



**Renewable Energy Group (REG) Carbon Intensity Report:
Renewable Diesel Produced from Soy Oil, Used Cooking Oil, Animal Fats, Canola
Oil, and Corn Oil**

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Executive Summary

In 2009, the California Air Resources Board (CARB) adopted the original Low Carbon Fuel Standard (LCFS) regulation. In late 2018, CARB re-adopted the LCFS program and created a new simplified Biodiesel-Renewable Diesel (BD-RD) Calculator used in this report.

The BD-RD calculator is a simplified version of the GREET model. GREET, or Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation, is a life-cycle model developed by Argonne National Laboratory, a US Department of Energy national research lab. The GREET framework is currently the standard life-cycle model used by the US Environmental Protection Agency (EPA) and CARB to implement their respective biofuel programs. As mentioned in its name, the GREET model calculates the emission of greenhouse gases in transportation by simulating various fuel production pathways to calculate the emissions within a given supply chain. The functional unit, or result from this version of GREET model, is the carbon intensity of biodiesel or renewable diesel. Carbon intensity (CI), or the emissions intensity associated with production of a given unit of fuel is most often expressed in grams of CO₂e per megajoule of fuel.

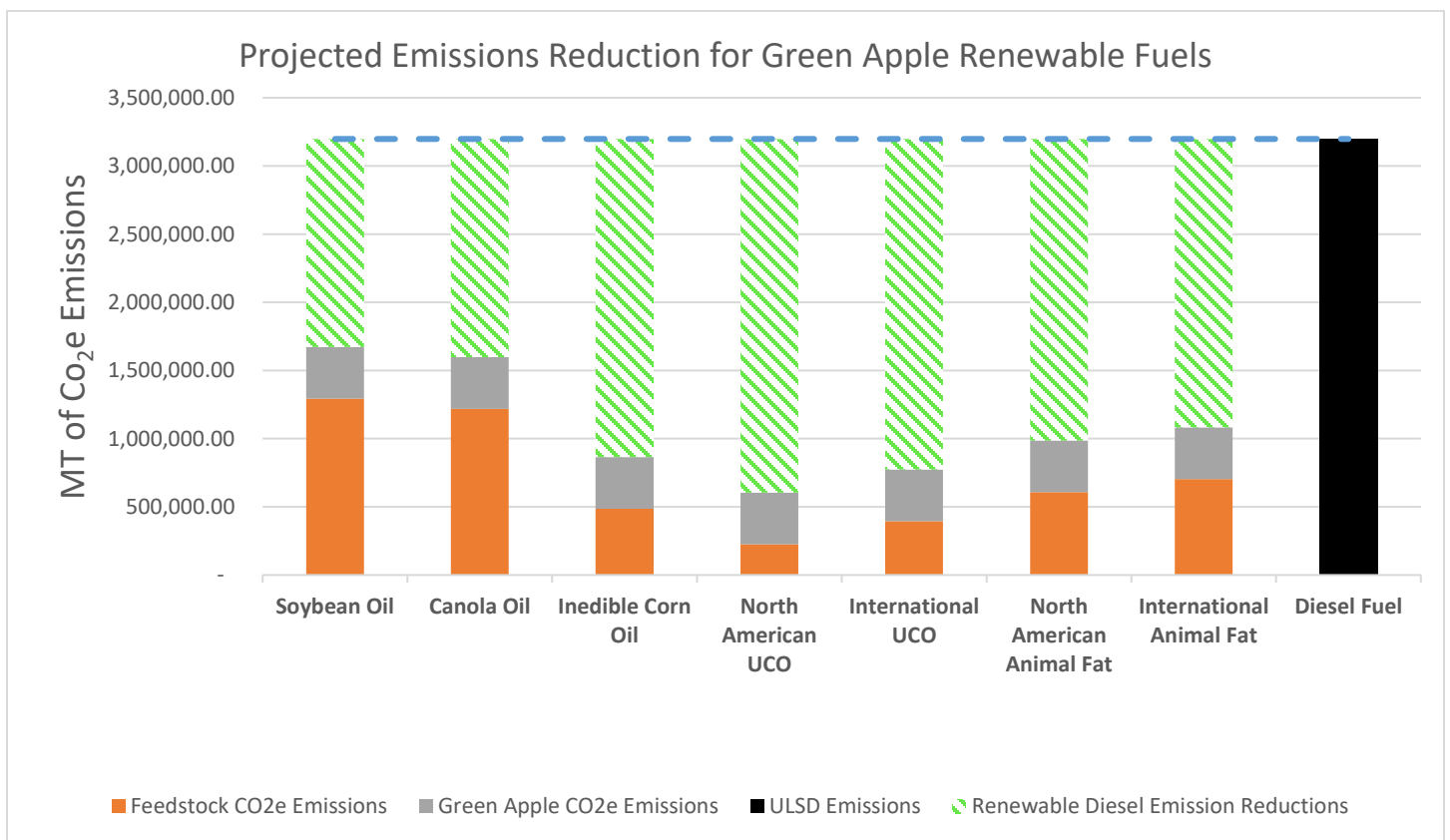
Renewable Energy Group and Phillips 66 have proposed the Green Apple Renewable Fuels, LLC (Green Apple) joint venture to produce renewable fuels near Ferndale, Washington. The projected nameplate capacity for the Green Apple Renewable Fuels facility is 250 MMGY of renewable fuel products. Green Apple is designed to be a multi-feedstock plant capable of processing high free fatty acid ("FFA") renewable feedstocks and has the ability to receive renewable feedstock by truck, rail, and ocean vessel. Green Apple will use natural gas and electricity for process energy and produce renewable transportation fuels including renewable diesel (RD), renewable naphtha, renewable propane, and renewable jet fuel (future). In addition to those on-road products, the naturally exothermic reaction will also produce excess thermal energy to be consumed in the production of hydrogen. Finished renewable diesel fuel will leave the facility by truck, rail, or ocean vessel.

This report contains information to support the GREET model conclusions for RD produced from soy oil, used cooking oil (UCO), animal fats, canola oil, and inedible corn oil at the Green Apple facility. This report documents the modifications made to the simplified BD-RD Calculator, the data and sources utilized, and the modeled results. The data in this report is based on 12 months of estimated operating data. The table below summarizes the life cycle analysis results based on use of the CARB BD-RD calculator.

Table 1: Lifecycle GHG Emission Green Apple Renewable Fuels, LLC

Life Cycle Stage	CO₂e g/MJ
Soy Oil RD	53.06
Canola Oil RD	50.75
Inedible Corn Oil RD	27.84
North America Used Cooking Oil RD	19.67
International Used Cooking Oil RD	24.99
North America Animal Fats RD	31.65
International Animal Fats RD	34.63

Based on results from the CARB BD-RD calculator, the Graph below illustrates GHG emissions associated with renewable feedstock production and transportation (in orange), operation of the Green Apple facility and renewable fuel product transportation (in grey), and fossil fuel GHG emissions displaced (in green). At reasonable expectations for renewable feedstock mix, operation of the Green Apple facility will reduce life-cycle GHG emissions by over 2 million metric tons CO₂e per year compared to equivalent fossil fuels.



To put 2 million metric tons CO₂e in perspective, using information from U.S. EPA’s “Inventory of U.S. Greenhouse Gas Emissions and Sinks 1190-2016”, this is roughly the annual CO₂e emissions from 450,000 passenger cars. The Green Apple facility will roughly reduce CO₂e by the same amount as if removing all passenger cars in Whatcom, Skagit, Okanogan, and Chelan counties of Washington State.

Contents

Executive Summary.....	3
1. Pathway Overview	7
1.1 Facility Overview	7
1.2 Model Design	9
2. Renewable Feedstock	10
2.1 Renewable Feedstock Transportation Data.....	10
3. Renewable Diesel Production	11
3.1 Energy Inputs	11
3.2 Chemical Inputs.....	11
3.3 RD Production Carbon Intensity Summary	11
4. Renewable Diesel Transportation.....	11
5. Tank-to-Wheels.....	12
6. Indirect Land Use Change	12
7. Summary	12
8. Acronyms	13
9. Block Flow Diagram for Green Apple Facility Production Process.....	14
10. Summary of CA-GREET Results	15

List of Figures

Figure 1: REG BioSynfining™ Overview. Images are of REG Geismar.....	8
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List of Tables

Table 1: Lifecycle GHG Emission Green Apple Renewable Fuels, LLC.....	3
Table 2: Region selection for the Green Apple facility	9
Table 3: Breakdown of the modeled renewable feedstock consumption at the Green Apple facility	10
Table 4: Modeled transportation distance	10
Table 5: Green Apple facility Energy Inputs.....	11
Table 6: Green Apple facility CI values associated with renewable diesel processing and transport	11
Table 7: Green Apple Renewable Fuels, LLC RD Life Cycle CI	12





1. Pathway Overview

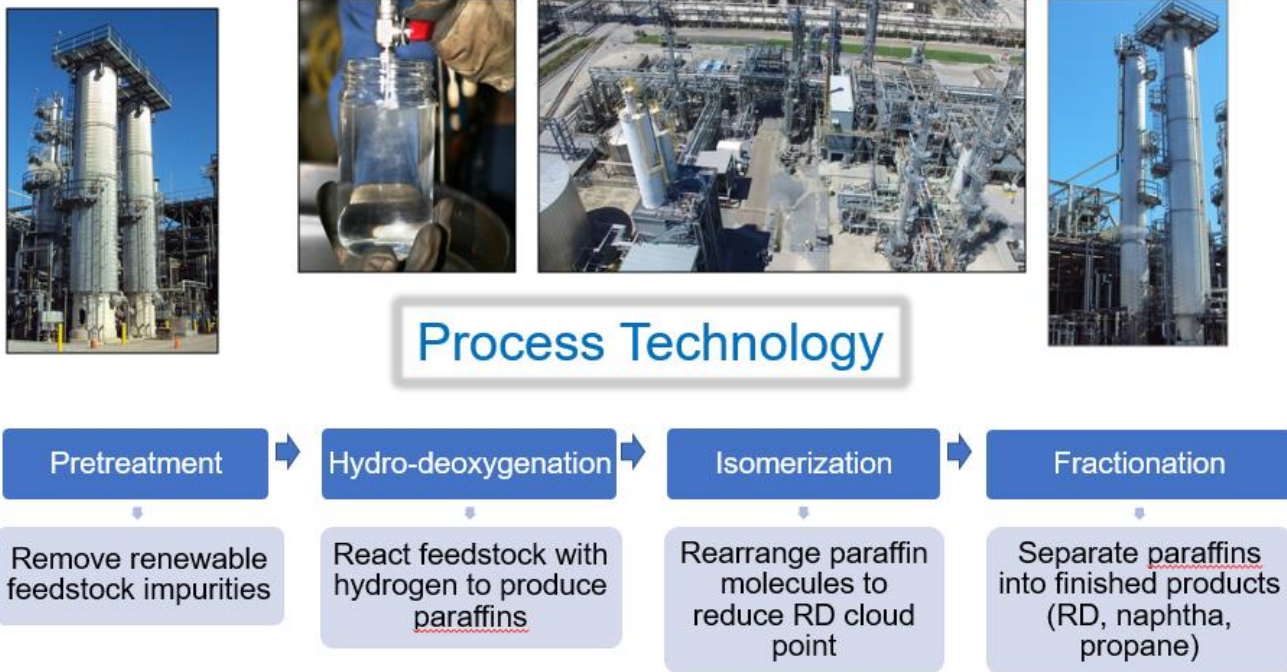
This is a report for the Green Apple Renewable Fuels, LLC joint venture project between Phillips 66 and Renewable Energy Group. This report calculates the cradle-to-grave CO₂e emissions for seven renewable feedstocks converted to renewable fuels and used as transportation fuel. All emission factors utilized in this analysis are on a life cycle basis. This means that this report does not segregate emissions as scope 1, 2, or 3. For example, the emission factor used for this report, associated with the natural gas used to produce hydrogen includes all emissions associated with natural gas extraction, processing, transportation and leakage. Due to the inclusive nature of these emission factors, the results presented in this report are likely to be more conservative than AP-42 or 40 CFR Part 98 emission factors. Green Apple fuels will be sold into incentivized markets led by California. California's model is considered the most sophisticated of the various incentivized markets. This report is based on California's GREET model.

1.1

1.2 Facility Overview

Green Apple Renewable Fuels, LLC is proposing to construct a 250 MMGY renewable diesel facility capable of processing renewable feedstocks including, but not limited to soy oil, used cooking oil, animal fats, canola oil, and inedible corn oil. Engineering estimates project that this facility would process over 1.8 billion pounds of feedstock to produce over 220 million gallons of RD per year with the balance of fuel produced being renewable propane, renewable naphtha, and (future) renewable jet fuel. For air permitting purposes, we are estimating the facility to be capable of 325 mmgal/yr renewable fuel production for "potential". For purposes of this GHG discussion, the "potential" 325 mmgal/yr production could happen if processes outperform the design basis. That outperformance shows better GHG performance than the nameplate capacity, on a per gallon basis. The conservative approach for GHG is to discuss the nameplate operating scenario. The nameplate scenario is considered for this report. The Green Apple facility will not be capable of or permitted to process petroleum oils.

Figure 1: REG BioSynfining™ Overview. Images are of REG Geismar.



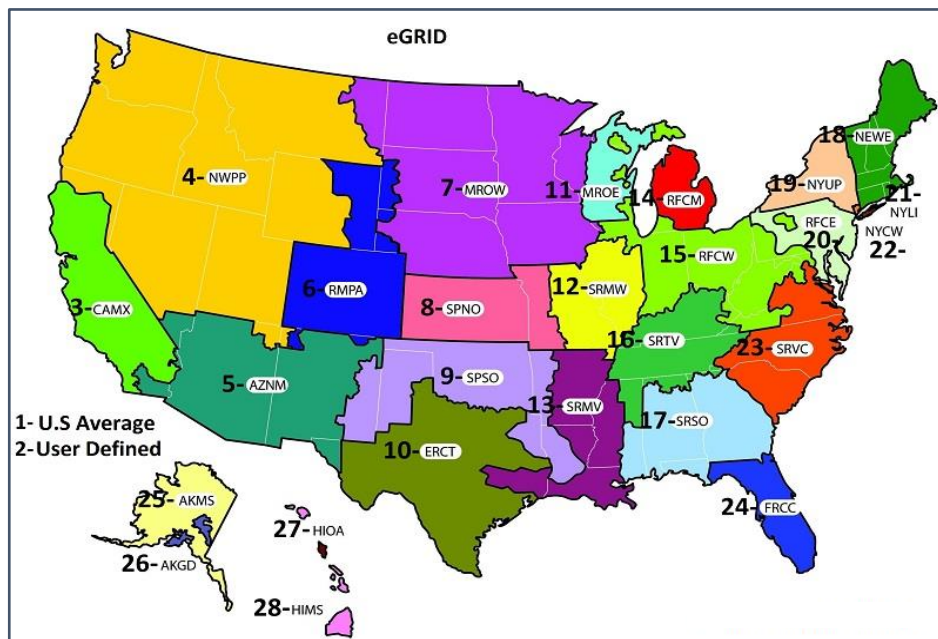
1.3 Model Design

This report calculates the carbon intensity of RD produced at Green Apple Renewable Fuels, LLC using a variety of renewable lipid feedstocks. The carbon intensity is generated using CARB’s simplified BD-RD GREET calculator, and includes all supply chain processes from renewable feedstock collection or production to the delivery of the finished RD. The initial region selection for the calculation is in the table below. Renewable feedstock emissions will have standard values unless otherwise specified.

In addition to standardized renewable feedstock values, it is also required to set regionally specific parameters for the analysis. For the energy that may be used throughout the life cycle of the products, a US average was selected. This provides representative emission factors for energy that may be used across our supply chain and within the biorefinery. The US average electricity grid is assumed within the default renewable feedstock emissions in the GREET model; for the Green Apple facility, EPA’s E-Grid NWPP – 4 is utilized. We believe this is a very conservative assumption considering that in reality the power provided by the local utility is predominantly hydroelectricity.

Table 2: Region selection for the Green Apple facility

Section	Value Selected
2.1 Regional Electricity Mix	4-NWPP Mix
2.3 Regional Crude Mix (Transportation)	U.S. Average Crude
2.5 Regional Natural Gas Source	U.S Average Mix



2. Renewable Feedstock

This section of the report describes the various renewable feedstocks included in the model. The volumes of renewable feedstock below are illustrative, but allow for the calculation of representative values within the model. The model contains multiple renewable feedstocks; the total renewable feedstock consumption is calculated based on the facility's capacity and the estimated yield. The annual total for renewable feedstock is divided evenly among the different renewable feedstock types for this report. For actual operation, Green Apple will be incentivized to use the lowest CI renewable feedstocks available at any given time according to the incentivized market's models.

Table 3: Breakdown of the modeled renewable feedstock consumption at the Green Apple facility

Feedstock Type	Quantity (LBS)
Soy Oil	262,989,250
Canola Oil	262,989,250
Inedible Corn Oil	262,989,250
North America used cooking oil	262,989,250
International used cooking oil	262,989,250
North America animal fats	262,989,250
International animal fats	262,989,250

2.1 Renewable Feedstock Transportation Data

Green Apple will receive renewable feedstocks from locations around the world. The transportation distance of the renewable feedstock to the Green Apple facility can range from a few miles for local used cooking oil to thousands of miles. Renewable feedstocks will arrive by truck, rail, and ocean vessel. Due to the wide variety of underlying environmental properties and distances associated with different loads of feedstock, this report calculates a weighted average travel distance for each renewable feedstock type and transportation mode. However, because most programs incentivize renewable fuel based on their life cycle emission, this acts as an incentive to use local feedstock and to sell into local markets, minimizing the emissions from transportation. Since we do not have historical supply chain data for Green Apple, we have estimated representative values for the various feedstocks purposed in this analysis. REG experts develop these models for our currently operating biofuels facilities (including REG Geismar, REG's commercial RD plant in Louisiana) on a daily basis and use the models for renewable feedstock sourcing decisions. The incentivized low carbon fuels markets use actual values. The intent is to be conservative for this report before actual values are available.

Table 4: Modeled transportation distance

Feedstock Type	Modeled transportation method miles
Soy Oil	Rail 1758 miles
Canola Oil	Marine 1053 miles, Rail 1053 miles
Inedible Corn Oil	Truck 1323 miles, Rail 1323 miles
North America used cooking oil	Truck 905 miles, Rail 905 miles
International used cooking oil	Marine 6070 miles
North America animal fats	Truck 500 miles, Rail 1580 miles
International animal fats	Marine 9652 miles

3. Renewable Diesel Production

The production of RD requires renewable feedstock, energy, and chemical inputs. The Green Apple facility will produce RD as well as a variety of co-products, including renewable naphtha, renewable propane, and (future) renewable jet fuel. This section summarizes the inputs and outputs of the proposed Green Apple facility excluding renewable feedstock (discussed above). The final pathway results are included in Table 1 of the Executive Summary.

3.1 Energy Inputs

The Green Apple facility will use pipeline natural gas and grid electricity as process energy. Natural gas is used as both process energy and to supply the SMR for production of hydrogen. The table below shows the estimated energy usage during the 12 months simulation period covered in this application.

Table 5: Green Apple facility Energy Inputs

Period	Natural Gas (MMBTU)	Electricity (KWH)
Annual	5,505,000	134,817,000

3.2 Chemical Inputs

The primary chemicals used by the Green Apple facility will be citric acid and dimethyl disulfide (DMDS). CARB has calculated the emissions from these chemicals to be 0.03 g/MJ.

3.3 RD Production Carbon Intensity Summary

The following table summarizes the carbon intensity of the fuel production, excluding feedstock, based on assumptions included in the GREET model.

Table 6: Green Apple facility CI values associated with renewable diesel processing and transport

Life Cycle Stage	Value (g/MJ)
Natural Gas	12.54
Electricity	2.01
Other Fuel	0.00
Chemical Use	0.03
Finished Fuel Transportation	0.50
Displacement Credit (hydrogen)	-0.96
Displacement Credit (steam)	-2.24
Renewable Diesel Production Carbon Intensity	11.88

4. Renewable Diesel Transportation

Green Apple will distribute finished RD by ocean vessel, rail, and truck to various facilities in Washington, California, Oregon, British Columbia, and other incentivized markets. To estimate the emissions from finished fuel transportation we assumed specific shares of fuels to various end markets. We believe the value calculated is conservative for fuel that will be delivered locally.

5. Tank-to-Wheels

The tank-to-wheels emissions are the same for all RD fuels. This emission represents the amount of methane and nitrous oxide associated with the combustion of RD in a vehicle. The default value in the CARB simplified BD-RD Calculator is 0.76 CO₂e/MJ.

6. Indirect Land Use Change

Certain pathways included in this application may have an indirect land use change penalty associated with them. REG applied iLUC where required by the LCFS. No internal REG calculations were done to modify iLUC where it is applicable.

7. Summary

The emissions calculated for the individual stages sum up to an overall CI of the fuel pathway. The following table summarizes the calculated full life-cycle CI for RD produced at the Green Apple facility, including a comparison to the CI of petroleum diesel.

Table 7: Green Apple Renewable Fuels, LLC RD Life Cycle CI

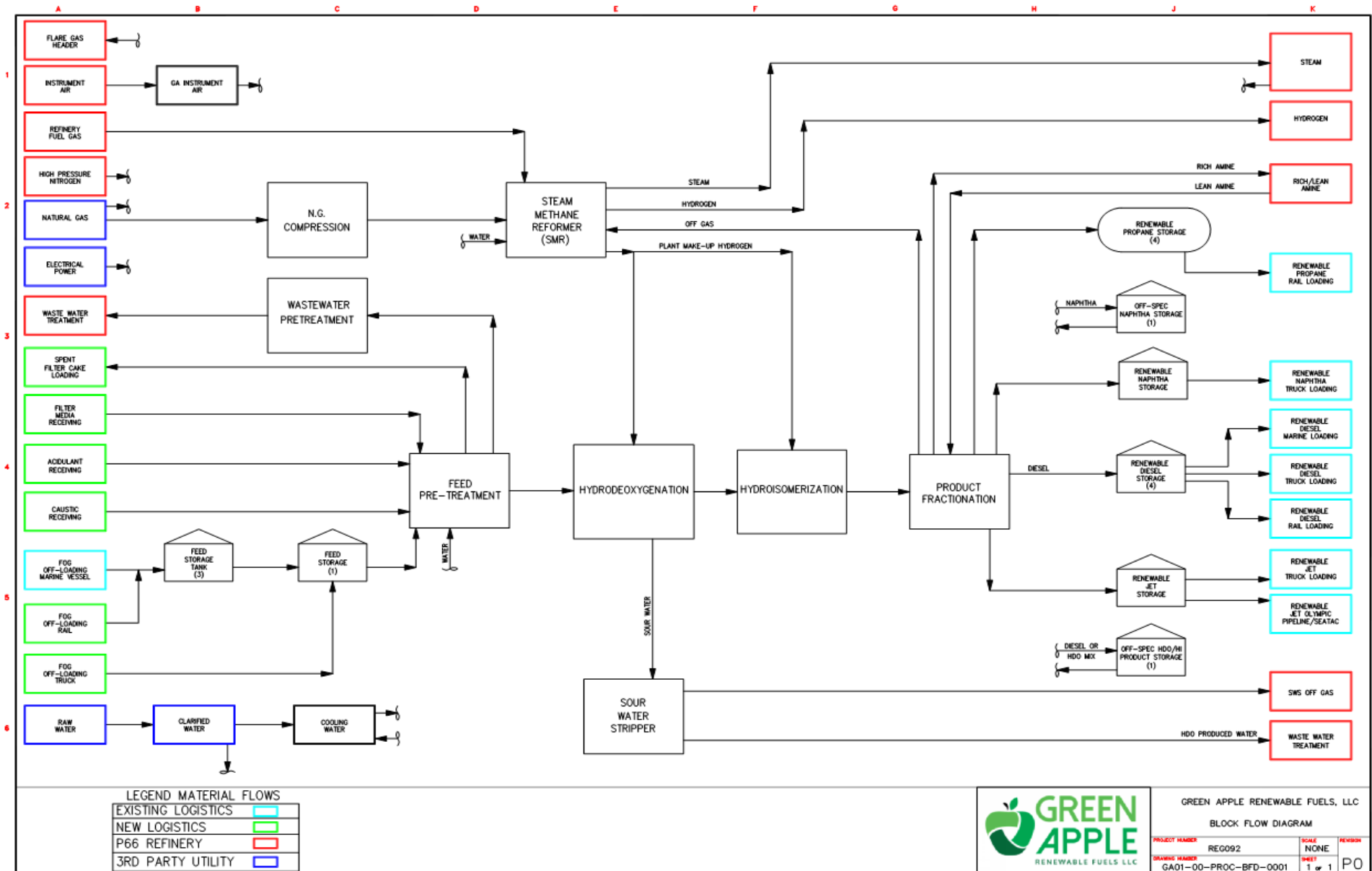
Life Cycle Stage*	Soy Oil	Canola Oil	Inedible Corn Oil**	North America UCO	Inter-national UCO	North America Animal Fats	Inter-national Animal Fats	Fossil Diesel ¹ (for comparison)
Feedstock Production	11.32	23.61	4.99	7.03	12.35	19.01	21.99	
Fuel Production	11.88	11.88	11.88	11.88	11.88	11.88	11.88	
Indirect Land Use, g/MJ	29.10	14.50	0.0	0.0	0.0	0.0	0.0	
Tailpipe Emissions g/MJ	0.76	0.76	0.76	0.76	0.76	0.76	0.76	
Total Well-to-Wheel CI, g/MJ	53.06	50.75	27.84	19.68	24.99	31.65	34.63	100.45
* Data is representative of operations at Green Apple Renewable Fuels, LLC ** Inedible Corn Oil use as debit in DGS in Corn Ethanol is 10.22 g/MJ.								

¹ https://ww3.arb.ca.gov/fuels/lcfs/fro_oal_approved_clean_unofficial_010919.pdf

8. Acronyms

- Biodiesel.....BD
- Renewable Diesel RD
- California Air Resources BoardCARB
- Carbon Intensity.....CI
- Greenhouse Gases, Regulated Emissions, and Energy Use in TransportationGREET
- Free Fatty Acids.....FFA
- Indirect Land Use ChangeiLUC
- Used Cooking Oil.....UCO
- Steam Methane ReformerSMR

9. Block Flow Diagram for Green Apple Facility Production Process



10. Summary of CA-GREET Results



Tier 1 Simplified CI Calculator for Renewable Diesel

Section 1. Applicant Information for Biodiesel Production and Pathway Summary and Estimated CI (g/MJ)								
1.1 Applicant	Green Apple Renewable LLC			1.2 Facility Location (City, State, Country)	Ferndale, WA, USA		1.5 Application #	
1.3 Pathway Description	Renewable Diesel produced from Soy Oil, Canola Oil, Corn Oil, UCO, and Mixed Animal Fats			1.4 Provisional Pathway?	No		1.6 Facility #	
MM/DD/YYYY	CI, gCO ₂ e/MJ	Gallons @ 60°F	CI, gCO ₂ e/MJ	Gallons @ 60°F	CI, gCO ₂ e/MJ	Gallons @ 60°F	CI, gCO ₂ e/MJ	MMBTU
Soy Oil	53.06	31,185,684	53.06	2,169,391	53.06	3,021,817	53.06	
Canola Oil	50.75	31,185,684	50.75	2,169,391	50.75	3,021,817	50.75	
Corn/Sorghum Oil	27.84	31,185,684	27.84	2,169,391	27.84	3,021,817	27.84	
UCO 1	19.67	31,185,684	19.67	2,169,391	19.67	3,021,817	19.67	
UCO 2	24.99	31,185,684	24.99	2,169,391	24.99	3,021,817	24.99	
UCO 3	0.00	0	0.00	0	0.00	0	0.00	
Tallow 1	31.65	31,185,684	31.65	2,169,391	31.65	3,021,817	31.65	
Tallow 2	34.63	31,185,684	34.63	2,169,391	34.63	3,021,817	34.63	
Tallow 3	0.00	0	0.00	0	0.00	0	0.00	