CARB METHOD 2 FUEL PATHWAY REPORT
UCO BIODIESEL

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Date: September 13, 2013
Revised: Feb 6, 2014
Revised: May 20, 2014
Revised: August 18, 2014

EXECUTIVE SUMMARY

In 2009 the California Air Resources Board (ARB/Board) approved the California Low Carbon Fuel Standard (LCFS). The LCFS establishes a compliance schedule that requires fuel providers to reduce the carbon intensity of the fuels they provide each year between 2011 and 2020.

The LCFS requires fuel providers to determine the carbon intensity of the fuels they provide, and to report that information to ARB. ARB uses approved fuel carbon intensities to determine whether providers are in compliance with the regulation. Most transportation fuels sold in California are subject to the provisions of the LCFS.

Fuel providers may use one of two methods to determine the carbon intensities of the transportation fuels they provide to the California market. Under Method 1, fuel providers select carbon intensity values from the fuel carbon intensity lookup table found in the LCFS Regulation. Under Method 2, any entity, whether a regulated party or not, may seek Board or Executive Officer approval of additional fuel pathways or sub-pathways. If a proposed pathway or sub-pathway is approved, it is added to the lookup table, and becomes available to all fuel providers. The use of a new pathway or sub-pathway may begin as soon as it has been added to the lookup table.

Under Method 2A, fuel providers may apply for the addition of new sub-pathways to the lookup table. A sub-pathway is a modified version of a pathway currently present in the table. New sub-pathways are added when a fuel provider can demonstrate that a new or improved fuel production, transport, storage, and/or dispensing process significantly reduces the lifecycle carbon intensity of an existing reference pathway.

The modified pathway that is covered by this application is for an identical concept except that the biodiesel production is located in Ontario, Canada. The biodiesel transportation distances have been altered and the carbon intensity of the electric power in Ontario is different than it is in the other regions included in the CA GREET model. In addition, the proponent, BIOX, utilizes a slightly different biodiesel production process, which uses more energy than the typical biodiesel plant modelled by CARB. The differences in each stage of the production process are described in more detail in later sections of this report.

The GHG emissions for each stage of the lifecycle for the reference case and for the BIOX case are summarized in the following table.

Table ES- 1 Lifecycle GHG Emissions

Parameter	Base Case	Ontario
	g/MJ	
UCO Rendering	5.69	4.67
UCO Transport	0.30	0.14
Biodiesel Production	6.06	9.86
Biodiesel Transport	2.19	3.30
Total Tank to Wheel	14.24	17.97
Vehicle Operation	4.48	4.48
Total	18.72	22.45

The BIOX pathway emissions are about 20% higher than the reference case due to the increased transportation distances for the product and higher energy use in the plant. These are partially offset by the lower CI of the electric power in Ontario compared to the US Midwest and the shorter feedstock transportation distance.

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1. INTRODUCTION

In 2009 the California Air Resources Board (ARB/Board) approved the California Low Carbon Fuel Standard (LCFS). The LCFS establishes a compliance schedule that requires fuel providers to reduce the carbon intensity of the fuels they provide each year between 2011 and 2020.

The 2020 carbon intensity level is ten percent below the baseline 2010 level. “Carbon intensity” is the total greenhouse gas emissions from the production, transport, storage, dispensing and use of a fuel. It is expressed as grams of carbon-dioxide-equivalent per megajoule of fuel energy (g CO_2e/MJ). In the context of the LCFS, the term “carbon intensity” refers to the full lifecycle greenhouse gas emissions associated with a specific fuel “pathway.”

The LCFS requires fuel providers to determine the carbon intensity of the fuels they provide, and to report that information to ARB. ARB uses approved fuel carbon intensities to determine whether providers are in compliance with the regulation. Most transportation fuels sold in California are subject to the provisions of the LCFS.

Regulated parties must report the carbon intensities of the fuels they provide using a table of Board-approved carbon intensity values (a “lookup table”). Carbon intensities outside of the core set developed by staff are the responsibility of fuel providers.

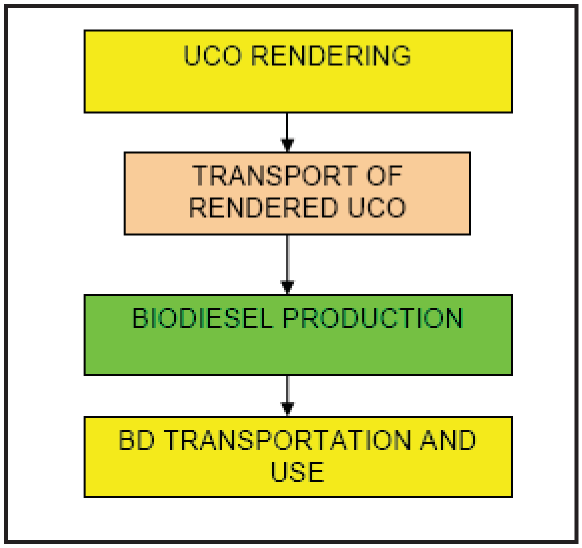
Fuel providers may use one of two methods to determine the carbon intensities of the transportation fuels they provide to the California market. Under Method 1, fuel providers select carbon intensity values from the fuel carbon intensity lookup table found in the LCFS Regulation. Under Method 2, any entity, whether a regulated party or not, may seek Board or Executive Officer approval of additional fuel pathways or sub-pathways. If a proposed pathway or sub-pathway is approved, it is added to the lookup table, and becomes available to all fuel providers. The use of a new pathway or sub-pathway may begin as soon as it has been added to the lookup table.

Under Method 2A, fuel providers may apply for the addition of new sub-pathways to the lookup table. A sub-pathway is a modified version of a pathway currently present in the table. New sub-pathways are added when a fuel provider can demonstrate that a new or improved fuel production, transport, storage, and/or dispensing process significantly reduces the lifecycle carbon intensity of an existing reference pathway.

1.1 REFERENCE PATHWAY

CARB published a Used Cooking Oil to biodiesel pathway in June 2011. That pathway was approved by the Board Feb 21, 2012. It is identified as BIOD004 in the CARB lookup table. The components of the pathway are shown in the following figure.

Figure 1-1 UCO Biodiesel Discrete Components



The biodiesel production scenario covered by this pathway was for the biodiesel production to be in the US Midwest. Two options were provided, one with and one without cooking in the rendering process. The calculated well to wheel emissions for the cooking process are shown in the following table.

Table 1-1 Lifecycle CI Results for UCO Biodiesel – US Production

Stage	Emissions, g CO_2eq/MJ
UCO Rendering	5.69
UCO Transport	0.30
Biodiesel Production	6.06
Biodiesel Transport	2.19
Total Tank to Wheel	14.24
Vehicle Operation	4.48
Total	18.72

These emissions have been verified with the base GREET model used for this work, ca_greet1.8b_dec09_CA_Corn_OilWDGS_01302012.xls.

1.2 Modified Pathway Description

The modified pathway that is covered by this application is for an identical concept except that the biodiesel production is located in Ontario, Canada. The biodiesel transportation distances have been altered and the carbon intensity of the electric power in Ontario is different than it is in the other regions included in the CA GREET model. In addition, the proponent, BIOX, utilizes a slightly different biodiesel production process, which uses more energy than the typical biodiesel plant modelled by CARB. The differences in each stage of the production process are described in more detail in later sections of this report.

1.2.1 Ontario Power

The marginal power production in the Province of Ontario has been added to the base GREET model that was obtained from CARB. This model is identified as ca_greet1.8b_dec09_CA_Corn_OilWDGS_01302012.xls.

The average power production in Ontario and the assumed marginal mix is summarized in the following table. The power mix is derived from IEOS, it is updated biannually with the last update Oct 23, 2013. The marginal mix is derived by adding the coal, nuclear and hydro percentages to natural gas. New coal fired electricity production has been effectively banned in Canada as plants will only be approved if the emission intensity is less than 420 kg/MWh, about the same level as an advanced natural gas fired plant. Existing plants will be allowed to continue operation until the end of their economic life. Ontario has an aggressive policy to expand renewable power generation and to exit coal fired power production by 2014.

Table 1-2 Ontario Power Mix

	Average	Marginal
Residual oil	0.0%	0.0%
Natural gas	28.4%	94.7%
Coal	6.6%	0.0%
Nuclear	37.0%	0.0%
Biomass	0.4%	0.4%
Wind	4.9%	4.9%
Hydro	22.7%	0.0%

The look up table on the Regional LT tab has been modified to include an Ontario average and Ontario marginal option. The marginal power production has a higher carbon intensity than the average power production.

Changes to the model inputs on the UCO BD sheet are highlighted with a light orange background. The results are summarized on rows 279 to 287, columns I to N.

2. RENDERING

No changes are made to the rendering stage of the pathway. The rendering energy assumptions are based on the CARB UCO Biodiesel Pathway. The only allocation of energy and emissions in the biodiesel pathway involves an allocation for glycerine production. The glycerine production is 0.105 lb./lb. of biodiesel (cell C39 on the UCO BD sheet).

2.1 ENERGY

The rendering assumptions are for the “with cooking” rendering process. Most of the modelling assumptions are the same as used in the CARB pathway and are:

- Rendering uses 1,073 Btu/lb. UCO,
- 89.77% of the energy is supplied by natural gas,
- 10.23% of the energy is electric power, and

The feedstock to biodiesel ratio has been modelled as 1.00 rather than 1.11, as the BIOX process is able to convert the FFA to biodiesel.

2.2 EMISSIONS

The emissions for the rendering stage are shown in the following table. The only factor that has changed for the proposed pathway is the electric power mix.

Table 2-1 UCO Rendering Emissions

Parameter	Base Case	Ontario
	g/MJ Biodiesel	
VOC	0.0007	0.0006
CO	0.0035	0.0024
CH_4	0.0100	0.0091
N_2O	0.0000	0.0000
CO_2	5.42	4.43
GHG Emissions	5.69	4.67

The total GHG emissions for this stage are lower than the reference pathway due to the different electricity CI for Ontario compared to the Midwest and the improved feedstock conversion ratio.

3. RENDERED UCO TRANSPORT

Generally, the renderer and the biodiesel plant are not co-located and there are transportation emissions associated with moving the feedstock from one site to the other. BIOX have one UCO feedstock supplier close by.

3.1 DISTANCES

In the CARB scenario, the UCO is assumed to be transported 50 miles by HHD truck to the biodiesel plant. The biodiesel is produced outside of California and then transported to California for blending and use there.

For this pathway we have assumed that the UCO is shipped 25 miles by HHD truck to the biodiesel plant in Ontario. BIOX have three suppliers of UCO. Their locations and distances to the BIOX plant are summarized in the following table.

Table 3-1 UCO Suppliers

Supplier	Address	Distance, miles
Rothsay	880 Highway 5 West, Dundas, ON	7.3
Sanimax	800 Parkdale Ave. N, Hamilton, Ontario	3.3
Sil-tri Biofuels	7 Portside, Binbrook, ON	13.7

3.2 EMISSIONS

The emissions for the UCO production stage are shown in the following table. The longer transportation distances result in higher emissions.

Table 3-2 UCO Transport Emissions

Parameter	Base Case	Ontario
	g/MJ	
VOC	0.0002	0.0001
CO	0.0007	0.0002
CH_4	0.0005	0.0001
N_2O	0.0000	0.0000
CO_2	0.45	0.13
GHG Emissions	0.47	0.14

4. BIODIESEL PRODUCTION

The BIOX process utilizes a co-solvent to speed the reaction process. The co-solvent is recycled as part of the process and the net consumption is very low, less than 0.00075 gal/gal biodiesel. The BIOX process can produce biodiesel from free fatty acids as well as from triglycerides.

4.1 ENERGY

The biodiesel energy consumption in the reference pathway is 2,116 BTU/lb. plus 171 BTU/lb. for pre-processing of the high FFA feedstock. This includes the process energy and the energy embedded in the chemicals consumed in the process. The breakdown is shown in the following table.

Table 4-1 Biodiesel Energy Consumption – Reference Case

Component	Value	BTU/lb.
Total	2,116 BTU/lb.	2,116
Natural gas	42.0%	889
Electricity	2.2%	47
Methanol	40.9%	865
Sodium Hydroxide	2.0%	42
Sodium Methoxide	9.9%	209
Hydrochloric acid	3.0%	63

The BIOX process does use higher than normal quantities of natural gas and electric power due to the process design and the fact that the glycerin is upgraded to technical specifications. The quantities of other chemicals, other than the co-solvent are typical for other biodiesel plants. The adjusted GREET model inputs are shown in the following table. There is no provision in the GREET model for additional chemicals to be used but other than methanol the chemicals in the GREET model do not influence the GHG emissions.

The energy consumption is based on data for the period April 1, 2012 to March 31, 2013. During a portion of this period the plant did not operate due to market conditions and the power and energy consumption during this period have been removed from the calculation. The revised biodiesel production energy for modelling is shown in the following table. There is no additional pre-processing energy required for the BIOX process.

Table 4-2 Biodiesel Energy Consumption – BIOX

Component	Value	BTU/lb.
Total	3,131 BTU/lb.	3,131
Natural gas	56.18%	1,759
Electricity	6.16%	193
Methanol	27.63%	865
Sodium Hydroxide	1.34%	42
Sodium Methoxide	6.68%	209
Hydrochloric acid	2.01%	63

The BIOX process also uses a catalyst, [redacted], that is not included in the GREET model. The carbon footprint of this material is reported to be 5.6 kg CO_2eq/kg (Delft

University of Technology). At the consumption rate of 0.000745 gal [redacted]/gal of biodiesel this increases the emissions of BIOX biodiesel by 0.11 g CO_2eq/MJ. This value has been added to the emissions calculated by the GREET model.

One of the advantages of the BIOX process is higher yield of methyl esters. The feedstock requirement for the reference case is 1.11 lb. of feedstock per lb. of biodiesel produced. The BIOX requirements are 1.0 lb./lb. of feedstock.

4.2 EMISSIONS

The emissions for this stage of the lifecycle are shown in the following table.

Table 4-3 Biodiesel Production Emissions

Parameter	Base Case	Ontario
	g/MJ	
VOC	0.0018	0.0023
CO	0.0044	0.0059
CH_4	0.0179	0.0258
N_2O	0.0000	0.0001
CO_2	5.59	9.07
GHG Emissions	6.06	9.75
GHG Emissions (Plus THF)	6.06	9.86

5. BIODIESEL TRANSPORTATION AND DISTRIBUTION

5.1 DISTANCES

In the CARB reference case, biodiesel is transported 1,400 miles by rail to blending stations, then 90 miles by HDDT (100%) to refueling stations.

For this pathway the rail distance is increased to 2,500 miles, the distance from Hamilton, Ontario to Los Angeles. 80% of the Biodiesel is transported by heavy duty truck 50 miles from the plant to bulk terminals; the remaining 20% is distributed directly from the plant. All BD is then transported 90 miles by heavy duty truck from the bulk terminal to refueling stations.

5.2 EMISSIONS

The emissions for this stage are shown in the following table for the reference case and the BIOX case.

Table 5-1 Biodiesel Transportation Emissions

Parameter	Base Case	Ontario
	g/MJ	
VOC	0.0012	0.0032
CO	0.0045	0.0076
CH_4	0.0021	0.0036
N_2O	0.0000	0.0001
CO_2	1.88	3.17
GHG Emissions	1.95	3.30

6. Vehicle Operation

The final stage of the lifecycle is the use stage. In the CARB framework, the fossil carbon that was in the methanol is oxidized when the fuel is combusted and is accounted for when the biodiesel is burned.

6.1 Emissions

The vehicle operation emissions are the same for all biodiesels. These emissions are 4.48 g CO_2eq/MJ.

7. SUMMARY

The GHG emissions for each stage of the lifecycle for the reference case and for the BIOX case are summarized in the following table.

Table 7-1 Lifecycle GHG Emissions

Parameter	Base Case	Ontario
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UCO Transport	0.30	0.14
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The BIOX pathway emissions are about 20% higher than the reference case due to the increased transportation distances for the product and higher energy use in the plant. These are partially offset by the lower CI of the electric power in Ontario compared to the US Midwest and the shorter feedstock transportation distance.

8. References

CARB. 2011. Detailed California Modified GREET Pathway for Biodiesel Produced in the Midwest from Used Cooking Oil and Used in California. http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/15day-mw-uco-bd-rpt-022112.pdf

Delft University of Technology. 2014. The Model of the Eco-costs / Value Ratio (EVR). http://www.ecocostsvalue.com/EVR/img/Ecocosts2012_LCA_data_on_products_and_services_EI_V2-2%2BIdemat2012.xlsx

IEOS. Ontario Power Mix. http://www.ieso.ca/imoweb/media/md_supply.asp accessed Feb 6, 2014.

9. APPENDIX 1 - GREET MODEL CHANGES

Parameters	Cell Locations	Original GREET values	Company values	Note
Electric Power	C83-Regional LT	2.7%	0.0%	Ontario Marginal Power
	C84-Regional LT	18.9%	94.7%	
	C85-Regional LT	50.7%	0.0%	
	C86-Regional LT	18.7%	0.0%	
	C87-Regional LT	1.3%	0.0%	
	C88-Regional LT	7.7%	4.9%	
UCO transport	IH93-T&D	50	25	Transportation distance
Biodiesel Transportation (100% Rail Pathway)	AC 1388-T&D Flowchart	1200	0	
Total Energy	B13-UCO BD	2,116	3,131	BD Processing Energy
Yield	B21-UCO BD	1.11	1.00	
NG	F174-UCO BD	42.0%	56.2%	
Power	F177-UCO BD	2.2%	6.2%	
Methanol	F179-UCO BD	40.9%	27.6%	
Sodium Hydroxide	F180-UCO BD	2.0%	1.3%	
Sodium Methylate	F181-UCO BD	9.9%	6.7%	
Hydrochloric acid	F182-UCO BD	3.0%	2.0%	
Rail Transport	F1394-T&D Flowchart	1400	2500	BD Transport
HD Truck Transport	F1398-T&D Flowchart	50	50	
HD Truck Transport	M1390-T&D Flowchart	90	90	