CARB METHOD 2 FUEL PATHWAY REPORT

CANOLA OIL BIODIESEL

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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 – Canola Biodiesel

Parameter	Base Case	Ontario
	g/MJ	
Canola farming	2.08	1.94
Ag Chemical production	4.87	4.59
N_2O emissions from fertilizer	9.47	9.27
Canola Transport	0.49	0.48
Canola oil extraction	2.65	2.37
Canola oil transportation	1.18	0.03
Biodiesel production	5.20	9.86
Biodiesel transport	1.54	3.30
Total Tank to Wheel	27.48	31.84
Vehicle Operation	4.45	4.48
Total	31.93	36.32

The BIOX pathway emissions are about 14% higher than the reference case due to the increased transportation distances for the feedstock, as well as 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 average and the higher process yield.

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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.

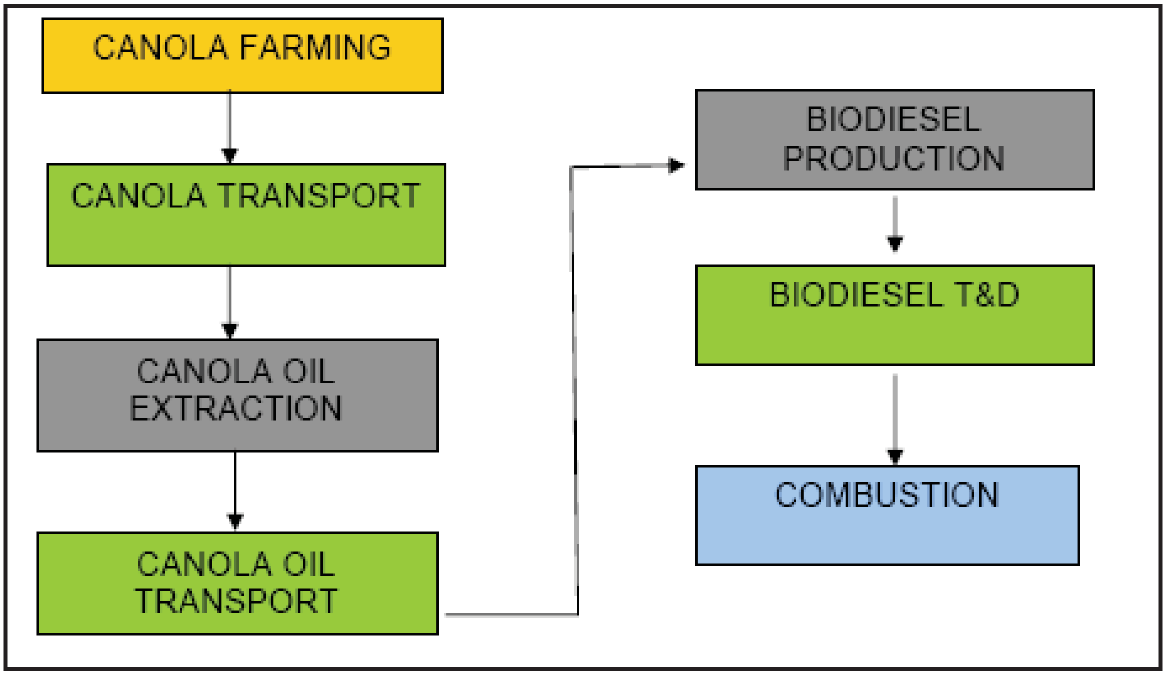
Fuel providers may use one of two methods to determine the carbon intensities of the transportation fuels they provide to the California market. Under Method 1, fuel providers select carbon intensity values from the fuel carbon intensity lookup table found in the LCFS Regulation. Under Method 2, any 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 canola oil to biodiesel pathway in December 2010. The hearing date for this pathway has not yet been scheduled. The components of the pathway are shown in the following figure.

Figure 1-1 Canola Oil Biodiesel Discrete Components



The scenario CARB modelled assumes that the farming and the oil extraction are to be done in Canada and the oil shipped to the U.S. facilities for biodiesel production and shipping to California. The calculated well to wheel emissions for the cooking process are shown in the following table.

Table 1-1 Lifecycle CI Results for Canola Oil Biodiesel – US Production

Stage	Emissions, g CO_2eq/MJ
Canola farming	2.08
Ag Chemical production	4.87
N_2O emissions from fertilizer	9.47
Canola Transport	0.49
Canola oil extraction	2.65
Canola oil transportation	1.18
Biodiesel production	5.20
Biodiesel transport	1.54
Total Tank to Wheel	27.48
Vehicle Operation	4.45
Total	31.93

The version of GREET that has been used for this work, ca_greet1.8b_dec09_v2_Canola_BD_Dec14_2010.xlsm, was able to duplicate these results with two small exceptions that increase the emissions by 0.06 g/MJ (N_2O emissions and biodiesel transport).

1.2 Modified Pathway Description

The modified pathway that is covered by this application is for an identical concept except that the canola growing, extraction, and 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_v2_Canola_BD_Dec14_2010.xlsm.

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. Canola Farming

The canola farming will take place in Canada rather than the US Midwest. All of the other input parameters are the same as the reference case. While Ontario is outside of the main canola growing region of Canada and the United States, there is some canola produced in Ontario (Statistics Canada). There is sufficient Ontario canola oil to meet BIOX's needs.

2.1 Energy

The breakdown of energy use for canola farming is shown in the following table.

Table 2-1 Canola Farming Energy

Fuel	Direct Energy Use
Diesel (Btu/bushel)	15,763
Electricity (Btu/bushel)	1,419
Total Energy Use (Btu/bushel)	17,182

2.2 Emissions

The base case emissions were calculated using the US average electricity mix. The Ontario case uses the Ontario marginal power data and benefits from the better yield with the BIOX process.

Table 2-2 Canola Farming Emissions

Parameter	Base Case	Ontario
	g/MJ Biodiesel	
VOC	0.0020	0.0020
CO	0.0078	0.0074
CH_4	0.0024	0.0025
N_2O	0.0000	0.0000
CO_2	1.99	1.85
GHG Emissions	2.08	1.84

The farming emissions are slightly lower in Ontario than they are in the US.

3. AGRICULTURAL CHEMICALS PRODUCTION

The production of fertilizers and pesticides requires energy and produces GHG emissions.

3.1 MATERIALS

The materials used in canola farming are summarized in the following table. It is assumed that it is the same in Ontario.

Table 3-1 Energy Associated with Agricultural Chemicals

Product	Product Use Rate g/bu	Total Production Energy Btu/g	Total Energy Consumption Btu/bu
Nitrogen	1,136.9	45.84	52,117
Phosphate (P_2O_5)	303.19	13.31	4,035
Potash (K_2O)	227.39	8.42	1,914
Herbicides	5.18	273.26	1,417
Pesticides	1.35	312.43	422
Total Energy Consumption due to Production of Ag. Chemicals used in Farming			59,904

3.2 EMISSIONS

The GHG emissions from the production of these chemicals are shown in the following table. The US average power data is used again to generate the base case emissions. The Ontario emissions are calculated using the Ontario marginal power.

Table 3-2 Ag Chemical Production Emissions

Parameter	Base Case	Ontario
	g/MJ Biodiesel	
VOC	0.0081	0.0079
CO	0.0084	0.0078
CH_4	0.0036	0.0025
N_2O	0.0021	0.0021
CO_2	4.11	3.84
GHG Emissions	4.87	4.59

The emissions are slightly lower due to the different electric power carbon intensity and higher yield.

4. N_2O EMISSIONS

N_2O emissions are created during the decomposition of synthetic fertilizers, manure, and crop residues.

The N_2O emissions are a function of the crop, the fertilizer rate and the N_2O emission factor. None of these parameters change between the reference case and the Ontario case. The different biodiesel yield does have an impact. There is a small discrepancy between the canola GREET model and the reported values. The model calculates N_2O emissions as 9.50 g/MJ, whereas the reported value in the pathway document is 9.48. We show the model value in the following table since we use the model to also calculate the canola value for Ontario.

Table 4-1 N_2O Emissions

Parameter	Base Case	Ontario
	g/MJ Biodiesel	
VOC	0.0000	0.0000
CO	0.0000	0.0000
CH_4	0.0000	0.0000
N_2O	0.0319	0.0311
CO_2	0.00	0.00
GHG Emissions	9.50	9.27

5. CANOLA TRANSPORT

In the reference case, the canola was transported 10 miles from the field to the stacks and then 40 miles to the crushing plant. The same parameters are used for the BIOX case.

5.1 ENERGY

The distances used for modelling are shown in the following table.

Table 5-1 Canola Transportation Distances

	Distance
Medium Duty truck, field to stack	10 miles
Heavy Duty Truck. Stack to crusher	40 miles

5.2 EMISSIONS

The emissions associated with the transport of canola are shown in the following table. There is only a small difference in the emissions for the two cases resulting from the different biodiesel yield.

Table 5-2 Canola Transport Emissions

Parameter	Base Case	Ontario
	g/MJ Biodiesel	
VOC	0.0002	0.0002
CO	0.0008	0.0008
CH_4	0.0005	0.0005
N_2O	0.0000	0.0000
CO_2	0.47	0.46
GHG Emissions	0.49	0.48

6. CANOLA OIL EXTRACTION

Once the canola has arrived at a canola oil extraction facility, the oil needs to be extracted from the seeds. The U.S. average electricity mix is assumed for canola oil extraction in the base case.

6.1 ENERGY

The reference case energy consumption data is also used for the BIOX case. The model data is shown in the following table.

Table 6-1 Canola Oil Extraction Energy

Fuel	Fuel Shares	BTU/lb. canola oil
Natural gas	82.10	1,006
Electricity	14.50	178
Hexane	3.40	42
Total		1,226

The feedstock to biodiesel ratio has been modelled as 1.00 rather than 1.026 as the BIOX process is able to convert the FFA to biodiesel.

6.2 EMISSIONS

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

Table 6-2 Canola Oil Extraction Emissions

Parameter	Base Case	Ontario
	g/MJ Biodiesel	
VOC	0.0003	0.0003
CO	0.0017	0.0012
CH_4	0.0045	0.0047
N_2O	0.0000	0.0000
CO_2	2.53	2.24
GHG Emissions	2.65	2.37

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

7. Canola Oil Transport

Generally, the oil extraction facility and the biodiesel plant are not co-located and there are transportation emissions associated with moving the feedstock from one site to the other. In the BIOX case the plants are located very close to each other (one mile apart).

7.1 Distances

In the CARB scenario, the canola oil is assumed to be transported 1200 miles by rail to the biodiesel plant. The biodiesel is produced outside of California and then transported to California for blending and use there.

The BIOX plant is actually less than one mile from a Bunge oilseed crushing facility (515 Victoria Avenue North, Hamilton, ON L8N 3K7, Canada) which supplies vegetable oils to BIOX. For this pathway we have assumed that the canola oil is shipped 5 miles by HHD truck to the biodiesel plant in Ontario.

7.2 Emissions

The emissions for the canola oil transportation stage are shown in the following table. The shorter transportation distances result in lower emissions.

Table 7-1 Canola Oil Transport Emissions

Parameter	Base Case	Ontario
	g/MJ	
VOC	0.0008	0.0000
CO	0.0029	0.0000
CH_4	0.0013	0.0000
N_2O	0.0000	0.0000
CO_2	1.13	0.03
GHG Emissions	1.17	0.03

8. BIODIESEL PRODUCTION

In the reference pathway the biodiesel is produced outside of California. 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.

8.1 ENERGY

The biodiesel energy consumption in the reference pathway is 2,116 BTU/lb. 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 8-1 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 8-2 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 1.026 lb. of feedstock per lb. of biodiesel produced. The BIOX requirements are 1.0 lb./lb. of feedstock.

8.2 Emissions

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

Table 8-3 Biodiesel Production Emissions

Parameter	Base Case	Ontario
	g/MJ	
VOC	0.0017	0.0023
CO	0.0038	0.0059
CH_4	0.0164	0.0258
N_2O	0.0000	0.0001
CO_2	4.77	9.07
GHG Emissions	5.20	9.75
GHG Emissions (plus THF)	5.20	9.86

9. BIODIESEL TRANSPORTATION AND DISTRIBUTION

9.1 DISTANCES

In the CARB reference case, biodiesel is assumed to travel 800 miles by rail from a BD plant outside of California to a railyard in California. It is assumed that 80% of the BD is transported by heavy duty truck 50 miles from the railyard to a bulk terminal; the remaining 20% is stored in a bulk terminal next to the railyard, and distributed directly. The BD is then transported 90 miles by heavy duty truck from the bulk terminal 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.

9.2 EMISSIONS

The emissions for this stage are shown in the following table for the reference case and the BIOX case. Note that in the appendices to the CARB canola report these emissions are calculated as 1.57 but on the summary table they are 1.54 g/MJ.

Table 9-1 Biodiesel Transportation Emissions

Parameter	Base Case	Ontario
	g/MJ	
VOC	0.0019	0.0032
CO	0.0034	0.0076
CH_4	0.0017	0.0036
N_2O	0.0000	0.0001
CO_2	1.50	3.17
GHG Emissions	1.57	3.30

10. Combustion

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.

10.1 Emissions

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

11. 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 11-1 Lifecycle GHG Emissions

Parameter	Base Case	Ontario
	g/MJ	
Canola farming	2.08	1.94
Ag Chemical production	4.87	4.59
N_2O emissions from fertilizer	9.47	9.27
Canola Transport	0.49	0.48
Canola oil extraction	2.65	2.37
Canola oil transportation	1.18	0.03
Biodiesel production	5.20	9.86
Biodiesel transport	1.54	3.30
Total Tank to Wheel	27.48	31.84
Vehicle Operation	4.45	4.48
Total	31.93	36.32

The BIOX pathway emissions are about 14% higher than the reference case due to the increased transportation distances for the feedstock, as well as 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 average.

12. REFERENCES

CARB. 2010. Detailed California-Modified GREET Pathway for Conversion of North American Canola to Biodiesel (Fatty Acid Methyl Esters-FAME). http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/121410lcfs-canola-bd.pdf

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13. 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%	
Canola oil transport	GB93-T&D	0	5	Transportation distance
Canola oil Transportation (100% Rail Pathway)	AC 1388-T&D Flowchart	1200	0	
Total Energy	C12- BD	2,116	3,131	BD Processing Energy
Yield	C19- BD	1.11	1.00	
NG	AZ172- BD	42.0%	56.2%	
Power	AZ175- BD	2.2%	6.2%	
Methanol	AZ177- BD	40.9%	27.6%	
Sodium Hydroxide	AZ178- BD	2.0%	1.3%	
Sodium Methylate	AZ179- BD	9.9%	6.7%	
Hydrochloric acid	AZ180- BD	3.0%	2.0%	
Rail Transport	F1394-T&D Flowchart	1400	2500	BD Transport
HD Truck Transport	F1397-T&D Flowchart	50	50	
HD Truck Transport	M1390-T&D Flowchart	90	90	