Renewable Fuels Agency

Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation

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

Renewable Fuels Agency

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The independent sustainable fuels regulator

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The RFA is the UK's independent sustainable fuels regulator. Further information about biofuels in the UK can be found on the RFA website, www.renewablefuelsagency.org.

Contents

1 Introduction 1

2 Using qualitative information to calculate a known carbon intensity 2

2.1 What selected defaults are available? 2
2.2 How are selected defaults used? 3

3 Editing pre-defined fuel chains with actual data 4

3.1 Structure of default fuel chains 4
3.2 Providing actual data on co-products 8
3.2.1 Example of allocation by market value 11
3.3 Make adjustments to the structure of existing fuel chains 12
3.4 Adding modules 13
3.5 Building a new fuel chain 15
3.6 General Default values 18
3.7 Selected default values 26

4 Wheat to ethanol 27

5 Sugar beet to ethanol 34

6 Sugar cane to ethanol 39

7 Molasses to Ethanol 44

8 Corn to ethanol 47

9 Spent sulphite liquor to ethanol 55

10 Oilseed rape to ME biodiesel 58

11 Soy to ME biodiesel 71

12 Palm to ME biodiesel 80

13 Used cooking oil to ME biodiesel 92

14 Tallow to ME biodiesel 97

15 Sunflower to ME biodiesel 102

16 Coconut to ME biodiesel 113

17 Jatropha to ME biodiesel 126

18 Corn oil to ME biodiesel 136

19 HVO biodiesel 141

20 Co-processed HVO 149

21 Oilseed rape to pure plant oil 160

22 Soy to pure plant oil 175

23 Ethanol to ETBE.....182
24 Manure to biogas.....183
25 Municipal solid waste to biogas.....186

List of tables and figures

1 Introduction 1

2 Using qualitative information to calculate a known carbon intensity 2

3 Editing pre-defined fuel chains with actual data 4

Figure 1 Modules used to define a biofuel fuel chain 4
Figure 2 Example fuel chain defined using common modules 5
Table 1 Removing modules 13
Table 2 Most important sources of GHG emissions 14
Table 3 Compulsory linkages for all fuel chains, by module 17
Table 4 Fertiliser and pesticide emissions factors 18
Table 5 Fossil fuel emission factors 20
Table 6 Transport mode fuel efficiency 20
Table 7 Emissions factor for electricity 21
Table 8 General information about fuels 23
Table 9 Other emission factor 23
Table 10 Fertiliser emission factors 26
Table 11 Fossil fuel emission factors 26

4 Wheat to ethanol 27

Table 12 Fuel chain summary 27
Table 13 Selected default options 27
Table 14 Default fuel chain 28
Table 15 Default value tables 31

5 Sugar beet to ethanol 34

Table 16 Fuel chain summary 34
Table 17 Selected default options 34
Table 18 Default fuel chain 35
Table 19 Default value tables 37

6 Sugar cane to ethanol 39

Table 20 Fuel chain summary 39
Table 21 Selected default options 39
Table 22 Default fuel chain 40
Table 23 Default value tables 42

7 Molasses to Ethanol 44

Table 24 Fuel chain summary 44
Table 25 Selected default options 44
Table 26 Default fuel chain 45
Table 27 Default value tables 46

8 Corn to ethanol 47

Table 28 Fuel chain summary 47
Table 29 Selected default options..... 47
Table 30 Default fuel chain - France 48
Table 31 Default fuel chain – USA 50
Table 32 Default value tables 52

9 Spent sulphite liquor to ethanol 55

Table 33 Fuel chain summary 55
Table 34 Spent sulphite liquor to ethanol - selected default options..... 55
Table 35 Spent sulphite liquor to ethanol - Default fuel chain 56
Table 36 Spent sulphite liquor to ethanol - Default value tables.. 57

10 Oilseed rape to ME biodiesel 58

Table 37 Fuel chain summary 58
Table 38 Selected default options..... 60
Table 39 Default fuel chain..... 61
Table 40 Default value tables 65

11 Soy to ME biodiesel 71

Table 41 Fuel chain summary 71
Table 42 Selected default options..... 71
Table 43 Default fuel chain..... 73
Table 44 Default value tables 76

12 Palm to ME biodiesel 80

Table 45 Fuel chain summary 80
Table 46 Selected default options..... 80
Table 47 Default fuel chain..... 82
Table 48 Default value tables 88

13 Used cooking oil to ME biodiesel 92

Table 49 Fuel chain summary 92
Table 50 Selected default options..... 92
Table 51 Default fuel chain..... 93
Table 52 Default value tables 95

14 Tallow to ME biodiesel.....97

Table 53 Fuel chain summary 97
Table 54 Selected default options..... 97
Table 55 Default fuel chain..... 98
Table 56 Default value tables 99

15 Sunflower to ME biodiesel 102

Table 57 Fuel chain summary 102
Table 58 Sunflower to ME biodiesel - Selected default options ...102
Table 59 Sunflower to ME biodiesel -Default fuel chain 104
Table 60 Sunflower to ME biodiesel -Default value tables.....107

16 Coconut to ME biodiesel 113

Table 61 Fuel chain summary 113
Table 62 Coconut to ME biodiesel - Selected default options 113
Table 63 Coconut to ME biodiesel - Default fuel chain 115
Table 64 Coconut to ME biodiesel - Default value tables 123

17 Jatropha to ME biodiesel 126

Table 65 Fuel chain summary 126
Table 66 Jatropha to ME biodiesel - Selected default options 127
Table 67 Jatropha to ME biodiesel – Default fuel chain 128
Table 68 Jatropha to ME biodiesel - Default value tables 133

18 Corn oil to ME biodiesel 136

Table 69 Fuel chain summary 136
Table 70 Corn oil to ME biodiesel – selected default options 136
Table 71 Soy to pure plant oil - Default fuel chain 137
Table 72 Corn oil to ME biodiesel - Default value tables 138

19 HVO biodiesel 141

Table 73 OSR to HVO biodiesel – Fuel chain summary 141
Table 74 Soy to HVO biodiesel – Fuel chain summary 141
Table 75 Palm to HVO biodiesel – Fuel chain summary 142
Table 76 Sunflower to HVO biodiesel – Fuel chain summary 143
Table 77 Coconut to HVO biodiesel – Fuel chain summary 143
Table 78 Jatropha to HVO biodiesel – Fuel chain summary 144
Table 79 Selected default options 144
Table 80 Default fuel chain 146
Table 81 Default value tables 147

20 Co-processed HVO 149

Table 82 OSR to CHVO biodiesel – Fuel chain summary 149
Table 83 Soy to CHVO biodiesel – Fuel chain summary 150
Table 84 Palm to CHVO biodiesel – Fuel chain summary 151
Table 85 Sunflower to CHVO biodiesel – Fuel chain summary 151
Table 86 Coconut to CHVO biodiesel – Fuel chain summary 152
Table 87 Jatropha to CHVO biodiesel – Fuel chain summary 153
Table 88 Tallow to CHVO biodiesel – Fuel chain summary 153
Table 89 Selected default options 153
Table 90 Default fuel chain 155
Table 91 Default value tables 158

21 Oilseed rape to pure plant oil 160

Table 92 Fuel chain summary 160
Table 93 Oil seed rape (OSR) to pure plant oil - Selected default options 163
Table 94 Oil seed rape (OSR) to pure plant oil - Default fuel chain 164

Table 95 Oil seed rape (OSR) to pure plant oil - Default value fuel tables 171

22 Soy to pure plant oil 175

Table 96 Fuel chain summary 175
Table 97 Soy to pure plant oil - Selected default options 176
Table 98 Soy to pure plant oil - Default fuel chain 177
Table 99 Soy to pure plant oil - Default value tables 179

23 Ethanol to ETBE 182

24 Manure to biogas 183

Table 100 Fuel chain summary 183
Table 101 Selected default options 183
Table 102 Default fuel chain 183
Table 103 Default value tables 184

25 Municipal solid waste to biogas 186

Table 104 Fuel chain summary 186
Table 105 Selected default options 186
Table 106 Default fuel chain 186
Table 107 Default value tables 187

Annex A Default value sources 189

Table 108 Common across several fuel chains 189
Table 109 Wheat to ethanol chain 191
Table 110 Sugar beet to ethanol chain 191
Table 111 Sugar cane to ethanol chain 192
Table 112 Molasses to ethanol chain 193
Table 113 US corn to ethanol chain 193
Table 114 EU corn to ethanol chain 193
Table 115 Spent sulphite liquor to ethanol chain 194
Table 116 Oilseed rape to biodiesel chain 194
Table 117 Soy to biodiesel chain 194
Table 118 Palm to biodiesel chain 195
Table 119 UCO / tallow to biodiesel (methyl ester) chain 197
Table 120 Coconut to biodiesel (methyl ester) chain 197
Table 121 Jatropha to biodiesel (methyl ester) chain 197
Table 122 CHVO biodiesel chain 198
Table 123 Biomethane 198

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.

2.1 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).

2.2 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.

3.1 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.

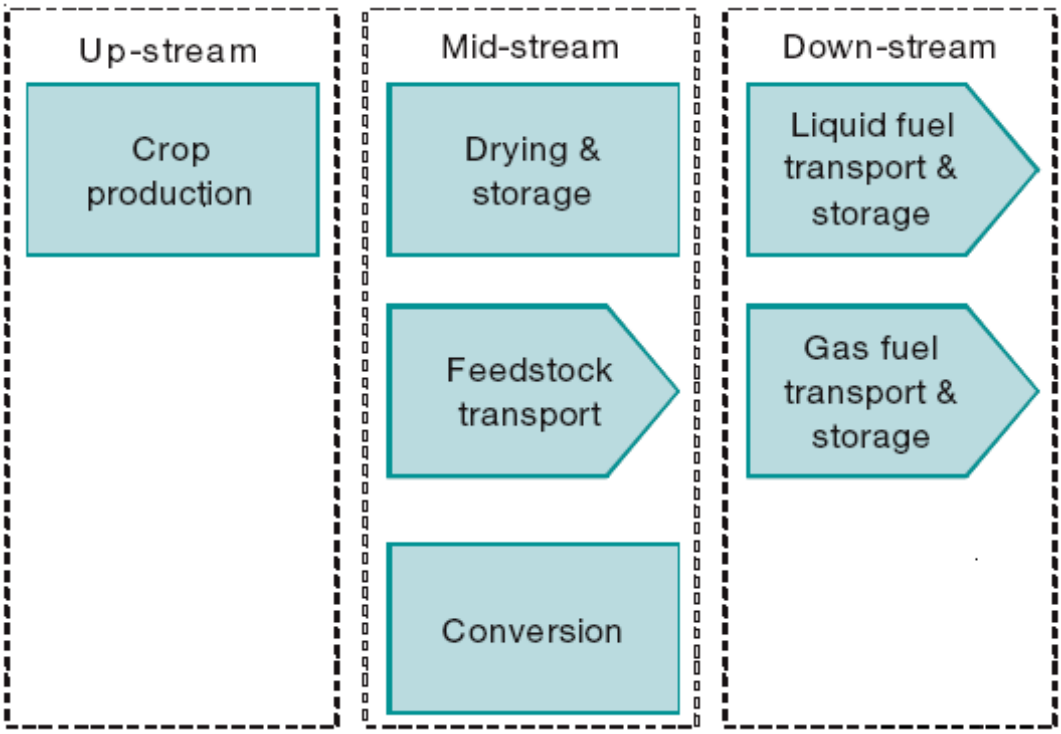

Figure 1 Modules used to define a biofuel fuel chain

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).

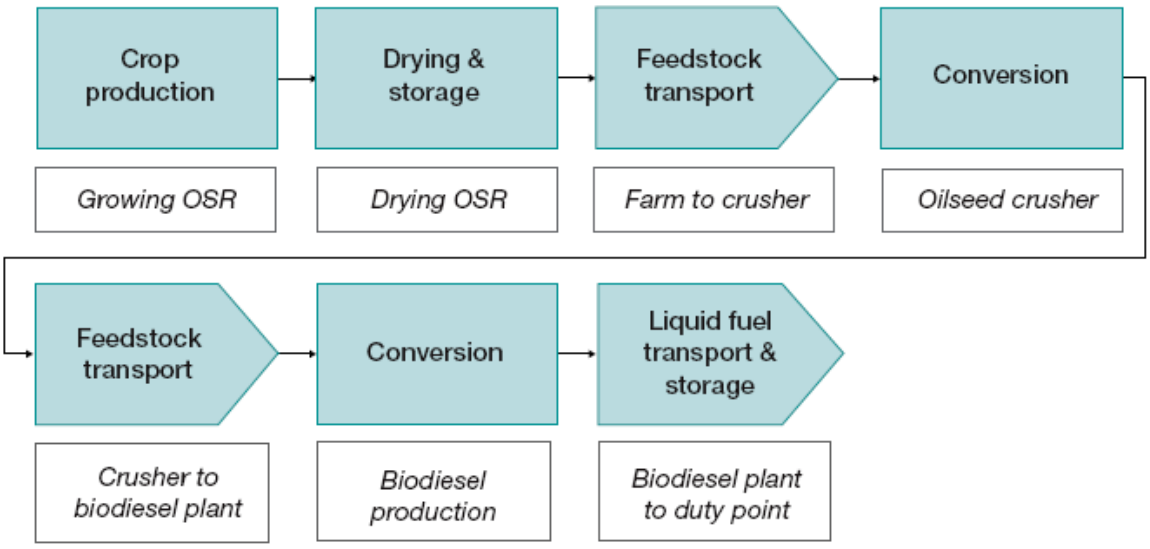

Figure 2 Example fuel chain defined using common modules

3.1.2 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”.

3.1.3 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.

[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 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.
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).

3.2 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 product2.
	Step 3:	Establish the quantity of the marginal product which is substituted for every tonne of co-product3.
	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 product4. Note that market values for existing co-products are fixed by the

[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.

[4] 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.

		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.

3.2.1 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

3.3 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.

Table 1 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).

3.4 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 2 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).

[5] 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.

[6] Product at this point in the chain.

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 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 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).

3.5 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 3 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.

3.6 General Default values

Table 4 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 (15-15-15, 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	

* Note that this NPK emissions factor can only be used for this specific composition of different fertilisers. Emissions factors for other types of NPK fertiliser can be calculated from the individual products.

Table 5 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 6 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
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 7 Emissions factor for electricity

Country / Region	Grid average	Marginal baseload generation
	kg CO_2/MJ	
Argentina	0.0763	*
Australia	0.241	*
Brazil	0.0220	*
Canada	0.062	*
China	0.214	*
Finland	0.0826	*
France	0.0228	*
Germany	0.139	*
India	0.253	0.106
Indonesia	0.216	*
Ireland	0.165	*

Malaysia	0.137	*
Mozambique	0.0009	*
Netherlands	0.130	*
Pakistan	0.103	*
Philippines	0.128	*
Poland	0.184	*
Portugal	0.115	*
South Africa	0.237	*
Spain	0.106	*
Sweden	0.016	*
Russia	0.091	*
Ukraine	0.095	*
United Kingdom	0.131	*
United States	0.160	*

* The baseload generation should be defined. See co-products procedures on Page 8.

Table 8 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
Biogas	--	45.1	--

Table 9 Other emission factor

Item	Units	Emissions factor
Emissions from burning sugar cane trash in field		
Nitrous oxide (N_2O) emissions	[kgCO_2e/kg trash]	0.022
Methane (CH_4) emissions	[kgCO_2e/kg trash]	0.0585
Chemicals		
Hexane	[kgCO_2e/kg product]	0.702
Methanol	[kgCO_2e/kg product]	2.75
Sulphuric acid	[kgCO_2e/kg product]	0.136
Potassium hydroxide	[kgCO_2e/kg product]	2.43
Nitrogen	[kgCO_2e/kg product]	0.0652

Phosphoric acid (H_3PO_4)	[kgCO_2e/kg product]	1.73
Sodium borohydride ($NaBH_4$)	[kgCO_2e/kg product]	1.65
Emissions from soils		
Nitrous oxide (N_2O) emissions	[kg N_2O / kg N]	6.163

Emissions factor for steam and electricity sourced from a CHP system

Industrial sites sometimes provide their tenants with steam from a centralized source, in some cases this is a CHP plant. Because it is very difficult to identify a "typical" CHP system, it is not appropriate to establish a default emissions factor for steam or electricity sourced from a CHP system. Instead general guidance is give below on how to derive the appropriate emissions factor based on information about the CHP plant should be given.

Guidance is given below for two different situations: when the steam is sourced from an industrial site CHP plant that was built primarily to meet the on-site steam demands and when the steam is sourced from a power station (i.e. an electricity generating plant that would exist regardless of the demand for steam on the industrial site).

Industrial site CHP systems

The emissions factor for the steam from an industrial site CHP system is equal to:

- The GHG emissions produced by burning fuel at the CHP plant, per unit of steam produced – i.e. CHP fuel consumption per MJ of steam produced multiplied by the emissions factor of the fuel used in the CHP plant
- Minus, the GHG emissions avoided by the export of electricity from the CHP plant (per unit of steam produced) – i.e. CHP electricity generated per MJ of steam multiplied by the emissions factor for grid electricity in the country in which the CHP system is situated (since it is grid electricity that would otherwise be used).

For example:

A simple CHP system (located in the UK) comprises of a natural gas boiler (90% efficiency), with a back pressure steam turbo generator. The heat to power ratio of the system is 5:1.

The GHG emissions produced by the CHP system are:

CHP fuel consumption per MJ steam = 1 / 0.90 = 1.111 MJ natural gas / MJ steam

Emissions factor for natural gas = 62 g CO_2e / MJ natural gas

GHG emissions = 68.89 g CO_2e / MJ steam

The GHG emissions avoided by the export of electricity:

CHP electricity generated = 1/5 = 0.2 MJ electricity / MJ steam

Grid electricity emissions factor = 131 g CO_2e / MJ electricity

GHG emissions avoided = 26.2 g CO_2e / MJ steam

Therefore, the emissions factor for steam used from this CHP system would be: 42.69 g CO_2e / MJ steam.

And, the emissions factor for electricity from the CHP plant is equal to:

The emissions factor for grid electricity in the country in which the CHP system is situated.[6]

Steam from a power station

The emissions factor for the steam from a power station is equal to:

The emissions factor of providing heat from the marginal alternative. In most cases this would be a fossil fuel (probably natural gas) boiler operating with an efficiency of 90%.

[6] Emissions factors for co-products are set on a marginal basis (i.e. equal to the emissions factor of the next unit of electricity); because the CHP plant's electricity is not the determining product the marginal source of electricity would be grid electricity. Another way to think of this is: the CHP plant exists as a result of the demand for steam – therefore all of the GHG consequences (i.e. emissions and avoided emissions) associated with the plant are attributed to the steam; the electricity is therefore attribute an emissions factor equivalent to the product that would be used if there was no steam demand and therefore no CHP plant (i.e. grid electricity).

3.7 Selected default values

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

Table 10 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 11 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

Table 12 Fuel chain summary

Module	Carbon intensity [kg CO_2 / t ethanol]				
	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

Table 13 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	Triple superphosphate (TSP), Rock phosphate, Mono

		emissions factor	ammonium phosphate (MAP)
2	Drying and storage	Fuel emissions factor	Diesel, 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

Table 14 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					
				Emissions co-efficient [$kgCO_{2e}$/MJ]		Total emissions [$kgCO_{2e}$ / t_{wheat}]	
Fuel / input type							
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				
				Emissions co-efficient [$kgCO_{2e}$/MJ]		Total emissions [$kgCO_{2e}$ / $_{wheat}$]	
Totals							
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 [$kgCO_{2e}$ / $t_{ethanol}$]	
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

Table 15 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
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	1270012 700	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 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

Table 16 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

Table 17 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, Natural gas, Heavy fuel oil, Biomass
4	Liquid fuel	Transport	Truck (by geographic region),

	transport	mode fuel efficiency	Rail (by geographic region), Shipping

Table 18 Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvest of sugar beet						
Basic Data							
Yield	Units [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
Totals						Emissions [$kgCO_{2e}$/t sugar beet]	
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

Table 19 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 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

Table 20 Fuel chain summary

Module	Carbon intensity [kg CO_2/t ethanol]			
	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

Table 21 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	Truck (by geographic region), Rail (by geographic region),

		efficiency	Shipping
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
5	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 22 Default fuel chain

Stage 1 - Crop Production

Description	Sugar cane cultivation and harvesting						
Basic Data							
Yield	Units [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 [$kgCO_{2e}$/kg N]		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
Totals						Emissions [$kgCO_{2e}$/t cane]	
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 ÷ z2 =	*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				
Totals				Emissions factor [kgCO2e/MJ]		Total Emissions [$kgCO_{2e}$/t cane]	
Module total	[MJ/t cane]	*value*	x	*value*	=	*calculation*	11
						Total emissions [kg CO_{2e} / t ethanol]	
Contribution to fuel chain					11 ÷ z2 =	*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*	z2				
				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

Table 23 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
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
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

Table 24 Fuel chain summary

Module	Carbon intensity [kg CO_2 / t ethanol]		
	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

Table 25 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
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region),

			Shipping

Table 26 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

Table 27 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				
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

Table 28 Fuel chain summary

Module	Carbon intensity [kg CO_2 / t ethanol]	
	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

Table 29 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	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

Table 30 Default fuel chain - France

Stage 1 - Crop Production

Description	Cultivation and harvest of corn						
Basic Data							
Yield @ traded moisture content	Units [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

Table 31 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*					
				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
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				
				Emissions factor [kgCO2e/MJ]		Emissions [$kgCO_{2e}$/t ethanol]	
Totals							
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				
				Emissions factor [kgCO2e/MJ]		Emissions [$kgCO_{2e}$/t ethanol]	
Totals							
Module total	[MJ/t ethanol]	value	x	value	=	calculation	20
Contribution to fuel chain					20 =	Total emissions [kg CO_{2e} / t ethanol] calculation	Stage_6

Table 32 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
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
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
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 Spent sulphite liquor to ethanol

Table 33 Fuel chain summary

Module	Carbon intensity [kg CO_2 / t ethanol]
	Sweden
1 – Conversion	26
2 – Liquid fuel transport and storage	116
3 – Liquid fuel transport and storage	16
Total	158

Table 34 Spent sulphite liquor to ethanol - selected default options

Stage	Module	Input	Options
2	Liquid fuel transport and storage	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
3	Liquid fuel transport and storage	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 35 Spent sulphite liquor to ethanol - Default fuel chain

Stage 1 - Conversion

Description	Bioethanol plant						
Basic data							
Plant yield	[t bioethanol / t waste sulphite liquor]	*value*	(z1)				
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Sulfamic acid	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	1
Phosphoric acid	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	2
Sodium borohydride	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	3
Electricity	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	4

Co-products	**Description**	**Treatment**
CO2	In the fermentation process CO2 is formed and collected as a product	In this calculation no emissions are allocated to the CO2 production
2nd grade ethanol	Formed in the distillation process	Used as fuel in a steam boiler, no credit are given to the ethanol due to use of steam in the ethanol production process

Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					1 + 2 + 3 + 4 =	*calculation*	5
Contribution to fuel chain					5 =	*calculation*	Stage_1

Stage 2 - Liquid fuel transport and storage

Description	From port to bioethanol plant						
Transport distance	[km]	*value*	dist_3				
Fuel consumption	[MJ/t-km]	*value*	FC_3				
Totals				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t bioethanol)	
Module total	[MJ/t feedstock]	*value*	x	*value*	=	*calculation*	4
Contribution to fuel chain					4 =	*calculation*	Stage_2

Stage 3 - 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]		Emissions ($kgCO_{2e}$/t bioethanol)	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	5
Contribution to fuel chain					5 =	*calculation*	Stage_3

Table 36 Spent sulphite liquor to ethanol - Default value tables

Stage / Input	Units	Feedstock country of origin
		Sweden
Stage 1 – Conversion*		
Plant yield	[t bioethanol / t spent sulphite liquor]	0.02
Phosphoric acid	[kg/t ethanol]	2.00
Sodium borohydride	[kg/t ethanol]	2.00
Electricity	[MJ/t ethanol]	1154
Stage 2 – Liquid fuel transport and storage		
Transport distance	[km]	877
Fuel consumption	[MJ/t-km]	1.53
Fuel type		Diesel
Stage 3 – Liquid fuel transport and storage		
Transport distance	[km]	890
Fuel consumption	[MJ/t-km]	0.20
Fuel type		HFO

*Use of sulfamic acid is likely to contribute less than 1% of total fuel chain GHG emissions and is therefore ignored

10 Oilseed rape to ME biodiesel

Table 37 Fuel chain summary

Module	Carbon intensity [kg CO_2/t biodiesel]								
	Australia	Canada	Finland	France	Germany	Poland	Ukraine	UK	USA
1 - Crop production	1933	1853	1903	1591	1598	1475	2028	1945	3189
2 - Drying and storage	0	65	67	62	71	75	68	71	73
3 - Feedstock transport	22	109	29	87	87	87	62	29	28
4 - Feedstock transport	693	0	0	0	0	0	89	0	0
5 - Conversion (crushing)	-469	-490	-484	-503	-466	-451	-480	-468	-459
6 - Feedstock transport	8	86	0	7	11	25	0	0	23
7 - Feedstock transport	0	0	0	0	0	0	0	0	116
7 - Conversion (esterification)	471	471	471	471	471	471	471	471	471
8 - Liquid fuel transport and storage	0	0	35	0	0	0	0	0	0

Total	2658	2094	2021	1715	1772	1682	2238	2048	3441

Table 38 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, 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, 7	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
8	Conversion (esterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass

9	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 39 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
Totals						Total Emissions ($kgCO_{2e}$/t OSR)	
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	*calculation*	8
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					8 ÷ z1 ÷ z2 × AF=	*calculation*	Stage_1

Stage 2 - Drying and storage

Description	Drying and storage of oilseed rape						
Basic Data							
Moisture removed	% by weight	*value*					
Drying and storage inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t OSR)	
Fuel for heating	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	9
Electricity	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	10
Totals						Emissions ($kgCO_{2e}$/t OSR)	
Module total					9 + 10 =	*calculation*	11
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					11 ÷ z1 ÷ z2 × 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				
Totals						Emissions ($kgCO_{2e}$/t OSR)	
Module total	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	12
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					12 ÷ z1 ÷ z2 × 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				
Totals						Emissions ($kgCO_{2e}$/t OSR)	
Module total	[MJ/t OSR]	*value*	x	*value*	=	*calculation*	13
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					13 ÷ z1 ÷ z2 × 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 × 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 - Feedstock Transport

Description	From extraction facility to biodiesel plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	value	dist_4				
Fuel consumption	[MJ/t-km]	value	FC_4				
Totals						Emissions ($kgCO_{2e}$/t rapeseed oil)	
Module total	[MJ / t rapeseed oil]	value	x	value	=	calculation	19
Contribution to fuel chain					19 ÷ z2 x AF =	calculation	Stage_7

Stage 8 - 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	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							
				Market value [£ / t gylcerine]			
Co-product 1: Glycerine							
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	value	x	value	=	calculation	24
				Market value [£ / t potassium sulphate]			
Co-product 2: Potassium sulphate							
Quantity of potassium sulphate produced and sold as chemical	[t potassium suplhate / t biodiesel]	value		value	=	calculation	25
				Market value [£ / t biodiesel]			
Primary product: biodiesel							
Market value of biodiesel				value	=	calculation	26
Total market value of products							
Total market value	[£ / t biodiesel]				24 + 25 + 26 =	calculation	27
Allocation factor (%age of emissions attributable to biodiesel)	%				26 ÷ 27 =	calculation	AF
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(20 + 21 + 22 + 23) x AF =	calculation	28
Contribution to fuel chain					27 =	calculation	Stage_8

Stage 9 - 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_9

Table 40 Default value tables

Stage / Input	Units	Feedstock country of origin								
		Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom	USA
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	1.56
Traded moisture content	%	9	9	9	9	9	9	9	9	9
N fertiliser	[kg N /ha.a]	61	75	67	155	170	102	60	185	150
Type of N fertiliser		AN	AN	AN	AN	AN	AN	AN	AN	AN
P fertiliser	[kg P_2O_5/ha.a]	16	20	18	45	45	35	15	45	120
Type of P fertiliser		TSP	TSP	TSP	TSP	TSP	TSP	TSP	TSP	TSP

K fertiliser	[kg K_2O/ha.a]	12	15	13	80	90	44	12	48	80
Lime	[kg CaO/ha.a]	271	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	0.28
Diesel fuel consumption	[litres/ha.a]	66	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	3
Fuel for heating	[MJ/t OSR]	0	318	318	318	318	318	318	318	318
Electricity	[MJ/t OSR]	0	35	35	35	35	35	35	35	35
Stage 3 – Feedstock Transport										
Transport distance	[km]	300	3000	100	300	300	300	1700	100	100
Fuel consumption	[MJ/t-km]	0.38	0.19	1.53	1.53	1.53	1.53	0	1.53	1.46
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel

Stage 4 – Feedstock Transport										
Transport distance	[km]	18000	0	0	0	0	0	2300	0	0
Fuel consumption	[MJ/t-km]	0.2	N/A	N/A	N/A	N/A	N/A	0.2	N/A	N/A
Fuel type		HFO	N/A	N/A	N/A	N/A	N/A	HFO	N/A	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	0.43
Natural gas	[MJ/t rapeseed oil]	1986	1986	1986	1986	1986	1986	1986	1986	1986
Electricity imported	[MJ/t rapeseed oil]	337	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	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32

	oil]									
Credit for co-product 1	[kgCO_2e/t rape meal]	-504	-504	-504	-504	-504	-504	-504	-504	-504
Stage 6 – Feedstock Transport										
Transport distance	[km]	500	5200	0	450	650	1500	0	0	1500
Fuel consumption	[MJ/t-km]	0.2	0.2	0	0.2	0.2	0.2	0	0	0.19
Fuel type		HFO	HFO	N/A	HFO	HFO	HFO	N/A	N/A	Diesel
Stage 7 – Feedstock Transport										
Transport distance	[km]	0	0	0	0	0	0	0	0	7000
Fuel consumption	[MJ/t-km]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.20
Fuel type		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	HFO
Stage 8 – Conversion										
Plant yield	[t biodiesel/t rapeseed	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

	oil]									
Natural gas	[MJ/t biodiesel]	1690	1690	1690	1690	1690	1690	1690	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335	335	335	335	335	335	335	335
Methanol	kg/t biodiesel	113	113	113	113	113	113	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	26	26	26	26	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	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	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	0.04
Market value of potassium sulphate	[£/t potassium sulphate]	75	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	340
Allocation factor	%	90	90	90	90	90	90	90	90	90
Stage 9 – Liquid fuel transport and storage										
Transport distance	[km]	0	0	2000	0	0	0	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0.2	0	0	0	0	0	0
Fuel Type		N/A	N/A	HFO	N/A	N/A	N/A	N/A	N/A	N/A

11 Soy to ME biodiesel

Table 41 Fuel chain summary

	Carbon intensity [kg CO_2/t biodiesel]				
	Argentina	Brazil	Canada	Spain	USA
1 – Crop production	1827	2062	2311	2034	2406
2 – Drying and storage	73	68	72	75	61
3 – Feedstock transport	286	1301	70	147	70
4 – Conversion (crushing)	-1101	-1177	-1121	-1059	-984
5 – Feedstock transport	0	0	16	0	23
6 – Feedstock transport	215	166	99	44	116
7 – Conversion (esterification)	471	471	471	471	471
8 – Liquid fuel transport	0	0	0	0	0
Total	1771	2891	1918	1712	2163

Table 42 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	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

Table 43 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
Totals						Emissions (kgCO2e/t soy)	
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					
Drying and storage inputs				Emissions factor [kgCO2e/MJ]			
Diesel	[MJ/t soy]	value	x	value	=	calculation	10
Electricity	[MJ/t soy]	value	x	value	=	calculation	11
Totals						Emissions (kgCO2e/t soy)	
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				
Totals						Emissions (kgCO2e/t soy)	
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	

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

Table 44 Default value tables

Stage / Input	Units	Feedstock country of origin				
		Argentina	Brazil	Canada	Spain	USA
Stage 1 – Crop Production						
Yield @ traded moisture content	[t/ha.a]	2.54	2.54	2.28	2.57	2.60
Moisture content	%	13	13	13	13	13
N fertiliser	[kg N/ha.a]	10	10	25	14	24
Type of N fertiliser		Urea	Urea	Urea	AN	AN
P fertiliser	[kg P_2O_5/ha.a]	5	50	50	6	100
Type of P fertiliser		MAP	MAP	MAP	MAP	TSP
K fertiliser	[kg K_2O/ha.a]	3	60	85	6	55
Pesticides	[kg/ha.a]	1.31	1.31	1.31	1.31	1.31
Electricity	[kWh/ha.a]	11.00	11.00	0	11.0	11.00
Diesel fuel consumption	[litres/ha.a]	75.6	75.6	75.6	75.6	75.6
Stage 2 – Drying and storage						
Moisture removed	%	2	2	2	2	2
Fuel for heating	[MJ/t soy]	138	138	138	138	138
Fuel type		Diesel	Diesel	Diesel	Diesel	Natural gas
Electricity	[MJ/t soy]	15	15	15	15	15

Stage 3 – Feedstock Transport						
Transport distance	[km]	330	1500	100	200	100
Fuel consumption	[MJ/t-km]	1.8	1.8	1.46	1.53	1.46
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel
Stage 4 – Conversion						
Yield	[t soy oil/t soy]	0.17	0.17	0.17	0.17	0.17
Natural gas	[MJ/t soy oil]	5447	5447	5447	5447	5447
Electricity imported	[MJ/t soy oil]	1476	1476	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	4.32	4.32
Credit	[kgCO_2e/t soy meal]	-373	-373	-373	-373	-373
Stage 5 – Feedstock Transport						
Transport distance	[km]	0	0	1000	0	1500
Fuel consumption	[MJ/t-km]	0	0	0.19	0	0.19
Fuel type		None	None	Diesel	None	Diesel
Stage 6 – Feedstock Transport						
Transport	[km]	13000	10000	6000	2640	7000

distance						
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2	0.2
Fuel type		HFO	HFO	HFO	HFO	HFO
Stage 7 – Conversion						
Yield	[t biodiesel / t soy oil]	0.95	0.95	0.95	0.95	0.95
Natural gas	[MJ/t biodiesel]	1690	1690	1690	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335	335	335	335
Methanol	kg/t biodiesel	113	113	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	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	0.1	0.1
Market value of glycerine	[£/t glycerine]	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
Market value of potassium sulphate	[£/t potassium sulphate]	75	75	75	75	75
Primary product:						

biodiesel						
Market value of biodiesel	[£/t biodiesel]	340	340	340	340	340
Allocation factor	%	90	90	90	90	90
Stage 8 – Liquid fuel transport and storage						
Transport distance	[km]	0	0	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0	0	0

12 Palm to ME biodiesel

Table 45 Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]	
	Indonesia	Malaysia
1 – Crop Production	313	344
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	1743	1742

Table 46 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

Table 47 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
Totals						Emissions ($kgCO_{2e}$/t FFB)	
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				
						Emissions ($kgCO_{2e}$/t FFB)	
Totals							
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							
Co-product 5: Palm kernel				Market value [RM / t palm kernel]			
Quantity of palm kernel produced	[t palm kernel / t CPO]	*value*	x	*value*	=	*calculation*	14
Primary product: crude palm oil				Market value [RM / t CPO]			
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
Totals						Emissions ($kgCO_{2e}$/t CPO)	
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				
Totals						Emissions ($kgCO_{2e}$/t CPO)	
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				
						Emissions ($kgCO_{2e}$/t palm olein)	
Totals							
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

Table 48 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]	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 CO_2e / 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]	1.8	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			
Market value of palm	[USD/t palm olein]	438	438

olein			
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	Description	Treatment	
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	
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	[£/t biodiesel]	340	340

biodiesel			
Allocation factor	%	90	90
Stage 8 – Liquid fuel transport and storage			
Transport distance	[km]	0	0
Fuel consumption	[MJ/t-km]	0	0

13 Used cooking oil to ME biodiesel

Table 49 Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]
1 – Feedstock Transport	7
2 – Conversion	471
3 – Liquid fuel transport	0
Total	478

Table 50 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

Table 51 Default fuel chain

Stage 1 - Feedstock Transport

Description	From central aggregation point to biodiesel plant. 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 - Conversion

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

Table 52 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		
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-products	Description	Treatment
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

14 Tallow to ME biodiesel

Table 53 Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]		
	Denmark	United Kingdom	United States of America
1 – Feedstock Transport	34	7	25
2 – Feedstock Transport	19	0	126
2 – Conversion	471	471	471
3 – Liquid fuel transport	0	0	0
Total	524	478	622

Table 54 Selected default options

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

Table 55 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_2

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_3

Stage 4 - 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_4

Table 56 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
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	Allocation by market	Allocation by market
Quantity of potassium	[t potassium	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 4 – Liquid fuel transport and storage				
Transport distance	[km]	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0

15 Sunflower to ME biodiesel

Table 57 Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]					
	Argentina	China	France	Russian Fed.	Ukraine	USA
1 – Crop production	698	1802	1933	2334	2122	550
2 – Drying and storage	66	77	62	68	68	73
3 – Feedstock transport	309	36	87	17	14	4
4 – Feedstock transport	0	94	0	18	0	0
5 – Conversion (crushing)	-486	-442	-503	-481	-480	-459
6 – Feedstock transport	199	328	7	124	111	23
7 – Feedstock transport	0	0	0	0	0	116
8 – Conversion (transesterification)	471	471	471	471	471	471
9 – Liquid fuel transport and storage	0	0	0	0	0	0
Total	1257	2366	2057	2551	2306	778

Table 58 Sunflower to ME biodiesel - 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 (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, 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, 7	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
8	Conversion (transesterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
9	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 59 Sunflower to ME biodiesel -Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvesting of sunflower seeds						
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 sunflower seeds)	
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 sunflower seeds)	
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 × AF=	*calculation*	Stage_1

Stage 3 - Feedstock Transport

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

Stage 4 - Feedstock Transport

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

Stage 5 - Conversion

Description	Oil extraction						
Basic Data							
Plant yield	[t sunflower oil / t sunflower seed]	*value*	z1				
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Natural gas	[MJ/t sunflower oil]	*value*	x	*value*	=	*calculation*	14
Electricity imported	[MJ/t sunflower oil]	*value*	x	*value*	=	*calculation*	15
Co-products	**Description**	**Treatment**					
Co-product 1:	sunflower cake - sold as animal feed	Substitution					
Co-products treated by substitution							
Co-product 1: sunflower cake							
- substitutes US soy meal (soybeans crushed in EU)				Credit [$kgCO_{2e}$/t sunflower cake]			
Quantity of sunflower cake produced & sold as animal feed	[t sunflower cake / t sunflower 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_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 sunflower oil)	
Module total	[MJ / t sunflower oil]	*value*	x	*value*	=	*calculation*	18
Contribution to fuel chain					18 ÷ z2 × AF =	*calculation*	Stage_6

Stage 7 - Feedstock Transport

Description	From extraction facility to biodiesel plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_4				
Fuel consumption	[MJ/t-km]	*value*	FC_4				
Totals						Emissions ($kgCO_{2e}$/t sunflower oil)	
Module total	[MJ / t sunflower oil]	*value*	x	*value*	=	*calculation*	19
Contribution to fuel chain					19 ÷ z2 × AF =	*calculation*	Stage_7

Stage 8 - Conversion

Description	Biodiesel plant						
Basic data							
Plant yield	[t biodiesel / t sunflower 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: Glycerine				Market value [£ / t glycerine]			
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 sulphate / 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]				24 + 25 + 26 =	*calculation*	27
Allocation factor (%age of emissions attributable to biodiesel)	%				26 ÷ 27 =	*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_8

Stage 9 - 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_9

Table 60 Sunflower to ME biodiesel -Default value tables

Stage / Input	Units	Feedstock country of origin					
		Argentina	China	France	Russian Federation	Ukraine	USA
Stage 1 – Crop production							
Yield @ traded moisture content	[t/ha.a]	1.8	1.6	2.3	1.0	1.1	2.3
Traded moisture content	%	9	9	9	9	9	9
N fertilizer	[kg N /ha.a]	25	80	130	60	60	25
Type of N fertiliser		AN	AN	AN	AN	AN	AN
P fertilizer	[kg P_2O_5/ha.a]	5	30	80	60	60	10
Type of P fertiliser		TSP	TSP	TSP	TSP	TSP	TSP
K fertilizer	[kg K_2O/ha.a]	2	50	180	50	50	10
Lime	[kg CaO/ha.a]	271	271	271	271	271	271

Pesticides	[kg/ha.a]	0.28	0.28	0.28	0.28	0.28	0.28
Diesel fuel consumption	[litres/ha.a]	66	66	66	66	66	66
Stage 2 – Drying and storage							
Moisture removed	% by weight	3	3	3	3	3	3
Fuel for heating	[MJ/t sunflower]	318	318	318	318	318	318
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Electricity	[MJ/t sunflower]	35	35	35	35	35	35
Stage 3 – Feedstock Transport							
Transport distance	[km]	900	100	300	50	400	100
Fuel consumption	[MJ/t-km]	1.8	1.89	1.53	1.82	0.19	0.19
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Stage 4 – Feedstock Transport							
Transport distance	[km]	0	1500	0	500	0	0

Fuel consumption	[MJ/t-km]	0	0.33	0	0.19	0	0
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Stage 5 – Conversion							
Plant yield	[t sunflower oil / t sunflower seed]	0.43	0.43	0.43	0.43	0.43	0.43
Natural gas	[MJ/t sunflower oil]	1986	1986	1986	1986	1986	1986
Electricity imported	[MJ/t sunflower oil]	337	337	337	337	337	337
Co-product 1: Sunflower cake – sold as animal feed							
Quantity of sunflower cake	[t rape meal / t sunflower oil]	1.32	1.32	1.32	1.32	1.32	1.32
Credit for co-product 1	[kgCO_2e/t	-501	-501	-501	-501	-501	-501

	sunflower cake]						
Stage 6 – Feedstock Transport							
Transport distance	[km]	12000	19800	450	7500	6700	1500
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2	0.2	0.19
Fuel type		HFO	HFO	HFO	HFO	HFO	Diesel
Stage 7 – Feedstock Transport							
Transport distance	[km]	0	0	0	0	0	7000
Fuel consumption	[MJ/t-km]	0	0	0	0	0	0.2
Fuel type		None	None	None	None	None	HFO
Stage 8 – Conversion							
Plant yield	[t biodiesel / t sunflower oil]	0.95	0.95	0.95	0.95	0.95	0.95
Natural gas	[MJ/t biodiesel]	1690	1690	1690	1690	1690	1690
Electricity imported	[MJ/t biodiesel]	335	335	335	335	335	335

Methanol	kg/t biodiesel	113	113	113	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	26	26	26	26
Co-products							
Co-product 1	Crude glycerine						
Quantity of crude glycerine	[t glycerine/ t biodiesel]	0.1	0.1	0.1	0.1	0.1	0.1
Market value of glycerine	[£/t glycerine]	345	345	345	345	345	345
Co-product 2:	Potassium sulphate						
Quantity of potassium sulphate	[t potassium sulphate /t biodiesel]	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

Primary product: biodiesel							
Market value of biodiesel	[£/t biodiesel]	340	340	340	340	340	340
Allocation factor	%	90	90	90	90	90	90
Stage 9 – Liquid fuel transport and storage							
Transport distance	[km]	0	0	0	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0	0	0	0
Fuel Type		None	None	None	None	None	None

16 Coconut to ME biodiesel

Table 61 Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]		
	India	Philippines	Indonesia
1 – Crop production	697	802	625
2 – Conversion	0	0	0
3 – Feedstock transport	6	31	88
4 – Feedstock transport	0	0	0
5 – Conversion (crushing)	-27	-75	-41
6 – Feedstock transport	20	0	0
7 – Feedstock transport	199	298	248
8 – Conversion (transesterification)	471	471	471
9 – Liquid fuel transport and storage	0	0	0
Total	1366	1527	1347

Table 62 Coconut to ME biodiesel - 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 (UAN); NPK (Urea / TSP / MOP)

1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
3, 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, 7	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
8	Conversion (transesterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
9	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 63 Coconut to ME biodiesel - Default fuel chain

Stage 1 - Crop Production

Description	Cultivation and harvest of coconuts						
Basic Data							
	Units						
Yield of coconuts	[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
Totals						Emissions ($kgCO_{2e}$/t coconuts)	
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		*calculation*	Stage_1

Stage 2 - Drying and storage

Description	Pre-drying of coconuts						
Basic Data							
Moisture removed	% by weight	*value*					
Drying and storage inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t coconuts)	
Fuel for heating	[MJ/t pre-dried coconut]	*value*	x	*value*	=	*calculation*	11
Electricity	[MJ/t pre-dried coconut]	*value*	x	*value*	=	*calculation*	12
Totals						Emissions ($kgCO_{2e}$/t coconuts)	
Module total					11 + 12 =	*calculation*	13
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					13 ÷ z1 ÷ z2 ÷ z3 × AF_1 =	*calculation*	Stage_2

Stage 3 - Conversion

Description: Removal of coconut meat from shells

Basic Data

Coconut meat	[t meat / t coconut]	*value*	z1

Extraction inputs

				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t coconut meat)	
Fuel for process heat	[MJ / t coconut meat]	*value*	x	*value*	=	*calculation*	14
Electricity	[MJ / t coconut meat]	*value*	x	*value*	=	*calculation*	15

Co-products	**Description**	**Treatment**
Co-product 1:	Coconut shells	Considered within system boundaries
Co-product 2:	Coir	Treated by market value allocation: market value of coir is likely to be close to zero; yield of coir is likely to be less than 0.1 tonne / tonne coconut oil. Hence market value allocation would attribute very close to 100% of emissions to the copra.

Stage 4 - Drying and storage

Description	Drying and storage of copra						
Basic Data							
Moisture removed	% by weight	*value*					
Drying and storage inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t copra)	
Fuel for heating	[MJ/t copra]	*value*	x	*value*	=	*calculation*	16
Electricity	[MJ/t copra]	*value*	x	*value*	=	*calculation*	17
Totals						Emissions ($kgCO_{2e}$/t copra)	
Module total					16 +17 =	*calculation*	18
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					18 ÷ z2 ÷ z3 × AF_1 =	*calculation*	Stage_4

Stage 5 - Feedstock Transport

Description	Transport of copra to a crushing mill						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_1				
Fuel consumption	[MJ/t-km]	*value*	FC_1				
Totals						Emissions ($kgCO_{2e}$/t copra)	
Module total	[MJ/t copra]	*value*	x	*value*	=	*calculation*	19
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					19 ÷ z2 ÷ z3 × AF_1 =	*calculation*	Stage_5

Stage 6 - Feedstock Transport

Description	Transport of copra to a crushing mill						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_2				
Fuel consumption	[MJ/t-km]	*value*	FC_2				
Totals						Emissions ($kgCO_{2e}$/t copra)	
Module total	[MJ/t copra]	*value*	x	*value*	=	*calculation*	20
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					20 ÷ z2 ÷ z3 × AF_1 =	*calculation*	Stage_6

Stage 7 - Conversion

Description	Crushing of copra to coconut oil						
Basic Data							
Palm oil mill yield	[t coconut oil / t copra]	*value*	z2				
Extraction Inputs						Emissions ($kgCO_{2e}$/t coconut oil)	
Fuel for process heat	[MJ/t coconut oil]	*value*	x	*value*	=	*calculation*	21
Electricity for process	[MJ/t coconut oil]	*value*	x	*value*	=	*calculation*	22
Co-products	**Description**	**Treatment**					
Co-product 1:	Copra cake	Substitution					
Co-products treated by substitution							
Co-product 1: rape meal							
- substitutes US soy meal				Credit [$kgCO_{2e}$/t copra cake]			
Quantity of copra cake produced & sold as animal feed	[t copra cake / t coconut oil]	*value*	x	*value*	=	*calculation*	23
Totals							
Module total					21 + 22 + 23 =	*calculation*	24
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					24 ÷ z3 × AF_1 =	*calculation*	Stage_7

Stage 8 - Feedstock Transport

Description	Transport of coconut oil from mill to port						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_3				
Fuel consumption	[MJ/t-km]	*value*	FC_3				
Totals						Emissions ($kgCO_{2e}$/t CPO)	
Module total	[MJ/t CPO]	*value*	x	*value*	=	*calculation*	25
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					25 ÷ z3 × AF_1 =	*calculation*	Stage_8

Stage 9 - Feedstock Transport

Description	Transport of coconut oil from port to biodiesel plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_4				
Fuel consumption	[MJ/t-km]	*value*	FC_4				
Totals						Emissions ($kgCO_{2e}$/t CPO)	
Module total	[MJ/t CPO]	*value*	x	*value*	=	*calculation*	26
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					26 ÷ z3 × AF_1 =	*calculation*	Stage_9

Stage 10 - Conversion

Description	Biodiesel plant						
Basic data							
Biodiesel plant yield	[t biodiesel / t coconut oil]	*value*	z3				
Conversion Inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t biodiesel)	
Natural gas	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	27
Electricity imported	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	28
				Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	*value*	x	*value*	=	*calculation*	29
Potassium hydroxide	kg/t biodiesel	*value*	x	*value*	=	*calculation*	30
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 glycerine]			
Quantity of crude glycerine produced	[t glycerine / t biodiesel]	*value*	x	*value*	=	*calculation*	31
Co-product 2: Potassium sulphate				Market value [£ / t potassium sulphate]			
Quantity of potassium sulphate produced and sold as chemical	[t potassium sulphate / t biodiesel]	*value*		*value*	=	*calculation*	32
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	33
Total market value of products							
Total market value	[£ / t biodiesel]					*calculation*	34
Allocation factor (%age of emissions attributable to biodiesel)	%				33 ÷ 34 x 100 =	*calculation*	AF_1
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(27 + 28 + 29 + 30) x AF_1 =	*calculation*	35
Contribution to fuel chain					35 =	*calculation*	Stage_10

Stage 11 - Liquid fuel transport and storage

Description	Transport from biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_5				
Fuel consumption	[MJ/t-km]	*value*	FC_5				
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	36
Contribution to fuel chain					36 =	*calculation*	Stage_11

Table 64 Coconut to ME biodiesel - Default value tables

Stage / Input	Units	Feedstock country of origin		
		India	Philippines	Indonesia
Stage 1 – Crop Production				
Yield of coconuts (i.e. flesh, shell but no husk)	[t/ha.a]	4.93	4.36	6.03
N fertiliser	[kg N/ha.a]	63	55	70
Type of N fertiliser		Urea	Urea	Urea
P fertiliser	[kg P_2O_5/ha.a]	20	17	22
Type of P fertiliser		Rock	Rock	Rock
K fertiliser	[kg K_2O/ha.a]	23	20	25
Pesticides	[kg/ha.a]	3	3	3
Diesel fuel consumption	[litres/ha.a]	25	25	25
Stage 2 – Conversion				
Yield of copra from coconut	[t copra / t coconut]	0.252	0.223	0.249
Fuel used	[MJ/t copra]	0	0	0
Fuel type		None	None	None
Stage 3 – Feedstock Transport				
Transport distance	[km]	27	140	200
Fuel consumption	[MJ/t-km]	1.94	1.8	1.8
Fuel type		Diesel	Diesel	Diesel
Stage 4 – Conversion				
Yield	[t coconut oil /t copra]	0.67	0.67	0.67

Natural gas	[MJ /t coconut oil]	0	0	0
Electricity imported	[MJ /t coconut oil]	403.2	403.2	403.2
Co-products	Description			
Co-product 1:	Coconut cake sold as animal feed			
Quantity of soy meal produced & sold as animal feed	[t coconut cake /t coconut oil]	0.552	0.552	0.552
Credit	[kgCO_2e /t coconut cake]	-236	-236	-236
Stage 5 – Feedstock Transport				
Transport distance	[km]	1300	0	0
Fuel consumption	[MJ/t-km]	0.19	0	0
Fuel type		Diesel	None	None
Stage 6 – Feedstock Transport				
Transport distance	[km]	12000	18000	15000
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
Methanol	kg/t biodiesel	113	113	113
Potassium hydroxide	kg/t biodiesel	26	26	26

Co-products				
Co-product 1	Crude glycerine			
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			
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	%	90.07	90.07	90.07
Stage 8 – Liquid fuel transport and storage				
Transport distance	[km]	0	0	0
Fuel consumption	[MJ/t-km]	0	0	0
Fuel type		None	None	None

17 Jatropha to ME biodiesel

Table 65 Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]
	India
1 – Crop production	169
2 – Feedstock transport	33
3 – Feedstock transport	0
4 – Conversion (crushing)	41
5 – Feedstock transport	20
6 – Feedstock transport	199
7 – Conversion (transesterification)	471
8 – Liquid fuel transport and storage	0
Total	933

Table 66 Jatropha to ME biodiesel - 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 (UAN); NPK (Urea / TSP / MOP)
1	Crop production	Phosphorus fertiliser emissions factor	Triple superphosphate (TSP), Rock phosphate, Mono ammonium phosphate (MAP)
2, 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, 6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
9	Conversion (transesterification)	Fuel emissions factor	Coal, Natural gas, Heavy fuel oil, Biomass
10	Liquid fuel transport	Transport	Truck (by

		mode fuel efficiency	geographic region), Rail (by geographic region), Shipping

Table 67 Jatropha to ME biodiesel – Default fuel chain

Stage 1 - Crop Production

Description	Cultivation & harvest of jatropha seeds (inc. drying & storage of fruit in field, & dehulling - all assumed to require no energy input)						
Basic Data							
Yield of jatropha fruit	Units [t/ha.a]	*value*	Y				
Soil Emissions							
N2O emissions	[total kg N/ha.a]	*calculation*	x	Emissions co-efficient [$kgCO_{2e}$/ha] *6.163*	÷ Y =	Total emissions *calculation*	1
Initial application							
Single super phosphate	[kg nutrient/ha.a]	Mass of input *value*	x	Emissions co-efficient [$kgCO_{2e}$/kg nutrient] *value*	÷ Y =	Total emissions *calculation*	2
Farming Inputs (First 5 years, amortized over 20 year productive plant life)							
N fertiliser	[kg nutrient/ha.a]	Mass of input *value*	x	Emissions co-efficient [$kgCO_{2e}$/kg nutrient] *value*	÷ Y =	Total emissions *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
Farming inputs (productive life - after 5 years), netting off press cake contribution to fertiliser input							
N fertiliser	[kg nutrient/ha.a]	Mass of input *value*	x	Emissions co-efficient [$kgCO_{2e}$/kg nutrient] *value*	÷ Y =	Total emissions *calculation*	6
P fertiliser (P2O5)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
K fertiliser (K2O)	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	8
Machinery and transport Inputs							
Replant and production	[litres/ha.a]	*value*	x	Emissions factor ($kgCO_{2e}$/l) *value*	÷ Y =	*calculation*	9
Harvest and collection	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	10
Totals							
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 =	Emissions ($kgCO_{2e}$/t seed) *calculation*	11
Contribution to fuel chain					11 ÷ z1 ÷ z2 × AF_1	Total Emissions [$kgCO_{2e}$/t biodiesel] *calculation*	Stage_1

Stage 2 - Feedstock Transport

Description	Transport of dried jatropha seeds to crushing plants							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_1					
Fuel consumption	[MJ/t-km]	*value*	FC_1					
Totals							Emissions ($kgCO_{2e}$/t seed)	
Module total	[MJ/t seed]	*value*		x	*value*	=	*calculation*	12
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						12 ÷ z2 ÷ z3 × AF_1 =	*calculation*	Stage_2

Stage 3 - Feedstock Transport

Description	Transport of dried jatropha seeds to crushing plants							
					Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_2					
Fuel consumption	[MJ/t-km]	*value*	FC_2					
Totals							Emissions ($kgCO_{2e}$/t seed)	
Module total	[MJ/t seed]	*value*		x	*value*	=	*calculation*	13
							Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain						18 ÷ z2 × AF_1 =	*calculation*	Stage_3

Stage 4 - Conversion

Description	Processing jatropha seeds to extract oil						
Basic Data							
Jatropha oil yield	[t jatropha oil / t seeds]	*value*	z1				
Extraction Inputs				Emissions factor [kgCO2e/MJ]		Emissions ($kgCO_{2e}$/t jatropha oil)	
Fuel for process	[MJ/t jatropha oil]	*value*	x	*value*	=	*calculation*	14
Electricity	[MJ/t jatropha oil]	*value*	x	*value*	=	*calculation*	15
				Emissions factor [kgCO2e/MJ]			
Co-products	**Description**	**Treatment**					
Co-product 1:	jatropha cake	Considered within system boundaries					
Totals						Emissions ($kgCO_{2e}$/t jatropha oil)	
Module total					14 + 15 =	*calculation*	16
Contribution to fuel chain					16 ÷ z2 × AF_1 =	Total Emissions [$kgCO_{2e}$/t biodiesel] *calculation*	Stage_4

Stage 5 - Feedstock Transport

Description	Transport of jatropha oil from the crusher to the port						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_3				
Fuel consumption	[MJ/t-km]	*value*	FC_3				
Totals						Emissions ($kgCO_{2e}$/t jatropha oil)	
Module total	[MJ/t jatropha oil]	*value*	x	*value*	=	*calculation*	17
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					17 ÷ z3 × AF_1 =	*calculation*	Stage_5

Stage 6 - Feedstock Transport

Description	Transport of jatropha oil from the port to the biodiesel plant						
				Emissions factor [kgCO2e/MJ]			
Transport distance	[km]	*value*	dist_4				
Fuel consumption	[MJ/t-km]	*value*	FC_4				
Totals						Emissions ($kgCO_{2e}$/t jatropha oil)	
Module total	[MJ/t jatropha oil]	*value*	x	*value*	=	*calculation*	18
						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Contribution to fuel chain					18 ÷ z3 × AF_1 =	*calculation*	Stage_6

Stage 7 - Conversion

Description	Biodiesel plant						
Basic data							
Biodiesel plant yield	[t biodiesel / t jatropha 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: crude glycerine				Market value [£ / t glycerine]			
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 sulphate / 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]				23 + 24 + 25 =	*calculation*	26
Allocation factor (%age of emissions attributable to biodiesel)	%				25 ÷ 26 x 100 =	*calculation*	AF_1
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(19 + 20 + 21 + 22) x AF_1 =	*calculation*	27
Contribution to fuel chain					27 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	Transport from biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist_5				
Fuel consumption	[MJ/t-km]	*value*	FC_5				
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	28
Contribution to fuel chain					28 =	*calculation*	Stage_8

Table 68 Jatropha to ME biodiesel - Default value tables

Stage / Input	Units	Feedstock country of origin
		India
Stage 1 – Crop Production		
Yield @ traded moisture content	[t/ha.a]	2.27
Initial application		
P fertiliser	[kg P_2O_5/ha.a]	27
Type of P fertiliser		Rock
First 5 years (amortised over 20 year lifetime of plant)		
N fertiliser	[kg N/ha.a]	12
Type of N fertiliser		Urea
P fertiliser	[kg P_2O_5/ha.a]	4.75
Type of P fertiliser		Rock
K fertiliser	[kg K_2O/ha.a]	13.25
After first 5 years		
N fertiliser	[kg N/ha.a]	0
Type of N fertiliser		None
P fertiliser	[kg P_2O_5/ha.a]	0
Type of P fertiliser		None
K fertiliser	[kg K_2O/ha.a]	0
Pesticides	[kg/ha.a]	0
Diesel fuel consumption	[litres/ha.a]	0
Stage 2 – Feedstock transport		

Transport distance	[km]	50
Fuel consumption	[MJ/t-km]	1.94
Fuel type		Diesel
Stage 3 – Feedstock transport		
Transport distance	[km]	0
Fuel consumption	[MJ/t-km]	0
Fuel type		None
Stage 4 – Conversion		
Yield	[t jatropha oil / t seeds]	0.240
Fuel for process	[MJ/t biodiesel]	0
Fuel type		None
Electricity imported	[MJ/t oil]	170
Co-products		
Co-product 1	Jatropha cake – considered within system boundaries	
Stage 5 – Feedstock transport		
Transport distance	[km]	1300
Fuel consumption	[MJ/t-km]	0.19
Fuel type		Diesel
Stage 6 – Feedstock transport		
Transport distance	[km]	12000
Fuel consumption	[MJ/t-km]	0.2
Fuel type		HFO
Stage 7 – Conversion		
Yield	[t biodiesel /t jatropha oil]	0.95

Fuel for process	[MJ/t biodiesel]	1690
Fuel type		Natural gas
Electricity imported	[MJ/t biodiesel]	335
Methanol	[kg/t biodiesel]	113
Potassium hydroxide	[kg/t biodiesel]	26
Co-products		
Co-product 1	Glycerine	
Quantity of crude glycerine	[t glycerine /t biodiesel]	0.10
Market value of glycerine	[£/t glycerine]	345
Co-product 2:	Potassium Sulphate	
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	%	90.07
Stage 9 – Liquid fuel transport and storage		
Transport distance	[km]	0
Fuel consumption	[MJ/t-km]	0
Fuel type		None

18 Corn oil to ME biodiesel

Table 69 Fuel chain summary

	Carbon intensity [kg CO_2/t pure plant oil]
	USA
1 – Feedstock transport	24
2 – Conversion (transesterification)	479
3 – Liquid fuel transport	26
4 – Liquid fuel transport	122
Total	651

Table 70 Corn oil to ME biodiesel – 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 (trans-esterification)	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
4	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 71 Soy to pure plant oil - Default fuel chain

Stage 1 - Feedstock Transport

Description	From corn ethanol plant to biodiesel plant.							
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]	*calculation*	x		*value*	=	*calculation*	1
Contribution to fuel chain						1 ÷ z1 × AF =	*calculation*	Stage_1

Stage 2 - Conversion

Description	Biodiesel plant						
Basic data							
Plant yield	[t biodiesel / t corn oil]	*value*	(z1)				
Conversion Inputs				Emissions factor ($kgCO_{2e}$/MJ)		Emissions ($kgCO_{2e}$/t biodiesel)	
Natural gas	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	2
Electricity imported	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	3
				Emissions factor (kgCO2e/kg)			
Methanol	kg/t biodiesel	*value*	x	*value*	=	*calculation*	4
Potassium hydroxide	kg/t biodiesel	*value*	x	*value*	=	*calculation*	5
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*	6
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*	x	*value*	=	*calculation*	7
Primary product: biodiesel				Market value [£ / t biodiesel]			
Market value of biodiesel				*value*	=	*calculation*	8
Total market value of products							
Total market value	[£ / t biodiesel]				6 + 7 + 8 =	*calculation*	9
Allocation factor (%age of emissions attributable to biodiesel)	%				8 ÷ 9 =	*calculation*	AF
Totals						Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total					(2 + 3 + 4 + 5) x AF =	*calculation*	10
Contribution to fuel chain					10 =	*calculation*	Stage_2

Stage 3 - Liquid fuel transport and storage

Description	From biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist				
Fuel consumption	[MJ/t-km]	*value*	FC				
Totals				Emissions factor (kgCO2e/MJ)		Total Emissions [$kgCO_{2e}$/t biodiesel]	
Module total	[MJ/t biodiesel]	*value*	x	*value*	=	*calculation*	11
Contribution to fuel chain					11 =	*calculation*	Stage_3

Stage 4 - Liquid fuel transport and storage

Description	From biodiesel plant to refinery / blending facility						
Transport distance	[km]	*value*	dist				
Fuel consumption	[MJ/t-km]	*value*	FC				
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_4

Table 72 Corn oil to ME biodiesel - Default value tables

Stage / Input	Units	Feedstock country of origin
		USA
Stage 1 – Feedstock transport		
Transport distance	[km]	200
Fuel consumption	[MJ/t-km]	1.46
Fuel type		Diesel
Stage 2 – Conversion		
Yield	[t biodiesel /t jatropha oil]	0.95
Fuel for process	[MJ/t biodiesel]	1690
Fuel type		Natural gas
Electricity imported	[MJ/t biodiesel]	335
Methanol	[kg/t biodiesel]	113
Potassium hydroxide	[kg/t biodiesel]	26
Co-products		
Co-product 1	Crude glycerine	
Quantity of crude glycerine	[t glycerine /t biodiesel]	0.1
Market value of glycerine	[£/t glycerine]	345
Co-product 2:	Potassium sulphate	
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	%	90.07
Stage 3 – Liquid fuel transport and storage		
Transport distance	[km]	1600
Fuel consumption	[MJ/t-km]	0.19
Fuel type		Diesel
Stage 4 – Liquid fuel transport and storage		
Transport distance	[km]	7000
Fuel consumption	[MJ/t-km]	0.2
Fuel type		HFO

19 HVO biodiesel

Table 73 OSR to HVO biodiesel – Fuel chain summary

Module	Carbon intensity [kg CO_2/t biodiesel]								
	Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom	USA
1 - Crop production	2510	2406	2471	2066	2075	1915	2633	2525	4140
2 - Drying and storage	0	84	87	80	92	97	88	92	95
3 - Feedstock transport	29	142	38	113	113	113	80	38	36
4 - Feedstock transport	900	0	0	0	0	0	116	0	0
5 - Conversion (crushing)	-609	-636	-628	-653	-605	-586	-608	-608	-596
6 - Feedstock transport	41	144	0	43	37	16	10	43	30
7 – Feedstock transport	0	0	0	0	0	0	0	0	149
8 - Conversion (hydrogenation)	488	488	488	488	488	488	488	488	488
9 - Liquid fuel transport and storage	35	35	35	35	35	35	35	35	35
Total	3394	2663	2491	2172	2235	2078	2842	2613	4377

Table 74 Soy to HVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2/t biodiesel]				
	Argentina	Brazil	Canada	Spain	USA

1 – Crop production	2372	2677	3000	2641	3124
2 – Drying and storage	95	88	93	97	79
3 – Feedstock transport	371	1689	91	191	91
4 – Conversion (crushing)	-1429	-1528	-1455	-1375	-1278
5 – Feedstock transport	0	0	20	0	30
6 – Feedstock transport	311	247	129	57	183
7 – Conversion (hydrogenation)	488	488	488	488	488
8 – Liquid fuel transport	35	35	35	35	35
Total	2243	3696	2401	2134	2752

Table 75 Palm to HVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2/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

Table 76 Sunflower to HVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]					
	Argentina	China	France	Russian Federation	Ukraine	United States
1 - Crop production	906	2340	2510	3030	2755	714
2 - Drying and storage	86	100	80	88	88	95
3 - Feedstock transport	401	47	113	22	18	5
4 - Feedstock transport	0	122	0	23	0	0
5 - Conversion (crushing)	-631	-574	-653	-625	-623	-596
6 - Feedstock transport	258	425	10	161	144	30
7 - Feedstock transport	0	0	0	0	0	150
8 - Conversion (hydrogenation)	488	488	488	488	488	488
9 - Liquid fuel transport and storage	35	35	35	35	35	35
Total	1543	2983	2583	3222	2905	921

Table 77 Coconut to HVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]		
	Indonesia	India	Philippines
1 - Crop production	811	905	1041

2 - Conversion	0	0	0
3 - Feedstock transport	57	8	40
4 - Feedstock transport	0	0	0
5 - Conversion (crushing)	-53	-35	-97
6 - Feedstock transport	0	26	0
7 - Feedstock transport	354	258	387
8 - Conversion (esterification)	488	488	488
9 - Liquid fuel transport and storage	35	35	35
Total	1692	1685	1894

Table 78 Jatropha to HVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2/t biodiesel]
	India
1 - Crop production	219
2 - Feedstock transport	43
3 - Feedstock transport	0
4 - Conversion (crushing)	53
5 - Feedstock transport	26
6 - Feedstock transport	258
7 - Conversion (transesterification)	488
8 - Liquid fuel transport and storage	35
Total	1122

Table 79 Selected default options

The selected default options are the same as the corresponding biodiesel ME chains, up to and including the conversion (crushing) module. The selected default options for the transport and hydrogenation steps are given below:

Stage	Module	Input	Options
6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
7	Conversion (hydrogenation)	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

Table 80 Default fuel chain

Stages 1 to 5 are identical to the fuel chain given for the corresponding type of 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	

Table 81 Default value tables

Default values for stages 1 to 5 are identical to those given for the corresponding type of ME biodiesel.

Stage / Input	Units	Feedstock country of origin																	
		Argentina	Australia	Brazil	Canada	China	Finland	France	Germany	India	Indonesia	Malaysia	Poland	Philippines	Russian Fed.	Spain	Ukraine	UK	USA
Stage 6 – Feedstock Transport																			
Transport distance	[km]	0	1900	0	6700	19800	0	2000	1700	1300	0	0	760	0	7500	0	500	2000	1500
Fuel consumption	[MJ/t-km]	0	0.2	0	0.2	0.2	0	0.2	0.2	0.19	0	0	0.2	0	0.2	0	0.19	0	0.19
Fuel type		None	HFO	None	HFO	HFO	None	HFO	HFO	Diesel	None	None	HFO	None	HFO	None	Diesel	HFO	Diesel
Stage7– Feedstock Transport																			
Transport distance		14500	0	11500	0	0	0	0	0	12000	16500	16500	0	18000	0	2640	0	0	8500
Fuel con-sumption		0.2	0	0.2	0	0	0	0	0	0.2	0.2	0.2	0	0.2	0	0.2	0	0	0.2
Fuel type		HFO	None	HFO	None	None	None	None	None	HFO	HFO	HFO	None	HFO	None	HFO	None	None	HFO
Stage 8 – Conversion																			

Plant yield	[t bio-diesel/t oil]	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	0.813	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	7660	7660	7660	7660	7660	7660	7660	7660	7660	7660
Electricity imported	[MJ/t biodiesel]	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
Stage 9 – Liquid fuel transport and storage																			
Transport distance	[km]	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	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	0.2	0.2	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	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO

20 Co-processed HVO

Table 82 OSR to CHVO biodiesel – Fuel chain summary

Module	Carbon intensity [kg CO_2/t biodiesel]								
	Australia	Canada	Finland	France	Germany	Poland	Ukraine	UK	USA
1 - Crop production	2262	2168	2227	1862	1870	1726	2373	2276	3732
2 - Drying and storage	0	76	78	73	83	88	80	83	85
3 - Feedstock transport	26	128	34	102	102	102	73	34	33
4 - Feedstock transport	811	0	0	0	0	0	104	0	0
5 - Conversion (crushing)	-549	-573	-566	-589	-545	-528	-548	-548	-537
6 - Feedstock transport	40	93	71	33	49	61	61	44	27
7 – Feedstock transport	0	0	0	0	0	0	0	0	122
8 - Conversion (hydrogenation)	511	511	511	511	511	511	511	511	511
9 - Liquid fuel transport and storage	40	40	40	40	40	40	40	40	40
Total	3141	2443	2395	2032	2110	2000	2694	2440	4013

Table 83 Soy to CHVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]				
	Argentina	Brazil	Canada	Spain	USA
1 – Crop production	2138	2413	2704	2380	2816
2 – Drying and storage	85	80	84	88	71
3 – Feedstock transport	335	1522	82	172	82
4 – Conversion (crushing)	-1288	-1377	-1312	-1239	-1152
5 – Feedstock transport	0	0	18	0	27
6 – Feedstock transport	200	181	93	7	122
7 – Conversion (hydrogenation)	511	511	511	511	511
8 – Liquid fuel transport	40	40	40	40	40
Total	2021	3370	2220	1959	2517

Table 84 Palm to CHVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]	
	Indonesia	Malaysia
1 – Crop Production	366	403
2 – Feedstock transport	13	13
3 – Conversion (palm oil extraction)	609	609
4 – Feedstock transport	74	46
5 – Conversion (palm oil refining)	137	128
6 – Feedstock transport	266	250
7 – Conversion (esterification)	511	511
8 – Liquid fuel transport	40	40
Total	2016	2000

Table 85 Sunflower to CHVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]					
	Argentina	China	France	Russian Federation	Ukraine	United States
1 - Crop production	817	2109	2262	2731	2483	644
2 - Drying and storage	77	90	73	80	80	85
3 - Feedstock transport	362	42	102	20	16	5
4 - Feedstock transport	0	110	0	21	0	0
5 - Conversion (crushing)	-569	-517	-589	-563	-562	-537

6 - Feedstock transport	200	334	33	77	61	27
7 - Feedstock transport	0	0	0	0	0	122
8 - Conversion (hydrogenation)	511	511	511	511	511	511
9 - Liquid fuel transport and storage	40	40	40	40	40	40
Total	1438	2719	2432	2917	2629	897

Table 86 Coconut to CHVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]		
	India	Philippines	Indonesia
1 - Crop production	731	816	939
2 - Conversion	0	0	0
3 - Feedstock transport	51	7	36
4 - Feedstock transport	0	0	0
5 - Conversion (crushing)	-48	-32	-88
6 - Feedstock transport	0	24	0
7 - Feedstock transport	266	186	306
8 - Conversion (esterification)	511	511	511
9 - Liquid fuel transport and storage	40	40	40
Total	1551	1552	1744

Table 87 Jatropha to CHVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]
	India
1 - Crop production	198
2 - Feedstock transport	39
3 - Feedstock transport	0
4 - Conversion (crushing)	48
5 - Feedstock transport	24
6 - Feedstock transport	186
7 - Conversion (transesterification)	511
8 - Liquid fuel transport and storage	40
Total	1046

Table 88 Tallow to CHVO biodiesel – Fuel chain summary

	Carbon intensity [kg CO_2 / t biodiesel]		
	Denmark	UK	USA
1 – Feedstock transport	37	7	27
2 – Feedstock transport	48	44	122
3 – Conversion (hydrogenation)	511	511	511
4 – Liquid fuel transport and storage	40	40	40
Total	636	602	700

Table 89 Selected default options

Stage	Module	Input	Options

6	Feedstock transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
7	Conversion (hydrogenation)	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

The selected default options are the same as the corresponding biodiesel ME chains, up to and including the conversion (crushing) module. The selected default options for the transport and hydrogenation steps are given below:

Table 90 Default fuel chain

Stages 1 to 5 are identical to the fuel chain given for the corresponding type of 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 CHVO biodiesel / t oil]	*value*	(z2)				
Conversion Inputs				Emissions factor [kgCO2e / MJ]		Emissions [$kgCO_{2e}$/t CHVO diesel]	
Natural gas	[MJ/t CHVO biodiesel]	*value*	x	*value*	=	*calculation*	20
Electricity	[MJ/t CHVO biodiesel]	*value*	x	*value*	=	*calculation*	21
Heavy fuel oil	[MJ/t CHVO biodiesel]	*value*		*value*		*calculation*	22
Totals						Total Emissions [$kgCO_{2e}$/t CHVO biodiesel]	
Module total					20 + 21 +22 =	*calculation*	23
Contribution to fuel chain					22 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	From CHVO 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 CHVO biodiesel]	
Module total	[MJ/t CHVO biodiesel]	*value*	x	*value*	=		*calculation*	24
Contribution to fuel chain						24 =	*calculation*	Stage_8

Table 91 Default value tables

Default values for stages 1 to 5 are identical to those given for the corresponding type of ME biodiesel

Stage / Input	Units	Feedstock country of origin																				
		Argentina	Australia	Brazil	Canada - Soy	Canada - OSR	China	Denmark	Finland	France	Germany	India	Indonesia	Malaysia	Poland	Philippines	Russian Fed.	Spain	Ukraine	UK	UK – tallow	USA
Stage 6 – Feedstock Transport																						
Transport distance	[km]	0	2060	0	1000	4810	17230	250	3690	1690	2520	1300	13730	12920	3150	0	3960	0	3150	2290	50	1500
Fuel consumption	[MJ/t-km]	0	0.2	0	0.19	0.2	0.2	1.53	0.2	0.2	0.2	0.19	0.2	0.2	0.2	0	0.2	0	0.2	0.2	1.53	0.19
Fuel type		None	HFO	None	Diesel	HFO	HFO	Diesel	HFO	HFO	HFO	Diesel	HFO	HFO	HFO	None	HFO	None	HFO	HFO	Diesel	Diesel
Stage7– Feedstock Transport																						
Transport distance	[km]	10320	0	9340	4810	0	0	2490	0	0	0	0	0	0	0	15800	0	360	0	0	2290	6320
Fuel consumption	[MJ/t-km]	0.2	0	0.2	0.2	0	0	0.2	0	0	0	0	0	0	0	0.2	0	0.2	0	0	0.2	0.2
Fuel type		HFO	None	HFO	HFO	None	None	HFO	None	None	None	None	None	None	None	HFO	None	HFO	None	None	HFO	HFO
Stage 8 – Conversion																						
Plant yield	[t bio-diesel/t oil]	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902
Natural	[MJ/t	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000

gas	biodiesel]																					
Electricity imported	[MJ/t biodiesel]	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231	231
Heavy fuel oil	[MJ/t CHVO biodiesel]	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572
Stage 9 – Liquid fuel transport and storage																						
Transport distance	[km]	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290	2290
Fuel consumpt-ion	[MJ/t-km]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	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	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO	HFO

21 Oilseed rape to pure plant oil

Table 92 Fuel chain summary

Module	Carbon intensity [kg CO_2/t biodiesel]								
	Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom	United States
1 - Crop production	2039	1955	2008	1678	1685	1556	2139	2052	3364
2 - Drying and storage	0	69	71	66	75	79	72	75	77
3 - Feedstock transport	23	115	31	92	92	92	65	31	29
4 – Feedstock transport	731	0	0	0	0	0	93	0	0
5 – Conversion (crushing)	-494	-517	-510	-531	-491	-476	-494	-494	-484
6 – Liquid fuel transport and	9	91	35	8	11	26	0	0	25

storage									
7 – Liquid fuel transport and storage	0	0	0	0	0	0	0	0	122
Total	2308	1713	1635	1313	1372	1277	1875	1664	3133

If additives are added to the pure plant oil, the volume and the carbon intensity of the chemical added should be included in the calculation of the overall emissions from the fuel chain, if it is likely to contribute to >1% of the total fuel chain emissions. Note that addition of <5% additive is unlikely to do this.

Table 93 Oil seed rape (OSR) to pure plant oil - 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 (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, 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
6,7	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping

Table 94 Oil seed rape (OSR) to pure plant oil - 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
Totals						Total Emissions ($kgCO_{2e}$/t OSR)	
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	*calculation*	8
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					8 ÷ z1 =	*calculation*	Stage_1

Stage 2 - Drying and storage

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

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					
Totals							Emissions ($kgCO_{2e}$/t OSR)	
Module total	[MJ/t OSR]	*value*	x		*value*	=	*calculation*	13
							Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain						13 ÷ z1 =	*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 (kgCO2e/t pure plant oil)	
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 [kgCO2e/t pure plant oil]	
Contribution to fuel chain					17 =	*calculation*	Stage_5

Stage 6 - Liquid fuel transport and storage

Description	From crusher to duty point							
				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 =	*calculation*	Stage_6

Stage 7 - Liquid fuel transport and storage

Description	From extraction facility to blending facility							
				Emissions factor [kgCO2e/MJ]				
Transport distance	[km]	*value*	dist_4					
Fuel consumption	[MJ/t-km]	*value*	FC_4					
Totals							Emissions ($kgCO_{2e}$/t rapeseed oil)	
Module total	[MJ / t rapeseed oil]	*value*	x	*value*	=		*calculation*	19
Contribution to fuel chain						19 =	*calculation*	Stage_7

Stage 8 - Liquid fuel transport and storage

Description	Transport from pure plant oil plant to refinery / blending facility							
Transport distance	[km]	*value*	dist_5					
Fuel consumption	[MJ/t-km]	*value*	FC_5					
Totals							Total Emissions [kgCO2e/t pure plant oil]	
Module total	[MJ/t pure plant oil]	*value*	x	*value*		=	*calculation*	20
Contribution to fuel chain						20 =	*calculation*	Stage_8

Table 95 Oil seed rape (OSR) to pure plant oil - Default value fuel tables

Stage / Input	Units	Feedstock country of origin								
		Australia	Canada	Finland	France	Germany	Poland	Ukraine	United Kingdom	USA
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	1.56
Traded moisture content	%	9	9	9	9	9	9	9	9	9
N fertiliser	[kg N /ha.a]	61	75	67	155	170	102	60	185	150
Type of N fertiliser		AN	AN	AN	AN	AN	AN	AN	AN	AN
P fertiliser	[kg P_2O_5 /ha.a]	16	20	18	45	45	35	15	45	120
Type of P fertiliser		TSP	TSP	TSP	TSP	TSP	TSP	TSP	TSP	TSP
K fertiliser	[kg K_2O /ha.a]	12	15	13	80	90	44	12	48	80
Lime	[kg CaO /ha.a]	271	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	0.28
Diesel fuel consumption	[litres /ha.a]	66	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	3
Fuel for heating	[MJ /t OSR]	0	318	318	318	318	318	318	318	318
Fuel type		None	Diesel							
Electricity	[MJ /t OSR]	0	35	35	35	35	35	35	35	35
Stage 3 – Feedstock Transport										
Transport distance	[km]	300	3000	100	300	300	300	1700	100	100
Fuel consumption	[MJ/t-km]	0.38	0.19	1.53	1.53	1.53	1.53	0	1.53	1.46
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
Stage 4 – Feedstock Transport										
Transport distance	[km]	18000	0	0	0	0	0	2300	0	0
Fuel consumption	[MJ/t-km]	0.2	N/A	N/A	N/A	N/A	N/A	0.2	N/A	N/A

Fuel type		HFO	N/A	N/A	N/A	N/A	N/A	HFO	N/A	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	0.43
Natural gas	[MJ/t rapeseed oil]	1986	1986	1986	1986	1986	1986	1986	1986	1986
Electricity imported	[MJ/t rapeseed oil]	337	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	1.32
Credit for co-product 1	[kgCO_2e/t rape meal]	-504	-504	-504	-504	-504	-504	-504	-504	-504
Stage 6 – Liquid fuel transport and storage										
Transport distance	[km]	500	5200	2000	450	650	1500	0	0	1500

Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2	0.2	0.2	0	0	0.19
Fuel Type		HFO	HFO	None	HFO	HFO	HFO	None	None	HFO
Stage 7 – Liquid fuel transport and storage										
Transport distance	[km]	0	0	0	0	0	0	0	0	7000
Fuel consumption	[MJ/t-km]	0	0	0	0	0	0	0	0	0.2
Fuel Type		None	None	None	None	None	None	None	None	HFO

22 Soy to pure plant oil

Table 96 Fuel chain summary

	Carbon intensity [kg CO_2/t pure plant oil]				
	Argentina	Brazil	Canada	Spain	USA
1 – Crop production	1927	2175	2438	2146	2538
2 – Drying and storage	77	72	76	79	64
3 – Feedstock transport	302	1372	74	156	74
4 – Conversion (crushing)	-1161	-1241	-1182	-1117	-1037
5 – Liquid fuel transport	0	0	16	0	25
6 – Liquid fuel transport	227	175	105	46	122
Total	1372	2553	1527	1310	1786

If additives are added to the pure plant oil, the volume and the carbon intensity of the chemical added should be included in the calculation of the overall emissions from the fuel chain, if it is likely to contribute to >1% of the total fuel chain emissions. Note that addition of <5% additive is unlikely to do this.

Table 97 Soy to pure plant oil - 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 (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	Liquid fuel transport	Transport mode fuel efficiency	Truck (by geographic region), Rail (by geographic region), Shipping
6	Liquid fuel	Transport mode	Truck (by geographic

	transport	fuel efficiency	region), Rail (by geographic region), Shipping

Table 98 Soy to pure plant oil - 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*					
Soil Emissions							
				Emissions factor ($kgCO_{2e}$/ha)		Total Emissions (kgCO2e/t soy)	
N2O emissions	[total kg N/ha.a]	*N_FERT*		*6.163*	÷ Y =	*calculation*	1
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*	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
				Emissions co-efficient [$kgCO_{2e}$/kg nutrient]			
Pesticides	[kg nutrient/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	5
Electricity	[kWh/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	6
Machinery Inputs							
Diesel fuel consumption	[litres/ha.a]	*value*	x	*value*	÷ Y =	*calculation*	7
Totals						Emissions (kgCO2e/t soy)	
Module total					1 + 2 + 3 + 4 + 5 + 6 + 7 =	*calculation*	8
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					8 ÷ z1 =	*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*	9
Electricity	[MJ/t soy]	*value*	x	*value*	=	*calculation*	10
Totals						Emissions (kgCO2e/t soy)	
Module total					9 + 10 =	*calculation*	11
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					11 ÷ z1 =	*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				
Totals						Emissions (kgCO2e/t soy)	
Module total	[MJ/t]	*value*	x	*value*	=	*calculation*	12
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					12 ÷ z1 =	*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 (kgCO2e/t pure plant oil)	
Conversion Inputs							
Natural gas	[MJ/t soy oil]	*value*	x	*value*	=	*calculation*	13
Electricity imported	[MJ/t soy oil]	*value*	x	*value*	=	*calculation*	14
Co-products	**Description**	**Treatment**					
Co-product 1:	Soy meal - sold as animal feed	Substitution					
Co-products treated by substitution							
Co-product 1: soy meal							
- substitutes EU wheat				Credit [$kgCO_{2e}$/t soy meal]			
Quantity of soy meal produced & sold as animal feed	[t soy meal / t soy oil]	*value*	x	*value*	=	*calculation*	15
Totals							
Module total					13 + 14 + 15 =	*calculation*	16
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					16 =	*calculation*	Stage_4

Stage 5 - Liquid fuel transport and storage

Description	From crusher to duty point						
				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*	17
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					17 =	*calculation*	Stage_5

Stage 6 - Liquid fuel transport and storage

Description	From crusher to duty point						
				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*	18
						Total Emissions [kgCO2e/t pure plant oil]	
Contribution to fuel chain					18 =	*calculation*	Stage_6

Table 99 Soy to pure plant oil - Default value tables

Stage / Input	Units	Feedstock country of origin				
		Argentina	Brazil	Canada	Spain	USA
Stage 1 – Crop Production						
Yield @ traded moisture content	[t/ha.a]	2.54	2.54	2.28	2.57	2.60
Moisture content	%	13	13	13	13	13
N fertiliser	[kg N/ha.a]	10	10	25	14	24
Type of N fertiliser		Urea	Urea	Urea	AN	AN
P fertiliser	[kg P_2O_5/ha.a]	5	50	50	6	100
Type of P fertiliser		MAP	MAP	MAP	MAP	TSP
K fertiliser	[kg K_2O/ha.a]	3	60	85	6	55
Pesticides	[kg/ha.a]	1.31	1.31	1.31	1.31	1.31
Electricity	[kWh/ha.a]	11.00	11.00	0	11.0	11.00
Diesel fuel consumption	[litres/ha.a]	75.6	75.6	75.6	75.6	75.6
Stage 2 – Drying and storage						
Moisture removed	%	2	2	2	2	2
Fuel for heating	[MJ/t soy]	138	138	138	138	138
Fuel type		Diesel	Diesel	Diesel	Diesel	Natural gas

Electricity	[MJ/t soy]	15	15	15	15	15
Stage 3 – Feedstock Transport						
Transport distance	[km]	330	1500	100	200	100
Fuel consumption	[MJ/t-km]	1.8	1.8	1.46	1.53	1.46
Fuel type		Diesel	Diesel	Diesel	Diesel	Diesel
Stage 4 – Conversion						
Yield	[t soy oil/t soy]	0.17	0.17	0.17	0.17	0.17
Natural gas	[MJ/t soy oil]	5447	5447	5447	5447	5447
Electricity imported	[MJ/t soy oil]	1476	1476	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	4.32	4.32
Credit	[kgCO_2e/t soy meal]	-373	-373	-373	-373	-373
Stage 5 – Liquid Fuel Transport						
Transport distance	[km]	0	0	1000	0	1500
Fuel consumption	[MJ/t-km]	0	0	0.19	0	0.19
Fuel type		None	None	Diesel	None	Diesel
Stage 6 – Liquid Fuel Transport						

Transport distance	[km]	13000	10000	6000	2640	7000
Fuel consumption	[MJ/t-km]	0.2	0.2	0.2	0.2	0.2
Fuel type		HFO	HFO	HFO	HFO	HFO

23 Ethanol to ETBE

The carbon intensity of ETBE is equal to that of the bioethanol fuel chain from which the ETBE is produced. Actual data can be used to replace default values for any of the production steps involved in producing the bioethanol – refer to the appropriate bioethanol fuel chain default values above.

24 Manure to biogas

Table 100 Fuel chain summary

	Carbon intensity [kg CO_2 / t biogas]
1 – Feedstock transport	290
2 – Conversion	1339
3 – Gaseous fuel transport and storage	0
Total	1630

Table 101 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

Table 102 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
Contribution to fuel chain					2 ÷ z1 =	Total emissions ($kgCO_2e$/tonne biomethane) 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
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
Contribution to fuel chain					7 x 45100 =	Total emissions ($kgCO_2e$/tonne biomethane) 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
Contribution to fuel chain					8 x 45100 =	Total emissions ($kgCO_2e$/tonne biomethane) calculation	Stage_3

Table 103 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 biogas/t manure	4297
Natural gas (import)	MJ/MJ biogas	0
Electricity (import)	MJ/MJ biogas	0.077
Methane losses	g CH_4 lost/MJ biogas	0.887
Emissions coefficient for methane	g CO_2e/g CH_4	23
Co-products	Description	Treatment
Co-product 1	Organic nitrogen fertiliser	Substitutes synthetic N fertiliser
Fertiliser	MJ N/MJ biogas	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

25 Municipal solid waste to biogas

Table 104 Fuel chain summary

	Carbon intensity [kg CO_2 / t biogas]
1 – Feedstock transport	290
2 – Conversion	1339
3 – Gaseous fuel transport and storage	0
Total	1630

Table 105 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

Table 106 Default fuel chain

Stage 1 - Feedstock Transport

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

Table 107 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 biogas/t waste	4297
Natural gas (import)	MJ/MJ biogas	0
Electricity (import)	MJ/MJ biogas	0.077
Methane losses	g CH_4 lost/MJ biogas	0.887
Emissions coefficient for methane	g CO_2e / g CH_4	23
Co-products	Description	Treatment
Co-product 1	Organic nitrogen fertiliser	Substitutes synthetic N fertiliser
Fertiliser	MJ N/MJ biogas	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

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.

Annex A Default value sources

Table 108 Common across several fuel chains

Input	Reference
Crop production inputs	
Agricultural yields	FAO Statistics (faostat.fao.org) (*average of 2000-2005 yields*)
N_2O emissions correlation	IPCC, (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published IGES, Japan.
N, P & K fertiliser application rates	FAO, 2002 *Fertiliser use by crop*. FAO/Rome.
N, P, K & NPK fertiliser emissions coefficients	Jenssen, T.K. and Kongshaug, G. (2003). Energy consumption and greenhouse gas emissions in fertiliser production. *Proceedings of the International Fertiliser Society*. Proc No 509
Lime application rates	DEFRA (2006). *The British survey of fertiliser practice - fertiliser use on farm crops for crop year 2005*. DEFRA, London.
Lime emissions coefficient	JEC (2006). Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Well to wheels report. CONCAWE, EUCAR and JRC.
Pesticide application rates	Garthwaite, D.G., Thomas, M.R., Anderson, H. and Stoddart, H. (2004) *Pesticide usage report 202 – arable crops in Great Britain 2004*. Central Science Laboratary.
Pesticide emissions coefficient	JEC (2006). Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Well to wheels report.

	CONCAWE, EUCAR and JRC.
Drying & storage	
Traded moisture content	Assumed on the basis of discussions with stakeholders and industry sources.
Moisture content removed	Assumed on the basis of discussions with stakeholders and industry sources.
Energy required for drying (both fuel for heating and electricity)	Based on: Hellevang, K.J. (1995). Grain drying. AE-701 (Revised). North Dakota State University Extension Service / US Department of Agriculture
Feedstock transport	
Distances	Assumed on the basis of discussions with stakeholders and industry sources.
Fuel consumption of all transport modes	WBSCD/IEA (2004) Transport spreadsheet model - Mobility 2030 Project. IEA/OECD & WBSCD.
Conversion plants	
All biodiesel (methyl ester) plant inputs	Mortimer, N.D. and Elsayed, M.A. (2006) *North east biofuel supply chain carbon intensity assessment*. North Energy Associates.
Emission coefficients of chemical inputs	ibid
All biodiesel (hydrogenated vegetable oil)	Adapted from: IFEU (2006). *An assessment of energy and greenhouse gases of NExBTL*. IFEU, for Neste Oil.
General default values	
Fossil fuel emissions coefficients	JEC (2006). Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Well to wheels report. CONCAWE, EUCAR and JRC.
Characteristics of fuels (e.g. lower heating values etc)	Ibid

Electricity emissions coefficients	IEA (2006). Online database. (data from 2003).

Table 109 Wheat to ethanol chain

Input	Reference
On-farm diesel use	Woods, J. Brown, G. and Estrin, A. (2005) Bioethanol Greenhouse gas calculator - user's guide. HGCA, London. http://www.hgca.com/publink.aspx?id=2732
Plant yield	Smith, T.C., Kindred, D.R., Brosnan, J.M., Weightman, R.M., Shepherd, M. and Sylvester-Bradley, R. (2006). Wheat as a feedstock for alcohol production. HGCA
Natural gas & electricity use	Adapted from: Punter, G., Rickeard D., Larivé, J-F., Edwards R., Mortimer, N., Horne, R., Bauen, A. and Woods, J. Well-to-wheel evaluation for production of ethanol from wheat. Low Carbon Vehicle Partnership Fuels Working Group.
Quantity of DDGS (per tonne ethanol)	Adapted from: ibid
Substitution ratio (DDGS to soy bean), calculated on the basis of protein content	Protein contents from: JEC (2006). Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Well to wheels report. CONCAWE, EUCAR and JRC.

Table 110 Sugar beet to ethanol chain

Input	Reference
Crop yield	Nix, J. (2006) Farm management pocketbook. 37th edition. Imperial College, London.
Na fertiliser	Industry sources

application rate	
Na fertiliser emissions coefficient	Assumed equal to Triple Super Phosphate
Transport distance – farm to plant	Tzilivakis, J., Jaggard, K.W., Lewis, K.A., May M. and Warner D.J. (2005). Environmental impact and economic assessment for UK sugar beet production systems. *Agriculture, Ecosystems and Environment* 07, 341-358
Conversion plant yield, natural gas use, electricity use, co-product yields	Mortimer, N.D., Elsayed, M.A. & Horne, R. E. (2004). *Energy and greenhouse gas emisions for bioethanol production from wheat grain and sugar beet*.

Table 111 Sugar cane to ethanol chain

Input	Reference
Percentage of cane burnt	Brazil: Macedo I. (2006), personal communication; other countries, assumed
Process heat and electricity requirements	Adapted from: Integrating Sweet Sorghum and Sugarcane for Bioenergy: Modelling the Potential for Electricity and Ethanol Production in SE Zimbabwe. J Woods, PhD Thesis, King's College London, 2000. Prakash R, Henham A, Krishnan Bhat I. Net energy and gross pollution from bioethanol production in India. Fuel 1998;77(14):1629e33. Beer T, Morgan G, Lepszewicz J, Anyon P, Edwards J, Nelson P, et al. Life-cycle emissions analysis of alternative fuels for heavy vehicles. CSIRO; 2001.
Fuel type for heat	Macedo I. (2006), personal communication. Data drawn from the Cane Technology Centres database of 110 mills in the Center-South Region of Brazil. Tomlinson, D. (2007), personal communication.

Table 112 Molasses to ethanol chain

Input	Reference
Process heat and electricity requirements	Adapted from: Integrating Sweet Sorghum and Sugarcane for Bioenergy: Modelling the Potential for Electricity and Ethanol Production in SE Zimbabwe. J Woods, PhD Thesis, King's College London, 2000. Prakash R, Henham A, Krishnan Bhat I. Net energy and gross pollution from bioethanol production in India. Fuel 1998;77(14):1629e33. Beer T, Morgan G, Lepszewicz J, Anyon P, Edwards J, Nelson P, et al. Life-cycle emissions analysis of alternative fuels for heavy vehicles. CSIRO; 2001.
Fuel type for heat	Macedo I. (2006), personal communication. Data drawn from the Cane Technology Centres database of 110 mills in the Center-South Region of Brazil. Tomlinson, D. (2007), personal communication.

Table 113 US corn to ethanol chain

Input	Reference
Diesel for crop production	Argonne National Laboratory (2006) *Greenhouse gases, regulated emissions, and energy use in transportation (GREET) model*. Version 1.7(beta), http://www.transportation.anl.gov/software/GREET/
All crop drying inputs	Ibid
All conversion plant inputs and yields	Ibid (coal fired wet mill)

Table 114 EU corn to ethanol chain

Input	Reference
Diesel for crop production	Assumed equal to use conditions given in Argonne National Laboratory (2006) *Greenhouse gases, regulated emissions, and energy use in transportation (GREET) model*. Version 1.7(beta), http://www.transportation.anl.gov/software/GREET/
All conversion plant inputs and yields	Assumed equal to use conditions given for dry mill in Argonne National Laboratory (2006) *Greenhouse gases, regulated emissions, and energy use in transportation (GREET) model*. Version 1.7(beta), http://www.transportation.anl.gov/software/GREET/

Table 115 Spent sulphite liquor to ethanol chain

Input	Reference
Quantity of chemicals used	Data from the Domsjö sulphite pulpmill, data provided by Univar and Kemira.
Quantity of electricity used	Data from the Domsjö sulphite pulpmill, data provided by Övik energi.

Table 116 Oilseed rape to biodiesel chain

Input	Reference
Lime fertiliser application rate	Mortimer, N.D., Cormack, P., Elsayed, M.A. and Horne, R.E. (2003) *Evaluation of the comparative energy, global warming and socio-economic costs and benefits of biodiesel*. DEFRA.
Diesel fuel consumption	Ibid
Transport distance – farm to crusher (in UK)	Mortimer, N.D. and Elsayed, M.A. (2006) *North east biofuel supply chain carbon intensity assessment*. North Energy Associates.
All crushing plant inputs	Ibid

Table 117 Soy to biodiesel chain

Input	Reference
Electricity input to crop production	Sheehan, J., Camobreco, V., Duffield, J., Graboski, M and Shapouri, H. (1998) *Life cycle inventory of biodiesel and petroleum diesel.* National Renewable Energy Laboratory
Soy crushing inputs and yields	Adapted from: Sheehan, J., Camobreco, V., Duffield, J., Graboski, M and Shapouri, H. (1998) *Life cycle inventory of biodiesel and petroleum diesel.* National Renewable Energy Laboratory

Table 118 Palm to biodiesel chain

Input	Reference
NPK fertiliser application rates	Goh KJ and Hardter R (2003) General oil palm nutrition. In: Fairhurst T and Hardter R (eds). *Oil palm management for large and sustainable yields.* Potash and Phosphate Institute/Potash and Phosphate Institute of Canada, pp 307-320.
Pesticide application rates	Turner PD and Gilbanks RA (2003) *Oil Palm Cultivation and Management.* 2nd Edition. Incorporated Society of Planters: Kuala Lumpur
Machinery inputs to crop production	Wood BJ and Corley RHV (1991) The energy balance of oil palm cultivation. P130-143. Proceedings of the 1991 PORIM International Palm Oil Conference. PORIM: Kuala Lumpur
Palm oil mill yield	Corley RHV and Tinker PB (2003) *The Oil Palm.* 4th Edition. Blackwell Science: Oxford
Energy inputs to palm oil mill	Wood BJ and Corley RHV (1991) The energy balance of oil palm cultivation. P130-143. Proceedings of the 1991 PORIM International Palm Oil Conference. PORIM: Kuala Lumpur
Palm oil mill effluent	Adapted from: Yacob S, Hassan MA, Shirai Y, Wakisaka M and Subash S (2006) Baseline study of methane emission from anaerobic ponds of palm oil mill effluent treatment. Science of the Total Environment 366 187-196
Palm oil	UNFCC (2006), Project 0249: Biomass Energy

refinery – all inputs	Plant – Lumut. UNFCCC.

Table 119 UCO / tallow to biodiesel (methyl ester) chain

Input	Reference
Plant yield	Elsayed, M.A., Mathews, R. and Mortimer, N.D. (2003) *Carbon and energy balances for a range of biofuel options.* DTI Sustainable Energy Programme.
Other plant inputs	Mortimer, N.D. and Elsayed, M.A. (2006) *North east biofuel supply chain carbon intensity assessment*. North Energy Associations.

Table 120 Coconut to biodiesel (methyl ester) chain

Input	Reference
All crop production inputs	Hemstock, S.L. (2008). *Coconut Fuel Chain Review for E4tech*, October 2008
Transport distances	ibid
Copra production yield	Trewren, K (2008). Personal Communication

Table 121 Jatropha to biodiesel (methyl ester) chain

Input	Reference
Crop yield & fertiliser inputs	IFEU (2007). *Screening LCA of Jatropha Biodiesel*.
Transport distances	D1BP (2008), Personal Communication
Electricity used for screw press oil extraction	Beerens, P. (2007). Screw-pressing of Jatropha seeds for fuelling purposes in less developed countries. Eindhoven University of Technology

Table 122 CHVO biodiesel chain

Input	Reference
Hydrogenation step inputs	JEC (2008) quoting Shonnard, D et al, Michigan Technology University, Department of Chemical Engineering: A LCA of Ecofining Process for Producing Green Diesel and Comparison to Biodiesel: CONCAWE Study Assumptions; Study Conducted for UOP LLC, Des Plaines, Il, USA; November 03, 2007 JEC (2008) quoting GEMIS, version 4.1.3.2: http://www.oeko-institut.org/service/gemis/index/htm JEC (2008) quoting Foster Wheeler: Decarbonisation of Fossil Fuels; Report Nr PH2/2; Prepared for the Executive Committee of the IEA Greenhouse Gas R&D Programme; March 1996

Table 123 Biomethane

Input	Reference
Electricity import	JEC (2006). Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Well to wheels report. CONCAWE, EUCAR and JRC.
Methane losses	ibid
Fertiliser production	ibid