September 17, 2014

Method 2 Application:
Camelina Sativa Feedstock Pathway
Life-Cycle Analysis Report

CAMELINA FEEDSTOCK PATHWAY DESCRIPTION

[redacted]

[redacted]

[redacted]

Executive Summary

This report summarizes details for a feedstock-only pathway for camelina oil for use as a biofuels feedstock under the California Low Carbon Fuel Standard (LCFS). CA-GREET was used to model the feedstock's direct emissions.

1 Introduction

As part of the Low Carbon Fuels Standard (LCFS), the California Air Resources Board (CARB) modeled the carbon intensities associated with several common fuel pathways, including soybean oil, canola oil and used cooking oil, as well as others. They also modeled several renewable diesel pathways. As a general approach, however, CARB did not model any fuel pathways based on novel or limited-volume feedstock like camelina sativa ("camelina").

Sustainable Oils has filed a Method 2B application for the recognition of its proprietary camelina feedstock for use as an input into biodiesel and renewable diesel produced both in California and out-of-state. This report details the production system and carbon intensity results associated with the production of camelina feedstock for conversion into biofuels.

2 Feedstock Summary

Camelina produces oil bearing seeds, which contain approximately 38 percent oil. The oil is high in omega-3 fatty acids and polyunsaturated fats. It also contains high levels of gamma tocopherol (Vitamin E), an antioxidant that stabilizes the oil and benefits the nutritional profile of the meal.

Native to Central Europe and the Mediterranean, with both annual and winter annual biotypes, camelina has been grown in Europe for centuries with evidence of cultivation dating back as early as 600 BC. Camelina oil was utilized for cooking and fuel oil and the meal was utilized for livestock feed. Production of camelina in Europe declined as rapeseed production increased, but scattered areas remain.

Very little classic breeding and genetic research has been performed on camelina. The limited quantity of cultivated acreage in other parts of the world is planted primarily with seeds sourced from wild-type accessions, which produce inconsistent yields. However, in the past several years modern breeding and plant science research focused on camelina has been conducted in the U.S. and Canada. This has led to elite varieties being developed, which exhibit consistent characteristics and significant yield improvement. The advancements in camelina genetics and agronomics have paved the way for it to be a preferred, novel and low-carbon intensity feedstock for the production of biofuels.

Camelina plants are heavily branched, growing to heights of one (1) to three (3) feet. They become woody as they mature and have little biomass versus the seed head. It is a short-seasoned (100 day) crop, best adapted to cooler climates where excessive heat during flowering does not occur. Future varieties currently in field trials are expected to: mature in as few as 85 days, produce increased yields and exhibit greater agronomic adaptability. A member of the mustard family, the plants produce prolific small, pale-yellow or greenish-yellow flowers consisting of four petals. Seed pods are approximately ¼-inch long with each pod containing roughly 10 small seeds. Wild-type seeds are very small (<1/16 inch), yellow-brown, oblong, and rough with a ridged surface. Modern breeding has resulted in elite varieties with seed size 20 percent greater than wild-types. Oil content of the seed is relatively high, typically around 38 percent on a dry matter basis. Its drought and spring freezing tolerance make it a good fit for areas with cool temperatures.

When integrated into dryland wheat farming systems, camelina's lifecycle is complete a few weeks sooner than spring and winter wheat and, as a result, does not impact planting. It matures on the stem and can be directly harvested with a standard combine as either a "straight-cut" or "swath/windrow" process. Existing wheat harvesting machinery can be used to direct harvest the seed without requiring any major adjustments.

In 2007, Sustainable Oils and its biotechnology parent organization commenced concentrated research efforts to develop high-yielding, elite varieties of camelina, uniquely adapted to several targeted growing regions, including the Midwestern U.S., the Pacific Northwest and California.

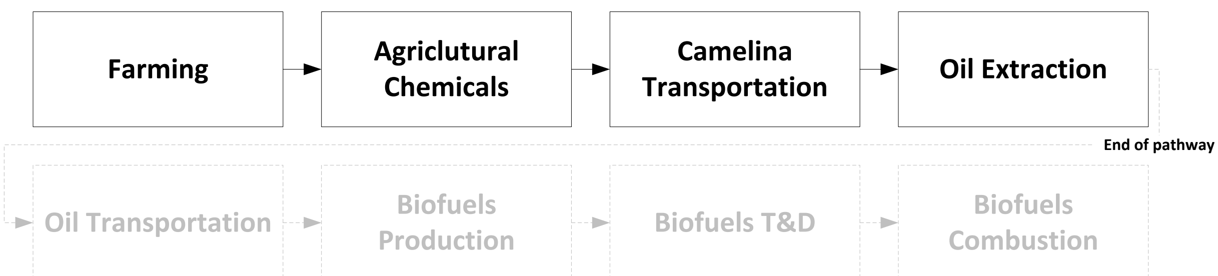
After extensive laboratory work, field trials and commercial trials, in 2010 Sustainable Oils was issued the only three patents to date on camelina seeds by the United States Patent and Trademark Office (USPTO). The patented varieties produce superior yield, greater consistency and better overall agronomic performance than wild-type accessions. In addition to the existing patents, Sustainable Oils has three more varieties that are pending submittal for patent, which will produce shorter gestation periods, greater yield and increased seed size.

2.1 Reference System

CARB has established several oilseed pathways, including soybean oil and canola oil. This pathway uses values from both existing oilseed pathways, as well as data from Argonne GREET 2013 and proprietary data from Sustainable Oils to produce a complete feedstock-only pathway.

2.2 Systems Boundaries

Certain stages from existing fuel pathways approved by CARB for biodiesel and renewable diesel were used as models for an equivalent camelina pathway. The feedstock-only camelina pathway includes the following discreet components.



3 Camelina Production

Camelina farming within the United States and Canada has been concentrated on idle acreage in various winter/fallow/spring wheat rotations, on land under other broadleaf cropping systems and on underutilized agricultural land during periods where other cash crops are not viable. Its agronomic attributes allow it to be grown in areas that are unsuitable for other major oilseed crops, such as soybean, sunflower and canola/rapeseed.

Camelina can also be used to break the continuous planting cycle of certain grains, effectively reducing the disease, insect and weed pressures in fields planted with grains (like wheat) during the following year. In the absence of other cash crop options, certain acreage is placed into a fallow rotation every third or fourth year to break pest cycles and to allow the land to be replenished to needed moisture and fertility levels. Normally fallowed land requires noxious and invasive weeds to be controlled – typically with chemical herbicides. As an alternative, many farmers plant a low-input cover crop to protect the land from erosion and moisture loss, and to improve soil tilth and break weed/pest growth cycles. These cover crops are tilled under or killed with herbicides to prepare for the next crop planting. Providing a cash crop option—camelina—as a low-input and short-season crop, allows for planting and harvesting without sacrificing the agronomic benefit of the fallow rotation. Camelina utilizes the same equipment used for harvesting wheat; therefore, farmers do not need to invest in new equipment to add camelina to the rotation with wheat.

3.1 Energy

The energy use profile for camelina cultivation is shown below. Because camelina is grown as a non-primary rotation crop, direct electricity consumption is negligible. Data shown represents liquid fuel use associated with camelina cultivation.

Table 3-1 Camelina Cultivation Energy

Fuel type	Direct energy use
Diesel (Btu/kg)	[redacted]
Electricity	[redacted]
Total Energy Use (Btu/mmBtu)	[redacted]

3.2 Emissions

The emissions associated with camelina farming were calculated using the U.S. average electricity mix.

Table 3-2 Camelina Cultivation Emissions

Parameter	Emissions (g/MJ)
VOC	[redacted]
CO	[redacted]
CH_4	[redacted]
N_2O	[redacted]
CO_2	[redacted]
Total Emissions (adjusted and allocated)	[redacted]

4 Agricultural Chemicals Production

Camelina is classified as a low-input, fast-growing crop. While cultivation requires the use of certain agrochemicals and fertilizers in order to maximize productivity, the quantities of these chemicals is significantly lower than with other crops, further reducing the energy and emissions associated with overall farming activities.

4.1 Products

The products used in camelina farming are summarized in the table below.

Table 4-1 Energy Associated with Agricultural Chemicals

Product	Product Use Rate (g/kg)	Total Energy Consumption (Btu/kg)
Nitrogen (N)	[redacted]	[redacted]
Phosphate (K_2O)	[redacted]	[redacted]

Potash (P_2O_5)	[redacted]	[redacted]
Total Energy (Btu/mmBtu, adjusted and allocated)		[redacted]

4.2 Emissions

Emissions associated with the production of agricultural chemicals are detailed in the following table. The emissions are calculated using CA-GREET.

Table 4-2 Ag Chemical Production Emissions

Parameter	Total Emissions (g/MJ biodiesel)
VOC	[redacted]
CO	[redacted]
CH_4	[redacted]
N_2O	[redacted]
CO_2	[redacted]
Total Emissions (adjusted and allocated)	[redacted]

4.3 N_2O Emissions

Nitrous oxide is produced from the use of nitrogen fertilizer input. Associated emissions result from decomposition of synthetic fertilizer, fixed nitrogen in the soil, manure and crop residues.

N_2O emissions are proportional to the quantity of fertilizer and associated emissions factor.

Table 4-3 N_2O Emissions

Emissions Type	Total Emissions
GHG emissions (gCO_2e/mmBtu)	[redacted]
Total emissions (adjusted and allocated, gCO_2e/mmBtu)	[redacted]
Total emissions (adjusted and allocated, gCO_2e/MJ)	[redacted]

5 Camelina Transport

Camelina is assumed to have a transportation profile identical to the soybean reference case in CA-GREET. Once harvested, grain is transported 10 miles in a medium-duty truck from the field to an elevator and then 40 miles in a heavy-duty truck to an extraction facility.

5.1 Energy

The distances modeled for transportation are detailed in the following table.

Table 5-1 Camelina Transportation Distances

Mode	Distance[1]
Medium-Duty Truck (MHDDT) – field to	10 miles

[1] CARB Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Biodiesel. Pg. 28, Table 2.01Transport Parameters and Energy Use Details for Soybean Transport

elevator	
Heavy-Duty Truck (HHDDT) – elevator to crush	40 miles

5.2 Emissions

Emissions resulting from the transportation of camelina grain to an elevator and extraction facility are detailed in the following table.

Table 5-2 Camelina Transport Emissions

Parameter	Total Emissions (g/MJ)
VOC	[redacted]
CO	[redacted]
CH_4	[redacted]
N_2O	[redacted]
CO_2	[redacted]
Total Emissions (adjusted and allocated)	[redacted]

6 Camelina Oil Extraction

Camelina is transported from a grain elevator to an oil extraction facility. For this pathway it is assumed camelina oil is extracted in an identical fashion to that of other oilseeds like soybean and canola. Default values from the canola CA-GREET pathway were used to compute associated Energy and Emissions, which are detailed in the tables below.

6.1 Energy

Camelina oil extraction is done in an identical fashion to that of other oilseeds like canola and soybean. Seeds are pretreated and prepared for extraction using an industry standard process. The following table captures the inputs used during the extraction phase for camelina and is calculated using CA-GREET input parameters and camelina production system data.

Table 6-1 Camelina Oil Extraction Energy

Fuel Type	Energy (Btu/lb oil)
Diesel	[redacted]
Natural gas	[redacted]
Electricity	[redacted]
Hexane	[redacted]
Total energy	[redacted]

6.2 Emissions

The emissions associated with operating a commercial oilseed extraction facility are detailed in the table below. Inputs parameters were based on canola CA-GREET values adapted for camelina oil processing.

Table 6-2 Camelina Oil Extraction Emissions

Emissions Type	Total Emissions (g/MJ)
VOC	[redacted]
CO	[redacted]
CH_4	[redacted]
N_2O	[redacted]
CO_2	[redacted]
Total Emissions	[redacted]

7 Pathway Summary

The GHG emissions for each stage of production for both camelina oil-based biodiesel and renewable diesel are outline in the following tables.

Table 7-1 Lifecycle GHG Emissions – Camelina Feedstock

Production Stage	Total Emissions (gCO_2e/MJ)
Farming	[redacted]
Ag. Chemicals production	[redacted]
N_2O Emissions from fertilizer use	[redacted]
Transportation	[redacted]
Extraction	[redacted]
Total Feedstock-only CI	**7.58**

8 Pathway Compliance

This pathway covers biodiesel and renewable diesel that is produced in accordance with the parameters referenced in this report. The model utilizes agronomic input factors and yield data specific to Sustainable Oils' USPTO-protected varieties. As a result, this pathway is restricted to camelina-based biofuels produced from Sustainable Oils' patented camelina varieties that produce more consistent, superior yields. In order to produce fuels consistent with this pathway, fuel producers and obligated parties must maintain basic chain of custody documentation verifying that camelina-based biodiesel or renewable diesel was produced from pathway-compliant seeds.

9 Camelina and Sustainable Oils

Sustainable Oils was established by a leading biotechnology company and renewable fuels producer. Sustainable Oils is the world leader in camelina development and commercialization and holds the only patents for elite, high-yielding varieties. All other camelina available to growers and processors are wild-type accessions that produce inconsistent yields and are not specifically adapted to unique agronomic conditions. Currently, Sustainable Oils holds three USPTO-registered patents on elite camelina varieties developed using proprietary breeding technology. Three additional varieties have been developed, undergone field and commercial trials and are awaiting patent submittal, which is expected in 2014. Since 2008, its proprietary varieties have been used to grow over 40,000 domestic acres of camelina, and the resulting oil has been used in the production of biodiesel, renewable diesel and renewable jet fuel. In 2011, in fulfillment of a U.S. Department of Defense contract, Sustainable Oils provided camelina oil-based renewable jet fuel to the U.S. military that resulted in 27 tactical aircrafts being officially certified to utilize biofuels.

15 Summary of Camelina CA-GREET Inputs

Cell Location			Value	Source
Tab	Column	Row		
Inputs	E	323	[redacted]	Shonnard, David R., et. al, June, 2010, Camelina-Derived Jet Fuel and Diesel: Sustained Advanced Biofuels, Environmental Progress & Sustainable Energy (Vol. 29, No. 3).
Inputs	E	325	[redacted]	Shonnard, David R., et. al, June, 2010, Camelina-Derived Jet Fuel and Diesel: Sustained Advanced Biofuels, Environmental Progress & Sustainable Energy (Vol. 29, No. 3).
Inputs	E	326	[redacted]	Shonnard, David R., et. al, June, 2010, Camelina-Derived Jet Fuel and Diesel: Sustained Advanced Biofuels, Environmental Progress & Sustainable Energy (Vol. 29, No. 3).
Inputs	E	327	[redacted]	Shonnard, David R., et. al, June, 2010, Camelina-Derived Jet Fuel and Diesel: Sustained Advanced Biofuels, Environmental Progress & Sustainable Energy (Vol. 29, No. 3).
Inputs	I	323	[redacted]	Sustainable Oils
BD	G	130	[redacted]	GREET1_2013.xlsm 'BioOil F217'
BD	G	131	[redacted]	GREET1_2013.xlsm 'BioOil F218'
BD	D	49	1.0	GREET1_2013.xlsm 'BioOil E102'
BD	D	11	1,226	121410lcfs-canola-db-rpt.pdt Table A-19
BD	AO	170	100%	GREET1_2013.xlsm 'BioOil AX247'
BD	AX	170	32.1%	GREET1_2013.xlsm 'BioOil BF247'
BD	AX	172	58.6%	GREET1_2013.xlsm 'BioOil BF249'
BD	AX	175	4.2%	GREET1_2013.xlsm 'BioOil BF452'
BD	AX	176	5.1%	GREET1_2013.xlsm 'BioOil BF253'