California LCFS fuel pathway modification: Used cooking oil (UCO) to biodiesel by Eco Solutions- a South Korea company

GREET modeling technical support document

Table of Contents

I. Introduction

II. Eco Solutions Facility Details

III. Changes to Baseline CA-GREET Model Inputs for Eco Solutions Facility

IV. Basis for the Input Values

V. CA-GREET Model Output

VI. Discussion of Results

VII. Production Range of Eco Solutions Facility

VIII. Sustainability of Eco Solutions Facility

IX. Impact on Land Use

X. Conclusion

XI. References

XII. Data Supporting Annual Quantities of Biodiesel Production

I. Introduction

We are applying to add a new pathway to the California LCFS fuel carbon-intensity lookup table. This pathway is a modification to the CA-GREET 1.8b model [1], using the UCO rending energy assumptions in a Midwest used cooking oil (UCO) to biodiesel (with cooking) pathway developed by CARB [2].

Except for the points of deviation summarized below, our pathway is identical to the default UCO to biodiesel pathway in CA-GREET model. The pathway differs from the default in only the following ways:

1) The feedstock is collected and converted to biodiesel in South Korea, and the fuel is shipped to California via ocean tanker for distribution and consumption
2) The electricity mix for biodiesel production is specific to South Korea
3) High energy "cooking" assumptions as in pathway [2] are adopted.

This application is for UCO collected and processed in South Korea. Based on our modeling in CA-GREET, we find that the modified pathway has a carbon intensity of **20.36** $gCO_2e\ MJ^{-1}$.

II. Company Details

Eco Solutions Co., Ltd (referred to as Eco Solutions hereafter), is a company in South Korea which uses UCO as feedstock for biodiesel (BD) production. The UCO collectors collect crude UCO from restaurants and food processing companies in South Korea then deliver to the biodiesel company via tank truck. Delivered crude UCO is treated and converted at the Eco Solutions facility.

The environmental permits for the Eco Solutions biodiesel plant do not list any production capacity limits. The commercial business license decision of biofuel, by the department of Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea states 85,000kL/year. The company has business license code 110111-1523623. The registered capacity of the BD plant is 85,000 kL per year. Since 1 US gallon is equal to 3.78 liters, the BD production capacity is:

85,000,000L/year x 1 gallon/3.78L = **22,486,772 gallons/year**

Under EPA's RFS program, the Eco Solutions biodiesel facility is capable of producing biodiesel (Fuel Code 20) under a renewable fuel D code of 4 utilizing waste oils/fats/greases (Feedstock Code 160) via transesterification, in a dedicated renewable biomass facility (Process Code 180). The facility intends to produce D4 biodiesel via transesterification utilizing waste oils/fats/greases (Feedstock Code 160). The ECO

Solutions biodiesel facility is able to process a variety of waste fats including used cooking oil, tallow, and chicken fats to make a biodiesel product. However, the company uses only used cooking oil (UCO) as the feedstock.

The UCO collectors collect crude UCO from restaurants and food processing companies in South Korea then deliver to the biodiesel company via tank truck. Delivered crude UCO is treated and converted at the Eco Solutions facility. Due to the lack of the energy consumption data for UCO rendering, the high energy that is associated with UCO cooking in the default Midwest CA-GREET model is adopted [2].

The Eco Solutions facility adopts a typical transesterification method for biodiesel production. The feedstock, methanol and catalyst (Sodium methoxide) are pumped into a batch transesterification reactor. Heat and pressure are applied to accelerate the transesterification reaction to produce biodiesel and glycerin as co-product. Biodiesel, fatty acid methyl ester (FAME), is the primary product in the ECO Solutions biodiesel facility produces. After reaction, the reaction product mixture undergoes vacuum flashing to recover a portion of the excess methanol. Methanol-partially-removed biodiesel/glycerin mixture is then allowed to stand for sufficient time to separate the biodiesel and glycerin. After biodiesel-glycerin separation, 4 times water washings were applied to remove residual catalyst, glycerin, and other water soluble impurities. The washed biodiesel then goes to a vacuum flashing system to remove residual water. Then the crude biodiesel is stored in the tank before going to a distillation column where the methylesters are evaporated and recondensed. The distillation column bottoms are used (Biopitch) as a boiler fuel in the plant. The final polished biodiesel is pumped into the storage tanks for temporary storage. The biodiesel is tested on a regular schedule with samples submitted to an accredited laboratory to ensure that the quality of biodiesel meets or surpasses ASTM Method D6751 standards prior to off-site shipment to buyers. Crude Glycerin is removed from the process and pumped into a storage tank for temporary storage proper to off-site shipment to buyers.

The on-site engineering review on February 7, 2014 was conducted by Jin-Suk Lee, an independent Professional Engineer (PE) working for Control Union Certifications.

III. Changes to baseline CA-GREET model inputs for Eco Soluctions facility

The modified input values to CA GREET spreadsheet are listed in Table 1, and in the "1.0 Changes made to CA GREET" tab of a separate spreadsheet named "Eco Solutions UCO to BD Original Data File" as well. CI calculation results can be found in the "UCO BD Results" tab of the modified CA-GREET spreadsheet.

Table 1. Changes made to CA GREET model

Parameter	Cell location	Default US value	Eco Solutions UCO value	Units
Select Region for Analysis	Regional LT!C2	Midwest	South Korea	
Res. oil electric generation	Regional LT!J83	2.70%	4.0%	%
Natural gas electric generation	Regional LT!J84	18.90%	53.9%	%
Coal electric generation	Regional LT!J85	50.70%	41.1%	%
Nuclear electric generation	Regional LT!J86	18.70%	0.0%	%
Biomass electric generation	Regional LT!J87	1.30%	0.0%	%
Other (renewables) electric generation	Regional LT!J88	7.70%	1.1%	%
Ocean tanker transport distance (miles)	T&D!GB93	NA	6,579	miles
Biodiesel truck transport distance (miles)	T&D!GC93	50	114	miles
Biodiesel ocean tanker payload (tons)	T&D!V5	--	35,664	tons
Biodiesel ocean tanker horsepower requirement	T&D!T12	--	12,672	hp
Column for biodiesel ocean tanker	T&D!GB90:132	Move right (insert new transport column)		
Title	T&D!GB91	--	Ocean Tanker	
Ocean tanker fraction diesel power	T&D!GB95	--	0%	%
Ocean tanker fraction residual oil power	T&D!GB96	--	100%	%
Ocean tanker outbound energy intensity	T&D!GB108	--	71	btu/ton-mile
Ocean tanker back-haul energy intensity	T&D!GB109	--	63	btu/ton-mile
Fraction of biodiesel transported by ocean tanker	T&D!CL138	0	100	%
Fraction of biodiesel transported by truck	T&D!CL142	80	100	%
NG for UCO rendering	UCO BD!C189	838	963	btu/lb
Electricity for UCO rendering	UCO BD!C192	234	110	btu/lb

IV. Basis for the Input Values

This pathway is similar to the published CA GREET model for default UCO biodiesel, with changes in the following areas as further detailed below.

1. Electricity generation mix (2.0 Electricity Mix)
2. Transport modes and distances (3.0 Transportation)

3. UCO rendering energy (4.0 UCO rendering)

Next to each item in parentheses is the supporting documentation reference in the “Eco Solutions UCO to BD Original Data File” reference.

The modified CA-GREET spreadsheet is included in the application package; results can be found in the “UCO BD Results” tabs.

For the rendering of UCO, steam and electricity are consumed. Since no detailed consumption data is available for rendering, the default value for Midwest US of 1,073 btu/lbs UCO for high-energy rendering scenario (cooking) in the CA GREET UCO to biodiesel pathway is adopted [2]. For electricity, the electricity mix is for South Korea, which is different from default CA GREET values, as mentioned previously.

Grid electricity is used by the facility for the conversion of UCO to biodiesel in the Eco Solutions biodiesel facility. The current electricity generation mix in Andhra Pradesh, India is 41.1% coal, 26.7% natural gas, 25.6% nuclear, 4.0% residue oil, 1.5% hydro, and 1.1% others [3]. The nuclear and hydro power is marginalized as natural gas, so the electric mix used in modelling is 4.0% residual oil, 41.1% coal, 53.9 % natural gas, 0% biomass, 0% nuclear, and 1.1% other renewables. Biodiesel produced is transported by truck from the biodiesel plant to Port Pyeongtaek , and then shipped via ocean tanker to the CA port, and finally distributed in CA using trucks. The distances of truck and ocean tanker transport are 114 miles [4] and 6579 miles [5].

The way the ocean tanker transport of biodiesel is modeled as follows:

1. Insert a new column to the left of column GB, and put “Ocean tanker” in cell GB91
2. Copy cells B92 to B125, and paste them DIRECTLY into cells GB92 to GB125.
3. Change Cell GB92 to 0, GB93 to 6579 (the transport distance for Eco Solutions)
4. Change formula of cell GB108 from “=$B$49*$B$12*$B$48/$B$5/$B$46” to”=$B$49*$T$12*$B$48/$V$5/$B$46”.
5. Change formula of cell GB109 from “=$B$52*$B$12*$B$51/$B$5/$B$46” to “=$B$52*$T$12*$B$51/$V$5/$B$46”
6. In cells GB111 to GB125, Change “Fuel_Specs!$B$7” and “Fuel_Specs!$E$7”, to “Fuel_Specs!$B$29” and “Fuel_Specs!$E$29”,respectively.

Default values of energy use and chemical inputs in CA-GREET model are adopted for Eco Solutions facility. This is reasonable as Eco Solutions runs a typical transesterification process for biodiesel production. This application is only for a new pathway for UCO biodiesel at the Eco Solutions biofuel facility, which has a carbon intensity of **20.36 $gCO_2e\ MJ^{-1}$**.

V. CA-GREET Model Output

Table 2: Fossil energy use and emissions from UCO biodiesel produced in the Midwest U.S. and by Eco Solutions, South Korea, separated by life cycle stage. Figures are rounded.

	UCOME Cooking Required, Fuel produced in the Midwest		**UCOME Cooking Required, Fuel produced in S. Korea**			
	Energy (BTU/MMBTU BD)	**Emissions (gCO2e/MJ)**	**Energy (BTU/MMBTU BD)**	**Emissions (gCO2e/MJ)**	**% difference**	
UCO Transport to Rendering Plant	-	0.00	-	0.00	-	-
Rendering of UCO	88,681	5.69	89,599	5.77	1%	1%
UCO Transport (after rendering)	3,912	0.30	3,918	0.30	0%	1%
Biodiesel Production	174,956	6.06	175,409	6.11	0%	1%
Biodiesel Transport	28,384	2.19	45,644	3.70	61%	69%
Total (Well To Tank)	**295,933**	**14.24**	**314,570**	**16.11**	7%	**13%**
Total (Tank To Wheel)	**1,000,000**	**4.48**	**1,000,000**	**4.48**	0%	**0%**
Total (Well To Wheel)	**1,295,933**	**18.72**	**1,314,570**	**20.36**	1%	**9%**

VI. Discussion of Results

Table 2 compares energy use and emissions from the proposed pathway to those from reference [2] for UCO biodiesel produced in the Midwestern U.S. For the default pathway, the most energy consuming and GHGs intensive step is the biodiesel production, followed by the rendering of UCO, biodiesel transport, and UCO transport. Due to the longer transport distance, Eco Solutions UCO BD has 69% higher GHG emissions than default for biodiesel transport stage. Emissions from other stages are similar. Overall, the Eco Solutions UCO biodiesel process has 9% higher GHGs emissions than that of the UCO biodiesel produced in Midwest U.S.

VII. Production Range of the Eco Solutions biodiesel facility

The new pathway should be applicable to the Eco Solutions biodiesel facility for 100% (**22,486,772** gallons/year) of the Permitted Capacity issued by the department of Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea

VIII. Sustainability of the Eco Solutions biofuel facility

The Eco Solutions biodiesel facility was designed and constructed using well-established modern designs and equipment and is managed by professional, well-qualified staff to ensure that the energy efficiency of and emissions from the facility do not deteriorate over time. Any deterioration in efficiency would result in a less profitable business. Thus the sustainability of the plant is well aligned with the business objectives of the owners.

IX. Impact on Land Use

Since the raw material discussed is UCO, a waste stream from food industry, there is no land use impact.

X. Conclusion

Based on our modeling in CA-GREET and the available data, we find that biodiesel produced from UCO at the Eco Solutions biodiesel plant has a carbon intensity of **20.36 $gCO_2e\ MJ^{-1}$**.

XI. References

1. *California Environmental Protection Agency, Air Resource Board, 2009. CA_GREET 1.8b_dec09.*

2. *California Environmental Protection Agency, Air Resource Board, 2012. Detailed California-Modified GREET PathwayFor Biodiesel Produced in the Midwest fromUsed Cooking Oil (UCO) and Used in California. Last updated February 21, 2012. Available at:* http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/15day-mw-uco-bd-022112.pdf (Accessed Dec 4th9th, 2015)
3. *International Energy Agency. Korea: Electricity and Heat for 2013. http://www.iea.org/statistics/statisticssearch/report/?country=KOREA&product=electricityandheat&year=2013*

4. Distance from Jeongeup, South Korea to Pyeongtaek, South Korea. http://www.bing.com/maps/?FORM=Z9LH2#Y3A9MzYuMjcxNTYzfjEyNy4wMTE4MDMmbHZsPTgmc3R5PXImcnRwPXBvcy4zNS41NjIwOTJfMTI2Ljg1MjIxOV9KZW9uZ2V1cCUyQyUyMFNvdXRoJTIwS29yZWFfX19lX35wb3MuMzYuOTcwMzA2XzEyNy4xMDc2NjZfUHllb25ndGFlay1kb25nJTJDJTIwU291dGglMjBLb3JlYV9fX2VfJm1vZGU9RCZydG9wPTB+MH4wfg==

5. Distance from Port Pyeongtaek, South Korea to Long Beach, USA. http://www.searates.com/services/routes-explorer/?filter-st=1&container=&from=&alat=36.9921075&alng=127.11294509999993&to=&blat=33.7700504&blng=-118.19373949999999&etca=undefined&etcb=undefined&terminal=undefined&pa=22617&pb=15873

XII. Data supporting Annual Quantities of biodiesel production

The data supporting the annual quantities of biodiesel production, as well as the modifications to the CA-GREET model are documented in a separate spreadsheet named "Eco Solutions UCO to BD Original Data File".