Application No. B0599

June 6, 2024

California LCFS Tier 2 fuel pathway LCA report: Renewable diesel produced from animal fat, soy oil, canola oil and distillers corn oil by Vertex Renewables Alabama LLC using natural gas and electricity as process energy

-GREET modelling technical support document

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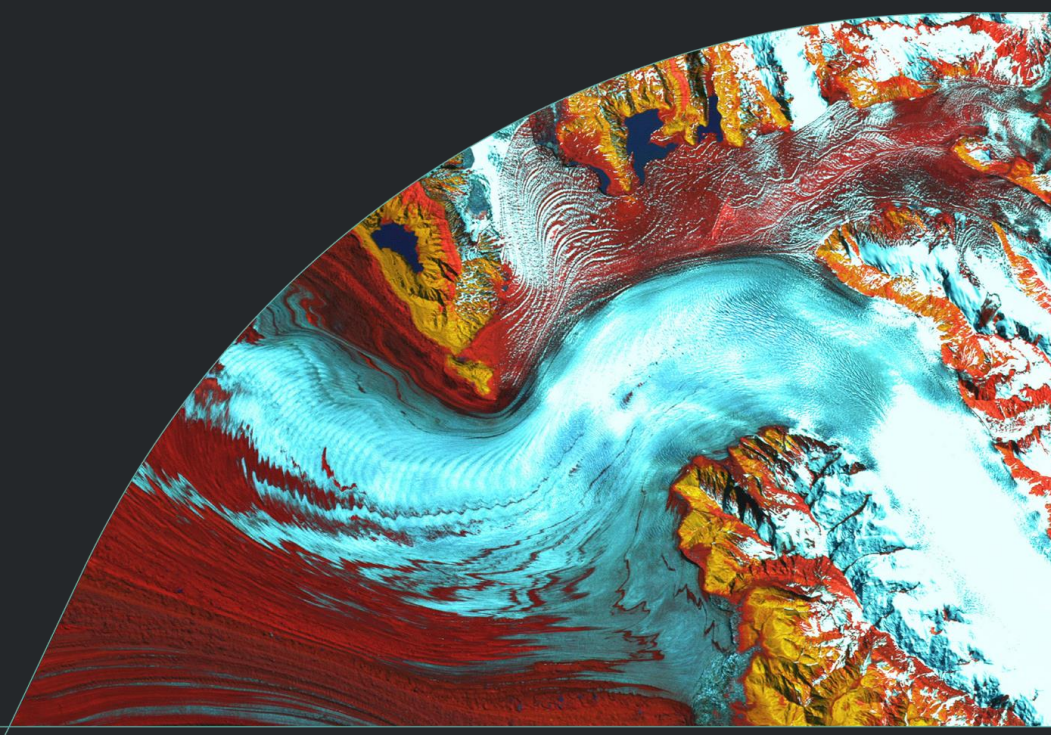


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1. Introduction

This life-cycle analysis (LCA) report was prepared for animal fat, canola oil, soy oil, and distillers corn oil (DCO) to renewable diesel (RD) pathways for Vertex Renewables Alabama LLC (referred to as Vertex hereafter, Company ID: 2215).

These pathways are for processing animal fat (including tallow), canola oil, soy oil, and DCO in the same hydrotreater into RD at the Vertex Renewables Mobile Site facility, located at 400 Industrial Pkwy, Saraland, AL, US 36571. The carbon intensities (CIs) of the RD fuel are calculated using a modified version of the Tier 1 BDRD Calculator [1] because certain modifications are needed to accurately calculate the CIs.

Based on our modeling, we find that the RD produced with animal fat, canola oil, soy oil, and DCO have carbon intensities as listed below, **with the data from September 2023 to December 2023 from VERTEX RENEWABLES ALABAMA LLC:**

- Animal fat to RD 35.89 (gCO_{2e}/MJ)
- Canola oil to RD 53.78 (gCO_{2e}/MJ)
- Soy oil to RD 56.65 (gCO_{2e}/MJ)
- DCO to RD 28.84 (gCO_{2e}/MJ)

2. Vertex Facility Details

Vertex Renewables Mobile Site is located at 400 Industrial Pkwy, Saraland, AL, US 36571. The location of the project site is shown in Figure 1. Feedstock is received from either storage tanks located on Blakeley Island, barges at the refinery dock, and/or from pipelines. RD products are transported off-site either via pipeline, on tank trucks loaded at a truck rack, or on marine vessels loaded at a marine dock.



Figure 1 **Site Location**

The RD production process is comprised of 1) feedstock receipt and storage, 2) renewable diesel production, 3) renewable diesel storage and transport off site, and 4) sour water stripping, sour water treatment, and sulfur recovery. A block process flow diagram is included at the end of this section as Figure 2. The RDU uses the refinery's utility systems that are currently used by the existing OFH Unit. Those systems are: Sour Water Storage, Sour Water Stripper, SRU, WWTP, Fuel Gas System, 180# Steam, 50# Steam, Condensate, Cooling Water, Electricity, Raw Water, Matheson Hydrogen Supply, Lean Amine Supply, Rich Amine Recovery, and HP Flare.

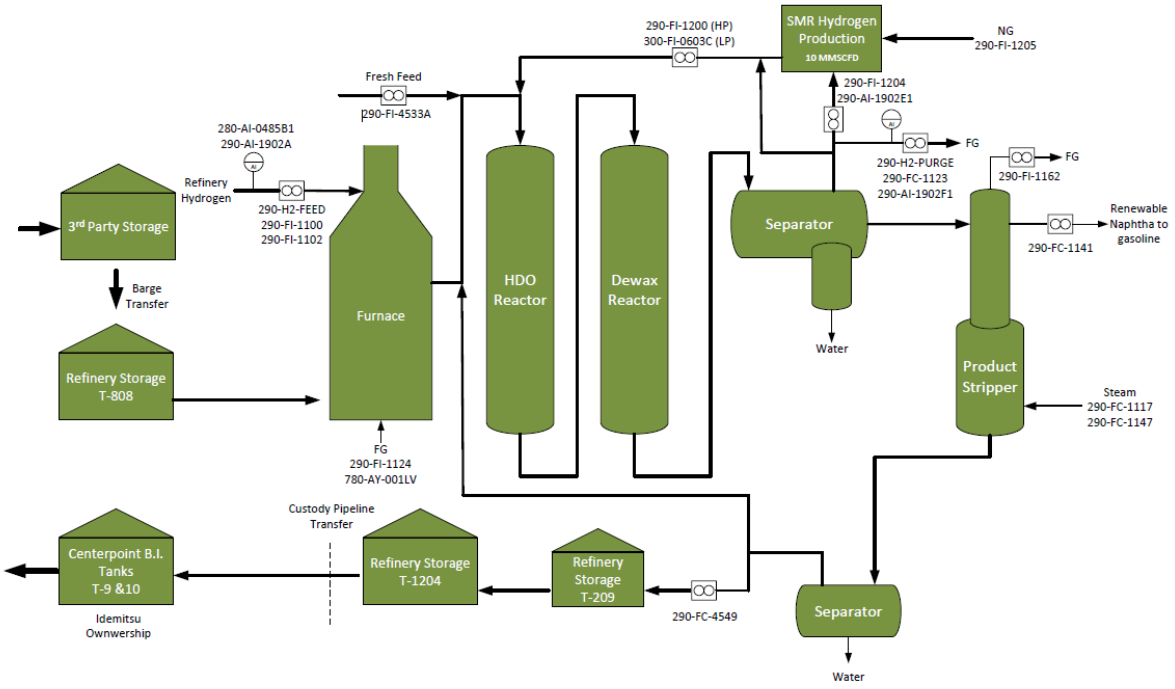


Figure 2 RDU Process Block Flow Diagram

Weaver and Tidwell, LLP ("Weaver") was contracted to perform an engineering review of the facility in accordance with 40 CFR 80.1450(b)(2). Weaver's scope of work included:

1) Collecting and reviewing relevant documents that represent and document information required pursuant to 40 CFR 80.1450(b)(1).
2) Visiting the facility to confirm the accuracy of the information.
3) Producing a summary report of our findings.

The latest Third-Party Engineering Review was completed in May 2023. Charlie Gooding, PE, performed the on-site visit on March 30, 2023. See Attachment A of the Third-Party Engineering Review for a detailed process description.

The facility is capable of producing below renewable fuels at a nameplate capacity of 221,729,288 gallons/year:

- (40) Non-ester Renewable Diesel (EV 1.7) under a D code of 4 utilizing Biogenic Waste Oils/Fats/Greases (Feedstock Code 160); Soybean Oil (Feedstock Code 210); Distillers Corn Oil (Feedstock Code 201); and Canola oil (Feedstock Code 360) using a Hydrotreating, Dedicated Renewable Biomass Facility (Process Code 200). This feedstock can be pretreated or raw depending on its origin.

3. Basis for the Input Values

Operational data from 09/01/2023 to 12/31/2023 was used to determine the energy and material inputs for animal fat, canola oil, soy oil, and DCO RD production.

3.1. Changes to the BD-RD Calculator

These pathways are similar to the published Tier 1 BDRD Calculator for animal fat, soy oil, canola oil and DCO RD, with change in the following area as detailed below:

1) Heating Values and emission factor modified based on table:

Table 1 Modified Heating Values and emission factor.

Tab	Cell	Original Value	New Value	Source of new value
Fuel_Specs	B24	290	274	**GREET3.0 model, 'Fuel_Specs' tab, cell B62**
Fuel_Specs	C24	290	274	**GREET3.0 model, 'Fuel_Specs' tab, cell C62**
Fuel_Specs	D24	343	325	**GREET3.0 model, 'Fuel_Specs' tab, cell D62**
RD-Production	J132	106907	29634	**GREET 2023 model, steam_Cracking, cell C254**
RD-Production	H52	-	73424.19	**GREET3.0 model, 'Fuel_Specs' tab, cell D62**
Steam	D8	-	1198.66	**Saturated Steam Table by Pressure**
RD-Production	K53	-	95882.37	**Calculation based on test analysis**

3.2. Feedstock Inventory and Production

Vertex obtains feedstock from Suppliers throughout the United States and Canada, and also from South America. Upon receiving feedstock, the factory enters information from each load's Bill into its inventory system. Vertex's plant accountants reconcile feedstock inventory monthly. To reconcile data, they compare the amount of feedstock received on invoices to unloading

meters and tank levels. These records are collected in RD Daily Inventory RF spreadsheets for each month.

No specific information was provided for pre-processing of the feedstocks or the agricultural practices used to produce canola oil, soy oil, and distillers corn oil. Default values were adopted for these parameters as they were believed to be conservative estimates developed by CARB.

3.3. Feedstock Transportation Data

As shows in table 2, the feedstock transportation distance to Vertex might vary from hundreds to thousands of miles. Shipments may arrive by rail, barge, or ocean transport. Vertex estimates a weighted average journey distance for each feedstock type and transportation mode, considering the varying environmental conditions and distances involved. The information regarding the origins and destinations of the feedstocks is documented in file *Vertex Renewables - Feedstock Receipt Tracking*. Default values in CA-GREET 3.0 related to cargo carrying capacities and fuel shares are adopted in this analysis.

Table 2 List all incoming feedstock providers, type, a, and distance travelled to facility.

Feedstock Provider	Feedstock Type	Distance Travelled to Facility
Vendor 1	Soybean Oil	560 miles
Vendor 2	Distiller's Corn Oil	805 miles
Vendor 3	Distiller's Corn Oil	1029 miles
Vendor 4	Tallow	8566 miles (Ocean tanker)/376 (Truck)/262 (Barge)
Vendor 5	Canola/Soybean Oil	180 miles
Vendor 6	Canola/Soybean Oil/Poultry Fat RB	376 miles
Vendor 7	Soybean Oil	338 miles (rail)/377 (barge)
Vendor 8	Canola Oil	11500 miles (ocean tanker)/ 2090 (rail)
Vendor 9	Canola Oil	1618 miles

3.4. RD Production

This section describes the information considered on the RD-Production tab. Producing RD requires feedstock, energy, and chemical inputs.

RD inventory data in the Calculator was obtained from RD Daily Inventory RF spreadsheets. Utility and hydrogen information was obtained from RDU Process Data spreadsheet provided by Vertex.

The renewable diesel hydrotreater uses process technology from Haldor Topsoe. Vertex uses Haldor Topsoe catalyst and they performed all the heat and material balances used for the conversion from conventional hydrocracking to renewable diesel hydrotreating. The catalyst used is a combination of nickel-molybdenum and nickel-tungsten metals on alumina-silica base. The main chemical added to the process is mono-ethanol amine (MEA), which is used to moderate the reaction.

The RDU uses hydrogen produced from SMR and naphtha reformer. Hydrogen that is supplied to the renewable diesel unit comes from both conventional and renewable sources. Co-products from renewable diesel manufacture are naphtha, high pressure vent gas, low pressure vent gas, 50 psig steam and 180 psig steam. The renewable naphtha produced is fed to our naphtha hydrotreater and used in conventional gasoline manufacture. The high pressure vent gas is primarily used as feed to the SMR and a portion to refinery fuel gas. The low pressure vent gas is all used in fuel. The steam is used as process heat for the rest of the refinery (Figure 2).

Hydrogen that is supplied to the renewable diesel unit comes from both conventional and renewable sources. The refinery hydrogen comes from naphtha reforming and the renewable hydrogen comes from steam methane reforming of renewable off gases (propane). The naphtha reformers are used for gasoline production and hydrogen is a co-product.

The RDU is co-located with a conventional refinery. However, it only interacts with the SMR and naphtha reforming unit directly. The co-located SMR is operated by Matheson via a capital lease. Vertex provides all the feedstocks and utilities. Matheson sends Vertex pure hydrogen and 270 psig steam generated from energy recovery boilers. All natural gas used to operate the Matheson SMR is metered from the local utility. Vertex supplies water used for steam production. Vertex pays the bill for electricity and natural gas. A new steam methane reformer is under construction that would allow the RDU to receive more renewable hydrogen. A new steam methane reformer is under construction that would allow the RDU to receive more

renewable hydrogen. SMR uses both the off-gas stream from the RDU and natural gas and sends all the hydrogen product back to the RDU. Because the off-gas stream comes from the RDU itself, it can be considered as an internal stream. Therefore, only the natural gas and grid electricity consumption by the SMR is accounted for in the RD production CI. The naphtha reformer uses both petroleum from the conventional refinery side and renewable naphtha generated by the RDU to produce H_2. It is conservatively assumed all the H_2 sent from the naphtha reformer to RDU is from petroleum source. Emission factor related to H_2 production from naphtha reformer comes from "GREET1_2023 ZW 03202024-Petroleum Naphtha" file and U.S Ave emission factors are used for all feedstocks except Tallow. Per guidance from CARB staff, a user-defined oil rendering GHG Emission Factor (266.69 gCO_2e/lb oil) was applied to tallow, given its origin in Uruguay, while the electricity emission factor was set at 120.33 gCO_2e/kWh[1]. During fuel production stage, the 17-SRSO Mix regional electricity mix was considered.

RDU both consumes and generates off-gas. Other than SMR, the off gas from RDU is sent to the heating system. Therefore, displacement credits are assigned to these off-gas streams. In addition, RDU is a net steam exporter. The exported steam is assumed to displace natural gas at a 80% natural gas to steam efficiency. Energy content of the steam is entered into "2.14 Alternate Fuel/ Credit for Co-product Use", with an emission factor of that of NG's multiplied by "-1/0.8".

Based on operational data from September 2023 to December 2023, for each gallon of RD product, 0.0104 mmbtu NG, 0.706 kWh grid electricity, 0.0044 mmbtu fuel gas, and 32.7 scf H2 from naphtha reformer is consumed, while 0.0055 mmbtu fuel gas and 0.022 gallons of naphtha is produced as co-products of the system.

The RD produced is transported from Vertex to CA destinations by ship for no more than 5,042 miles. RD is then transported to blending terminals and further distributed in CA by truck with default distance values.

[1] https://lowcarbonpower.org/region/Uruguay

4. Model Output

This report has assessed the LCA stages that comprise the pathways for animal fat, soy oil, canola oil and DCO RD processed in a hydrotreater at Vertex.

Details on the CI of each stage for each pathway are shown in Table See file "tier1-Vertex-AA-02262024-Sep-to-Corrected-05132024" for how the CI components from calculator were combined to arrive at the final CI results.

Table 3 Emissions (gCO_2e/MJ) from animal fat, soy oil, and DCO RD produced by Vertex, separated by life cycle stage. Figures are rounded.

Life-cycle Stage	Animal fat RD	Soy oil RD	DCO RD	Canola Oil
Feedstock oil production	16.23	13.29	13.67	23.91
Feedstock oil transportation	5.54	0.14	1.04	1.24
RD production	13.36	13.36	13.36	13.36
RD transportation and distribution	3.33	3.33	3.33	3.33
iLUC	0	29.10	0	14.50
Total (Well to Tank)	**35.89**	**55.89**	**28.07**	**53.02**
Total (Tank to Wheel)	**0.76**	**0.76**	**0.76**	**0.76**
Total (Well to Wheel)	**35.89**	**56.65**	**28.84**	**53.78**

5. Discussion of Results

As show in Table 2, feedstock oil production and RD production are the two major contributors to the final RD CI, as calculated using a modified version of Tier 1 BDRD Calculator published by CARB. In addition to these two factors, iLUC played a significant role for plant-based oil feedstocks- soy oil and canola oil, while feedstock and fuel transportation also have minor contribution to the final CI.

6. Production Range of Vertex Renewables Alabama LLC

This pathway should be applicable to Vertex for 100% of the Permitted Capacity for RD production.

7. Sustainability of Vertex

Vertex Renewables Alabama LLC was designed and constructed using established modern designs and equipment and is managed by professional, 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 aligned with the business objectives of the owners.

8. Impact on Land Use

For the RD derived from animal fat, a waste stream from food industry, there is no land use impact. Similarly, DCO is a by-product from ethanol production industry, and there is no land use impact. For the RD derived from soy oil and canola oil, the default iLUC value of 29.10 g CO_{2e}/MJ and 14.5 CO_{2e}/MJ respectively in LCFS regulation were adopted.

9. Conclusion

Based on our modeling using the modified Tier 1 BDRD Calculator, we find that RD produced from each feedstock through the process at Vertex has CIs as listed below:

- Animal fat to RD 35.89 (gCO_{2e}/MJ)
- Canola oil to RD 53.78 (gCO_{2e}/MJ)
- Soy oil to RD 56.65 (gCO_{2e}/MJ)
- DCO to RD 28.84 (gCO_{2e}/MJ)

10. Data supporting Annual Quantities of Electricity, Natural Gas, Steam, Hydrogen, Feedstock Use, RD Production, and Distance for Feedstock and Fuel Transportation

The data supporting the quantities of electricity, natural gas, steam, hydrogen, feedstock test result and use, RD production, distance for feedstock and fuel transportation, as well as ER are collected in supporting folder.

11. References

[1] Tier 1 Simplified CI Calculator for Biodiesel and Renewable Diesel. Available 01/26/2024, at:

https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation

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