Application No. D0025

HIF USA eFuels Design Based Pathway

LCA.8177.4.2024

Prepared by:

Stefan Unnasch

Love Goyal

Fabiola Albright

September 23, 2024

DISCLAIMER

This report was prepared by Life Cycle Associates, LLC for HIF USA, LLC. Life Cycle Associates is not liable to any third parties who might make use of this work. No warranty or representation, express or implied, is made with respect to the accuracy, completeness, and/or usefulness of information contained in this report. Finally, no liability is assumed with respect to the use of, or for damages resulting from the use of, any information, method or process disclosed in this report. In accepting this report, the reader agrees to these terms.

ACKNOWLEDGEMENT

Life Cycle Associates, LLC performed this study under contract to HIF USA LLC. Anthony Welty was the project manager for HIF USA LLC.

Contact Information:

Stefan Unnasch
Life Cycle Associates, LLC
1.650.461.9048
unnasch@LifeCycleAssociates.com
www.LifeCycleAssociates.com

Recommended Citation: Unnasch, S., L. Goyal, and F. Albright, (2024). HIF USA eFuels Design Based Pathway. Life Cycle Associates Report LCA.8177.4.2024, Prepared for HIF USA, LLC.

Contents

Tables

Figures

Terms and Abbreviations

Btu	British thermal unit
BOL	Beginning of Life
BOP	Balance of Plant
BTM	Behind-the-meter
CA	California
CA-GREET	California Greenhouse gases Regulated Emissions Energy use in Transportation Model
CARB	California Air Resources Board
CI	Carbon Intensity
EOL	End of Life
GHG	Greenhouse Gas
GREET	Greenhouse gases, Regulated Emissions, Energy Use in Transportation Model
kWh	kilo-Watt hour
LCFS	Low Carbon Fuel Standard
LHV	Lower Heating Value
MJ	MegaJoule
MW	Mega-Watt
SAF	Sustainable Aviation Fuel

1. Pathway Summary

HIF USA LLC (HIF) is a project development and technology company, headquartered in Houston, TX, that is developing a power to fuel project in Texas (the Project). HIF's parent company, HIF Global, is developing power to fuel projects globally.

HIF has developed an innovative process that combines waste carbon dioxide (CO_2) and the on-site produced low-carbon H_2 in a series of synthesis processes to derive eFuels. Overall, the CO_2 and hydrogen molecules react together to produce AA grade methanol that will meet customary specifications. The methanol is then further processed (or can be sold) to produce synthetic fuels, including sustainable aviation fuel (SAF), diesel, and a naphtha stream. HIF's SAF will comply with ASTM D7566 Annex 5[1] and is fungible with petroleum jet at a 50% level which is the same rate for other SAF types. The diesel and naphtha streams are fungible with conventional fuels. HIF's process produces low-carbon hydrogen (H_2) via electrolysis of water using energy from renewable and other low carbon energy source(s).

The Project uses 2,000 MW of low CI power to produce about 780 tonnes per day of hydrogen which reacts with CO_2 to produce about 221 million gallons per year of jet, methanol, diesel, and naphtha.

2. Well to Wheels Fuel Life Cycle

The system boundary diagram in Figure 1 shows the components of the fuel production pathway. The key sources of GHG emissions include:

- Waste CO_2 recovery and transport
- Renewable power for hydrogen production
- Renewable power for balance of plant
- Process fuel gas combustion
- Fuel transport
- Aircraft fuel combustion

The CO_2 feedstock is derived from various sources with the expectation of defining a fuel pathway for concentrated sources, which require less process energy, and dilute sources, which require additional processing energy for CO_2 capture. The HIF process may potentially use CO_2 from direct air capture or from natural gas-fueled power plants.[2] The process will use hydrogen produced from eligible low CI renewable power. Process electricity will be based on renewable power delivered behind-the-meter on power lines not owned by the utility. All of the CO_2 sources shown in Figure 1 represent flows that otherwise would be emitted to the atmosphere.

[1] DOE (2020). Sustainable Aviation Fuel Review of Technical Pathways DOE/EE–2041

[2] The evaluation of GHG emissions from natural gas power plants or direct air capture would include the scope of life cycle GHG emissions involved in the capture equipment.

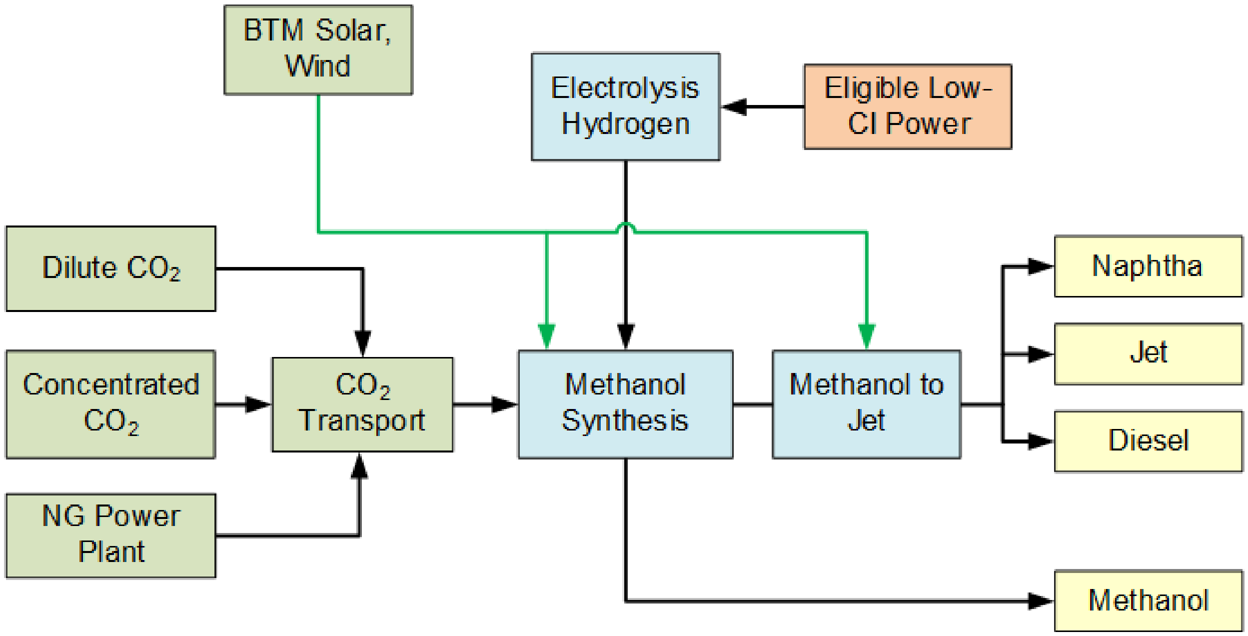

Figure 1. System Boundary Diagram for HIF SAF Production from Waste CO_2[3]

3. Fuel Production Feedstocks and Input

All CO_2 inputs for eFuel production are obtained from permitted sources that are currently emitting to the atmosphere. CO_2 will be delivered to the Project within a pipeline network and the volume of CO_2 is tracked on a mass balance basis.

3.1 Carbon Dioxide Sources

The capture and diversion of CO_2 for a new industrial use may result in some additional effects on the broader CO_2 market. CO_2 for eFuel production will be exclusively based on sources that would otherwise be released to the atmosphere. The determination of the GHG impact of CO_2 depends on the source of CO_2. Table 1 shows examples of candidate CO_2 sources that spans the spectrum of potential options.

[3] All sources of CO_2 would alternatively remain in or enter the atmosphere. Dilute CO_2 sources occur from combustion sources such as reformer furnaces and natural gas power plants. Concentrated CO_2 is the result of chemical reactions such as the reactants from shift reactors, ethylene oxide production, or ethanol fermentation. Direct air capture is another potential source of CO_2. For all CO_2 sources, HIF will quantify the energy inputs and emissions associated with CO_2 capture and movement.

Table 1. Landscape of CO_2 Sources

CO_2 Source	Current Fate of CO_2	Utilization Status	Carbon Footprint
Concentrated Sources with Potential Indirect Impacts			
Corn Ethanol	Sales by railcar	Utilized for Industrial Applications	Consequential Analysis of Make-Up CO_2
Ammonia, etc.	Sales by pipeline		
Dilute Sources			
Power Plant CO_2	Operating plant with with air emissions	No Utilized New Sources	Neutral
Oil Refinery			
Concentrated			
Corn Ethanol	Venting	No Utilized New Sources	Neutral
Ammonia, etc.			
Direct Air Capture			
Direct Air Capture	In atmosphere	No Utilized New Sources	Neutral
Atmosphere			

If CO_2 is diverted from an already utilized source that the Project did not enable to capture CO_2, additional CO_2 would need to be provided from other sources to make up for the diverted CO_2. This type of analysis is referred to as a consequential analysis that would take into account the potential new sources of CO_2, the market impacts and other displacement effects. The Project does not plan to utilize any CO_2 source that leads to such additional market effects.

The next category of CO_2 is concentrated CO_2 which is currently venting to the atmosphere. Examples include ammonia plants and ethanol plants. For new sources of CO_2, the carbon intensity would be neutral other than emissions associated with its direct capture and transport.

Dilute sources such as power plants, reformers and refinery heaters are also an option. Currently no dilute sources are used for industrial applications. All dilute CO_2 sources represent a new CO_2 source and therefore CO_2 from such sources would also be carbon neutral except for energy inputs to capture, compress and transport the CO_2. Finally, CO_2 from direct air capture would also be carbon neutral other than the emissions required for the air capture. As indicated previously, CO_2 is only derived from new sources which will be subject to verification.

Table 2 shows the candidate CO_2 sources that HIF is considering. This includes a mix of concentrated and dilute sources. The projected power and natural gas process heat consumption associated with the CO_2 capture is shown for each of the sources along with the amount of CO_2.

Table 2. CO_2 Sources

CO_2 Source	Current Fate	Expected Supply (tonne)	Utilization Status
Corn Ethanol Concentrated	Venting CO_2	XXX	XXX
	Power Input	XXX kWh/tonne	
	Natural Gas	XXX	
Ethylene Oxide Concentrated	Venting CO_2	XXX	XXX
	Power Input	XXX kWh/tonne	
	Natural Gas	XXX MMBtu/tonne	
Ammonia Plant Concentrated	Venting CO_2	XXX	XXX
	Power Input	XXX kWh/tonne	
	Natural Gas	XXX MMBtu/tonne	
Power Plant CO_2	Operating plant with with air emissions	XXX	XXX
Dilute	Power Input	XXX kWh/tonne	
	Natural Gas	XXX MMBtu/tonne	
Oil Refinery	Operating plant with with air emissions	XXX	XXX
Dilute	Power Input	XXX kWh/tonne	
	Natural Gas	XXX MMBtu/tonne	
Hydrogen Plant	Operating plant with with air emissions	XXX	XXX
Dilute	Power Input	XXX kWh/tonne	
	Natural Gas	XXX MMBtu/tonne	

Confidential business information has been redacted by the applicant

4. Material Inputs for Fuel Production

The only material inputs to the process are carbon dioxide, electric power, and water. Equipment is periodically maintained and catalyst is replaced every 4 years.

5. CO_2 Transport Modes

CO_2 is transported to the power to fuel facility by the local pipeline network. The pressure for CO_2 at the recovery facility is sufficient to transport the gas (less than 100 miles). If booster compression is required, the energy use will be calculated based on the distance and measured pressure drop.

6. Facilities and Process Inputs

Hydrogen will be produced from low CI power via electrolysis and reacted with waste CO_2 to produce eMethanol. eMethanol will be processed further in a methanol to jet cut hydrocarbons unit to produce predominantly jet and small amounts of other hydrocarbon products. Some of the eMethanol may also be sold as a fuel for marine vessels. Approximately 2 million tonnes of CO_2 per year and 282,500 tonnes per year of hydrogen will be converted to 226 million gallons of liquid fuel products on an annual basis.

6.1 eFuel Production

eFuels will be produced at the Facility by combining hydrogen produced via electrolysis with waste CO_2 to produce eMethanol. Then, a secondary set of reactions converts eMethanol to HIF jet and other synthetic fuels.

The power requirements for eFuel production are shown in Table 3. Power consumption for the electrolyzers depends on their load as well as age. Table 3 shows the projected power consumption for the electrolyzers at beginning and end of life (BOL, EOL). The weighted average power consumption for the electrolyzers is currently estimated to be 1,800 MW. Electrolyzer power will be sourced from eligible low-CI renewable power source(s). All power for remaining processes, referred to as "balance of plant" as shown in the Table 3, will be supplied by direct connected solar plants and wind turbines, both measured separately from power used by the electrolyzers. The CI for renewable power used to produce all of the hydrogen generated for the process is zero based on the LCFS regulation.

Table 3. Power Requirements for eFuel Production

	Electrolyzer Requirement		
	XXX Electrolyzers	XXX	MW
	XXX Electrolyzers	XXX	MW
	Average Power to Make Hydrogen[a]	**1,800**	**MW**
		XXX	MWhr/day
		XXX	kWh/mo
100%	Eligible Low-CI power	XXX	kWh/mo
	Balance of Plant Requirement		
100%	BTM Renewable Power[b]	XXX	kWh/mo

[a]The average power to produce hydrogen will depend on electrolyzer maintenance strategies. 1800 MW of power is consistent with the expected consumption rate over the life of the Project.

[b] Renewable power produced on-site via solar and potentially wind.

Confidential business information has been redacted by the applicant

Table 4 shows the capacity and CO_2 use rate for the Project. Since the CI of CO_2 varies among sources, HIF is requesting a separate pathway for concentrated and dilute CO_2 sources. If CO_2 from natural gas power plants or direct air capture becomes available, such sources may also be used for HIF fuel production. The GHG intensity of each CO_2 stream will be monitored with instrumentation that measures the CO_2 captured and injected and withdrawn from a common pipeline as well as power and energy used for CO_2 capture.

Table 4. CO_2 Sources

Source	Type	Capacity CO_2 t/mo	Use Rate CO_2 t/mo
A (Steam Methane Reformer)	Dilute	XXX	XXX
B (Ammonia Prod)	Concentrated	XXX	XXX
Total		XXX	XXX

Confidential business information has been redacted by the applicant

6.2 Electric Power Sourcing

Electric power provides the energy to produce hydrogen by electrolysis, which is reacted with CO_2 to make eMethanol. Additional power is required for operation of the balance of plant, reactor systems as well as CO_2 recovery. All power inputs for electrolysis will be supplied by eligible low-CI renewable electricity source(s). The balance of plant power will be supplied by a combination of behind-the-meter solar and wind sources, with a use of 100% renewable power during the operating life of the Project.

It's essential to consider various factors that contribute to the overall cost structure. XXX XXX charges constitute a significant portion of these costs, encompassing XXX. These charges reflect the XXX XXX XXX XXX XXX incurred during XXX XXX XXX , as well as charges levied by XXX for their services. Furthermore, XXX XXX savings play a pivotal role in cost reduction by offsetting XXX XXX XXX through the XXX XXX XXX XXX, thus optimizing overall expenses. Additionally, XXX XXX XXX serves as a key indicator of revenue generation, reflecting the income derived from XXX XXX XXX XXX while acting as a XXX XXX XXX in the ERCOT market.

Confidential business information has been redacted by the applicant

6.2.1 Renewable Power for Hydrogen Production

As described above, all power inputs for electrolysis will be initially supplied by eligible low-CI electricity source(s). HIF's goal is to increase the use of behind the meter renewable sources for electrolysis during the operating life of the Project.

6.2.2 Power for Balance of Plant

Renewable Power

HIF's goal for the balance of plant power demand is also to utilize 100% new renewable power. HIF is using a co-located behind-the-meter (BTM) solar power plant to meet the balance of plant power demand. HIF may also be able to utilize renewable power from repowered wind farms to supplement the on-site solar. Both wind and solar power have 0 CI and are thus interchangeable in terms of CI modelling. The BTM solar power will also be connected to the grid with net metering in place.

7. Combustion Equipment

The facility produces tail gas, which is used to generate process heat. The source of tail gas is light hydrocarbons from the methanol synthesis reactor and methanol-to-jet plant. The hydrocarbons are burned in a boiler to generate steam or sent to a flare. The GHG contribution of combustion emissions includes the methane and N_2O from combustion.

8. Co-Products, By-Products, and Waste Products

The facility will produce predominantly jet fuel, with lesser quantities of diesel and naphtha. Methanol can also be sold as a product. Life cycle GHG emissions are allocated to diesel, jet, and other products based on their energy content. The eFuel facility also produces wastewater which is managed in a detention pond. As much water as practical is recycled in the plant.

8.1.1 Allocation to Co-Products

Energy allocation assigns emissions to all products based on their energy content with the same resulting CI for each product. The Tier1 BDRD calculator treats diesel as a primary product with an allocation factor based on the energy content of all products[4]. Thus, diesel, SAF, naphtha, and methanol are inputs to the calculator. The calculator is only modified to add additional product and the CI is calculated based on the diesel allocation factor.

Energy inputs and emissions are allocated to diesel, jet, naphtha, and methanol on an energy basis as configured in the Tier1 BDRD calculator. The role of the primary product does not affect the CI and would simply result in a different allocation factor. Methanol will be sold depending upon market conditions. The allocation factor for HIF diesel is based on the approach in the regulation such that:

$$\chi_{diesel} = \frac{m_{diesel} \times LHV_{diesel}}{(m_{Diesel} \times LHV_{Diesel} + m_{Jet} \times LHV_{Jet} + m_{Naphtha} \times LHV_{Naphtha} + m_{MeOH} \times LHV_{MeOH})}$$

Where:

χ_{diesel} = energy allocation factor

m = mass of each component sold

LHV = lower heating value of each component

$$CI_{diesel} = \frac{\sum(e + NG + H2 + CO2)}{(m_{Diesel} \times LHV_{Diesel})} \quad \times \quad \chi_{diesel}$$

$$CI_{diesel} = \frac{\sum(e + NG + H2 + CO2)}{(m_{Diesel} \times LHV_{Diesel} + m_{Jet} \times LHV_{Jet} + m_{Naphtha} \times LHV_{Naphtha} + m_{MeOH} \times LHV_{MeOH})}$$

[4] Even though diesel is only 1 to 2% of the product the Tier1 BDRD calculator treats diesel as a primary product with an allocation factor to jet as discussed below. Making jet the primary product would require more calculator modifications.

9. Pathway CI Calculations

A Well-To-Tank (WTT) fuel cycle analysis of HIF's proposed pathways include the steps from the recovery of waste CO_2 to production of jet for aircraft use and other eFuels. Tank-to-wheel (TTW) analysis also includes fuel combusted in a vehicle or other end-use consumer. WTT plus TTW emissions provide a total well-to-wheel or well-to-wake (WTW) analysis that determines the fuel cycle greenhouse gas (GHG) emissions associated with jet and other eFuels.

Life Cycle GHG emissions are calculated using the GREET framework as implemented in the Tier1 BDRD calculator. CO_2 feedstock is input on the modified tallow sheet and eFuel production is calculated on a modified RD production sheet.

9.1 CO_2 Consumption and CI

Monthly CO_2 use is input into the feedstock portion of the Tier1 calculator. The carbon intensity of each CO_2 source is calculated based on the natural gas and power consumption such that:

CI of CO_2 = NG use (MMBtu/mo) × EF_{NG} + Power use (kWh/mo) × EF_{Power}.

The emission factors for natural gas are available on the Tier1 BDRD calculator, EF Table sheet.

Table 5. Emission factor for power and NG

Variable	Value		Cell Location
EF_{Power}	10-ERCT Mix, gCO_2e/kWh	638.59	EF!L53
EF_{NG}	NG, $gCO_2e/MMBtu,LHV$	73,424.19	NG!C30

Transmission Loss Factor

A loss factor of 6.5% is used per the standard value in CA-GREET3. Given the location and high distribution voltage to the eFuel facility this value is conservative.

10. Energy Inputs and Electrical Energy Consumption

The eFuel process combines hydrogen produced through electrolysis with waste CO_2 to produce eMethanol, which is then converted to HIF Jet and other synthetic fuels via a secondary reaction.

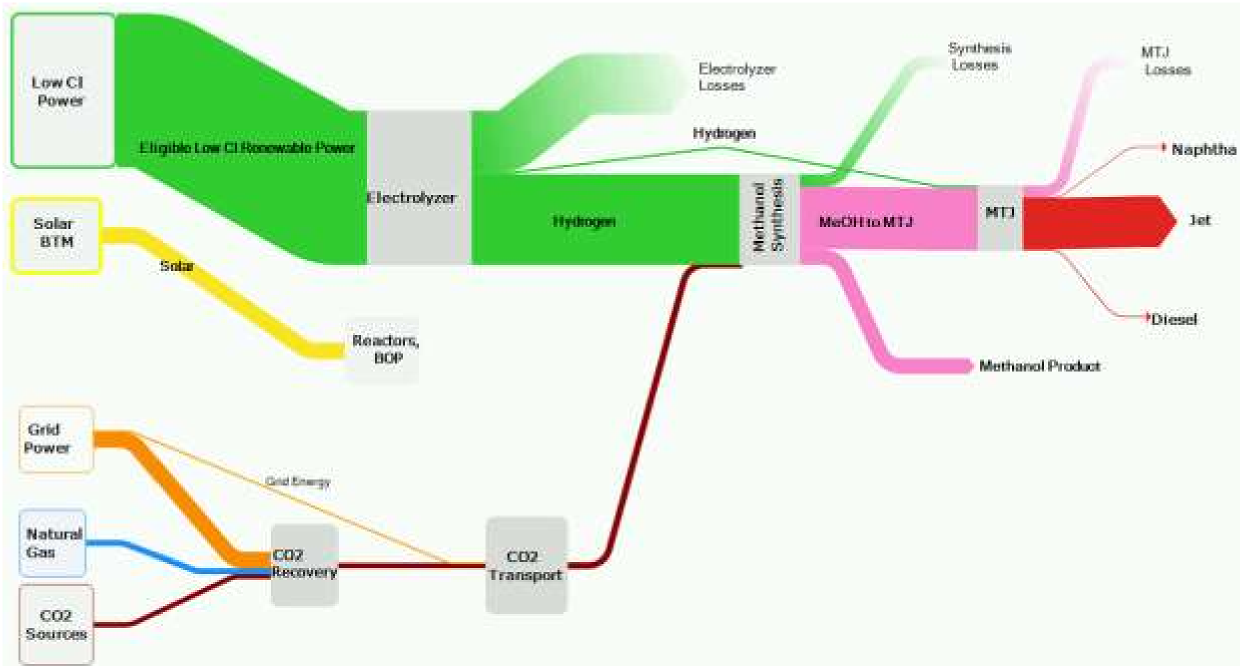

Figure **2** shows the flow of energy inputs for electrolysis, balance of plant (30% renewable scenario), CO_2 recovery, methanol production, and MTG. The energy inputs, products, and losses are reflected in the flow streams.

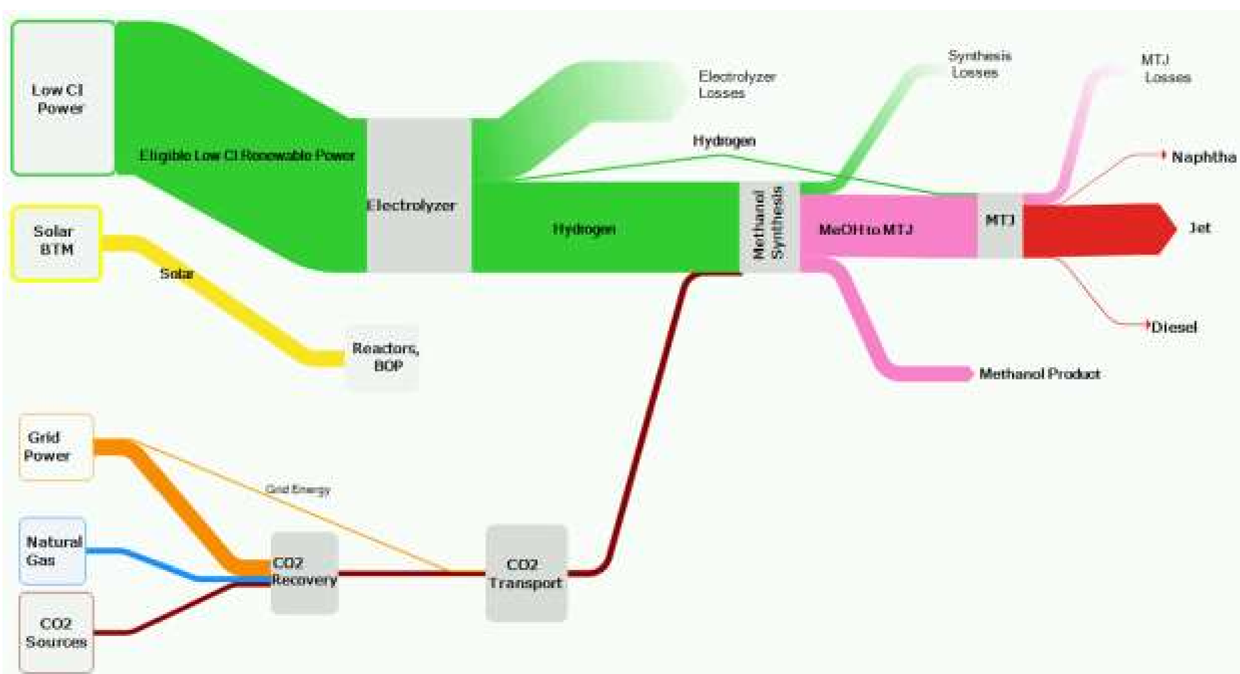

Figure 2. Sankey diagram showing energy flows for power to eFuel production.

10.1 California GREET3.0 Input Values and Calculator Modifications

The CARB Tier1 BDRD calculator was modified to determine the CI values for eFuels. All site-specific inputs are listed in Table 6. The projected use rate for total CO_2 is shown in Table 4. The CO_2 input is treated in the same manner as oils and fats in the BRDR calculator. Power consumption and fuel production yields shown in Table 6. The analysis shows a situation where only jet, diesel, and naphtha are produced for 3 months and about 30% of the product as methanol for three months. Methanol may be sold as a marine fuel or for industrial applications. Methanol could also potentially be sold as fuel in California.

Table 6. Tier1 Calculator Inputs

Section 2. Information for eFuel Production					CALCULATE			
Region	2.1 Regional Electricity Mix for Fuel			10-ERCT Mix				
	2.3 Regional Crude Mix			U.S Average Crude				
	2.5 Regional Natural Gas Source			U.S Average NG				
Process	Inputs for HIF Diesel Production				Co-Products			
2.7 Reporting Month (MM/YYYY)	2.9 HIF Diesel Produced (Calculated)	2.11 HIF Diesel Sales	2.13c Grid Power to Make Hydrogen with RECs	2.13d Solar power behind the meter	2.17 Renewable Jet Production	2.18 Renewable Naphtha Production	2.19 Renewable Propane Production	2.20. Methanol Fuel or Other (Specify Other here)
	gallons (@ 60°F)	gallons (@ 60°F)	kWh	kWh	gallons (@ 60°F)	gallons (@ 60°F)	gallons (@ 60°F)	gallons (@ 60°F) or specify applicable unit
October								
November								
December								
January								
February								
March								

Confidential business information has been redacted by the applicant

Table 6 shows the inputs for eFuel productions in the modified Tier 1 calculator. None of the calculator functions were modified other than adding naphtha as a co-product and into the allocation factor calculation. The calculator presents the CI for renewable diesel and shows the same CI for fuel products and co-products as shown in Table 7.

Table 7. Detailed GHG Emissions from Modified Tier1 BDRD Calculator

Feedstock Production										
Feedstock Production	Process	Inputs		Values	GHG Emissions, gCO_2e	CI, gCO_2e/MMBtu of RD	GHG EF Factors	GHG EF Unit	Unallocated, gCO_2e/MJ	Mass and Energy Allocation, gCO_2e/MJ
Region	CO_2 Production	CO_2- 1	1-U.S Ave Mix		GHG Emissions, gCO_2e	CI, gCO_2e/MMBtu of RD	GHG EF Factors	GHG EF Unit		
	CO_2	Yield, (gal Dsl+Jet+Naphtha+ MeOH)/tonne CO_2								
	CO_2 Capture				41,597,949,530	1,287,774.83	281,171	gCO_2e/tonne CO_2		
	CO_2 Transport									
		Tallow Oil transported by Heavy Duty Diesel Truck, miles		0	0.00	0.00	154	gCO_2e/ton Oil - Mile		
		Rendered Tallow transported by Ocean Tanker, miles		0	0.00	0.00	35	gCO_2e/ton Oil - Mile		
		Rendered Tallow transported by Rail, miles		0	0.00	0.00	27	gCO_2e/ton Oil - Mile		
		Rendered Tallow transported by Barge, miles		0	0.00	0.00	22	gCO_2e/ton Oil - Mile		
Renewable Diesel Production with Jet treated as Co-product via Energy Allocation										
Region					GHG Emissions, gCO_2e	CI, gCO_2e/MMBtu of RD	GHG EF Factors	EF Unit	Unallocated, gCO_2e/MJ	Energy Allocation, gCO_2e/MJ
10-ERCT	Hydrotreating/ HIF Process	Average RD Yield, lb. RD/lb. Fee								
		Natural gas, MMBtu (HHV)		0.00						
		Convert to Btu/lb. RD (LHV)		-	0.00	0.00	73,424	gCO_2e/MMBtu NG		
		Electricity, kWh		0						
		Convert to Btu/lb. fuel (LHV)		*0.000*	0.00	0.00	639	gCO_2e/kWh		
		Other Fuel, MMBtu (HHV)								
		Convert to Btu/lb. fuel (LHV)		-	0.00	0.00	0	gCO_2e/MMBtu of Other Fuel		
		Other Electricity Use, kWh		0						
		Convert to Btu/lb. fuel (LHV)		*0.0*	0	0.00	11.5	gCO_2e/kWh		
		Hydrogen Use, ft^3 (HHV)		0						
		Convert to Btu/lb. fuel (LHV)		0	0.00	0.00	106,907	gCO_2e/MMBtu Hydrogen		
		Chemical Use CI, g/MJ								
		Total Thermal energy, Btu/lb. f		-						
		Total Electricity energy, Btu/lb.		-						
		Total Energy, Btu/lb. fuel		-						
	HIF Fuel Transport									
		by Diesel HDT, miles		0	0.00	0	0.41	gCO_2e/gallon RD - Mile		
		by Rail, miles					0.09	gCO_2e/gallon RD - Mile		
		by Ocean Tanker, miles		0	0.00	0	0.1	gCO_2e/gallon RD - Mile		
		by Barge, miles		0	0.00	0	0.07	gCO_2e/gallon RD - Mile		
	Tailpipe Emissions									

Confidential business information has been redacted by the applicant

Table 8. CI Results for HIF eFuels

Section 1. Applicant Information for Biodiesel Production and Pathway Summary and Estimated CI (g/MJ)						
1.1 Applicant	HIF Americas			1.2 Facility Location (City, State, Country)		
1.3 Pathway Description	eFuel production based on the reaction of waste CO_2 with hydrogen to produce methanol with processing to jet.			1.4 Provisional Pathway?	Yes	
1.7 Application Date	HIF Diesel(eDiesel)		e Naphtha (eN)		e Jet (eJ)	
MM/DD/YYYY	CI, gCO_2e/MJ	Gallons @ 60°F	CI, gCO_2e/MJ	Gallons @ 60°F	CI, gCO_2e/MJ	Gallons @ 60°F
CO2 1	24.18		24.18		24.18	
CO2 2	5.38		5.38		5.38	
Feed 3	0.00	0	0.00	0	0.00	0

Confidential business information has been redacted by the applicant

10.2 Modifications to the CA_GREET Model

The lifecycle analysis was performed using the framework of the Tier1 BDRD calculator. The fuel properties of renewable diesel (RD) were assumed as those for HIF diesel and the CI of tallow was replaced with the CI of CO_2. The yield from CO_2 to diesel was then provided as an intermediate input with no significant change to the calculator. The key modifications to the calculator include the following:

- CI of CO_2 is an input on Tallow1, Tallow2, and Tallow3
- Naphtha and Methanol LHVs are user inputs

Table 9 shows the modifications made to the Tier1 BDRD calculator.

Table 9. List of Tier1 BDRD Calculator Modifications

Input	Cell Location	Original Value	New Value
Renaming Tab Renaming Tab	Tab Name Tab Name	Tallow 1 Tallow 2	CO2 1 CO2 2
CO_2-1 Production EF CO_2-2 Production EF	Tallow1!G11 Tallow2!G11	303.82 g CO_2e/lb Oil 303.82 g CO_2e/lb Oil	XXX g CO_2e/tonne CO_2 XXX g CO_2e/tonne CO_2
Feedstock EF Selection Feedstock EF Selection	Tallow1!D11 Tallow2!D11	Standard Value Standard Value	User Defined User Defined
Renaming Tab	Tab Name	RD-Production	HIF-Production
Eligible Low-CI Power Use	RD-Production!I27	New Column	XXX kWh/mo
Solar BTM Power Use	RD-Production!J27	2.14 Alternate Fuel/Credit for Co-product Use	XXX kWh/mo
Renewable Jet Production	RD-Production!M27	New Column	XXX gal
Methanol Fuel	RD-Production!O30	2.19 Jet Fuel or Other (Specify Other Here)	XXX gal
Jet Lower Heating Value	RD-Production!M53	New Column	XXX Btu/gal
Co-product Energy Allocation Factor	RD-Production!R53	(Fuel_Specs!E31*C52/((Fuel_Specs!E31*C52)+M51*M53+O51*O53+N51*N53))	(Fuel_Specs!E31*C52/((Fuel_Specs!E31*C52)+M51*M53+O51*O53+N51*N53+P51*P53))

Confidential business information has been redacted by the applicant

10.3 CO_2 Capture and transport

The CA_GREET model is configured with upstream fuel cycle data for natural gas with the following energy inputs:

- Natural Gas Process Heat
- Power for Compression
- Pipeline transport

The total upstream fuel cycle emissions for natural gas are shown in Table 3 for three CO_2 sources already identified by HIF. The first two sources are dilute and require absorption systems to capture the CO_2. Grid power is used to compress the gas to a supercritical state. Energy inputs for capture occur at the collection site and the gas and the CO_2 will be transported in a common transport pipeline or by rail in some cases. CO_2 from the collection site will be measured and balanced with the CO_2 consumed at the HIF site. The CO_2 will be compressed sufficiently at the Project site to account for transport to HIF. In instances where a booster compressor is required, the power required for CO_2 movement will be based on calculations in the CA-GREET model.

Table 10. Total WTT Emissions for CO_2 Capture and Transport

Source	Total CO_2 Produced	Natural Gas	Power		GHG	g CO_2e/ tonne CO_2
	t/h	MMBtu/h	hp	kWh		
A (Steam methane reformer)	XXX	XXX	XXX	XXX	48,145,775	281,171
B (Ammonia Prod)	XXX	XXX	XXX	XXX	24,345,957	44,876

Emission Factors: 66,302 g CO_2/MMBtu, HHV for Natural Gas, 638.59 g CO_2e/kWh ERCOT power

Confidential business information has been redacted by the applicant

Inputs will be measured at the capture site or based on invoices from utility providers. The lifecycle GHG analysis herein follows the framework laid out in CARB Tier1 BDRD calculator. Energy inputs and emissions are calculated on a monthly basis and allocated to HIF diesel and other eFuels based on energy content. The emission allocation per MJ of diesel is the same as that per MJ of jet (eSAF). This document details the energy and inputs required to produce HIF jet and other eFuels from two distinct categories of CO_2 that may be utilized. Specifically, the pathways described herein are:

- eFuels from concentrated CO_2 (such as vent streams from an ammonia plant)
- eFuels from dilute CO_2 sources (such as flue gas streams from refineries)

11. CI Score Summary

Life Cycle GHG emissions by production step are shown in Table 11 based in the calculations in the modified Tier1 BDRD calculator illustrating the effect of increasing the share of renewable power for balance of plant.

Table 11. Disaggregated GHG emissions

Balance of Plant Power Sourcing	100% Renewable	
Emission Source	**Concentrated**	**Dilute**
CO_2 Production	XXX	XXX
Other	XXX	XXX
Transport	XXX	XXX
Vehicle	XXX	XXX
Total	5.38	24.18

Confidential business information has been redacted by the applicant

Table 11 summarizes the WTW total carbon intensity for the considered scenarios. Each of the hydrocarbon fuels has the same CI based on energy allocation. These CI values represent a closed carbon balance within the system boundary.

Table 12. Carbon Intensity for HIF eFuel Pathways (g CO_2e/MJ)

Pathway	Direct CI	Indirect LUC	Total
On-Site Pathways			
Jet, dilute CO_2	24.18	0	24.18
Jet, Concentrated CO_2	5.38	0	5.38
Naphtha, dilute CO_2	24.18	0	24.18
Naphtha, Concentrated CO_2	5.38	0	5.38
Diesel, dilute CO_2	24.18	0	24.18
Diesel, Concentrated CO_2	5.38	0	5.38
Methanol, dilute CO_2[5]	N/A	N/A	N/A
Methanol, Concentrated CO_2	N/A	N/A	N/A

12. Co-Located Facilities

The eFuel facility is located in close proximity to a power plant.

13. Appendix: Entitlements and Permitting

The Project is applying for a XXX XXX XXX from the XXX XXX XXX.

Confidential business information has been redacted by the applicant

[5] Methanol is not currently listed as a fuel under the LCFS; however, California does have a specification for methanol fuel.

14. REFERENCES

Argonne National Laboratories. 2019. Greenhouse gases Regulated Emissions, and Energy use in Technologies (GREET1_2019) Model. https://greet.es.anl.gov/publication-update_ng_2019. Accessed 6.15.20.

California Air Resources Control Board. (CARB) 2014. Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Proposed Re-adoption of the Low Carbon Fuel Standard.

CARB. 2018a. Resolution 18-34 LCFS Attachment A Final Regulation Order. https://www.arb.ca.gov/regact/2018/lcfs18/frolcfs.pdf

CARB. 2018b. California Greenhouse gases Regulated Emissions, and Energy use in Technologies (GREET)3 Model. https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation.