Method 2B Application: Renewable Diesel Pathway Life-Cycle Analysis Report

Diamond Green Diesel
Revised 28 February, 2014

Summary of CA-GREET Model Inputs and Carbon Intensity Results

Summary

This pathway report summarizes details for fourteen (14) distinct pathways for Diamond Green Diesel (DGD) Renewable Diesel under the Low Carbon Fuel Standard (LCFS). The CA-GREET model (version 1.8b, December 2009) was used to assess the life-cycle (LCA) emissions of greenhouse gases for these 14 pathways which represent different operating scenarios for the Diamond Green Diesel renewable diesel plant in St. Charles, LA. This report supports the proposed 2 new DGD Used Cooking Oil (UCO) pathways with truck delivery of up to 488 miles of UCO to St. Charles, LA. All of the DGD pathways include renewable diesel from Midwest soy oil, Midwest corn oil (from dry DGS), Midwest used cooking oil (cooking required), Midwest used cooking oil (no cooking), US animal fat (cooking required), US animal fat (no cooking). The pathways have renewable diesel carbon intensities for renewable diesel delivered to California blending terminals by rail or oceanic freight ship. The sixteen pathways are all renewable diesel pathways with this report supporting the 2 new truck delivery pathways of up to 488 miles.

Diamond Green Diesel Site Location and Capacity

The Diamond Green Diesel Plant is a 420,000 gallon/day renewable diesel production facility located in St. Charles Parish, Louisiana. The plant has been operating since July of 2013.

Diamond Green Diesel Production Process Overview

Production of renewable diesel (all pathways) utilizes the UOP Econofining Process to meet the increasing demand for a sustainable high quality renewable diesel. In summary, the Econofining Process hydrogenates triglycerides and the free fatty acid feedstocks (soy oil, corn oil, used cooking oil, animal fat). The resulting paraffins are then isomerized to create a high quality hydrocarbon known as green diesel (i.e., renewable diesel). The benefits to the Econofining process includes low capital and operating costs allowing licensees to produce a low cost renewable diesel fuel that will help California meet its fuel carbon intensity goals.

Feedstock Rendering, Acquisition, and Storage

The feedstock will be tracked by type in an inventory management system that is integrated into the plant's account system. There are six (6) distinct types of feedstocks for conversion to renewable diesel and will be tracked accordingly. The proposed 2 new pathways are shown in red below (RNWD 24 and RNWD 25).

1. Soy oil (RNWD 10 & RNWD 11)
2. Corn oil from dry DGS (RNWD 12 & RNWD 13)

3. Used cooking oil with cooking (RNWD 16, RNWD 17, RNWD 24, and RNWD 25)
4. Used cooking oil without cooking (RNWD 18 & RNWD 19)
5. Tallow, high energy (RNWD 20, RDWD 21)
6. Tallow, low energy (RNWD 22, RDWD 23)

The various feedstocks will be charged into the process unit (UOP Ecofining Process) and daily production will be tracked according to the six types. Daily production of renewable diesel will be based on actual inventory measurement shipments by rail or ship will be used to apportion daily volumes by feedstock type to the individual 14 pathways (presented in table 1 below). Since yield of the renewable diesel is not determined by the feedstock, a proportional volume of renewable diesel will be reconciled on a daily basis based on the type of feedstock. The Diamond Green Diesel plant in St. Charles, Louisiana will use the UOP process and not the FAME or Co-Process Hydroprocessing options both of which are believed to be more costly and energy intensive than the UOP process. Economic comparisons using FAME compared to Renewable Diesel estimated $0.22 cents/gallon less for UOP renewable diesel vs. FAME diesel. It has been estimated that renewable diesel using the UOP process requires 1,851 Btu/lb for clean feedstocks and 2,175 Btu/lb for feedstocks like tallow and UCO which have lower FFA contents. This will be a net reduction in energy consumption compared to the conventional processes and a lower end product carbon intensity. The table below presents the energy input assumptions used for the scenarios considered.

Feedstock	Process Energy Input (Btu/lb)	Electricity and thermal energy shares (%electric/%thermal)
Soy Oil	1851	61.4% / 38.6%
Corn Oil	1851	61.4% / 38.6%
Used Cooking Oil (UCO)	2175	61.4% / 38.6%
Tallow	2175	61.4% / 38.6%

Table 1: Diamond Green Renewable Diesel Pathway Descriptions and Carbon Intensities

Proposed DGD Pathway	Scenario	CI Estimated using CA-GREET (RD transported by rail)	CI Estimated using CA-GREET (RD transported by ocean tanker)
MW Soy Oil to RD	Soy Oil collected in the MW; shipped 1,100 miles by rail to RD plants in Louisiana (LA). Finished RD transported 1,187 mi by rail (or 5,500 miles by ship) to California (CA) blending terminals; 80% of the RD then transported 50 mi to blending terminals and 90 mi to stations by HDT. 20% offloaded to blending terminal adjacent to rail yard.	83.70	83.48
MW Corn Oil from Dry DGS to RD	Corn Oil from Dry DGS collected in MW, shipped 800 miles to LA by rail, and then transported 50 mi by HDT to nearby RD plants. RD made in LA, transported and 1,187 mi by rail from LA to CA (or 5,500 miles by ship); 80% of the RD then transported 50 mi to blending terminals and 90 mi to stations by HDT. 20% offloaded to blending terminal adjacent to rail yard.	6.00	5.56
MW UCO to RD by rail, Cooking Required	UCO collected and rendered in other states, transported 700 mi by rail to RD plant in LA. RD made in LA, transported 1,187 mi by rail from LA to CA (or 5,500 miles by ship); 80% of the RD then transported 50 mi to blending terminals and 90 mi to stations by HDT. 20% offloaded to blending terminal adjacent to rail yard.	18.40	18.18
MW UCO to RD by truck, Cooking Required	UCO collected and rendered in other states, transported 488 mi by truck to RD plant in LA. RD made in LA, transported 1,187 mi by rail from LA to CA (or 5,500 miles by ship); 80% of the RD then transported 50 mi to blending terminals and 90 mi to stations by HDT. 20% offloaded to blending terminal adjacent to rail yard.	21.10	20.89
MW UCO to RD, No Cooking	Same as above with no cooking required.	13.85	13.63
US Animal Fat to US RD, High Energy Rendering	Tallow collected and rendered in other states and transported 600 mi by rail to RD plant in LA. RD made in LA, transported 1,187 mi by rail from LA to CA (or 5,500 miles by ship); 80% of the RD then transported 50 mi to blending terminals and 90 mi to stations by HDT. 20% offloaded to blending terminal adjacent to rail yard.	40.34	40.12
US Animal Fat to US RD, Low Energy Rendering	Same as above with no cooking required.	19.91	19.70

Energy use and emissions data is available for three renewable diesel production processes: the super cetane and UOP standalone processes contained in the Argonne-GREET, and the petroleum co-production process modeled in the ARB tallow renewable diesel pathway (California Air Resources Board. September 23, 2009). The results presented in this document are based on the UOP standalone process data (referred to as "RD II" in GREET; see cell B14 of the BD tab). The production energy for the UOP process is 1,851 BTU per pound of renewable diesel from soy and corn oil, and 2175 BTU per pound of renewable diesel from tallow and used cooking oil.

The file name references for the new proposed modified pathways and the initial unmodified ARB reference CA-GREET model file names are shown below.

DGD Pathway	Starting CA-GREET Model File Name	Proposed CA-GREET Model File Name
Soy oil RD	ca_greet1.8b_dec09-SoyOil-RD	ca_greet1.8b_dec09-SoyOil-RD_DGD
Corn oil RD	ca_greet1.8b_Dec09_ARB_corn_oil	ca_greet1.8b_Dec09_ARB_corn_oil_DGD
UCO RD (by Rail)	Generic CA-GREET 1.8b from LCFS web site	ca_greet1.8b_Dec09_Tallow & UCO_DGD
UCO RD (by Truck)	Generic CA-GREET 1.8b from LCFS web site	ca_greet1.8b_Dec09_Tallow & UCO_DGD_Trucked
Tallow RD	Generic CA-GREET 1.8b from LCFS web site	ca_greet1.8b_Dec09_Tallow & UCO_DGD

The table below presents a description of each input change made to the reference pathway CA-GREET model. The fuel T&D changes apply to all feedstocks evaluated.

Proposed DGD Pathway	Summary of Default Model Changes	Modified Values
All Scenarios	**These modifications apply to all proposed pathways**	T&D!GH93 = 5500 T&D!GH108:GH109 – modified to allow ocean tanker use T&D!GJ93 = 1187 T&D!GK93 = 140 T&D!CO142 = 100% T&D!CN141 or T&D!CN139 = 100% Region set to "US Average" for all feedstock and refining scenariosT&D!CN142 =80%
MW Soy Oil to RD	Refining using "US Average" Region; increased soy oil rail transport distance to refiners; modified fuel T&D to increase rail distance, and add transport by oceanic tanker	
MW Corn Oil to RD	Refining using "US Average" Region; production uses RD II pathway instead of BD pathway; increased soy oil rail transport distance to refiners; modified fuel T&D to increase rail distance, and add transport by oceanic tanker; removed "carbon in fuel" because methanol is not used in RD production	EtOH!E222:E226 & EtOH!E293 & EtOH!I307– modified for RD energy content EtOH!C252:D256 – modified for correct T&D EtOH!D264:D268 – referenced RD production emissions EtOH!C276:CD280 – modified to reference RD T&D EtOH!C271:E271 – change to RD allocation factor EtOH!E296 = 0, no carbon in fuel
MW UCO to RD, Cooking Required	Refining using "US Average" Region; increased UCO rail transport distance to refiners; modified fuel T&D to increase rail distance, and add transport by oceanic tanker; used lower process energy estimate	T&D!IH93 = 700 T&D!IH91 = "Rail" T&D!IG93 =488 miles T&D!IH107:IH132 – modified for rail transport calculation

<table>
<tr><td>MW UCO to RD,
No Cooking</td><td>Refining using “SRMV” Region; increased soy oil rail transport distance to refiners; modified fuel T&D to increase rail distance, and add transport by oceanic tanker; used higher process energy estimate</td><td>Duplicate RD II pathway added to the UCO BD tab in ‘UCO BD’!B163:D222 and ‘UCO BD’!D228:E254 to model UCO with and without cooking.
‘UCO BD’!C167 and ‘UCO BD’!F167 – modified to reference high and low energy inputs
‘UCO BD’!C174 and ‘UCO BD’!F174 – modified to reference high and low energy inputs natural gas share
‘UCO BD’!C177 and ‘UCO BD’!F177 – modified to reference high and low energy inputs electricity share</td></tr>
<tr><td>US Animal Fat to US RD,
High Energy Rendering</td><td>Refining using “U.S Average” Region; increased soy oil rail transport distance to refiners; modified fuel T&D to increase rail distance, and add transport by oceanic tanker; used higher process energy estimate</td><td rowspan="2">T&D!IH93 = 600
Duplicate RD II pathway added to the Tallow RD tab in ‘Tallow RD’!B163:D222 and ‘Tallow RD’!D228:E254 to model UCO with and without cooking.

‘Tallow RD’!C167 and ‘Tallow RD’!F167 – modified to reference high and low energy inputs
‘Tallow RD’!C174 and ‘Tallow RD’!F174 – modified to reference high and low energy inputs natural gas share
‘Tallow RD’!C177 and ‘Tallow RD’!F177 – modified to reference high and low energy inputs electricity share</td></tr>
<tr><td>US Animal Fat to US RD,
Low Energy Rendering</td><td>Refining using “US Average” Region; increased soy oil rail transport distance to refiners; modified fuel T&D to increase rail distance, and add transport by oceanic tanker; used higher process energy estimate</td></tr>
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The electricity mix of the Louisiana region is SRMV (Mississippi Valley). According to eGRID[1], the mix is as in Table below:

	Average Resource Mix	Allocated Marginal Mix	
Coal	22.9107%	22.9107%	
Oil	1.1187%	2.13%	Oil + Other Fossil
Gas	46.9265%	73.06%	Gas + Hydro + Nuclear + Others
Other Fossil	1.0137%		
Biomass	1.8933%	1.8933%	
Hydro	1.3544%		
Nuclear	24.5124%		
Others/unknown	0.2703%		

[1] 2010 U.S. EPA eGRID Summary Table: http://epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf - Page 5

Comparison of UOP Ecofining and co-production methods

The UOP and co-production methods differ in terms of fuel shares used as follows:

Table 2: Fuel Shares: UOP versus Co-Production Methods

	UOP	Co-production
Natural Gas (%)	4.5	3.8
Hydrogen (%)	7.1	6.1
Electricity (%)	88.4	90.1

The UOP results are consistent with the proposed pathway energy consumption and emissions values. Diamond Green Diesel intends to maintain monthly energy consumption records documenting energy consumed producing renewable diesel for a 2 year period of time (rolling 2 year records). Those energy consumption records (power and gas energy) will be submitted annually to CARB. As the proposed pathways were derived from CARB's existing pathways, the new pathways will be available to other producers per Method 1.

References

California Air Resources Board. September 23, 2009. *Detailed California-Modified GREET pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced).* Version 2.0. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_tallow_rd.pd

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 models for the sub-pathways.

- **Diamond Green Construction Air Permit –** Issued March 1, 2010
- **Soy RD Model:** ca_greet1.8b_dec09-SoyOil-RD_DGD
- **Corn Oil RD Model:** ca_greet1.8b_Dec09_ARB_corn_oil_DGD
- **UCO RD Models:** ca_greet1.8b_Dec09_Tallow & UCO_DGD
  ca_greet1.8b_Dec09_Tallow & UCO_DGD_Trucked
- **Tallow RD Model:** ca_greet1.8b_Dec09_Tallow & UCO_DGD