Renewable Fuels Agency

Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation

Technical Guidance Part Two Carbon Reporting – Default Values and Fuel Chains

Office of the Renewable Fuels Agency

V1.2

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Change History

Version No	Date Issued	Details
v1.0	11th January 2008	
v1.1	25th January 2008	Corrections identified in Addendum 001 - sugarcane ethanol fuel chain summary table - oilseed rape to ME biodiesel fuel chain summary table - oilseed rape to HVO biodiesel fuel chain summary table
v1.2	1st April 2008	Corrections made to the following sections, identified in Addendum 002: - General Default values - Sugar beet to ethanol - Molasses to Ethanol - Oilseed rape to ME biodiesel - Palm to ME biodiesel - Used cooking oil and tallow to ME biodiesel - Soy to HVO biodiesel - Palm to HVO biodiesel - Ethanol to ETBE - Manure and organic solid waste to biomethane

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1 Introduction

This document provides detailed information on the process for calculating the carbon intensity of a batch of biofuel for the purposes of carbon and sustainability (C&S) reporting under the RTFO. It is intended as supplementary guidance to part one of the document. It can be used by parties who wish to carry out more detailed calculations (and who do not wish to rely upon the high level default values supplied in Part 1 of the Guidance.

This part of the document provides guidance on how to calculate a known carbon intensity using the following information collected about the biofuel production activities:

- Use of qualitative information to calculate a carbon intensity (Chapter 2);
- Use of actual quantitative data (Chapter 3) to:
  - Edit pre-defined (default) fuel chains
  - Make adjustments to the structure of existing fuel chains
  - Construct a new fuel chain.

This document provides detailed information on each of the key fuel chains.

2 Using qualitative information to calculate a known carbon intensity

A number of selected "default values" have been defined to enable transport fuel suppliers to use qualitative data to calculate a "known" carbon intensity for their biofuels. This document contains the default values for each of a number of fuel chains. For certain sources of GHG emissions qualitative information can be used to characterise different ways of producing the biofuel – for example the mode of transport (truck, ship, rail etc) or the fuel used in a biofuel plant (coal, natural gas, fuel oil etc). When companies have qualitative evidence to demonstrate that a batch of fuel is produced in a certain way they can use the appropriate selected default value.

What selected defaults are available?

Selected defaults are available to transport fuel suppliers to allow them to change the following parameters within their calculations:

- Type of nitrogen fertiliser. This selected default can be used to calculate emissions from crop production
- Type of phosphorus fertiliser. This selected default can be used to calculate emissions from crop production
- Transport mode (e.g. truck, ship, rail etc). This selected default can be used to calculate emissions from transport of any type of product
- Type of fuel used to provide heat (e.g. diesel, coal, heavy fuel oil, natural gas etc)
- This selected default can be used to calculate emissions in the following processes
- Drying of crops (drying and storage)
- Oil crop crushing plants (conversion)
- Biofuel plants (conversion).

How are selected defaults used?

Each default fuel chain includes a “selected default options” table which summarises the selected defaults available for that particular fuel chain. To make use of a selected default value as outlined in section 3 below:

- Select the option desired
- Follow the procedures outlined in the following section (Chapter 3) to establish the known carbon intensity of the batch of fuel.

3 Editing pre-defined fuel chains with actual data

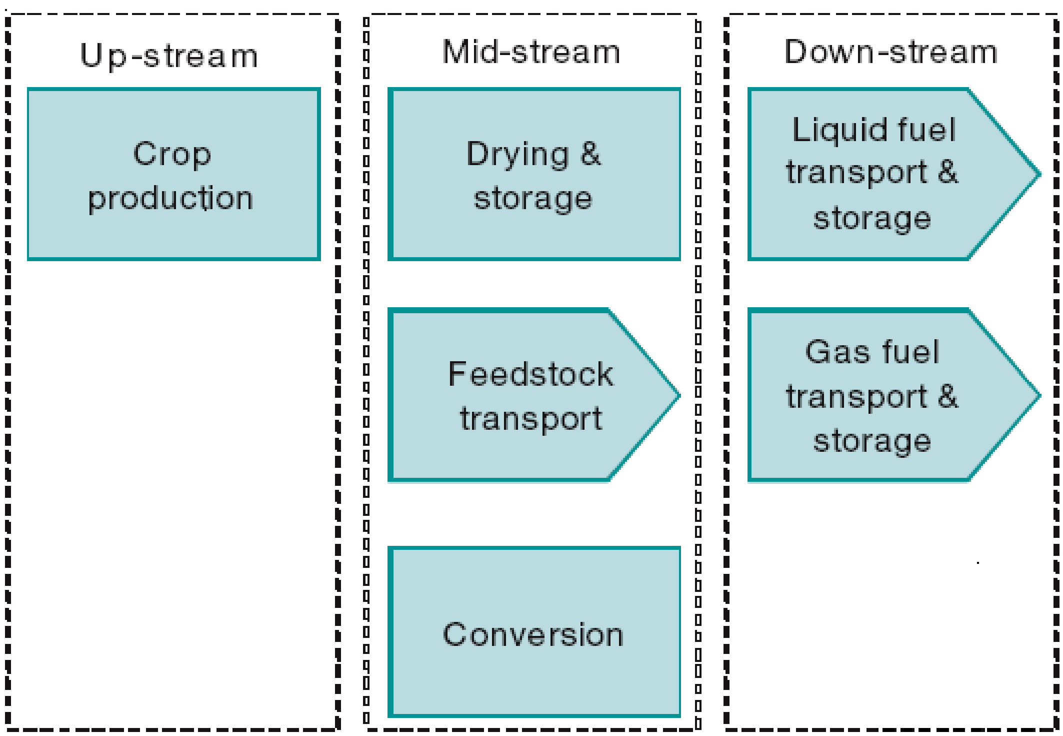
This section describes how to use actual quantitative data and selected default values to calculate a carbon intensity by editing an existing fuel chain. It does not describe how to make changes to the structure of the fuel chains (e.g. add new conversion or transport steps).

NOTE: An existing default fuel chain can only be edited when both the type of feedstock and its origin are known.

Structure of default fuel chains

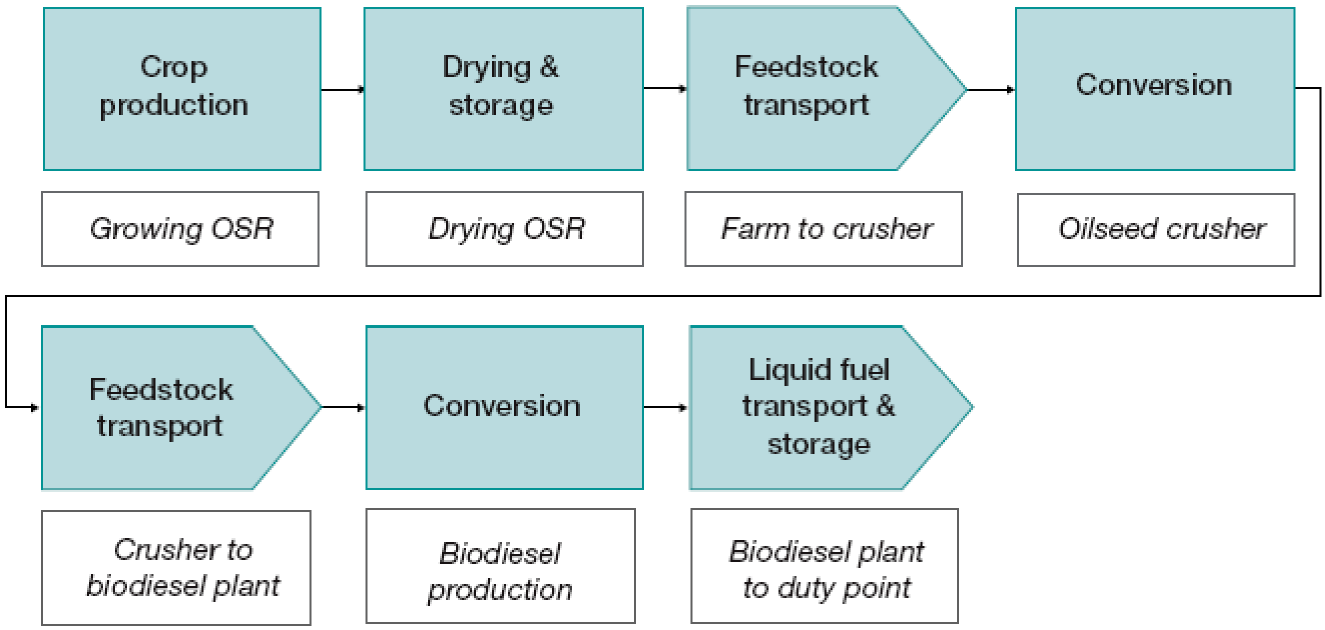
The fuel chains given later in this document are constructed by arranging common "modules" into a series of sequential stages. Figure 1 shows the common modules which make up every fuel chain and Figure 5-3 illustrates how they are arranged into a fuel chain.

Figure 1 Modules used to define a biofuel fuel chain



Module Name	**Description**
Crop production	Growing a biofuel feedstock (e.g. palm, wheat, soy etc)
Drying & storage	Drying and storage of biofuel feedstocks (where this is done outside of a biofuel conversion plant)
Feedstock transport	Transport of a biofuel feedstock (e.g. from a farm to a biofuel conversion plant)
Conversion	Any process which changes the physical nature of a feedstock or a biofuel (e.g. oilseed crushing, fermentation etc). The process will typically also result in the production of co-products (e.g. soy meal).
Liquid fuel transport & storage	Transport of a liquid biofuel (e.g. from a biofuel conversion plant to a refinery).
Gas fuel transport & storage	Transport of a gaseous biofuel (e.g. from a biofuel conversion plant to a refuelling point).

Figure 2 – Example fuel chain defined using common modules



Validity of actual data over time

The actual data which can be used to edit a default fuel chain does not have to be "real-time" data (e.g. companies will not be required to assess conversion plant characteristics such as yield and natural gas use at the exact moment that a particular batch of biofuel is processed). Instead, all actual data in conversion modules can be based on characteristics averaged over a 12 month period.

Actual data for crop production

It will be permissible for evidence in support of actual data provided for crop production to take the form of a statistically accurate survey of farm level data. Such surveys would be considered valid for one crop growing season and should be based on:

- data specific to an individual field or,
- average data for all crops produced on a farm (e.g. if a farmer has the following two fields of wheat, the average crop yield of 11.2 t/ha could be reported, rather than the individual crop yields: Field 1: 20 ha, 200 t; Field 2: 32 ha; 384 t). Note: this approach can also be used outside of a surveying context

For detailed information relating to the default assumptions about crop residue treatment and for a discussion on more sophisticated approaches to calculating N2O emissions from soils please see "*Carbon reporting within the RTFO: Methodology".*

Editing a fuel chain

NOTE: also see next section if changes are to be made to how co-products are treated.

Step 1: Select the appropriate default fuel chain to be edited based on

the biofuel's feedstock type and origin.

Step 2: Refer to the **compulsory linkages** section below to establish whether there are compulsory links between the actual data to be used and any other data inputs. If there are such a links, actual data must be used for both data inputs.

Step 3: **In the appropriate module within the default fuel chain, complete** all the data input fields in the module being edited using the available actual data. Complete the remaining fields in the module using default values obtained from the tables in the relevant section below. The default values in these tables are arranged by "country of origin" – care must be taken to ensure the correct values are used. NOTE: Default values for "emission factors", which are generally in the second column of the module's data input fields, can be found in the General Default Values section. NOTE: If the actual data which is known is not a specific data point, but is the carbon intensity of an entire product (e.g. wheat with 300 kg CO_2e/tonne or rapeseed oil with 850 kg CO_2e/tonne) it is not necessary to fill in the data input fields for the entire module. Instead, the known carbon intensity value should be inserted directly into the "Fuel Chain Summary" Table – see Step 5.[1]

Step 4: Perform all the required **calculations** (i.e. in the fields marked "calculation") in the module. The numbers and letters given in formulas are "Field references" which are generally found immediately to the right of a field (some are given inside the field itself). Calculations should be performed working from the top left, to the bottom right of the module – including the three "Total" fields at the very bottom.

Step 5: The "**Fuel Chain Summary**" table (which appears at the beginning of the relevant fuel chain) can now be updated with the new total for this module: identify the appropriate module in the "Fuel Chain Summary" table, and replace it with the "Contribution to overall fuel chain" field from the module which has just been recalculated.

Step 6: The new **fuel chain carbon intensity** can be calculated by summing all the rows given in the "Fuel Chain Summary" table for the specified country of origin – including the new value for the module which has been recalculated.

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[1] Note that, in this situation, default values for the other upstream stages are not required as these should have already been taken into account in the carbon intensity of the product which has been purchased.

Step 7: For reporting to the Renewable Fuels Agency, this value must be converted to carbon intensity per MJ – using the standard energy content values (lower heating values specified in the General Default Values section).

3.1 Providing actual data on co-products

The impact of co-products must be taken into account when calculating the carbon intensity of a renewable fuel. The approach taken depends on the co-product and its use. The default fuel chains already indicate how to address the main co-products and fixed credits have already been determined for most of the different uses of the co-products. These credits are provided within the detailed default value tables for each fuel chain. Market prices have also been set for each of the co-products which is treated by market value allocation.

Where a company knows and can verify that the co-product has a different end use to that defined as a default the company may use the appropriate credit within the default value table for the fuel chain. In this case the company need only identify the end-use of the co-product and should not undertake the detailed analysis required to produce the credit.

If a new co-product is being produced that is not listed within the Guidance then an approach to assessing its impact must be selected using the following rules (the approaches are described in more detail below):

- Co-products must, wherever possible, be accounted for using the **substitution** (also known as system expansion) approach.
- Where the data required to undertake the substitution approach is not available, the co-products may be accounted for using the **allocation by market value** approach. Allocation by market value is compatible with the substitution approach (i.e. both can be used simultaneously to assess the impact of different co-products): co-products which have appropriate credit data available are accounted for by substitution and do not form part of the allocation.

If a co-product is not listed within the default fuel chains and it is likely to have a significant impact on the final carbon intensity of the biofuel (i.e. 10 percent or more relative to the carbon intensity of the fuel chain without this co-product) and it will be supplied for a period of 12 months or more then the approach taken must be discussed and agreed with the Renewable Fuels Agency. For co-products which do not meet these criteria, verifiers will check that the above rules have been correctly applied.

The procedure below is only required if the co-product end use and fixed credit is not provided within the Guidance.

Approach	Description of approach	
Substitution	Step 1:	Identify the “marginal product” which is substituted as a result of the co-product entering the market.
	Step 2:	Establish the carbon intensity of the marginal product[2].
	Step 3:	Establish the quantity of the marginal product which is substituted for every tonne of co-product[3].
	Step 4:	Give the biofuel a credit which is equal to the amount of co-product produced (per tonne of biofuel), multiplied by the amount of marginal product which is displaced (per tonne of co-product), multiplied by the carbon intensity of the marginal product (per tonne of marginal product). This credit should be negative (i.e. reduces the carbon intensity of the biofuel) – unless the marginal product has a negative carbon intensity.
Allocation by market value	Step 1:	Calculate the market value (based on a three-year average – preferably of the international market price if possible) of the products exported from the conversion plant – expressed per tonne of the biofuel product. Note that market values for existing co-products are fixed by the Renewable Fuels Agency (i.e. the market value used in the allocation procedure is the one listed in the default value tables, not the price a company receives for its co-product)
	Step 2:	Calculate the total market value of all products exported from the plant (including the biofuel and the co-products) – expressed per tonne of the biofuel product.
	Step 3:	Divide the value of a tonne of biofuel product by the total value of all exported products (from Step 2) – this is the allocation factor, the proportion of emissions which should be allocated to the biofuel.
	Step 4	Multiply the emissions which occurred in this module and all upstream emissions by this allocation factor.

[2] This analysis will need to be verifiable and should be based on public, peer reviewed studies or, for example carried out to a certain standard – e.g. ISO 14040.

[3] In the case where products are not direct substitutes. For example, animal protein feeds might have different protein contents, in which case 1 tonne of the co-product might only substitute 0.8 tonnes of the marginal product.

Example of allocation by market value

An oilseed rape to biodiesel plant is producing biodiesel, glycerine and potassium sulphate.

Step 1: Market value of exported products
Biodiesel: 1 tonne of biodiesel = £340 / tonne of biodiesel
Glycerine: 0.1 tonne glycerine/tonne biodiesel x £345 / tonne of glycerine = £35 / tonne of biodiesel
Potassium sulphate: 40 kg / tonne biodiesel x £75 / tonne = £3 / tonne of biodiesel
Step 2: Total market value of products exported from plant
Total market value = 340 + 35 + 3 = £378 / tonne of biodiesel

Step 3: Divide value of a tonne of biofuel by total value of products per tonne of biofuel
Allocation factor = 340 / 378 = 90 %

Step 4: Multiply upstream emissions and this module's emissions by the allocation factor
Upstream emissions (e.g. production of oilseed rape) = 1,725 kg CO_2e/t biodiesel
Conversion plant emissions = 523 kg CO_2e/t biodiesel
Carbon intensity of biodiesel = (1725 + 532) x 90 = 2,031 kg CO_2e/t biodiesel

3.2 Make adjustments to the structure of existing fuel chains

This section describes how the structure of the default fuel chains can be changed. Examples of situations in which companies may wish to do this include:

- If a certain transport step does not occur because, for example the oilseed crushing plant and the biodiesel conversion plant are co-located.
- If feedstock drying occurs within the biofuel plant – removing the drying and storage module would mean that energy consumption for drying and storage could be reported within the biofuel conversion module.
- If oilseed crushing and biodiesel conversion take place within the same plant – using one conversion module means energy consumption could be reported for the plant as a whole and would not have to be allocated between crushing and conversion operations.

Companies will be required to maintain evidence that the biofuel was produced in the way represented by the revised fuel chain, for example, that a certain transport step does not occur or that crushing and esterification take place on the same site. If modules are removed from the default fuel chain, companies will be required to use actual data for data points down stream of this module which may have been affected by the changes made – verifiers will review the entire fuel chain and the data used to ensure there are no inconsistencies. For example, within a biodiesel chain, it would not be possible to claim that oilseed crushing and biodiesel conversion take place within one plant, remove the oilseed crushing conversion module and then rely on default values for the biodiesel conversion module. Any changes to a default fuel chain must be recorded transparently – ideally in a format as close as possible to the existing default fuel chains (either electronic or paper-based). Verifiers may request access to this information.

Removing modules

Step 1: Select the appropriate **default fuel chain** to be edited based on the biofuel's feedstock type and origin.

Step 2: Remove the module(s) that is not required.

Step 3: Adjust the structure of the remaining modules to ensure that the new fuel chain is accurate and complete. Changes may need to be made to e.g. :

- Inputs and related units (e.g. for yields and emission totals)
- The types of co-product being exported.

Step 4: Actual data must be used in place of single default values for any inputs which might have changed as a result of removing a module.

Step 5: Complete all necessary calculations in modules which have been changed – and record changes in the "Fuel Chain Summary" table.

Step 6: If any "yields" have been changed then the "contribution to overall fuel chain" of all upstream modules will need to be recalculated and recorded in the "Fuel Chain Summary" table.

Step 7: The new **fuel chain carbon intensity** can be calculated by summing all the rows given in the "Fuel Chain Summary" table for the specified country of origin (excluding the module which has been removed)

Step 8: For reporting to the Renewable Fuels Agency, this value must be converted to carbon intensity per MJ – using the standard energy content values (lower heating values specified in the General Default Values Section).

3.3 Adding modules

With the exception of crop production, the modules listed in Figure 2 can be added to an existing default fuel chain. Table 1 provides a list of the most important sources of GHG emissions which need to be considered within each module. This list is not exhaustive and it is the reporting company's responsibility to ensure that all sources of GHG emission which will influence the final carbon intensity of the biofuel by 1 percent or more are taken into account.

Table 1 - Most important sources of GHG emissions

Module	**Major influences of GHG emissions**
Drying and storage	Fuel (e.g. diesel, fuel oil, natural gas, coal) Electricity
Conversion	Yields[4] Fuel (e.g. natural gas, fuel oil, coal) Electricity Chemicals Co-products
Feedstock transport	Diesel or other fuel for transport
Liquid fuel transport & storage	Diesel or other fuel
Gaseous fuel transport & storage	Gas or other fuel

Every module must include two "totals": the module total (kg CO_2e/t product[5]) and the fuel chain contribution total (kg CO_2e/t biofuel).

Step 1: Select the appropriate **default fuel chain** to be edited based on the biofuel's feedstock type and origin.

Step 2: Add the new module(s) which is required.

Step 3: Adjust the <u>structure</u> of the remaining modules to ensure that the new fuel chain is accurate and complete. Changes may need to be made to e.g.:

- Inputs and related units (e.g. for yields and emission totals)
- The types of co-product being exported.

[4] While yields (i.e. tonne output / tonne input) are not a "source" of GHG emissions, they are required to enable the fuel chain contribution total to be calculated within existing modules that are upstream of the added module.

[5] Product at this point in the chain.

Step 4: Actual data will need to be used for all inputs required within the new module – emission factors may be taken from the General Default Values section. In addition, actual data will be required in place of single default values for any inputs which might have changed as a result of adding the new module.

Step 5: Complete all necessary calculations in the modules which have been changed – and record changes in the "Fuel Chain Summary" table (remembering to add the new module as a new row in the table).

Step 6: If the new module has a "yield" associated with it and/or if other modules have had their "yields" altered then the "contribution to overall fuel chain" of all upstream modules will need to be recalculated and recorded in the "Fuel Chain Summary" table.

Step 7: The new **fuel chain carbon intensity** can be calculated by summing all the rows given in the "Fuel Chain Summary" table for the specified country of origin – including the value for the new module which has been added.

Step 8: For reporting to the Renewable Fuels Agency, this value must be converted to carbon intensity per MJ – using the standard energy content values (lower heating values specified in the General Default Values section).

3.4 Building a new fuel chain

An entirely new fuel chain can be constructed; however, it will almost always be easier to edit an existing default fuel chain. Note that, if a new fuel or feedstock is being introduced to the UK market and none of the existing default fuel chains represent the production processes, it will be necessary to follow the procedures outlined in the main Technical Guidance (Part 1).

Step 1: Define the steps which occur during the production of a biofuel using the modules shown in Figure 2.

Step 2: Identify the main product which is exported from each module (e.g. wheat, ethanol etc). All emissions within a module must be calculated per tonne of this product.

Step 3: Within each module identify all sources of GHG emissions which will influence the final carbon intensity of the biofuel by 1 percent or more.

Step 4: Within each conversion module identify the co-products which will be produced and decide on the most appropriate treatment based on the rules outlined below.

Step 5: Ensure that each conversion module contains the yield data which is needed to establish the contribution that upstream emissions make to the final carbon intensity of a biofuel i.e. for deriving the "overall contribution to fuel chain emissions" box.

Step 6: Complete a fuel chain structure in the same format which has been used for the default fuel chains below – verifiers may review this template.

Step 7: Complete the fuel chain structure using actual data and emission factors from the General Default Values section.

Step 8: The new **fuel chain carbon intensity** can be calculated by adding up the contribution of all the different modules.

Step 9: For reporting to the Renewable Fuels Agency, this value must be converted to carbon intensity per MJ – using the standard energy content values (lower heating values specified in the General Default Values section).

Compulsory linkages

There are several input fields within a carbon intensity calculation which are interdependent – for example, the yield of many crops is influenced heavily by the amount of nitrogen which has been applied. To avoid the possibility of default values being used in an inappropriate fashion a number of "compulsory linkages" have been defined – these are listed in Table 2.

If actual data is used for either of the two inputs listed in Table 2, actual data must also be used for the other input. Note it is possible to have actual data which is equal to the default value; however, the reporting company must have evidence to support this claim.

Table 2 – Compulsory linkages for all fuel chains, by module.

Input one	**Input two**
Crop production	
Crop yield*	Nitrogen fertiliser application rate*
Drying and storage	
Moisture removed	Fuel for heating or electricity
Feedstock transport	
None	
Conversion	
Yield	Any co-product yield
Yield	Fuel or electricity use
Electricity or heat exported	Fuel use
Liquid fuel transport	
None	

* This compulsory linkage does not apply to sugar beet.

3.5 General Default values

Table 3– Fertiliser and pesticide emissions factors.

Fertiliser Type	Units	Emissions factor	N content (%)
Nitrogen fertiliser			
Ammonium nitrate (AN)	[kgCO_2e/kg N]	6.80	35
Ammonium sulphate (AS)	[kgCO_2e/kg N]	1.62	21
Urea	[kgCO_2e/kg N]	1.33	46
Calcium nitrate (CN)	[kgCO_2e/kg N]	10.9	15.5
Urea ammonium nitrate liquid (UAN)	[kgCO_2e/kg N]	4.09	32
NPK (Urea / TSP / MOP)	[kgCO_2e/kg N]	2.00	15
Phosphate fertiliser			
Triple superphosphate (TSP)	[kgCO_2e/kg P_2O_5]	0.354	
Rock phosphate	[kgCO_2e/kg P_2O_5]	0.095	
Mono ammonium phosphate (MAP)	[kgCO_2e/kg P_2O_5]	0.596	11
Other fertilisers			
Potassium Chloride (K fertiliser)	[kgCO_2e/kg K_2O]	0.333	
Lime (CaO) fertiliser	[kgCO_2e/kg CaO]	0.124	
Magnesium (MgO) fertiliser	[kgCO_2e/kg MgO]	0.769	
Sodium (Na) fertiliser	[kgCO_2e/kg Na]	1.62	
Pesticides			
Pesticides	[kgCO_2e/kg active subs]	17.3	

Table 4 – Fossil fuel emission factors.

	Emissions factor [$kgCO_2e$/MJ fuel]
Gasoline	0.085
Diesel	0.086
LPG	0.069
Heavy fuel oil	0.087
Coal	0.112
Natural gas	0.062

Table 5– Transport mode fuel efficiency

	Emissions factor [MJ/tonne-km]
Truck – OECD North America	1.46
Truck – OECD Europe	1.53
Truck – OECD Pacific	1.61
Truck – FSU	1.82
Truck – Eastern Europe	1.72
Truck – China	1.89
Truck – Other Asia	1.8
Truck – India	1.94

	Emissions factor
	[MJ/tonne-km]
Truck – Middle East	1.89
Truck – Latin America	1.8
Truck – Africa	1.94
Rail – OECD North America	0.19
Rail – OECD Europe	0.38
Rail – OECD Pacific	0.38
Rail – FSU	0.19
Rail – Eastern Europe	0.24
Rail – China	0.33
Rail – Other Asia	0.24
Rail – India	0.19
Rail – Middle East	0.24
Rail – Latin America	0.24
Rail – Africa	0.24
International shipping	0.20

Table 6– Emissions factor for electricity

Country/Region	Grid average	Marginal baseload generation
	kg CO_2/MJ	
Argentina	0.076	*
Australia	0.241	*
Brazil	0.022	*
France	0.023	*
Germany	0.139	*
Indonesia	0.216	*
Malaysia	0.137	*
Netherlands	0.130	*
Poland	0.184	*
United Kingdom	0.131	0.106
United States	0.160	*

* The baseload generation should be defined. See co-products procedures on Page 10.

Table 7 – General information about fuels

Fuel	Density	Lower heating value	
	kg/litre	MJ/kg	MJ/litre
Gasoline	0.745	43.2	32.2
Diesel	0.832	43.1	35.9
HFO	0.970	40.5	39.3
Biodiesel	0.890	37.2	33.1
Ethanol	0.794	26.8	21.3
ETBE	0.750	36.3	27.2
MTBE	0.745	35.1	35.1
Biomethane	--	45.1	--

Selected default values

The following tables contain values for selected defaults. For selected defaults on transport mode fuel efficiency see Table 5.

Table 8 – Fertiliser emission factors.

Fertiliser Type	Units	Emissions factor
Nitrogen fertiliser		
Ammonium nitrate (AN)	[kgCO_2e/kg N]	6.80
Ammonium sulphate (AS)	[kgCO_2e/kg N]	1.62
Urea	[kgCO_2e/kg N]	1.33
Calcium nitrate (CN)	[kgCO_2e/kg N]	10.9
Urea ammonium nitrate liquid (UAN)	[kgCO_2e/kg N]	4.09
NPK (Urea / TSP / MOP)	[kgCO_2e/kg N]	2.00
Phosphate fertiliser		
Triple superphosphate (TSP)	[kgCO_2e/kg P_2O_5]	0.354
Rock phosphate	[kgCO_2e/kg P_2O_5]	0.095
Mono ammonium phosphate (MAP)	[kgCO_2e/kg P_2O_5]	0.596

Table 9 – Fossil fuel emission factors

	Emissions factor
	[kgCO_2e/MJ fuel]
Diesel	0.0864
Heavy fuel oil	0.0873
Coal	0.112
Natural gas	0.0620

4 Wheat to ethanol

Fuel chain summary

	Carbon intensity [kg CO_2/t ethanol]				
Module	**Canada**	**France**	**Germany**	**Ukraine**	**United Kingdom**
1 – Crop production	1394	1416	1234	2253	1275
2 – Drying and storage	45	43	49	47	49
3 – Feedstock transport	169	34	34	96	68
4 – Feedstock transport	299	27	39	138	0
5 – Conversion	231	231	231	231	231
6 – Liquid fuel transport and storage	0	0	0	0	0
TOTAL	2138	1751	1587	2765	1623

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel,

Stage	Module	Input	Options
			Heavy fuel oil, Coal, Natural gas
3	Feedstock transport (Mode 1)	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Feedstock transport (Mode 2)	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
5	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
6	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvest of wheat						
Basic Data							
	Units						
Yield @ traded moisture content	[t/ha.a]	value	Y				
Traded moisture content	%	value					
Soil Emissions							
				Emissions co-efficient [$kgCO_{2e}$/ha]		Total emissions [$kgCO_{2e}$ / t_{wheat}]	
N2O emissions	[total kg N/ha.a]	N_FERT	x	6.163	÷ Y =	calculation	1
Farming Inputs							
		Mass of input		Emissions co-efficient [$kgCO_{2e}$/kg nutrient]		Total emissions [$kgCO_{2e}$ / t_{wheat}]	
N fertiliser	[kg nutrient/ha.a]	value (N_FERT)	x	value	÷ Y =	calculation	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	value	x	value	÷ Y =	calculation	3
K fertiliser (K2O)	[kg nutrient/ha.a]	value	x	value	÷ Y =	calculation	4
Lime (CaO)	[kg nutrient/ha.a]	value	x	value	÷ Y =	calculation	5
				Emissions co-efficient [$kgCO_{2e}$/kg]			
Pesticides	[kg /ha.a]	value	x	value	÷ Y =	calculation	6
Machinery Inputs							
				Emissions co-efficient [$kgCO_{2e}$/litre]		Total emissions [$kgCO_{2e}$ / t_{wheat}]	
Diesel fuel consumption	[litres/ha.a]	value	x	value	÷ Y =	calculation	7
Totals						Total emissions [$kgCO_{2e}$ / t_{wheat}]	
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	calculation	8
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					8 ÷ z1 =	calculation	Stage_1

Stage 2 - Drying and storage

Description	Drying of wheat						
Moisture removed	% by weight	2					
Fuel / input type				Emissions co-efficient [$kgCO_{2e}$/MJ]		Total emissions [$kgCO_{2e}$ / t_{wheat}]	
Fuel for heating	[MJ/t wheat]	value	x	value	=	calculation	9
Electricity	[MJ/t wheat]	value	x	value	=	calculation	10
Totals						Total emissions [$kgCO_{2e}$ / t_{wheat}]	
Module total					9 + 10 =	calculation	11
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					11 ÷ z1 =	calculation	Stage_2

Stage 3 - Feedstock Transport

Description	Drying facility to ethanol plant (Mode 1)						
Transport distance	[km]	value	dist_1				
Fuel consumption	[MJ/t-km]	value	FC_1				
Totals				Emissions co-efficient [$kgCO_{2e}$/MJ]		Total emissions [$kgCO_{2e}$ / t_{wheat}]	
Module total	[MJ/t wheat]	= dist_1 x FC_1	x	value	=	calculation	12
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					12 ÷ z1 =	calculation	Stage_3

Stage 4 - Feedstock Transport

Description	Drying facility to ethanol plant (Mode 2)							
Transport distance	[km]	*value*	dist_2					
Fuel consumption	[MJ/t-km]	*value*	FC_2					
Totals					Emissions co-efficient [kgCO_{2e}/MJ]		Total emissions [kgCO_{2e} / t_{wheat}]	
Module total	[MJ/t wheat]	*= dist_2 x FC_2*		x	*value*	=	*calculation*	13
							Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain						13 ÷ z1 =	*calculation*	Stage_4

Stage 5 - Conversion

Description	Ethanol plant							
Basic data								
Plant yield	[t ethanol / t wheat]	*value*	(z1)					
Conversion Inputs					Emissions factor [kgCO_{2e}/MJ]		Emissions [kgCO_{2e}/t ethanol]	
Natural gas	[MJ/t pure ethanol]	*value*		x	*value*	=	*calculation*	14
Co-products	**Description**	**Treatment**						
Co-product 1:	DDGS - sold as animal feed	Substitution						
Co-products treated by substitution								
Co-product 1: DDGS								
- substitutes US soy, converted to meal in EU					Credit [kgCO_{2e}/t DDGS]			
Quantity of DDGS produced & sold as animal feed	[t DDGS / t ethanol]	*value*		x	*value*	=	*calculation*	15
Totals							Total emissions [kg CO_{2e} / t ethanol]	
Module total						14 + 15 =	*calculation*	16
Contribution to fuel chain						16 =	*calculation*	Stage_5

Stage 6 - Liquid fuel transport and storage

Description	Ethanol plant to refinery/blending facility							
Transport distance	[km]	*value*	dist_3					
Fuel consumption	[MJ/t-km]	*value*	FC_3					
Totals					Emissions co-efficient [kgCO_{2e}/ha]		Total emissions [kgCO_{2e} / $t_{ethanol}$]	
Module total	[MJ/t ethanol]	*calculation*		x	*value*	=	*calculation*	17
Contribution to fuel chain						17 =	*calculation*	Stage_6

Default value tables

Stage/Input	Units	Feedstock country of origin				
		Canada	France	Germany	Ukraine	United Kingdom
Stage 1 – Crop Production						
Yield @ traded moisture content	[t/ha.a]	2.28	6.99	7.36	2.60	7.76
Traded moisture content	%	15	15	15	15	15
N fertiliser	[kg N/ha.a]	50	183	165	90	183
Type of N fertiliser		AN	AN	AN	AN	AN
P fertiliser	[kg P_2O_5/ha.a]	26	40	30	80	40
Type of P fertiliser		TSP	TSP	TSP	TSP	TSP
K fertiliser	[kg K_2O/ha.a]	6	45	40	80	45
Lime	[kg CaO/ha.a]	363	363	363	363	363
Pesticides	[kg/ha.a]	0.38	0.38	0.38	0.38	0.38
Diesel fuel consumption	[litres/ha.a]	70	141	141	141	141
Straw removed	[t/ha.a]	0	0	0	0	0
Stage 2 – Drying and storage						
Moisture removed	% by weight	2	2	2	2	2
Fuel for heating	[MJ/t wheat]	141	141	141	141	141
Fuel Type		Diesel	Diesel	Diesel	Diesel	Diesel

Stage/Input	Units	Feedstock country of origin				
		Canada	France	Germany	Ukraine	United Kingdom
Electricity	[MJ/t wheat]	16	16	16	16	16
Stage 3 – Feedstock Transport						
Transport distance	[km]	3000	300	300	1700	150
Fuel consumption	[MJ/t-km]	0.19	0.38	0.38	0.19	1.53
Stage 4 – Feedstock Transport						
Transport distance	[km]	5000	450	650	2300	0
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2	0
Stage 5 – Conversion						
Yield	[t ethanol/t wheat]	0.292	0.292	0.292	0.292	0.292
Natural gas	[MJ/t pure ethanol]	12700	127001 2700	12700	12700	12700
Co-products						
Co-product 1:	DDGS sold as animal feed	Substitutes for US soymeal (converted to beans in EU)				
Quantity of DDGS produced & sold as animal feed	[t DDGS/t ethanol]	1.14	1.14	1.14	1.14	1.14
Credit for co-product 1	[kg CO_2e/t DDGS]	-491	-491	-491	-491	-491

Stage/Input	Units	Feedstock country of origin				
		Canada	France	Germany	Ukraine	United Kingdom
Stage 6 – Liquid fuel transport and storage						
Transport distance	[km]	0	0	0	0	
Fuel consumption	[MJ/t-km]	0	0	0	0	

5 Sugar beet to ethanol

Fuel chain summary

	Carbon intensity [kg CO_2/t ethanol]
Module	**United Kingdom**
1 – Crop production	530
2 – Feedstock transport	176
3 – Conversion	645
4 – Liquid fuel transport	0
TOTAL	1351

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
3	Conversion	Fuel emissions factor	Coal,

Stage	Module	Input	Options
			Natural gas, Heavy fuel oil, Biomass
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvest of sugar beet						
Basic Data							
	Units						
Yield	[t/ha.a]	*value*	Y				
Soil Emissions							
				Emissions co-efficient [$kgCO_{2e}$/ha]		Total emissions [$kgCO_{2e}$/t sugar beet]	
N2O emissions	[total kg N/ha.a]	*N_FERT*	x	*6.163*	÷ Y =	*calculation*	1
Farming Inputs							
		Mass of input		Emissions co-efficient [$kgCO_{2e}$/kg nutrient]		Total emissions [$kgCO_{2e}$/t sugar beet]	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*	x	*value*	÷ Y =	*calculation*	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	3
K fertiliser (K2O)	[kg/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	4
Na Fertiliser	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
Lime (CaO)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
				Emissions co-efficient [$kgCO_{2e}$/kg]			
Pesticides	[kg/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
Machinery Inputs							
Diesel fuel consumption	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	8
On-farm transport to storage clamp	[litres/tonne beet]	*value*	x	*value*	=	*calculation*	9
On-farm cleaning and loading	[litres/tonne beet]	*value*	x	*value*	=	*calculation*	10
						Emissions [$kgCO_{2e}$/t sugar beet]	
Totals							
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 =	*calculation*	11
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					11 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Feedstock Transport

Description	Farm to crushing facility							
Transport distance	[km]	*value*	dist_1					
Fuel consumption	[MJ/t-km]	*value*	FC_1					
Totals					Emissions factor [kgCO2e/MJ]		Emissions [$kgCO_{2e}$/t sugar beet]	
Module total	[MJ/t]	*value*		x	*value*	=	*calculation*	12
							Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain						12 ÷ z1 =	*calculation*	Stage_2

Stage 3 - Conversion

Description	Ethanol plant							
Basic data								
Plant yield	[t ethanol / t sugar beet]	*value*	(z1)					
Conversion Inputs					Emissions factor [$kgCO_{2e}$/MJ]		Emissions [$kgCO_{2e}$/t ethanol]	
Natural gas	[MJ/t pure ethanol]	*value*		x	*value*	=	*calculation*	13
Electricity import	[MJ/t pure ethanol]	*value*		x	*value*	=	*calculation*	14
Lime	[kg / t pure ethanol]	*value*		x	*value*	=	*calculation*	15
Co-products	**Description**	**Treatment**						
Co-product 1:	Pulp	Substitution						
Co-product 2:	Lime	Substitution						

Co-products treated by substitution							
Co-product 1: Pulp							
- *substitutes whole UK grown wheat*				Emissions factor [$kgCO_{2e}$/t pulp]			
Quantity of pulp produced & sold as animal feed	[t pulp / t ethanol]	*value*	x	*value*	=	*calculation*	16
Co-product 2: Lime							
- *substitutes for lime produced in a kiln*				Emissions factor [$kgCO_{2e}$/t lime]			
Quantity of lime produced & sold as fertiliser	[t lime / t ethanol]	*value*	x	*value*	=	*calculation*	17
Totals						Total emissions [kg CO_{2e} / t ethanol]	
Module total					13 + 14 + 15 + 16 + 17 =	*calculation*	18
Contribution to fuel chain					18 =	*calculation*	Stage_3

Stage 4 - Liquid fuel transport and storage

Description	From ethanol plant to refinery/blending facility							
Transport distance	[km]	*value*	dist_2					
Fuel consumption	[MJ/t-km]	*value*	FC_2					
					Emissions factor [kgCO2e/MJ]		Total emissions [kg CO_{2e} / t ethanol]	
Module total	[MJ/t ethanol]	*value*		x	*value*	=	*calculation*	19
Contribution to fuel chain						19 =	*calculation*	Stage_4

Default value tables

Stage/Input	**Units**	**Value**
Stage 1 – Crop Production		
Yield	[t/ha.a]	58
N2O emissions from soils	[kgCO_2e/ha.a]	616
N fertiliser	[kg N/ha.a]	100
Type of N fertiliser		AN
P fertiliser	[kg P_2O_5/ha.a]	50
Type of P fertiliser		TSP
K fertiliser	[kg K_2O/ha.a]	120
Na Fertiliser	[kg/ha.a]	100
Lime	[kg CaO/ha.a]	300
Pesticides	[kg/ha.a]	0.3
Diesel fuel consumption	[litres/ha.a]	168
On-farm transport to storage clamp	[litres/tonne beet]	0.8
On-farm cleaning and loading	[litres/tonne beet]	0.5
Stage 2 – Feedstock Transport		
Transport distance	[km]	100
Fuel consumption	[MJ/t-km]	1.53
Fuel type		Diesel

Stage/Input	Units	Value
Stage 3 – Conversion		
Yield	[t ethanol/t sugar beet]	0.0752
Natural gas	[MJ/t pure ethanol]	13333
Electricity import	[MJ/t pure ethanol]	1800
Lime	[kg / t pure ethanol]	306
Co-products:		
Co-product 1:	Pulp sold as animal feed	Substitutes for UK wheat
Quantity of pulp produced & sold as animal feed	[t pulp/t ethanol]	1.25
Credit for co-product 1	[kgCO_2e/t pulp]	-337
Co-production 2:	Lime	Substitutes for agricultural lime
Quantity of lime produced & sold as fertiliser	[t lime/t ethanol]	0.598
Credit for co-product 2	[kgCO_2e/t lime]	-49
Stage 4 – Liquid fuel transport and storage		
Transport distance	[km]	0
Fuel consumption	[MJ/t-km]	0

6 Sugar cane to ethanol

Fuel chain summary

	Carbon intensity [kg CO2/t ethanol]			
Module	**Brazil**	**Mozambique**	**Pakistan**	**South Africa**
1 – Crop production	348	425	597	425
2 – Feedstock transport	49	53	49	53
3 – Conversion	0	0	2152	2219
4 – Liquid fuel transport	93	101	93	101
5 – Liquid fuel transport	175	237	203	227
TOTAL	665	816	3094	3025

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region),

Stage	Module	Input	Options
			Rail (by geographic region), Shipping
5	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Crop Production

Description	Sugar cane cultivation and harvesting							
Basic Data								
	Units							
Yield	[t/ha.a]	*value*						
Sucrose % cane	[%]	*value*	S					
Trash yield (% cane)	[%]	*value*	St					
Sugar cane burning area	[%]	*value*	Bc					
Mechanical Harvesting Area	[%]	*value*	Mc					
Soil Emissions								
					Emissions co-efficient [$kgCO_{2e}$/ha]		Total Emissions [$kgCO_{2e}$/t cane]	
N2O emissions	[total kg N/ha.a]	*N_FERT*		x	*6.163*	÷ Y =	*calculation*	1
Farming Inputs								
		Mass of input			Emissions co-efficient [$kgCO_{2e}$/kg nutrient]		Total Emissions [$kgCO_{2e}$/t cane]	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*		x	*value*	÷ Y =	*calculation*	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*		x	*value*	÷ Y =	*calculation*	3
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*		x	*value*	÷ Y =	*calculation*	4
Lime (CaO)	[kg nutrient/ha.a]	*value*		x	*value*	÷ Y =	*calculation*	5
					Emissions co-efficient [$kgCO_{2e}$/kg]			
Pesticides	[kg/ha.a]	*value*		x	*value*	÷ Y =	*calculation*	6
Diesel use in agricultural operations								
Diesel	[litres/ha.a]	*value*		x	*value*	÷ Y =	*calculation*	7
Emissions from burning sugar cane trash								
					Emissions Factor kg CO2 eqv / kg trash			
N_2O	[kg trash / t cane]	*value*		x	*value*	x Bc =	*calculation*	8
Methane	[kg trash / t cane]	*value*		x	*value*	x Bc =	*calculation*	9
							Emissions [$kgCO_{2e}$/t cane]	
Totals								
Module total						1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 =	*calculation*	10
							Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain						10 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Feedstock Transport

Description	From farm to ethanol plant							
Average transport distance	[km]	*value*	dist_1					
Fuel consumption	[MJ/t.km]	*value*	FC_1					
					Emissions factor [kgCO2e/MJ]		Total Emissions [$kgCO_{2e}$/t cane]	
Totals								
Module total	[MJ/t cane]	*value*		x	*value*	=	*calculation*	11
							Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain						11 ÷ z1=	*calculation*	Stage_2

Stage 3 - Conversion

Description	Ethanol plant							
Basic Data								
Plant yield	[m3 ethanol / t cane]	*value*	z1					
Plant yield	[t ethanol / t cane]	*value*						
					Emissions factor [$kgCO_{2e}$/MJ]		Emissions [$kgCO_{2e}$/t ethanol]	
Fuel use	[MJ/t pure ethanol]	*value*		x	*value*	=	*calculation*	12
Electricity	[MJ/t pure ethanol]	*value*		x	*value*	=	*calculation*	13
							Total emissions [kg CO_{2e} / t ethanol]	
Module total						12 + 13 =	*calculation*	15
Contribution to fuel chain						15 =	*calculation*	Stage_3

Stage 4 - Liquid fuel transport and storage

Description	From ethanol plant to refinery/blending facility							
Transport distance	[km]	*value*	dist_2					
Fuel consumption	[MJ/t-km]	*value*	FC_2					
					Emissions factor [kgCO2e/MJ]		Total emissions [kg CO_{2e} / t ethanol]	
Module total	[MJ/t ethanol]	*value*		x	*value*	=	*calculation*	16
Contribution to fuel chain						16 =	*calculation*	Stage_4

Stage 5 - Liquid fuel transport and storage

Description	From ethanol plant to refinery/blending facility							
Transport distance	[km]	*value*	dist_3					
Fuel consumption	[MJ/t-km]	*value*	FC_3					
					Emissions factor [kgCO2e/MJ]		Total emissions [kg CO_{2e} / t ethanol]	
Module total	[MJ/ethanol]	*value*		x	*value*	=	*calculation*	17
Contribution to fuel chain						17 =	*calculation*	Stage_5

Default value tables

Stage/Input	Units	Feedstock Country of Origin			
		Brazil	Pakistan	South Africa	Mozambique
Stage 1 – Crop Production					
Yield	[t/ha.a]	71.6	47.3	67.2	67.2
Trash yield (% cane)	[%]	14	14	14	14
Sugar cane burning area	[%]	77	100	100	100

Stage/Input	Units	Feedstock Country of Origin			
		Brazil	**Pakistan**	**South Africa**	**Mozambique**
Mechanical Harvesting Area	[%]	34	0	0	0
N fertiliser	[kg N/ha.a]	80	130	92	92
Type of N fertiliser		Urea	Urea	Urea	Urea
P fertiliser	[kg P_2O_5/ha.a]	60	30	57	57
Type of P fertiliser		MAP	MAP	MAP	MAP
K fertiliser	[kg K_2O/ha.a]	100	50	133	133
Lime	[kg CaO/ha.a]	60	60	60	60
Pesticides	[kg/ha.a]	0.2	0.2	0.2	0.2
Diesel use in agricultural operations	[litres/ha.a]	65	65	65	65
N_2O from burning trash	[kg trash/t cane]	140	140	140	140
Methane from burning trash	[kg trash/t cane]	140	140	140	140
Stage 2 – Feedstock Transport					
Average transport distance	[km]	20	20	20	20
Fuel consumption	[MJ/t.km]	1.8	1.8	1.8	1.8
Stage 3 – Conversion					
Yield	[m3 ethanol/t cane]	0.08	0.08	0.08	0.08
Yield	[t ethanol / t cane]	0.0635	0.0635	0.0635	0.0635

Stage/Input	**Units**	**Feedstock Country of Origin**			
		Brazil	**Pakistan**	**South Africa**	**Mozambique**
No co-products					
Fuel Use		0	18750	18750	0
Fuel Type	[MJ/t pure ethanol]	Bagasse	Coal	Coal	Bagasse
Electricity	[MJ/t pure ethanol]	0	500	500	0
Stage 4 – Liquid fuel transport and storage					
Transport distance	[km]	600	600	600	600
Fuel consumption	[MJ/t-km]	1.8	1.8	1.94	1.94
Fuel Type		Diesel	Diesel	Diesel	Diesel
Stage 5 – Liquid fuel transport and storage					
Transport distance	[km]	10000	11600	13000	13600
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2
Fuel Type		HFO	HFO	HFO	HFO

7 Molasses to Ethanol

Fuel chain summary

	Carbon intensity [kg CO2/t ethanol]		
Module	**Pakistan**	**South Africa**	**UK**
1 – Feedstock transport	101	109	0
2 – Conversion	1679	1920	1062
3 – Liquid fuel transport	93	101	0
4 – Liquid fuel transport	203	227	0
TOTAL	2076	2357	1062

Selected default options

Stage	Module	Input	Options
1	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
2	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
3	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Stage	Module	Input	Options
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Feedstock Transport

Description	Sugar mill to ethanol plant							
Transport distance	[km]	*value*	dist_1					
Fuel consumption	[MJ/t-km]	*value*	FC_1					
					Emissions factor [kgCO2e/MJ]		Emissions [$kgCO_{2e}$/t sugar beet]	
Totals Module total	[MJ/t]	*value*		x	*value*	=	*calculation*	1
							Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain						1 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Conversion

Description	Ethanol plant							
Basic data								
Plant yield	[t ethanol / t molasses]	*value*	(z1)					
					Emissions factor [$kgCO_{2e}$/MJ]		Emissions [$kgCO_{2e}$/t ethanol]	
Conversion Inputs Natural gas	[MJ/t ethanol]	*value*		x	*value*	=	*calculation*	2
Electricity import	[MJ/t ethanol]	*value*		x	*value*	=	*calculation*	3
Lime	[kg / t ethanol]	*value*		x	*value*	=	*calculation*	4
							Total emissions [kg CO_{2e} / t ethanol]	
Totals Module total						2 + 3 + 4 =	*calculation*	5
Contribution to fuel chain						5 =	*calculation*	Stage_2

Stage 3 - Liquid fuel transport and storage

Description	From ethanol plant to refinery/blending facility							
Transport distance	[km]	*value*	dist_2					
Fuel consumption	[MJ/t-km]	*value*	FC_2					
					Emissions factor [kgCO2e/MJ]		Total emissions [kg CO_{2e} / t ethanol]	
Module total	[MJ/t ethanol]	*value*		x	*value*	=	*calculation*	6
Contribution to fuel chain						6 =	*calculation*	Stage_3

Stage 4 - Liquid fuel transport and storage

Description	From ethanol plant to refinery/blending facility							
Transport distance	[km]	*value*	dist_3					
Fuel consumption	[MJ/t-km]	*value*	FC_3					
					Emissions factor [kgCO2e/MJ]		Total emissions [kg CO_{2e} / t ethanol]	
Module total	[MJ/t ethanol]	*value*		x	*value*	=	*calculation*	7
Contribution to fuel chain						7 =	*calculation*	Stage_4

Default value tables

Stage/Input	**Units**	**Feedstock Country of Origin**		
		Pakistan	**South Africa**	**UK**
Stage 1 – Feedstock Transport				
Average transport distance	[km]	150	150	0
Fuel consumption	[MJ/t.km]	1.8	1.94	0
Stage 2 – Conversion				
Yield	[m3 ethanol/t cane]	0.231	0.231	0.231
Fuel Use		13333	13333	13333
Fuel Type	[MJ/t pure ethanol]	Coal	Coal	Natural gas
Electricity	[MJ/t pure ethanol]	1800	1800	1800
Stage 3 – Liquid fuel transport and storage				

Stage/Input	**Units**	**Feedstock Country of Origin**		
Transport distance	[km]	600	600	0
Fuel consumption	[MJ/t-km]	1.8	1.94	0
Fuel Type		Diesel	Diesel	Diesel
Stage 4 – Liquid fuel transport and storage				
Transport distance	[km]	11,600	13,000	0
Fuel consumption	[MJ/t-km]	0.2	0.2	0
Fuel Type		HFO	HFO	None

8 Corn to ethanol

Fuel chain summary

	Carbon intensity [kg CO2/t ethanol]	
Module	**USA**	**France**
1 – Crop production	913	999
2 – Drying and storage	55	19
3 – Feedstock transport	33	30
4 – Conversion	1752	263
5 – Liquid fuel transport and storage	27	8
6 – Liquid fuel transport and storage	122	-
TOTAL	2902	1319

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel, Heavy fuel oil,

Stage	Module	Input	Options
			Coal, Natural gas
3	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
5	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain - France

Stage 1 - Crop Production

Description	Cultivation and harvest of corn						
Basic Data							
	Units						
Yield @ traded moisture content	[t corn / ha.a]	*value* Y					
Traded moisture content	%	*value*					
Soil Emissions				Emissions co-efficient [$kgCO_{2e}$/ha]		Total Emissions [kgCO2e/t corn]	
N2O emissions	[total kg N/ha.a]	*N_FERT*	x	*6.163*	÷ Y =	*calculation*	1
Farming Inputs		Mass of input		Emissions co-efficient [$kgCO_{2e}$/kg nutrient]		Total Emissions [kgCO2e/t corn]	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*	x	*value*	÷ Y =	*calculation*	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	3
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	4
Lime (CaO)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
				Emissions co-efficient [$kgCO_{2e}$/kg]			
Pesticides	[kg/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
Machinery Inputs				Emissions factor [kgCO2e/litre]			
Diesel fuel consumption	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
Totals						Emissions [kgCO2e/t corn]	
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	*calculation*	8
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					8 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Drying and storage

Description	Drying of corn						
Moisture removed	% by weight	value					
				Emissions co-efficient [$kgCO_{2e}$/MJ]		Total emissions [$kgCO_{2e}$ / t_{corn}]	
Fuel / input type							
Fuel for heating	[MJ/t corn]	value	x	value	=	calculation	9
Electricity	[MJ/t corn]	value	x	value	=	calculation	10
						Total emissions [$kgCO_{2e}$ / t_{corn}]	
Totals							
Module total					9 + 10 =	calculation	11
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					11 ÷ z1 =	calculation	Stage_2

Stage 3 - Feedstock Transport

Description	Farm to ethanol plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_1				
Fuel consumption	[MJ/t-km]	value	FC_1				
						Emissions [kgCO2e/t corn]	
Totals							
Module total	[MJ/t]	value	x	value	=	calculation	12
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					12 ÷ z1 =	calculation	Stage_3

Stage 4 - Conversion

Description	Ethanol plant						
Basic data							
Plant yield	[t ethanol / t corn]	value	(z1)				
Conversion Inputs							
				Emissions factor [kgCO2e/MJ]		Emissions [$kgCO_{2e}$/t ethanol]	
Natural gas	[MJ/t pure ethanol]	value	x	value	=	calculation	13
Electricity import	[MJ/t pure ethanol]	value	x	value	=	calculation	14
Co-products	**Description**	**Treatment**					
Co-product 1:	DDGS - sold as animal feed	Substitution					
Co-products treated by substitution							
Co-product 1: DDGS sold as animal feed							
- substitutes US soy meal (imported as soy bean)				Credit [$kgCO_{2e}$/t DDGS]			
Quantity of DDGS	[t DDGS / t ethanol]	value	x	value	=	calculation	15
						Total emissions [kg CO_{2e} / t ethanol]	
Totals							
Module total					13 + 14 + 15 =	calculation	16
Contribution to fuel chain					16 =	calculation	Stage_4

Stage 5 - Liquid fuel transport and storage

Description	Ethanol plant to refinery/blending facility						
Transport distance	[km]	value	dist_2				
Fuel consumption	[MJ/t-km]	value	FC_2				
				Emissions factor [kgCO2e/MJ]		Total emissions [kg CO_{2e} / t ethanol]	
Totals							
Module total	[MJ/t ethanol]	value	x	value	=	calculation	17
Contribution to fuel chain					17 =	calculation	Stage_5

Default fuel chain – USA

Stage 1 - Crop Production

Description	Cultivation and harvest of corn						
Basic Data							
	Units						
Yield @ traded moisture content	[t corn / ha.a]	*value*	Y				
Traded moisture content	%	*value*					
Soil Emissions							
				Emissions co-efficient [kgCO_{2e}/ha]		Total Emissions (kgCO2e/t corn)	
N2O emissions	[total kg N/ha.a]	*N_FERT*	x	*6.163*	÷ Y =	*calculation*	1
Farming Inputs							
		Mass of input		Emissions co-efficient [kgCO_{2e}/kg nutrient]		Total Emissions (kgCO2e/t corn)	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*	x	*value*	÷ Y =	*calculation*	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	3
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	4
Lime (CaO)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
				Emissions co-efficient [kgCO_{2e}/kg]			
Pesticides	[kg/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
Machinery Inputs							
				Emissions factor (kgCO_{2e}/litre)			
Diesel fuel consumption	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
Totals						Emissions [kgCO2e/t corn]	
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	*calculation*	8
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					8 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Drying and storage

Description	Drying of corn						
Moisture removed	% by weight	*value*					
Fuel / input type				Emissions co-efficient [kgCO_{2e}/MJ]		Total emissions [kgCO_{2e} / t_{corn}]	
Fuel for heating	[MJ/t corn]	*value*	x	*value*	=	*calculation*	9
Electricity	[MJ/t corn]	*value*	x	*value*	=	*calculation*	10
Totals						Total emissions [kgCO_{2e} / t_{corn}]	
Module total					9 + 10 =	*calculation*	11
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					11 ÷ z1 =	*calculation*	Stage_2

Stage 3 - Feedstock Transport

Description	Farm to ethanol plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
Totals						Emissions [kgCO2e/t corn]	
Module total	[MJ/t]	*value*	x	*value*	=	*calculation*	12
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					12 ÷ z1 =	*calculation*	Stage_3

Stage 4 - Conversion

Description	Ethanol plant						
Basic data							
Plant yield	[t ethanol / t corn]	*value*	(z1)				
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions [kgCO2e/t ethanol]	
Coal	[MJ/t pure ethanol]	*value*	x	*value*	=	*calculation*	13

Co-products	**Description**	**Treatment**
Wet mill		
Co-product 1:	Corn oil	Substitution
Co-product 2:	Corn gluten meal	Substitution
Co-product 3:	Corn gluten feed	Substitution
Co-product 4:	Electricity	Substitution

Co-products treated by substitution

Co-product 1: Corn oil							
- substitutes US soybean oil				Credit [kgCO_{2e}/t corn oil]			
Quantity of corn oil produced	[t corn oil / t ethanol]	*value*	x	*value*	=	*calculation*	14
Co-product 2: Corn gluten meal							
- substitutes whole corn & nitrogen in urea				Credit [kgCO2e/t corn gluten			
Quantity of corn gluten meal produced	[t corn gluten meal / t ethanol]	*value*	x	*value*	=	*calculation*	15
Co-product 3: Corn gluten feed							
- substitutes whole corn & nitrogen in urea				Credit [kgCO2e/t corn gluten			
Quantity of corn gluten feed produced	[t corn gluten feed / t ethanol]	*value*	x	*value*	=	*calculation*	16
Co-product 4: Electricity				Credit [kgCO_{2e}/MJ electricity]			
Electricity exported	[MJ electricity export / t ethanol]	*value*	x	*value*	=	*calculation*	17

Totals						Emissions [kgCO_{2e}/t ethanol]	
Module total					13 + 14 + 15 + 16 + 17 =	*calculation*	18
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					18 =	*calculation*	Stage_4

Stage 5 - Liquid fuel transport and storage

Description	Ethanol plant to refinery/blending facility						
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
Totals				Emissions factor [kgCO2e/MJ]		Emissions [kgCO_{2e}/t ethanol]	
Module total	[MJ/t ethanol]	*value*	x	*value*	=	*calculation*	19
Contribution to fuel chain					19 =	*calculation*	Stage_5

Stage 6 - Liquid fuel transport and storage

Description	Ethanol plant to refinery/blending facility						
Transport distance	[km]	*value*	dist_3				
Fuel consumption	[MJ/t-km]	*value*	FC_3				
Totals				Emissions factor [kgCO2e/MJ]		Emissions [kgCO_{2e}/t ethanol]	
Module total	[MJ/t ethanol]	*value*	x	*value*	=	*calculation*	20
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					20 =	*calculation*	Stage_6

Default value tables

Stage/Input	**Units**	**Feedstock country of origin**	
		USA	**France**
Stage 1 – Crop Production			
Yield @ traded moisture content	[t corn/ha.a]	8.95	8.52
Traded moisture content	%	15	15
N fertiliser	[kg N/ha.a]	150	170
Type of N fertiliser		AN	AN
P fertiliser	[kg P_2O_5/ha.a]	70	59
Type of P fertiliser		TSP	TSP

Stage/Input	Units	Feedstock country of origin	
		USA	France
K fertiliser	[kg K_2O/ha.a]	90	36
Lime	[kg CaO/ha.a]	469	469
Pesticides	[kg/ha.a]	4	4
Diesel fuel consumption	[litres/ha.a]	131	131
Straw removed	[t/ha.a]	0	0
Stage 2 – Drying and storage			
Moisture removed	% by weight	3	1
Fuel for heating	[MJ/t corn]	214	70
Fuel Type			Diesel
Electricity	[MJ/t corn]	24	8
Stage 3 – Feedstock Transport			
Transport distance	[km]	80	300
Fuel consumption	[MJ/t-km]	1.46	0.38
Stage 4 – Conversion			
Yield	[t ethanol/t corn]	0.31	0.326
Coal	[MJ/t pure ethanol]	23038	0
Natural gas	[MJ/t pure ethanol]	0	11335
Electricity import	[MJ/t pure ethanol]	0	1260

Stage/Input	**Units**	**Feedstock country of origin**	
		USA	**France**
Co-products			
Co-product 1	Corn oil (USA only)	Substitutes for US soybean oil (crushed in US)	
Quantity of corn oil produced	[t corn oil/t ethanol]	0.122	N/A
Credit for co-product 1	[kgCO_2e/t corn oil]	-1655	N/A
Co-product 2	Corn gluten meal (USA only)	Substitutes for whole corn & nitrogen in urea	
Quantity of corn gluten meal produced	[t corn gluten meal/t ethanol]	0.152	N/A
Credit for co-product 2	[kgCO_2e/t corn gluten meal]	-124	N/A
Co-product 3	Corn gluten feed	Substitutes for whole corn & nitrogen in urea	
Quantity of corn gluten feed produced	[t corn gluten feed/t ethanol]	0.657	N/A
Credit for co-product 3	[kgCO_2e/t corn gluten feed]	-283	N/A
Co-product 4	DDGS (France only)	Substitutes US soymeal (crushed in EU)	
Quantity of DDGS	[t DDGS/t ethanol]	N/A	0.961
Credit for co-product 4	[kgCO_2e/t DDGS]	N/A	-491

Stage/Input	**Units**	**Feedstock country of origin**	
		USA	**France**
Co-product 5	Electricity		
Electricity exported	[MJ electricity export/t ethanol]	2661	N/A
Credit for co-product 5	[kgCO_2e/MJ electricity]	-0.16	N/A
Stage 5 – Liquid fuel transport and storage			
Transport distance	[km]	1600	450
Fuel consumption	[MJ/t-km]	0.19	0.2
Stage 6 – Liquid fuel transport and storage			
Transport distance	[km]	7000	0
Fuel consumption	[MJ/t-km]	0.2	0

9 Oilseed rape to ME biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]							
Module	**Australia**	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
1 - Crop production	1933	1853	1903	1591	1598	1475	2028	1945
2 - Drying and storage	0	65	67	62	71	75	68	71
3 - Feedstock transport	22	109	29	87	87	87	62	29
4 - Feedstock transport	693	0	0	0	0	0	89	0
5 - Conversion (crushing)	-469	-490	-484	-503	-466	-451	-480	-468
6 - Feedstock transport	8	86	0	7	11	25	0	0
7 - Conversion (esterification)	471	471	471	471	471	471	471	471
8 - Liquid fuel transport and storage	0	0	35	0	0	0	0	0
TOTAL	2658	2094	2021	1715	1772	1682	2238	2048

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel, Heavy fuel oil, Coal, Natural gas
3	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Conversion (crushing)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
5	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
6	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
7	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvesting of oilseed rape						
Basic Data							
	Units						
Yield @ traded moisture content	[t/ha.a]	*value*	Y				
Traded moisture content	%	*value*					
Soil Emissions							
				Emissions co-efficient [kgCO_{2e}/ha]		Total Emissions (kgCO_{2e}/t OSR)	
N2O emissions	[total kg N/ha.a]	*N_FERT*	x	*6.163*	÷ Y =	*calculation*	1
Farming Inputs							
		Mass of input		Emissions co-efficient [kgCO_{2e}/kg nutrient]		Total emissions	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*	x	*value*	÷ Y =	*calculation*	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	3
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	4
Lime (CaO)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
				Emissions co-efficient [kgCO_{2e}/kg]			
Pesticides	[kg/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
Machinery Inputs							
Diesel fuel consumption	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
						Total Emissions (kgCO_{2e}/t OSR)	
Totals							
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	*calculation*	8
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					8 ÷ z1 ÷ z2 x AF=	*calculation*	Stage_1

Stage 2 - Drying and storage

Description	Drying and storage of oilseed rape						
Basic Data							
Moisture removed	% by weight	*value*					
				Emissions factor [kgCO2e/MJ]		Emissions (kgCO_{2e}/t OSR)	
Drying and storage inputs							
Fuel for heating	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	9
Electricity	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	10
						Emissions (kgCO_{2e}/t OSR)	
Totals							
Module total					9 + 10 =	*calculation*	11
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					11 ÷ z1 ÷ z2 x AF =	*calculation*	Stage_2

Stage 3 - Feedstock Transport

Description	From farm to oilseed crusher						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
						Emissions (kgCO_{2e}/t OSR)	
Totals							
Module total	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	12
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					12 ÷ z1 ÷ z2 x AF =	*calculation*	Stage_3

Stage 4 - Feedstock Transport

Description	From farm to oilseed crusher							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_2					
Fuel consumption	[MJ/t-km]	value	FC_2					
							Emissions ($kgCO_{2e}$/t OSR)	
Totals								
Module total	[MJ/t OSR]	value		x	value	=	calculation	13
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						13 ÷ z1 ÷ z2 x AF =	calculation	Stage_4

Stage 5 - Conversion

Description	Oil extraction							
Basic Data								
Plant yield	[t rapeseed oil / t oilseed rape]	value	z1					
Conversion inputs								
					Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Natural gas	[MJ/t rapeseed oil]	value		x	value	=	calculation	14
Electricity imported	[MJ/t rapeseed oil]	value		x	value	=	calculation	15
Co-products	**Description**	**Treatment**						
Co-product 1:	Rape meal - sold as animal feed	Substitution						
Co-products treated by substitution								
Co-product 1: rape meal								
- substitutes US soy meal (soybeans crushed in EU)					Credit [$kgCO_{2e}$/t rape meal]			
Quantity of rape meal produced & sold as animal feed	[t rape meal / t rapeseed oil]	value		x	value	=	calculation	16
Totals								
Module total						14 + 15 + 16 =	calculation	17
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						17 ÷ z2 x AF =	calculation	Stage_5

Stage 6 - Feedstock Transport

Description	From extraction facility to biodiesel plant							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_3					
Fuel consumption	[MJ/t-km]	value	FC_3					
Totals							Emissions ($kgCO_{2e}$/t rapeseed oil)	
Module total	[MJ / t rapeseed oil]	value		x	value	=	calculation	18
Contribution to fuel chain						18 ÷ z2 x AF =	calculation	Stage_6

Stage 7 - Conversion

Description	Biodiesel plant							
Basic data								
Plant yield	[t biodiesel / t rapeseed oil]	value	(z2)					
Conversion inputs					Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Natural gas	[MJ/t biodiesel]	value		x	value	=	calculation	19
Electricity imported	[MJ/t biodiesel]	value		x	value	=	calculation	20
					Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	value		x	value	=	calculation	21
Potassium hydroxide	kg/t biodiesel	value		x	value	=	calculation	22
Co-products	**Description**	**Treatment**						
Co-product 1:	Crude glycerine sold as chemical	Allocation - by market value						
Co-product 2:	Potassium sulphate	Allocation - by market value						

Co-products treated by allocation by market value

Co-product 1: Glycerine				Market value [£ / t gylcerine]			
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	*value*	x	*value*	=	*calculation*	23
Co-product 2: Potassium sulphate				Market value [£ / t potassium sulphate]			
Quantity of potassium sulphate produced and sold as chemical	[t potassium suplhate / t biodiesel]	*value*		*value*	=	*calculation*	24
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	25
Total market value of products							
Total market value	[£ / t biodiesel]					*calculation*	26
Allocation factor (%age of emissions attributable to biodiesel)	%					*calculation*	AF
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(19 + 20 + 21 + 22) x AF =	*calculation*	27
Contribution to fuel chain					27 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	From biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_4				
Fuel consumption	[MJ/t-km]	*value*	FC_4				
Totals				Emissions factor [kgCO2e/MJ]		Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	28
Contribution to fuel chain					28 =	*calculation*	Stage_8

Default value tables

Stage/Input	Units	Feedstock country of origin							
		Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom
Stage 1 – Crop production									
Yield @ traded moisture content	[t/ha.a]	1.19	1.46	1.30	3.18	3.44	2.38	1.12	3.03
Traded moisture content	%	9	9	9	9	9	9	9	9
N fertiliser	[kg N /ha.a]	61	75	67	155	170	102	60	185
Type of N fertiliser		AN	AN	AN	AN	AN	AN	AN	AN
P fertiliser	[kg P_2O_5/ha.a]	16	20	18	45	45	35	15	45
Type of P fertiliser		TSP	TSP	TSP	TSP	TSP	TSP	TSP	TSP
K fertiliser	[kg K_2O/ha.a]	12	15	13	80	90	44	12	48
Lime	[kg CaO/ha.a]	271	271	271	271	271	271	271	271
Pesticides	[kg/ha.a]	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28

Stage/Input	Units	Feedstock country of origin							
		Australia	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
Diesel fuel consumption	[litres/ha.a]	66	66	66	66	66	66	66	66
Stage 2 – Drying and storage									
Moisture removed	% by weight	0	3	3	3	3	3	3	3
Fuel for heating	[MJ/t OSR]	0	318	318	318	318	318	318	318
Electricity	[MJ/t OSR]	0	35	35	35	35	35	35	35
Stage 3 – Feedstock Transport									
Transport distance	[km]	300	3000	100	300	300	300	1700	100
Fuel consumption	[MJ/t-km]	0.38	0.19	1.53	1.53	1.53	1.53	0	1.53
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Stage 4 – Feedstock Transport									
Transport distance	[km]	18000	0	0	0	0	0	2300	0

Stage/Input	Units	Feedstock country of origin							
		Australia	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
Fuel consumption	[MJ/t-km]	0.2	N/A	N/A	N/A	N/A	N/A	0.2	N/A
Fuel type		HFO	N/A	N/A	N/A	N/A	N/A	HFO	N/A
Stage 5 – Conversion									
Plant yield	[t rapeseed oil/t oilseed rape]	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Natural gas	[MJ/t rapeseed oil]	1986	1986	1986	1986	1986	1986	1986	1986
Electricity imported	[MJ/t rapeseed oil]	337	337	337	337	337	337	337	337
Co-product 1: Rape meal – sold as animal feed		Substitutes US soy meal (soybeans crushed in EU)							
Quantity of rape meal	[t rape meal/t rapeseed oil]	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Credit for co-product 1	[kgCO_2e/t rape meal]	-504	-504	-504	-504	-504	-504	-504	-504
Stage 6 – Feedstock									

Stage/Input	Units	Feedstock country of origin							
		Australia	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
Transport									
Transport distance	[km]	500	5200	0	450	650	1500	0	0
Fuel consumption	[MJ/t-km]	0.2	0.2	0	0.2	0.2	0.2	0	0
Stage 7 – Conversion									
Plant yield	[t biodiesel/t rapeseed oil]	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Natural gas	[MJ/t biodiesel]	1690	1690	1690	1690	1690	1690	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335	335	335	335	335	335	335
Methanol	kg/t biodiesel	113	113	113	113	113	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	26	26	26	26	26	26
Co-products									
Co-product 1	Crude glycerine	Allocation – by market value							

Stage/Input	**Units**	**Feedstock country of origin**							
		Australia	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
Quantity of crude glycerine	[t glycerine/t biodiesel]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Market value of glycerine	[£/t glycerine]	345	345	345	345	345	345	345	345
Co-product 2:	Potassium sulphate	Allocation – by market value							
Quantity of potassium sulphate	[t potassium sulphate/t biodiesel]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Market value of potassium sulphate	[£/t potassium sulphate]	75	75	75	75	75	75	75	75
Primary product: biodiesel									
Market value of biodiesel	[£/t biodiesel]	340	340	340	340	340	340	340	340
Allocation factor	%	90	90	90	90	90	90	90	90
Stage 8 – Liquid fuel transport and storage									
Transport distance	[km]	0	0	2000	0	0	0	0	0

Stage/Input	Units	Feedstock country of origin							
		Australia	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
Fuel consumption	[MJ/t-km]	0	0	0.2	0	0	0	0	0
Fuel Type		N/A	N/A	HFO	N/A	N/A	N/A	N/A	N/A

10 Soy to ME biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]		
	Argentina	**Brazil**	**USA**
1 – Crop production	1827	2062	2393
2 – Drying and storage	73	68	61
3 – Feedstock transport	286	1301	70
4 – Conversion (crushing)	-1101	-1177	-984
5 – Feedstock transport	0	0	24
6 – Feedstock transport	215	166	116
7 – Conversion (esterification)	471	471	471
8 – Liquid fuel transport	0	0	0
TOTAL	1771	2891	2151

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono

Stage	Module	Input	Options
			ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel, Heavy fuel oil, Coal, Natural gas
3	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Conversion (crushing)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
5	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
6	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
7	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvesting of soy						
Basic Data							
	Units						
Yield @ traded moisture content	[t/ha.a]	*value*	Y				
Moisture content	%	*value*	MC				
Soil Emissions							
				Emissions factor ($kgCO_{2e}$/ha)		Total Emissions (kgCO2e/t soy)	
N2O from nitrogen fertiliser	[total kg N/ha.a]	*N_FERT*	x	*6.163*	÷ Y =	*calculation*	1
N2O from crop residue				Y x (1 - MC / 100) x 157.3 + 141.9	÷ Y =	*calculation*	2
Farming Inputs							
				Emissions co-efficient [$kgCO_{2e}$/kg]		Total Emissions (kgCO2e/t soy)	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*	x	*value*	÷ Y =	*calculation*	3
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	4
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
				Emissions co-efficient [$kgCO_{2e}$/kg nutrient]			
Pesticides	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
Electricity	[kWh/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
Machinery Inputs							
Diesel fuel consumption	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	8
						Emissions (kgCO2e/t soy)	
Totals							
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 =	*calculation*	9
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					9 ÷ z1 ÷ z2 × AF =	*calculation*	Stage_1

Stage 2 - Drying and storage

Description	Drying of soy						
Basic Data							
Moisture removed	%	*value*					
				Emissions factor [kgCO2e/MJ]			
Drying and storage inputs							
Diesel	[MJ/t soy]	*value*	x	*value*	=	*calculation*	10
Electricity	[MJ/t soy]	*value*	x	*value*	=	*calculation*	11
						Emissions (kgCO2e/t soy)	
Totals							
Module total					10 + 11 =	*calculation*	12
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					12 ÷ z1 ÷ z2 × AF =	*calculation*	Stage_2

Stage 3 - Feedstock Transport

Description	From drying and storage facility to oil extraction plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
						Emissions (kgCO2e/t soy)	
Totals							
Module total	[MJ/t]	*value*	x	*value*	=	*calculation*	13
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					13 ÷ z1 ÷ z2 × AF =	*calculation*	Stage_3

Stage 4 - Conversion

Description	Oil extraction						
Basic Data							
Plant yield	[t soy oil / t soy]	*value*	z1				
				Emissions factor [kgCO2e/MJ]		Emissions (kgCO_{2e}/t biodiesel)	
Conversion Inputs							
Natural gas	[MJ/t soy oil]	*value*	x	*value*	=	*calculation*	14
Electricity imported	[MJ/t soy oil]	*value*	x	*value*	=	*calculation*	15
Co-products	**Description**	**Treatment**					
Co-product 1:	Soy meal - sold as animal feed	Substitution					
Co-products treated by substitution							
Co-product 1: soy meal							
				Credit [kgCO_{2e}/t soy meal]			
- substitutes EU wheat							
Quantity of soy meal produced & sold as animal feed	[t soy meal / t soy oil]	*value*	x	*value*	=	*calculation*	16
Totals							
Module total					14 + 15 + 16 =	*calculation*	17
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					17 ÷ z2 × AF =	*calculation*	Stage_4

Stage 5 - Feedstock Transport

Description	From crusher to port (Mode 1)							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_2					
Fuel consumption	[MJ/t-km]	value	FC_2					
Totals							Emissions (kgCO2e/t soy oil)	
Module total	[MJ/t soy oil]	value		x	value	=	calculation	18
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						18 ÷ z2 × AF =	calculation	Stage_5

Stage 6 - Feedstock Transport

Description	From port to biodiesel plant (Mode 2)							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_3					
Fuel consumption	[MJ/t-km]	value	FC_3					
Totals							Emissions (kgCO2e/t soy oil)	
Module total	[MJ/t soy oil]	value		x	value	=	calculation	19
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						19 ÷ z2 × AF =	calculation	Stage_6

Stage 7 - Conversion

Description	Biodiesel plant							
Basic data								
Plant yield	[t biodiesel / t soy oil]	value	(z2)					
Conversion Inputs					Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Natural gas	[MJ/t biodiesel]	value		x	value	=	calculation	20
Electricity imported	[MJ/t biodiesel]	value		x	value	=	calculation	21
					Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	value		x	value	=	calculation	22
Potassium hydroxide	kg/t biodiesel	value		x	value	=	calculation	23
Co-products	**Description**	**Treatment**						
Co-product 1:	Crude glycerine sold as chemical	Allocation - by market value						
Co-product 2:	Potassium sulphate	Allocation - by market value						

Co-products treated by allocation by market value							
Co-product 1: crude glycerine				Market value [£ / t gylcerine]			
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	*value*	x	*value*	=	*calculation*	24
Co-product 2: Potassium sulphate				Market value [£ / t potassium sulphate]			
Quantity of potassium sulphate produced and sold as chemical	[t potassium suplhate / t biodiesel]	*value*		*value*	=	*calculation*	25
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	26
Total market value of products							
Total market value	[£ / t biodiesel]					*calculation*	27
Allocation factor (%age of emissions attributable to biodiesel)	%					*calculation*	AF
Totals						Total Emissions [kgCO_{2e}/t biodiesel]	
Module total					(20 + 21 + 22 + 23) x AF=	*calculation*	28
Contribution to fuel chain					28 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	From biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_4				
Fuel consumption	[MJ/t-km]	*value*	FC_4				
Totals				Emissions factor [kgCO2e/MJ]		Total Emissions [kgCO_{2e}/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	29
Contribution to fuel chain					29 =	*calculation*	Stage_8

Default value tables

Stage/Input	**Units**	**Feedstock country of origin**		
		Argentina	**Brazil**	**USA**
Stage 1 – Crop Production				
Yield @ traded moisture content	[t/ha.a]	2.54	2.54	2.60
Moisture content	%	13	13	13
N fertiliser	[kg N/ha.a]	10	10	24
Type of N fertiliser		Urea	Urea	AN

Stage/Input	Units	Feedstock country of origin		
		Argentina	**Brazil**	**USA**
P fertiliser	[kg P_2O_5/ha.a]	5	50	100
Type of P fertiliser		MAP	MAP	TSP
K fertiliser	[kg K_2O/ha.a]	3	60	55
Pesticides	[kg/ha.a]	1.31	1.31	1.31
Electricity	[kWh/ha.a]	11.00	11.00	11.00
Diesel fuel consumption	[litres/ha.a]	75.6	75.6	75.6
Stage 2 – Drying and storage				
Moisture removed	%	2	2	2
Fuel for heating	[MJ/t soy]	138	138	138
Fuel type		Diesel	Diesel	Natural gas
Electricity	[MJ/t soy]	15	15	15
Stage 3 – Feedstock Transport				
Transport distance	[km]	330	1500	100
Fuel consumption	[MJ/t-km]	1.8	1.8	1.46
Fuel type		Diesel	Diesel	Diesel
Stage 4 – Conversion				
Yield	[t soy oil/t soy]	0.17	0.17	0.17
Natural gas	[MJ/t soy oil]	5447	5447	5447

Stage/Input	**Units**	**Feedstock country of origin**		
		Argentina	**Brazil**	**USA**
Electricity imported	[MJ/t soy oil]	1476	1476	1476
Co-products	Description	Treatment		
Co-product 1:	Soymeal sold as animal feed	Substitutes for EU wheat		
Quantity of soy meal produced & sold as animal feed	[t soy meal/t soy oil]	4.32	4.32	4.32
Credit	[kgCO_2e/t soy meal]	-373	-373	-373
Stage 5 – Feedstock Transport				
Transport distance	[km]	0	0	1500
Fuel consumption	[MJ/t-km]	0	0	0.19
Fuel type		None	None	Diesel
Stage 6 – Feedstock Transport				
Transport distance	[km]	13000	10000	7000
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2
Fuel type		HFO	HFO	HFO
Stage 7 – Conversion				
Yield	[t biodiesel / t soy oil]	0.95	0.95	0.95
Natural gas	[MJ/t biodiesel]	1690	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335	335

Stage/Input	**Units**	**Feedstock country of origin**		
		Argentina	**Brazil**	**USA**
Methanol	kg/t biodiesel	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	26
Co-products				
Co-product 1	Crude glycerine	Allocation by market value		
Quantity of crude glycerine	[t glycerine/t biodiesel]	0.1	0.1	0.1
Market value of glycerine	[£/t glycerine]	345	345	345
Co-product 2:	Potassium sulphate	Allocation by market value		
Quantity of potassium sulphate	[t potassium sulphate/t biodiesel]	0.04	0.04	0.04
Market value of potassium sulphate	[£/t potassium sulphate]	75	75	75
Primary product: biodiesel				
Market value of biodiesel	[£/t biodiesel]	340	340	340
Allocation factor	%	90	90	90
Stage 8 – Liquid fuel transport and storage				
Transport distance	[km]	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0

11 Palm to ME biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]	
	Indonesia	**Malaysia**
1 – Crop Production	344	313
2 – Feedstock transport	11	11
3 – Conversion (palm oil extraction)	520	520
4 – Feedstock transport	63	39
5 – Conversion (palm oil refining)	117	109
6 – Feedstock transport	248	248
7 – Conversion (esterification)	471	471
8 – Liquid fuel transport	0	0
TOTAL	1742	1743

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium

Stage	Module	Input	Options
			phosphate (MAP)
2	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
5	Conversion (palm oil refining)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
7	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
8	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvest of FFB						
Basic Data							
	Units						
Yield of FFB	[t/ha.a]	*value*	Y				
Soil Emissions							
				Emissions co-efficient [kgCO_{2e}/ha]		Total emissions	
N2O emissions	[total kg N/ha.a]	*N_FERT*	x	*6.163*	÷ Y =	*calculation*	1
Farming Inputs							
		Mass of input		Emissions co-efficient [kgCO_{2e}/kg nutrient]		Total emissions	
N fertiliser	[kg nutrient/ha.a]	*value (N_FERT)*	x	*value*	÷ Y =	*calculation*	2
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	3
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	4
Mg fertiliser (MgO)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
NPK fertiliser	[kg fertiliser/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
				Emissions co-efficient [kgCO_{2e}/kg]			
Pesticide	[kg/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
Machinery and transport Inputs							
				Emissions factor (kgCO_{2e}/l)			
Replant and production	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	8
Harvest and collection	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	9
						Emissions (kgCO_{2e}/t FFB)	
Totals							
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 =	*calculation*	10
						Total Emissions [kgCO_{2e}/t biodiesel]	
Contribution to fuel chain					10 ÷ z1 ÷ z2 ÷ z3 × AF_1 × AF_2 × AF_3	*calculation*	Stage_1

Stage 2 - Feedstock Transport

Description	Transport of FFB from field to palm oil mill							
				Emissions factor [kgCO2e/MJ]				
Transport distance	[km]	value	dist_1					
Fuel consumption	[MJ/t-km]	value	FC_1					
Totals							Emissions ($kgCO_{2e}$/t FFB)	
Module total	[MJ/t FFB]	value	x	value		=	*calculation*	11
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain				11 ÷ z1 ÷ z2 ÷ z3 × AF_1 × AF_2 × AF_3 =			*calculation*	Stage_2

Stage 3 - Conversion

Description	Processing FFB to extract palm oil and palm kernels							
Basic Data								
Palm oil mill yield	[t CPO / t FFB]	value	z1					
							Emissions ($kgCO_{2e}$/t CPO)	
Extraction Inputs								
Steam	[MJ/t CPO]	value						
Electricity	[MJ/t CPO]	value						
CHP plant efficiency	%	value						
				Emissions factor [kgCO2e/MJ]				
Fibre & Shell, CHP plant	[MJ/t CPO]	value	x	value		=	*calculation*	12
				Emissions factor (kgCO2e/kg)				
Mill effluent emissions (POME)	[kg/t CPO]	value	x	value		=	*calculation*	13

Co-products	Description	Treatment
Co-product 1:	EFB	Considered within system boundaries
Co-product 2:	Fibre	Considered within system boundaries
Co-product 3:	Shell	Considered within system boundaries
Co-product 4:	POME	Considered within system boundaries
Co-product 5:	Palm kernel	Allocation by market value

Co-products treated by allocation by market value							
				Market value [RM / t palm kernel]			
Co-product 5: Palm kernel							
Quantity of palm kernel produced	[t palm kernel / t CPO]	*value*	x	*value*	=	*calculation*	14
				Market value [RM / t CPO]			
Primary product: crude palm oil							
Market value of crude palm oil				*value*	=	*calculation*	15
Total market value of products							
Total market value	[RM / t CPO]					*calculation*	16
Allocation factor (%age of emissions attributable to biodiesel)	%					*calculation*	AF_1
						Emissions ($kgCO_{2e}$/t CPO)	
Totals							
Module total					(12 + 13) x AF_1 =	*calculation*	17
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					17 ÷ z2 ÷ z3 × AF_2 × AF_3 =	*calculation*	Stage_3

Stage 4 - Feedstock Transport

Description	Transport of CPO from palm oil mill to refinery						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
						Emissions ($kgCO_{2e}$/t CPO)	
Totals							
Module total	[MJ/t CPO]	*value*	x	*value*	=	*calculation*	18
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					18 ÷ z2 ÷ z3 × AF_2 × AF_3 =	*calculation*	Stage_4

Stage 5 - Conversion

Description	Refining, bleaching and deodorising of CPO, and fractionation to produce palm olein						
Basic Data							
Refinery yield	[t palm olein / t CPO]	*value*	z2				
Conversion Inputs							
				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t palm olein)	
Natural gas	[MJ/t palm olein]	*value*	x	*value*	=	*calculation*	19
Electricity imported	[MJ/t palm olein]	*value*	x	*value*	=	*calculation*	20
Co-products	**Description**	**Treatment**					
Co-product 1:	Palm stearin	Allocation by market value					
Co-product 2:	Palm olein	Allocation by market value					
Co-products treated by allocation by market value							
Co-product 1: Palm stearin				Market value [US$ / t palm stearin]			
Quantity of palm stearin produced	[t palm stearin / t palm olein]	*value*	x	*value*	=	*calculation*	21
Primary product: palm olein				Market value [US$ / t palm olein]			
Market value of palm olein				*value*	=	*calculation*	22
Total market value of products							
Total market value	[RM / t CPO]					*calculation*	23
Allocation factor (%age of emissions attributable to palm olein)	%					*calculation*	AF_2
Totals						Emissions ($kgCO_{2e}$/t palm olein)	
Module total					(19 + 20) x AF_2 =	*calculation*	24
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					24 ÷ z3 × AF_3 =	*calculation*	Stage_5

Stage 6 - Transport of palm olein

Description	Transport of palm olein from refinery to biodiesel plant							
				Emissions factor [kgCO2e/MJ]				
Transport distance	[km]	*value*	dist_3					
Fuel consumption	[MJ/t-km]	*value*	FC_3					
Totals							Emissions ($kgCO_{2e}$/t palm olein)	
Module total	[MJ/t palm olein]	*value*	x	*value*	=		*calculation*	25
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						25 ÷ z3 × AF_3 =	*calculation*	Stage_6

Stage 7 - Conversion

Description	Biodiesel plant						
Basic data							
Biodiesel plant yield	[t biodiesel / t palm olein]	*value*	(z3)				
				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Conversion Inputs							
Natural gas	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	26
Electricity imported	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	27
				Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	*value*	x	*value*	=	*calculation*	28
Potassium hydroxide	kg/t biodiesel	*value*	x	*value*	=	*calculation*	29

Co-products	**Description**	**Treatment**
Co-product 1:	Crude glycerine sold as chemical	Allocation - by market value
Co-product 2:	Potassium sulphate	Allocation - by market value

Co-products treated by allocation by market value

Co-product 1: crude glycerine				Market value [£ / t gylcerine]			
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	*value*	x	*value*	=	*calculation*	30
Co-product 2: Potassium sulphate				Market value [£ / t potassium sulphate]			
Quantity of potassium sulphate produced and sold as chemical	[t potassium suplhate / t biodiesel]	*value*		*value*	=	*calculation*	31
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	32
Total market value of products							
Total market value	[£ / t biodiesel]					*calculation*	33
Allocation factor (%age of emissions attributable to biodiesel)	%					*calculation*	AF_3
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(26 + 27 + 28 + 29) x AF_3 =	*calculation*	34
Contribution to fuel chain					34 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	Transport from biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_4				
Fuel consumption	[MJ/t-km]	*value*	FC_4				
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	35
Contribution to fuel chain					35 =	*calculation*	Stage_8

Default value tables

Stage/Input	**Units**	**Feedstock country of origin**	
		Malaysia	**Indonesia**
Stage 1 – Crop Production			
Yield of FFB	[t/ha.a]	19.0	17.7
N fertiliser	[kg N/ha.a]	100	95
Type of N fertiliser		SOA	Urea
P fertiliser	[kg P_2O_5/ha.a]	45	30

Stage/Input	Units	Feedstock country of origin	
		Malaysia	**Indonesia**
Type of P fertiliser		Rock	Rock
K fertiliser	[kg K_2O/ha.a]	205	75
Mg fertiliser (MgO)	[kg MgO /ha.a]	33	33
NPK fertiliser	[kg P_2O_5 /ha.a]	50	50
Pesticide	[kg/ha.a]	3	3
Replant and production	[litres/ha.a]	30	30
Harvest and collection	[litres/ha.a]	30	0
Stage 2 – Feedstock Transport			
Transport distance	[km]	17	17
Fuel consumption	[MJ/t-km]	1.8	1.8
Fuel type		Diesel	Diesel
Stage 3 – Conversion			
Palm oil mill yield	[t CPO/t FFB]	0.2	0.2
Mill effluent emissions (POME)	[kg/t CPO]	2500	2500
POME emissions coefficient	[kg CO2e / kg]	0.2472	0.2472
Co-products	Description	Treatment	
Co-product 1	Palm kernel	Allocation by market value	
Quantity of palm kernel	[t palm kernel/t CPO]	0.3	0.3

Stage/Input	Units	Feedstock country of origin	
		Malaysia	Indonesia
Market value of palm kernel	[RM/t palm kernel]	992	992
Primary product: CPO			
Market value of CPO	[RM/t palm olein]	1525	1524
Allocation factor	%	84	84
Stage 4 – Feedstock Transport			
Transport distance	[km]	250	400
Fuel consumption	[MJ/t-km]	1.8	1.8
Fuel type		Diesel	Diesel
Stage 5 – Conversion			
Refinery yield	[t palm olein/t CPO]	0.8	0.8
Heavy fuel oil	[MJ/t palm olein]	1366	1366
Electricity imported	[MJ/t palm olein]	121	121
Co-products	Description	Treatment	
Co-product 1	Palm stearin	Allocation by market value	
Quantity of palm stearin	[t palm stearin/t palm olein]	0.2	0.2
Market value of palm stearin	[USD/t palm stearin]	389	389
Primary product: palm olein			

Stage/Input	**Units**	**Feedstock country of origin**	
		Malaysia	**Indonesia**
Market value of palm olein	[USD/t palm olein]	438	438
Allocation factor	%	85	85
Stage 6 – Feedstock Transport			
Transport distance	[km]	15000	15000
Fuel consumption	[MJ/t-km]	0.2	0.2
Fuel type		HFO	HFO
Stage 7 – Conversion			
Biodiesel Yield	[t biodiesel / t palm oil]	0.95	0.95
Natural gas	[MJ/t biodiesel]	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335
Methanol	kg/t biodiesel	113	113
Potassium hydroxide	kg/t biodiesel	26	26
Co-products			
Co-product 1	Crude glycerine	Allocation by market value	
Quantity of crude glycerine	[t glycerine/t biodiesel]	0.1	0.1
Market value of glycerine	[£/t glycerine]	345	345
Co-product 2:	Potassium sulphate	Allocation by market value	

Stage/Input	Units	Feedstock country of origin	
		Malaysia	**Indonesia**
Quantity of potassium sulphate	[t potassium sulphate/t biodiesel]	0.04	0.04
Market value of potassium sulphate	[£/t potassium sulphate]	75	75
Primary product: biodiesel			
Market value of biodiesel	[£/t biodiesel]	340	340
Allocation factor	%	90	90
Stage 8 – Liquid fuel transport and storage			
Transport distance	[km]	0	0
Fuel consumption	[MJ/t-km]	0	0

12 Used cooking oil to ME biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]
1 – Feedstock Transport	8
2 – Conversion	471
3 – Liquid fuel transport	0
TOTAL	479

Selected default options

Stage	**Module**	**Input**	**Options**
1	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
2	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
3	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Feedstock Transport

Description	From central aggregation point to biodiesel plant. Note - includes credit for alternative waste treatment							
							Emissions ($kgCO_{2e}$/t feedstock)	
Alternative waste treatment								
Credit	[kg CO_{2e}/t feedstock]	*value*	x	*value*	=	*calculation*	1	
Transport								
Transport distance	[km]	*value*	dist_1					
Fuel consumption	[MJ/t-km]	*value*	FC_1					
				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t feedstock)		
Totals								
Module total	[MJ/t feedstock]	*value*	x	*value*	=	*calculation*	2	
Contribution to fuel chain					2 ÷ z1 × AF =	*calculation*	Stage_1	

Stage 2 - Conversion

Description	Biodiesel plant						
Basic data							
Plant yield	[t biodiesel / t used cooking oil]	*value*	(z1)				
				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Conversion Inputs							
Natural gas	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	3
Electricity imported	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	4
				Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	*value*	x	*value*	=	*calculation*	5
Potassium hydroxide	kg/t biodiesel	*value*	x	*value*	=	*calculation*	6
Co-products	**Description**	**Treatment**					
Co-product 1:	Crude glycerine sold as chemical	Allocation - by market value					
Co-product 2:	Potassium sulphate	Allocation - by market value					

Co-products treated by allocation by market value							
Co-product 1: crude glycerine				Market value [£ / t gylcerine]			
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	*value*	x	*value*	=	*calculation*	7
Co-product 2: Potassium sulphate				Market value [£ / t potassium sulphate]			
Quantity of potassium sulphate produced and sold as chemical	[t potassium suplhate / t biodiesel]	*value*		*value*	=	*calculation*	8
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	9
Total market value of products							
Total market value	[£ / t biodiesel]					*calculation*	10
Allocation factor (%age of emissions attributable to biodiesel)	%					*calculation*	AF
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(3 + 4 + 5 + 6) x AF =	*calculation*	11
Contribution to fuel chain					11 =	*calculation*	Stage_2

Stage 3 - Liquid fuel transport and storage

Description	From biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
Totals				Emissions factor [kgCO2e/MJ]		Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	12
Contribution to fuel chain					12 =	*calculation*	Stage_3

Default value tables

Stage/Input	**Units**	**Value**
Stage 1 – Feedstock Transport		
Credit for alternative waste treatment	[kg CO_2e/t feedstock]	0
Transport distance	[km]	50
Fuel consumption	[MJ/t-km]	1.53
Fuel type		Diesel
Stage 2 – Conversion		

Stage/Input	**Units**	**Value**
Yield	[t biodiesel/t used cooking oil]	0.875
Natural gas	[MJ/t biodiesel]	1690
Electricity imported	[MJ/t biodiesel]	335
Methanol	kg/t biodiesel	113
Potassium hydroxide	kg/t biodiesel	26
Co-product 1	Crude glycerine	Allocation by market value
Quantity of crude glycerine	[t glycerine/t biodiesel]	0.1
Market value of glycerine	[£/t glycerine]	345
Co-product 2:	Potassium sulphate	Allocation by market value
Quantity of potassium sulphate	[t potassium sulphate/t biodiesel]	0.04
Market value of potassium sulphate	[£/t potassium sulphate]	75
Primary product: biodiesel		
Market value of biodiesel	[£/t biodiesel]	340
Allocation factor	%	90
Stage 3 – Liquid fuel transport and storage		
Transport distance	[km]	0
Fuel consumption	[MJ/t-km]	0

13 Tallow to ME biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]		
	Denmark	United Kingdom	United States of America
1 – Feedstock Transport	34	7	25
2 – Feedstock Transport	11	0	126
2 – Conversion	471	471	471
3 – Liquid fuel transport	0	0	0
TOTAL	516	478	622

Selected default options

Stage	Module	Input	Options
1	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Stage	Module	Input	Options
2	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
3	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stage 1 - Feedstock Transport

Description	From central aggregation point to biodiesel plant or to port. Note - includes credit for alternative waste treatment						
Alternative waste treatment						Emissions ($kgCO_{2e}$/t feedstock)	
Credit	[kg CO_{2e}/t feedstock]	*value*	x	*value*	=	*calculation*	1
Transport							
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
Totals				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t feedstock)	
Module total	[MJ/t feedstock]	*value*	x	*value*	=	*calculation*	2
Contribution to fuel chain					2 ÷ z1 × AF =	*calculation*	Stage_1

Stage 2 - Feedstock Transport

Description	From port to biodiesel plant						
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
Totals				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t feedstock)	
Module total	[MJ/t feedstock]	*value*	x	*value*	=	*calculation*	3
Contribution to fuel chain					3 ÷ z1 × AF =	*calculation*	Stage_1

Stage 3 - Conversion

Description	Biodiesel plant						
Basic data							
Plant yield	[t biodiesel / t tallow]	*value*	(z1)				
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	

Natural gas	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	4
Electricity imported	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	5
				Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	*value*	x	*value*	=	*calculation*	6
Potassium hydroxide	kg/t biodiesel	*value*	x	*value*	=	*calculation*	7

Co-products	**Description**	**Treatment**
Co-product 1:	Crude glycerine sold as chemical	Allocation - by market value
Co-product 2:	Potassium sulphate	Allocation - by market value

Co-products treated by allocation by market value

Co-product 1: crude glycerine				Market value [£ / t gylcerine]			
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	*value*	x	*value*	=	*calculation*	8
Co-product 2: Potassium sulphate				Market value [£ / t potassium sulphate]			
Quantity of potassium sulphate produced and sold as chemical	[t potassium suplhate / t biodiesel]	*value*		*value*	=	*calculation*	9
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	10
Total market value of products							
Total market value	[£ / t biodiesel]					*calculation*	11
Allocation factor (%age of emissions attributable to biodiesel)	%					*calculation*	AF
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(4 + 5 + 6 + 7) x AF =	*calculation*	12
Contribution to fuel chain					11 =	*calculation*	Stage_2

Stage 3 - Liquid fuel transport and storage

Description	From biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
Totals				Emissions factor [kgCO2e/MJ]		Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	13
Contribution to fuel chain					12 =	*calculation*	Stage_3

Default value tables

Stage/Input	Units	Feedstock country of origin		
		Denmark	United Kingdom	United States of America
Stage 1 – Feedstock Transport				
Credit for alternative waste treatment	[kg CO_2e/t feedstock]	0	0	0
Transport distance	[km]	250	50	1500
Fuel consumption	[MJ/t-km]	1.53	1.53	0.19
Fuel type		Diesel	Diesel	Diesel
Stage 1 – Feedstock Transport				
Transport distance	[km]	50	0	7000
Fuel consumption	[MJ/t-km]	1.53	0	0.2
Fuel type		HFO	None	HFO
Stage 3 – Conversion				
Yield	[t biodiesel/t UCO or tallow]	0.875	0.875	0.875

Stage/Input	Units	Feedstock country of origin		
		Denmark	United Kingdom	United States of America
Natural gas	[MJ/t biodiesel]	1690	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335	335
Methanol	kg/t biodiesel	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	26
Co-product 1	Crude glycerine	Allocation by market value	Allocation by market value	Allocation by market value
Quantity of crude glycerine	[t glycerine/t biodiesel]	0.1	0.1	0.1
Market value of glycerine	[£/t glycerine]	345	345	345
Co-product 2:	Potassium sulphate	Allocation by market value	Allocation by market value	Allocation by market value
Quantity of potassium sulphate	[t potassium sulphate/t biodiesel]	0.04	0.04	0.04
Market value of potassium sulphate	[£/t potassium sulphate]	75	75	75
Primary product: biodiesel				
Market value of biodiesel	[£/t biodiesel]	340	340	340

Stage/Input	Units	Feedstock country of origin		
		Denmark	United Kingdom	United States of America
Allocation factor	%	90	90	90
Stage 4 – Liquid fuel transport and storage				
Transport distance	[km]	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0

14 Oilseed rape to HVO biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]							
Module	**Australia**	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
1 - Crop production	2510	2406	2471	2066	2075	1915	2633	2525
2 - Drying and storage	0	84	87	80	92	97	88	92
3 - Feedstock transport	29	142	38	113	113	113	80	38
4 - Feedstock transport	900	0	0	0	0	0	116	0
5 - Conversion (crushing)	-609	-636	-628	-653	-605	-586	-608	-608
6 - Feedstock transport	41	144	0	43	37	16	10	43
7 - Conversion (hydrogenation)	488	488	488	488	488	488	488	488
8 - Liquid fuel transport and storage	35	35	35	35	35	35	35	35
TOTAL	3394	2663	2491	2172	2235	2078	2842	2613

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel, Heavy fuel oil, Coal, Natural gas
3	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
5	Conversion (crushing)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
7	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
8	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stages 1 to 5 are identical to the fuel chain given for palm oil to ME biodiesel.

Stage 6 - Feedstock Transport

Description	From extraction facility to hydrogenation plant							
				Emissions factor [kgCO2e/MJ]				
Transport distance	[km]	value	dist_3					
Fuel consumption	[MJ/t-km]	value	FC_3					
Totals							Emissions ($kgCO_{2e}$/t rapeseed oil)	
Module total	[MJ / t rapeseed oil]	value	x	value		=	calculation	19
Contribution to fuel chain						19 ÷ z2 =	calculation	Stage_6

Stage 7 - Conversion

Description	Hydrogenation plant							
Basic data								
Plant yield	[t HVO biodiesel / t rapeseed oil]	value	(z2)					
Conversion Inputs				Emissions factor [kgCO2e / MJ]			Emissions [$kgCO_{2e}$/t HVO diesel]	
Natural gas	[MJ/t HVO biodiesel]	value	x	value		=	calculation	20
Electricity	[MJ/t HVO biodiesel]	value	x	value		=	calculation	21
Totals							Total Emissions [$kgCO_{2e}$/t HVO biodiesel]	
Module total						20 + 21 =	calculation	22
Contribution to fuel chain						22 =	calculation	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	From HVO biodiesel plant to refinery / blending facility							
Transport distance	[km]	value	dist_4					
Fuel consumption	[MJ/t-km]	value	FC_4					
Totals				Emissions factor [kgCO2e/MJ]			Total Emissions [$kgCO_{2e}$/t HVO biodiesel]	
Module total	[MJ/t HVO biodiesel]	value	x	value		=	calculation	23
Contribution to fuel chain						23 =	calculation	Stage_8

Default value tables

Stage/Input	Units	Feedstock country of origin							
		Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom
Stage 1 – Crop production									
Yield @ traded moisture content	[t/ha.a]	1.19	1.46	1.30	3.18	3.44	2.38	1.12	3.03
Traded moisture content	%	9	9	9	9	9	9	9	9
N fertiliser	[kg N /ha.a]	61	75	67	155	170	102	60	185
Type of N fertiliser		AN	AN	AN	AN	AN	AN	AN	AN
P fertiliser	[kg P_2O_5/ha.a]	16	20	18	45	45	35	15	45
Type of P fertiliser		TSP	TSP	TSP	TSP	TSP	TSP	TSP	TSP
K fertiliser	[kg K_2O/ha.a]	12	15	13	80	90	44	12	48
Lime	[kg CaO/ha.a]	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9
Pesticides	[kg/ha.a]	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Diesel fuel consumption	[litres/ha.a]	66	66	66	66	66	66	66	66

Stage/Input	Units	Feedstock country of origin							
		Australia	**Canada**	**Finland**	**France**	**Germany**	**Poland**	**Ukraine**	**United Kingdom**
Stage 2 – Drying and storage									
Moisture removed	% by weight	0	3	3	3	3	3	3	3
Fuel for heating	[MJ/t OSR]	0	318	318	318	318	318	318	318
Electricity	[MJ/t OSR]	0	35	35	35	35	35	35	35
Stage 3 – Feedstock Transport									
Transport distance	[km]	300	3000	100	300	300	300	1700	100
Fuel consumption	[MJ/t-km]	0.38	0.19	1.53	1.53	1.53	1.53	0.19	1.53
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Stage 4 – Feedstock Transport									
Transport distance	[km]	18000	0	0	0	0	0	2300	0
Fuel consumption	[MJ/t-km]	0.2	N/A	N/A	N/A	N/A	N/A	0.2	N/A
Fuel type		HFO	N/A	N/A	N/A	N/A	N/A	HFO	N/A

Stage/Input	Units	Feedstock country of origin							
		Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom
Stage 5 – Conversion									
Plant yield	[t rapeseed oil/t oilseed rape]	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Natural gas	[MJ/t rapeseed oil]	1986	1986	1986	1986	1986	1986	1986	1986
Electricity imported	[MJ/t rapeseed oil]	337	337	337	337	337	337	337	337
Co-product 1: Rape meal – sold as animal feed		Substitutes US soy meal (soybeans crushed in EU)							
Quantity of rape meal	[t rape meal/t rapeseed oil]	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Credit for co-product 1	[kgCO_2e/t rape meal]	-504	-504	-504	-504	-504	-504	-504	-504
Stage 6 – Feedstock Transport									
Transport distance	[km]	1900	6700	0	2000	1700	760	500	2000
Fuel consumption	[MJ/t-km]	0.2	0.2	0	0.2	0.2	0.2	0.19	0

Stage/Input	Units	Feedstock country of origin							
		Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom
Fuel type		HFO	HFO		HFO	HFO	HFO	Diesel	HFO
Stage 7 – Conversion									
Plant yield	[t biodiesel/t rapeseed oil]	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813
Natural gas	[MJ/t biodiesel]	7660	7660	7660	7660	7660	7660	7660	7660
Electricity imported	[MJ/t biodiesel]	159	159	159	159	159	159	159	159
Stage 8 – Liquid fuel transport and storage									
Transport distance	[km]	2000	2000	2000	2000	2000	2000	2000	2000
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fuel Type		HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO

15 Soy to HVO biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]		
	Argentina	**Brazil**	**USA**
1 – Crop production	2372	2677	3124
2 – Drying and storage	95	88	79
3 – Feedstock transport	371	1689	91
4 – Conversion (crushing)	-1429	-1528	-1278
5 – Feedstock transport	0	0	30
6 – Feedstock transport	311	247	183
7 – Conversion (hydrogenation)	488	488	488
8 – Liquid fuel transport	35	35	35
TOTAL	2243	3696	2752

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)

Stage	Module	Input	Options
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel, Heavy fuel oil, Coal, Natural gas
3	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Conversion (crushing)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
5	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
6	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
7	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stages 1 to 5 are identical to the fuel chain given for palm oil to ME biodiesel.

Stage 5 - Feedstock Transport

Description	From crusher to port (Mode 1)							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_2					
Fuel consumption	[MJ/t-km]	value	FC_2					
Totals							Emissions (kgCO2e/t soy oil)	
Module total	[MJ/t soy oil]	value		x	value	=	calculation	18
							Total Emissions [$kgCO_{2e}$/t HVO biodiesel]	
Contribution to fuel chain						18 ÷ z2 =	calculation	Stage_5

Stage 6 - Feedstock Transport

Description	From port to HVO biodiesel plant (Mode 2)							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_3					
Fuel consumption	[MJ/t-km]	value	FC_3					
Totals							Emissions (kgCO2e/t soy oil)	
Module total	[MJ/t soy oil]	value		x	value	=	calculation	19
							Total Emissions [$kgCO_{2e}$/t HVO biodiesel]	
Contribution to fuel chain						19 ÷ z2 =	calculation	Stage_6

Stage 7 - Conversion

Description	Hydrogenation plant							
Basic data								
Plant yield	[t HVO biodiesel / t rapeseed oil]	value	(z2)					
Conversion Inputs					Emissions factor [kgCO2e / MJ]		Emissions [$kgCO_{2e}$/t HVO diesel]	
Natural gas	[MJ/t HVO biodiesel]	value		x	value	=	calculation	20
Electricity	[MJ/t HVO biodiesel]	value		x	value	=	calculation	21
Totals							Total Emissions [$kgCO_{2e}$/t HVO biodiesel]	
Module total						20 + 21 =	calculation	22
Contribution to fuel chain						22 =	calculation	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	From HVO biodiesel plant to refinery / blending facility							
Transport distance	[km]	value	dist_4					
Fuel consumption	[MJ/t-km]	value	FC_4					
Totals					Emissions factor [kgCO2e/MJ]		Total Emissions [$kgCO_{2e}$/t HVO biodiesel]	
Module total	[MJ/t biodiesel]	value		x	value	=	calculation	23
Contribution to fuel chain						23 =	calculation	Stage_8

Default value tables

Stage/Input	Units	Feedstock country of origin		
		Argentina	**Brazil**	**USA**
Stage 1 – Crop Production				
Yield @ traded moisture content	[t/ha.a]	2.54	2.54	2.60
Moisture content	%	13	13	13
N fertiliser	[kg N/ha.a]	10	10	24
Type of N fertiliser		Urea	Urea	AN
P fertiliser	[kg P_2O_5/ha.a]	5	50	100
Type of P fertiliser		MAP	MAP	TSP
K fertiliser	[kg K_2O/ha.a]	3	60	55
Pesticides	[kg/ha.a]	1.31	1.31	1.31
Electricity	[kWh/ha.a]	11.00	11.00	11.00
Diesel fuel consumption	[litres/ha.a]	75.6	75.6	75.6
Stage 2 – Drying and storage				
Moisture removed	%	2	2	2
Fuel for heating	[MJ/t soy]	138	138	138
Fuel type		Diesel	Diesel	Natural gas

Stage/Input	Units	Feedstock country of origin		
		Argentina	**Brazil**	**USA**
Electricity	[MJ/t soy]	15	15	15
Stage 3 – Feedstock Transport				
Transport distance	[km]	330	1500	100
Fuel consumption	[MJ/t-km]	1.8	1.8	1.46
Fuel type		Diesel	Diesel	Diesel
Stage 4 – Conversion				
Yield	[t soy oil/t soy]	0.17	0.17	0.17
Natural gas	[MJ/t soy oil]	5447	5447	5447
Electricity imported	[MJ/t soy oil]	1476	1476	1476
Co-products	Description	Treatment		
Co-product 1:	Soymeal sold as animal feed	Substitutes for EU wheat		
Quantity of soy meal produced & sold as animal feed	[t soy meal/t soy oil]	4.32	4.32	4.32
Credit	[kgCO_2e/t soy meal]	-373	-373	-373
Stage 5 – Feedstock Transport				
Transport distance	[km]	0	0	1500
Fuel consumption	[MJ/t-km]	0	0	0.19

Stage/Input	Units	Feedstock country of origin		
		Argentina	**Brazil**	**USA**
Fuel type		None	None	Diesel
Stage 6 – Feedstock Transport				
Transport distance	[km]	14500	11500	8500
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2
Fuel type		HFO	HFO	HFO
Stage 7 – Conversion				
Plant yield	[t biodiesel/t soy oil]	0.813	0.813	0.813
Natural gas	[MJ/t biodiesel]	7660	7660	7660
Electricity imported	[MJ/t biodiesel]	159	159	159
Stage 8 – Liquid fuel transport and storage				
Transport distance	[km]	2000	2000	2000
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2
Fuel Type		HFO	HFO	HFO

16 Palm to HVO biodiesel

Fuel chain summary

	Carbon intensity [kg CO2/t biodiesel]	
	Indonesia	**Malaysia**
1 – Crop Production	406	447
2 – Feedstock transport	14	14
3 – Conversion (palm oil extraction)	675	675
4 – Feedstock transport	82	51
5 – Conversion (palm oil refining)	152	142
6 – Feedstock transport	354	354
7 – Conversion (esterification)	488	488
8 – Liquid fuel transport	35	35
TOTAL	2206	2206

Selected default options

Stage	Module	Input	Options
1	Crop production	Nitrogen fertiliser emissions factor	Ammonium nitrate (AN), Ammonium sulphate (AS),Urea, Calcium nitrate (CN), Urea ammonium nitrate liquid (UAN), NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
4	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
5	Conversion (palm oil refining)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
7	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
8	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain

Stages 1 to 5 are identical to the fuel chain given for palm oil to ME biodiesel.

Stage 6 - Transport of palm olein

Description	Transport of palm olein from refinery to HVO biodiesel plant							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_3					
Fuel consumption	[MJ/t-km]	*value*	FC_3					
							Emissions (kgCO_{2e}/t palm olein)	
Totals Module total	[MJ/t palm olein]	*value*		x	*value*	=	*calculation*	25
							Total Emissions [kgCO_{2e}/t HVO biodiesel]	
Contribution to fuel chain						25 ÷ z2 =	*calculation*	Stage_6

Stage 7 - Conversion

Description	Hydrogenation plant							
Basic data								
Plant yield	[t HVO biodiesel / t rapeseed oil]	*value*	(z2)					
Conversion Inputs					Emissions factor [kgCO2e / MJ]		Emissions [kgCO_{2e}/t HVO diesel]	
Natural gas	[MJ/t HVO biodiesel]	*value*		x	*value*	=	*calculation*	26
Electricity	[MJ/t HVO biodiesel]	*value*		x	*value*	=	*calculation*	27
							Total Emissions [kgCO_{2e}/t HVO biodiesel]	
Totals Module total						26 + 27 =	*calculation*	28
Contribution to fuel chain						28 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	Transport from HVO biodiesel plant to refinery / blending facility							
Transport distance	[km]	*value*	dist_4					
Fuel consumption	[MJ/t-km]	*value*	FC_4					
							Total Emissions [kgCO_{2e}/t HVO biodiesel]	
Totals Module total	[MJ/t biodiesel]	*value*		x	*value*	=	*calculation*	29
Contribution to fuel chain						29 =	*calculation*	Stage_8

Default value tables

Stage/Input	Units	Feedstock country of origin	
		Malaysia	**Indonesia**
Stage 1 – Crop Production			
Yield of FFB	[t/ha.a]	19.0	17.7
N fertiliser	[kg N/ha.a]	100	95
Type of N fertiliser		SOA	Urea
P fertiliser	[kg P_2O_5/ha.a]	45	30
Type of P fertiliser		Rock	Rock
K fertiliser	[kg K_2O/ha.a]	205	75
Mg fertiliser (MgO)	[kg MgO /ha.a]	33	33
NPK fertiliser	[kg P_2O_5 /ha.a]	50	50
Pesticide	[kg/ha.a]	3	3
Replant and production	[litres/ha.a]	30	30
Harvest and collection	[litres/ha.a]	40	40
Stage 2 – Feedstock Transport			
Transport distance	[km]	17	17
Fuel consumption	[MJ/t-km]	1.8	1.8
Fuel type		Diesel	Diesel

Stage/Input	Units	Feedstock country of origin	
		Malaysia	**Indonesia**
Stage 3 – Conversion			
Palm oil mill yield	[t CPO/t FFB]	0.2	0.2
Mill effluent emissions (POME)	[kg/t CPO]	2500	2500
POME emissions coefficient	[kg CO2e / kg]	0.2472	0.2472
Co-products	Description	Treatment	
Co-product 1	Palm kernel	Allocation by market value	
Quantity of palm kernel	[t palm kernel/t CPO]	0.3	0.3
Market value of palm kernel	[RM/t palm kernel]	992	992
Primary product: CPO			
Market value of CPO	[RM/t palm olein]	1525	1524
Allocation factor	%	84	84
Stage 4 – Feedstock Transport			
Transport distance	[km]	250	400
Fuel consumption	[MJ/t-km]	1.89	1.89
Fuel type		Diesel	Diesel
Stage 5 – Conversion			

Stage/Input	Units	Feedstock country of origin	
		Malaysia	**Indonesia**
Refinery yield	[t palm olein/t CPO]	0.8	0.8
Natural gas	[MJ/t palm olein]	1366	1366
Electricity imported	[MJ/t palm olein]	121	121
Co-products	Description	Treatment	
Co-product 1	Palm stearin	Allocation by market value	
Quantity of palm stearin	[t palm stearin/t palm olein]	0.2	0.2
Market value of palm stearin	[USD/t palm stearin]	389	389
Primary product: palm olein			
Market value of palm olein	[USD/t palm olein]	438	438
Allocation factor	%	85	85
Stage 6 – Feedstock Transport			
Transport distance	[km]	16500	16500
Fuel consumption	[MJ/t-km]	0.2	0.2
Fuel type		HFO	HFO
Stage 7 – Conversion			
Plant yield	[t biodiesel/t rapeseed	0.813	0.813

Stage/Input	Units	Feedstock country of origin	
		Malaysia	Indonesia
	oil]		
Natural gas	[MJ/t biodiesel]	7660	7660
Electricity imported	[MJ/t biodiesel]	159	159
Stage 8 – Liquid fuel transport and storage			
Transport distance	[km]	2000	2000
Fuel consumption	[MJ/t-km]	0.2	0.2
Fuel Type		HFO	HFO

17 Ethanol to ETBE

ETBE can be produced in two ways:

- Using isobutene in a refinery, in which case it is most likely to be substituting MTBE from the fuel mix, or
- Using isobutene imported from a dedicated isobutene plant, in which case it is most likely to be substitution gasoline from the fuel mix.

In the first case, the benefits of substituting MTBE (which is more carbon intensive than gasoline) from the fuel mix must be taken into account. Fuel suppliers who are able to prove that refinery by-product isobutene has been used in the production of ETBE will be able to report default values which specifically take this into account. Consequently, there are two sets of default values and two different fuel chains within this section.

Fuel chain summary

ETBE produced using refinery by-product isobutene

Feedstock	**Wheat**				
Origin	**Canada**	**France**	**Germany**	**Ukraine**	**United Kingdom**
1 - Conversion	2636	2461	2387	2919	2404
2 - Liquid fuel transport & storage	8	8	8	8	8
TOTAL	2644	2469	2395	2927	2412

Feedstock	**Sugar beet**	**Molasses**		
Origin	**UK**	**Pakistan**	**South Africa**	**UK**
1 - Conversion	2281	2608	2735	2151
2 - Liquid fuel transport & storage	8	8	8	8
TOTAL	2289	2616	2743	2159

Feedstock	Sugar cane				Corn	
Origin	Brazil	Mozambique	Pakistan	South Africa	France	USA
1 - Conversion	1974	2040	3069	3036	2267	2980
2 - Liquid fuel transport & storage	8	8	8	8	8	8
TOTAL	1982	2048	3077	3044	2275	2988

ETBE produced using isobutene from a dedicated plant

Feedstock	Wheat				
Origin	Canada	France	Germany	Ukraine	United Kingdom
1 - Conversion	3124	2949	2875	3407	2892
2 - Liquid fuel transport & storage	8	8	8	8	8
TOTAL	3132	2957	2883	3415	2900

Feedstock	Sugar beet	Molasses		
Origin	UK	Pakistan	South Africa	UK
1 - Conversion	2769	3096	3223	2639
2 - Liquid fuel transport & storage	8	8	8	8
TOTAL	2777	3104	3231	2647

Feedstock	Sugar cane				Corn	
Origin	**Brazil**	**Mozambique**	**Pakistan**	**South Africa**	**France**	**USA**
1 - Conversion	2462	2528	3557	3524	2755	3468
2 - Liquid fuel transport & storage	8	8	8	8	8	8
TOTAL	2470	2536	3565	3532	2763	3476

Selected default options (for both fuel chains)

Stage	Module	Input	Options
1	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
2	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Default fuel chain: ETBE produced using refinery by-product isobutene

Stage 1 - Conversion

Description — ETBE conversion facility

NOTE 1: When the isobutene used to make ETBE is taken from a refinery, it is assumed it would have otherwise been used to produce MTBE and, therefore, some methanol is being displaced (while some extra gasoline is required) for which ETBE is given a GHG credit. Furthermore, it is assumed that producing ETBE requires no marginal increase in natural gas, electricity or isobutene relative to MTBE production. See Methodology document for a full explanation

				Ethanol carbon intensity [kg CO2e / t ethanol]		Emissions [$kgCO_{2e}$/t ETBE]	
Inputs							
Ethanol	[t ethanol / t ETBE]	*value*	x	*value*	=	*calculation*	1
Credit for avoided methanol (minus additional gasoline required)							
Credit						*calculation*	2
Debit for fossil carbon						*calculation*	3
						Emissions [$kgCO_{2e}$/t ETBE]	
Totals							
Module total					1 + 2 + 3 =	*calculation*	4
Contribution to fuel chain					4 =	*calculation*	Stage_1

Stage 2 - Liquid fuel transport and storage

Description — From ETBE conversion facitity to duty point

Transport distance	[km]	*value*	dist				
Fuel consumption	[MJ/t-km]	*value*	FC				
				Emissions factor [kgCO2e/MJ]		Emissions [$kgCO_{2e}$/t ETBE]	
Totals							
Module total	[MJ/t ETBE]	*value*	x	*value*	=	*calculation*	5
Contribution to fuel chain					5 =	*calculation*	Stage_2

Default fuel chains: ETBE produced using isobutene from in a dedicated plant

Stage 1 - Conversion

Description	ETBE conversion facility						
Inputs				Ethanol carbon intensity [kg CO2e / t ethanol]		Emissions ($kgCO_{2e}$/t ETBE)	
Ethanol	[t ethanol / t ETBE]	value	x	value	=	calculation	1
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t ETBE)	
Natural gas	[MJ/t ETBE]	value	x	value	=	calculation	2
Electricity imported	[MJ/t ETBE]	value	x	value	=	calculation	3
				Emissions factor ($kgCO_{2e}$/t)			
Isobutene	[t / t ETBE]	value	x	value	=	calculation	4
Debit for fossil carbon						calculation	5
Totals						Emissions ($kgCO_{2e}$/t ETBE)	
Module total					1 + 2 + 3 + 4 + 5 =	calculation	6
Contribution to fuel chain					6 =	calculation	Stage_1

Stage 2 - Liquid fuel transport and storage

Description	From ETBE conversion facitity to duty point						
Transport distance	[km]	value	dist				
Fuel consumption	[MJ/t-km]	value	FC				
Totals				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t ETBE)	
Module total	[MJ/t ETBE]	value	x	value	=	calculation	7
Contribution to fuel chain					7 =	calculation	Stage_2

Default value tables (for both fuel chains)

Stage/Input	**Units**	**Refinery isobutene**	**Imported isobutene**
Stage 1 – Conversion			
Ethanol	[t ethanol/t ETBE]	0.451	0.451
Natural gas	[MJ/t ETBE]	0	2264
Electricity imported	[MJ/t ETBE]	0	145

Isobutene	[t / t ETBE]	0	0.549
Emissions coefficient for isobutene	[kg CO_2e /t isobutene]	N/A	500
Credit	[kgCO_2e/t ETBE]	-54	0
Debit for fossil carbon content of isobutene	[kgCO_2e/t ETBE]	1726	1726
Stage 2 – Liquid fuel transport and storage			
Transport distance	[km]	450	450
Fuel consumption	[MJ/t-km]	0.2	0.2
Fuel Type		HFO	HFO

18 Manure to biomethane

Fuel chain summary

	Carbon intensity [kg CO2/t biomethane]
1 – Feedstock transport	290
2 – Conversion	1339
3 – Gaseous fuel transport and storage	0
Total	1630

Selected default options

Stage	Module	Input	Options
1	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
2	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass

Default fuel chain

Stage 1 - Feedstock Transport

Description	From central aggregation point to digestion plant						
						Emissions ($kgCO_{2e}$/t feedstock)	
Alternative waste treatment							
Credit	[kg CO_{2e}/t feedstock]	*value*	x	*value*	=	*calculation*	1
Transport							
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t feedstock)	
Totals							
Module total	[MJ/t feedstock]	*value*	x	*value*	=	*calculation*	2
						Total emissions ($kgCO_2e$/tonne biomethane)	
Contribution to fuel chain					2 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Conversion

Description	Digestion plant						
Plant yield	MJ biomethane / t feedstock	*value*	z1				
				Emissions factor [kgCO2e/MJ]		Emissions (gCO_{2e}/MJ biomethane)	
Conversion Inputs							
Steam	MJ / MJ biomethane	*value*					
Overall efficiency	%	*value*					
Percent supplied from biogas	%	*value*					
Natural gas (import)	MJ / MJ biomethane	*value*	x	*value*	=	*calculation*	3
Electricity (import)	MJ / MJ biomethane	*value*	x	*value*	=	*calculation*	4
Methane losses	MJ CH4 lost / MJ biomethane	*value*					
				Emissions factor ($kgCO_{2e}/kgCH_4$)			
	kg CH4 lost / MJ biomethane	*value*	x	*value*	=	*calculation*	5

Co-products				Credit ($kgCO_{2e}/kg$)			
Fertiliser	MJ/MJ biomethane	*value*	x	*value*	=	*calculation*	6
Totals						Emissions (gCO_{2e}/MJ biomethane)	
Module total					3 + 4 + 5 + 6 =	*calculation*	7
						Total emissions ($kgCO_2e$/tonne biomethane)	
Contribution to fuel chain					7 x 45100 =	*calculation*	Stage_2

Stage 3 - Gas fuel transport and storage

Description	From biomethane plant to duty point						
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
Totals				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/MJ biomethane)	
Module total	[MJ/MJ]	*value*	x	*value*	=	*calculation*	8
						Total emissions ($kgCO_2e$/tonne biomethane)	
Contribution to fuel chain					8 x 45100 =	*calculation*	Stage_3

Default value tables

Stage/Input	**Units**	**Value**
Stage 1 – Feedstock Transport		
Credit	[kg CO_2e/t feedstock]	0
Transport distance	[km]	40
Fuel consumption	[MJ/t-km]	8
Stage 2 – Conversion		
Yield	MJ biomethane/t manure	4297
Natural gas (import)	MJ/MJ biomethane	0

Electricity (import)	MJ/MJ biomethane	0.077
Methane losses	g CH4 lost/MJ biomethane	0.887
Emissions coefficient for methane	g C02e / g CH4	23
Co-products	Description	Treatment
Co-product 1	Organic nitrogen fertiliser	Substitutes synthetic N fertiliser
Fertiliser	MJ N/MJ biomethane	0.02318
Credit	kgCO_2e/MJ N	-0.034
Stage 3 – Gas fuel transport and storage		
Transport distance	[km]	0.36
Fuel consumption	[MJ/t-km]	0

19 Municipal solid waste to biomethane

Fuel chain summary

	Carbon intensity [kg CO2/t biomethane]
1 – Feedstock transport	290
2 – Conversion	1339
3 – Gaseous fuel transport and storage	0
Total	1630

Selected default options

Stage	Module	Input	Options
1	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
2	Conversion	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass

Default fuel chain

Stage 1 - Feedstock Transport

Description	From central aggregation point to digestion plant						
Alternative waste treatment						Emissions ($kgCO_{2e}$/t feedstock)	
Credit	[kg CO_{2e}/t feedstock]	*value*	x	*value*	=	*calculation*	1
Transport							
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
Totals				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t feedstock)	
Module total	[MJ/t feedstock]	*value*	x	*value*	=	*calculation*	2
						Total emissions ($kgCO_2e$/tonne biomethane)	
Contribution to fuel chain					2 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Conversion

Description	Digestion plant						
Plant yield	MJ biomethane / t feedstock	*value*	z1				
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions (gCO_{2e}/MJ biomethane)	
Steam	MJ / MJ biomethane	*value*					
Overall efficiency	%	*value*					
Percent supplied from biogas	%	*value*					
Natural gas (import)	MJ / MJ biomethane	*value*	x	*value*	=	*calculation*	3
Electricity (import)	MJ / MJ biomethane	*value*	x	*value*	=	*calculation*	4
Methane losses	MJ CH4 lost / MJ biomethane	*value*					
				Emissions factor ($kgCO_{2e}/kgCH_4$)			
	kg CH4 lost / MJ biomethane	*value*	x	*value*	=	*calculation*	5

				Credit ($kgCO_{2e}$/kg)			
Co-products							
Fertiliser	MJ/MJ biomethane	*value*	x	*value*	=	*calculation*	6
						Emissions (gCO_{2e}/MJ biomethane)	
Totals							
Module total					3 + 4 + 5 + 6 =	*calculation*	7
						Total emissions ($kgCO_2e$/tonne biomethane)	
Contribution to fuel chain					7 x 45100 =	*calculation*	Stage_2

Stage 3 - Gas fuel transport and storage

Description	From biomethane plant to duty point						
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/MJ biomethane)	
Totals							
Module total	[MJ/MJ]	*value*	x	*value*	=	*calculation*	8
						Total emissions ($kgCO_2e$/tonne biomethane)	
Contribution to fuel chain					8 x 45100 =	*calculation*	Stage_3

Default value tables

Stage/Input	**Units**	**Value**
Stage 1 – Feedstock Transport		
Credit	[kg CO_2e/t feedstock]	0
Transport distance	[km]	40
Fuel consumption	[MJ/t-km]	8
Stage 2 – Conversion		
Yield	MJ biomethane/t waste	4297
Natural gas (import)	MJ/MJ biomethane	0

Electricity (import)	MJ/MJ biomethane	0.077
Methane losses	g CH4 lost/MJ biomethane	0.887
Emissions coefficient for methane	g C02e / g CH4	23
Co-products	Description	Treatment
Co-product 1	Organic nitrogen fertiliser	Substitutes synthetic N fertiliser
Fertiliser	MJ N/MJ biomethane	0.0232
Credit	$kgCO_2e$/MJ N	-0.034
Stage 3 – Gas fuel transport and storage		
Transport distance	[km]	0.36
Fuel consumption	[MJ/t-km]	0

1 Note that, in this situation, default values for the other upstream stages are not required as these should have already been taken into account in the carbon intensity of the product which has been purchased.

2 It is easiest to do this on the basis of the quantity of co-product produced for every tonne of biofuel produced.

3 This analysis will need to be verifiable and should be based on public, peer reviewed studies or, for example carried out to a certain standard – e.g. ISO 14040.

4 In the case where products are not direct substitutes. For example, animal protein feeds might have different protein contents, in which case 1 tonne of the co-product might only substitute 0.8 tonnes of the marginal product.

5 Where possible "market value" should be based on a three year average market price for the product – this can be recalculated annually at the beginning of the RTFO year.

6 While yields (i.e. tonne output / tonne input) are not a "source" of GHG emissions, they are required to enable the fuel chain contribution total to be calculated within existing modules that are upstream of the added module.

7 Product at this point in the chain.