redacted]			
[redacted]	[redacted]	[redacted]	
[redacted]			
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]		[redacted]	[redacted]
		[redacted]	[redacted]
[redacted]			[redacted]

For emission factors for burning the polypropylene, we assumed the emission factors of burning residual oil. The emissions for burning are 0.02 g/MJ. Total emissions for the polypropylene are 0.33 gCO2e/MJ.

[4] Franklin Assoc., 2011. "Cradle-to-Gate Life Cycle Inventory of Nine Plastic Resins and Four Polyurethane Precursors," Franklin Associates, Prairie Village, Kansas, August 2011.