



# Report

## Life cycle greenhouse gas emission model for New Zealand biodiesels

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Prepared for  
Energy Efficiency and Conservation Authority

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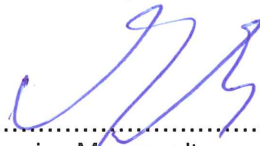
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## Executive Summary

The Energy Efficiency and Conservation Authority (EECA) are required to publish voluntary sustainability guidelines and information for biofuels in New Zealand in accordance with the New Zealand Energy Efficiency and Conservation Strategy (EECA, 2007).

EECA commissioned URS to develop models to calculate the greenhouse gas (GHG) emissions associated with the production of tallow, rapeseed and used cooking oil biodiesel. This report, the second report as part of this project, provides the GHG inventory models for each biodiesel source and associated information including recommended default values and emission factors.

URS developed each model in accordance with boundaries agreed with EECA (as documented in the first report for this project - URS, 2009) and an in-depth review of the UK ORFA (2009) report which included biofuel GHG emission data from the UK. The URS models are based on two data sets:

- **Activity data** reflecting the average or “representative” activity levels (for example electricity consumed, transport distances) within the agreed study boundary, with the potential to generate GHG emissions.
- **Emission factors** converting the representative activity levels to quantitative GHG emissions.

Please note – where applicable, conversion factors are also used to calculate the market value of input products and energy content of fuel.

To check the New Zealand emission models, URS applied UK input data and emission factors to the New Zealand models, resulting in similar emissions as reported in the UK Office of the Renewable Fuels Agency report *Carbon and sustainability reporting within the renewable transport fuel obligation* (ORFA, 2009). The final models were then populated with default activity level values and recognised emission factors reflecting New Zealand conditions, where possible.

URS surveyed industry members to collect data for activity data default values but received a low response rate (URS, 2009). Further assessment of each parameter was therefore completed and where required, an estimate of a representative default activity level value was made based on data available and/or other published data.

URS prepared the emission models in an excel spreadsheet format. Tables in each sheet outline the main process steps to produce biodiesel and the activity data associated with these processes. The models have been set up for biodiesel manufacturers to enter activity data where this is available, or where no activity data is available, to use the default values provided. Once activity data is entered, the built-in emission factors allow the user to view estimated total GHG emissions in “per unit of production” figures. Emissions estimated via the emissions model are as robust as possible, given both the representative nature of the activity data and the assumed life cycle boundaries. They should, however, only be reported with specific reference to the possible sources of uncertainty in the activity data and the assumed boundaries. This will avoid potential misinterpretation of the results or inappropriate comparisons.

Based on the survey data and the emission factors identified, URS used each model to estimate GHG emissions for each of the three biodiesel streams. The estimated total GHG emissions from biodiesel production for the different types of fuel are as follows:

- rapeseed: 2,201 kg CO<sub>2</sub>e/t biodiesel produced;
- tallow: 804 kg CO<sub>2</sub>e/t biodiesel produced;
- used cooking oil: 827 kg CO<sub>2</sub>e/t biodiesel produced.

## Executive Summary

The calculated GHG emissions for rapeseed based biodiesel are significantly greater than those calculated for either tallow or used cooking oil based biodiesel. This is because emissions arising from crop production were included in the rapeseed result. By contrast emissions arising from the upstream production stages of tallow and used cooking oil were not included in the model calculations. The approach taken for this study reflected the approach previously adopted by ORFA 2009, on the basis that both tallow and used cooking oil are “waste” products which would have been manufactured regardless of their use as a raw material for biodiesel. This approach is currently being widely discussed and the latest international guidance (BSI British Standards 2008 - PAS 2050 – How to assess the carbon footprint of goods and services) requires that all “processes used in the transformation of raw material” be included in a full life cycle boundary.

The boundaries for each of the three biodiesel products investigated through this study should be evaluated further in future updates of the GHG model. In the meantime URS also recommends that each biodiesel stream is only compared with other fuels which have a similar process boundary, e.g. tallow and used cooking oil.

The biodiesel sector in New Zealand is relatively new and is developing quickly. The emission figures are subject to a range of uncertainties resulting from the activity data, the emission factors used and the assumptions included in each model. The best estimates using the emission models will occur if actual activity data is entered. The emission factors in each model should be updated regularly.

Biodiesel manufacturers will be able to use the models to identify significant emission sources in their production process, understand the life cycle assessment approach to GHG emission estimates and compare emissions with other same source biodiesel estimates where boundaries are the same.

EECA will be able to evaluate emission estimates of individual producers and compare these with international figures. They will also be able to compare tallow, used cooking oil and rapeseed biodiesel GHG emissions with fossil fuel diesel GHG emissions where similar boundaries can be identified.

## Introduction

### 1.1 Background

The Energy Efficiency and Conservation Authority (EECA) are required to publish voluntary sustainability guidelines and information for biofuels in New Zealand in accordance with the New Zealand Energy Efficiency and Conservation Strategy (EECA, 2007). A key factor in evaluating the sustainability of biofuels is the volume of greenhouse gas (GHG) emissions emitted during production.

GHG emissions occur throughout the different stages of biofuel production – including generation of raw materials (depending on the biofuel these may range from waste products such as tallow and used cooking oil through to rapeseed grown to extract oils), transport, distribution and manufacturing processes. The first step in calculating total biofuel production GHG emissions is, therefore, to define the “contributing activities” within different stages of production. Contributing activities are any processes which generate GHG emissions. Once the contributing activities are defined for each life cycle stage, emission factors are applied to calculate GHG emissions arising from these activities. This is referred to as a life cycle approach. Total GHG emissions are then expressed as a volume per volume of biodiesel product

EECA commissioned URS New Zealand (URS) to provide guidance and assistance in preparing a model to enable New Zealand biodiesel producers to calculate the life cycle GHG emissions of their products.

This report is the second of two reports prepared to document this project. The first report, “Data collection for life cycle greenhouse gas emission default values for New Zealand biodiesels” was produced in May 2009. It contains a review of the appropriate life cycle boundaries for calculating total GHG emissions from biodiesel production, as well as documentation of a data collection exercise completed by URS including the limitations encountered and an agreed way forward.

This second report provides the life cycle GHG inventory models prepared by URS including recommended default values (to describe different contributing activity levels if actual data is not available) and emission factors. The two reports are designed to be read together and this report refers to content in the first report throughout.

### 1.2 Project purpose

EECA’s objective for this project is to provide robust and comparable models to enable producers of tallow, used cooking oil and rapeseed biodiesel to calculate the GHG emissions of their products. The use of these models will help ensure consistency, accuracy and comparability across the industry.

The GHG emission models contain three key components;

- cells for entry of activity data (for example kWh of electricity used in the conversion process)
- emission factors to convert activity data to GHG emissions
- built-in equations to calculate GHG emissions within each stage of the biodiesel production process and to calculate the total GHG emissions per unit of product.

In order to increase comparability across the industry and to improve ease of use for the industry, for some production data variables the models provide default values for activity data. This is a fall back option if the producer is not able to provide specific data. The three models will be provided to the biodiesel industry for voluntary use.

## 1 Introduction

In addition to providing the model to producers to calculate their own GHG emissions per unit of product, URS have also used the available default activity level data in the model to calculate an overall “generic” GHG emission estimate for the production of each of tallow, used cooking oil and rapeseed biodiesel.

### 1.3 Report purpose

The purpose of this report is to describe the three GHG emission models including the following specific information:

- A detailed description of the models including how they were derived and their intended use
- The default values used in the model and justification for their use
- The emission factors used in the model and their source
- The calculated GHG emission estimates (using a mix of actual data and representative default activity values) for each of tallow, used cooking oil and rapeseed biodiesels
- The limitations that exist in the model
- URS’ recommendations for the use of the model and next steps to develop the model further.

The three models are provided on an accompanying CD.

## Life cycle GHG emission models

### 2.1 Boundaries

Life cycle boundaries were defined for each of the three feedstock streams: tallow, used cooking oil, and rapeseed. The boundaries define those activities included and excluded from the GHG emission calculations. A detailed discussion of the LCA boundaries defined for this project is found in Section 2 of the first report (URS, 2009).

For tallow and used cooking oil, GHG emissions associated with the production of the raw material inputs were not included in the boundary. For rapeseed, GHG emissions from raw material production were included in the boundary. As discussed in our boundary review exercise (please refer first report – URS, 2009), a technically defensible GHG emission result for biodiesel manufacture from tallow and used cooking oil would need to take full account of any material emissions arising from the production of the raw material. This approach would align with recently established more general life cycle analysis principles, for example those described in PAS 2050. For the purposes of this study, however, URS agreed with EECA that default values for GHG emissions associated with producing the tallow or used cooking oil feedstocks would not be included. This approach is aligned with the current UK guidance for calculating biodiesel GHG emissions (ORFA, 2009). As discussed later in this report, the inclusion of upstream life cycle stages for tallow and used cooking oil should be re-evaluated in subsequent updates of these models.

### 2.2 Data collection

EECA commissioned URS to collect data on 26 parameters to feed into the default values used in the model (refer Chapter 3). EECA initially commissioned URS to collect data and provide minimum, maximum and average values for each of the selected parameters. Due to the small number of biodiesel manufacturers operating in New Zealand and commercial sensitivity issues, URS were only able to obtain one or two data points for many of the parameters. URS, therefore, completed further assessment of each parameter and where required, estimated a representative default value based on data available and/or other published data.

Chapters 3 and 4 describe the process URS used to derive default values and emission factors for the models.

### 2.3 UK model review

URS used the emission models and data provided in the UK Office of the Renewable Fuels Agency report *Carbon and sustainability reporting within the renewable transport fuel obligation* (ORFA, 2009) in order to gain a better understanding of the overall emission calculations and the significance of individual sources to the overall GHG emission result. URS also analysed the UK emission model structures and used them as a basis for the New Zealand system models, subject to our agreed boundaries (refer 2.1 above). Through this process URS identified a range of additional emission factors and data points that had not previously been collected and subsequently added these to the New Zealand emission models.

To check the New Zealand emission models URS used UK input data and emission factors, resulting in similar emission figures as those reported in the ORFA (2009) report. URS then populated the three models with the respective default values and emissions factors identified above, reflecting the different production processes of each biodiesel stream.

## 2 Life cycle GHG emission models

### 2.4 New Zealand model

URS prepared the life cycle GHG emission models for rapeseed, used cooking oil and tallow (in accordance with agreed boundaries) in an excel spreadsheet format.

The worksheets in this excel file calculate the GHG emissions associated with each of the biodiesel production process steps. Each table outlines the main process steps to produce biodiesel and the activity data associated with these processes, e.g. fuel use, electricity consumption and material consumption related emissions. Each emission source worksheet provides a data entry table calculating the greenhouse gas emissions associated with each production step. The model has been set up for biodiesel manufacturers to

- Enter activity data – where this is available – in the non-coloured fields of the spreadsheet
- In cases where no activity data is available, use the default values provided.

Once the data is entered, the model will use emission factors to calculate total GHG emissions for production. These are then converted to “per unit of production” figures. All emission factor and calculation cells in the model are locked to avoid confusion and potential changes. Emissions estimated via the emissions model need to be treated with care and always need to be referenced to the boundaries used for the calculations to avoid potential misinterpretation of the results.

A copy of the used cooking oil emissions calculations spread sheet is attached in **Appendix A**. This is only to illustrate the general structure of the emissions model and the emissions calculations. The full models (including emission calculations formulas) are provided as Excel spreadsheets on an accompanying CD.

## Default activity level values

This chapter outlines the process URS used to develop the default activity level values for the biodiesel emission model calculations. An analysis of each model parameter was undertaken to identify parameters for which default values would provide a technically credible alternative to actual primary activity data. This analysis was undertaken in response to challenges identified during the data collection process and to maintain data confidentiality. This is discussed further in Section 4 of the first report (URS, 2009). The parameter analysis consisted of the following steps:

1. A review of the UK RFA model (ORFA, 2009) to identify the significance of individual data points, i.e. to identify which parameters have the greatest impact on the emission calculation output.
2. A review of activity data received from New Zealand biodiesel producers and comparison against UK RFA data to identify variability between individual data points, i.e. to identify which parameters show the greatest variability.
3. Development of a matrix mapping the significance and variability of each parameter.

The matrix allowed URS to provide a recommendation to EECA on whether a default value could be reliably used for that parameter. The matrix also outlined potential issues with regards to the default value generation and ways to overcome these.

**Table 3-1 to Table 3-3** below provide an overview of the parameter matrix for each of the three biodiesel feedstocks: tallow, used cooking oil, and rapeseed. Copies of the complete default value matrix including the default values identified and the data source are attached in **Appendix B**.

Default values were set at a representative level for New Zealand conditions (where possible) rather than at a conservative level. This approach was taken to encourage producers to be informed by the model and to use the model. Default values were set using actual data where sufficient data was available, or international data as detailed in **Appendix B**. Use of international data was cross-checked against New Zealand data to ensure that it was indeed representative. The representative default values should be regarded as a first step only. As manufacturers in the sector collect their own data, the defaults will need to be relied upon less. Once the spread of the activity level data is better understood, both sector users and EECA will be able to establish a better understanding of “conservative” through to “optimistic” activity level estimates. The use of conservative default activity levels in future versions of these models would create a greater incentive for producers to obtain their own data.

**Table 3-1 Tallow biodiesel default value matrix**

Parameter	Significance	Variability	Default	Comments
Proportion that tallow makes from the total output from meat processing	Unknown	some variability	No	Outside current emissions boundary.
Transportation distance from rendering plant to the biodiesel conversion plant	low significance	high variability	No	Default value not applicable. Producer activity data required.
Heat (type and amount)	high significance	some variability	Yes	Provided default value based on UK ORFA report.
Electricity use	significant	some variability	Yes	Provided default value based on UK ORFA report.

### 3 Default activity level values

Methanol	high significance	some variability	Yes	Provided default value based on UK ORFA report.
Potassium Hydroxide (Sodium Hydroxide)	low significance	some variability	Yes	Provided default value based on UK ORFA report
Plant yield	some significance	some variability	Yes	Provided default value based on UK ORFA report
Total amount of Glycerine produced	low significance	some variability	Yes	Provided default value based on UK ORFA report

**Table 3-2 Used cooking oil biodiesel default value matrix**

Parameter	Significance	Variability	Default	Comments
Transportation distance from the point of collection to the biodiesel plant	low significance	high variability	No	Default value not applicable. Producer activity data required
Heat (type and amount)	high significance	some variability	Yes	Provided default value based on UK ORFA report
Electricity use	significant	high variability	Yes	Provided default value based on UK ORFA report
Methanol	high significance	some variability	Yes	Provided default value based on URS survey results.
Potassium Hydroxide (Sodium Hydroxide)	low significance	low variability	Yes	Provided default value based on URS survey results
Plant yield	some significance	some variability	Yes	Provided default value based on UK ORFA report
Glycerine produced	low significance	some variability	Yes	Provided default value based on UK ORFA report.

**Table 3-3 Rapeseed biodiesel default value matrix**

Parameter	Significance	Variability	Default	Comments
Yield and destination of rape straw	low significance	unknown	No	Default value not applicable. Producer activity data required.
Yield of rapeseed	significant	unknown	Yes	Provided default value based on UK ORFA report.
Traded moisture content of rapeseed	no impact	no variability	No	Provided default value based on URS survey results.
Fertiliser - Nitrogen	most significant	unknown	Yes	Provided default value based on URS survey results.
Fertiliser - Phosphorus	low significance	some variability	Yes	Provided default value based on URS survey results.
Fertiliser Potassium	low significance	some variability	Yes	Provided default value based on URS survey results.
Fertiliser - Lime	some significance	high variability	Yes	Provided default value based on UK ORFA report.
Pesticides (type and application rate)	low significance	some variability	Yes	Provided default value based on UK ORFA report.

### 3 Default activity level values

Parameter	Significance	Variability	Default	Comments
Diesel consumption in cultivation and harvesting	low significance	high variability	No	Default value not applicable. Producer activity data required.
Transportation distance (km) of rapeseed crop from farm to drying and storage facility	low significance	high variability	No	Default value not applicable. Producer activity data required.
Transportation distance (km) of rapeseed crop from the drying and storage facility to the oil extraction facility	low significance	high variability	No	Did not provide default value due to lack of NZ data (i.e. not applicable to current NZ operating conditions).
Transportation distance (km) of rapeseed crop from the oil extraction facility to the biodiesel plant	low significance	high variability	No	Did not provide default value due to lack of NZ data (i.e. not applicable to current NZ operating conditions).
Fuel use for (heat) drying and storage of rapeseed crop	low significance	low variability	Yes	Provided default value based on UK ORFA report.
Electricity use drying & heating	low significance	low variability	yes	Provided default value based on UK ORFA report.
Grown rotationally	unknown	unknown	No	Did not provide default value as no direct impact on emission calculations.
Moisture removed	no impact	low variability	No	Did not provide default value as no direct impact on emission calculations
Oil extraction plant yield	significant	some variability	Yes	Provided default value based on UK ORFA report.
Heat (type and amount) for oil extraction	significant	some variability	Yes	Provided default value based on UK ORFA report.
Electricity use oil extraction	low significance	some variability	Yes	Default value not applicable. Producer activity data required.
Quantity of rape meal produced	unknown	unknown	No	Unable to provide default value as no New Zealand data provided. Producer activity data required.
Carbon intensity of animal feed being replaced by rape meal	unknown	unknown	No	Unable to provide default value as no New Zealand data provided. Producer activity data required.
Heat (type and amount) transesterification	significant	some variability	Yes	Provided default value based on UK ORFA report.
Electricity use transesterification	significant	unknown	Yes	Provided default value based on UK ORFA report.
Methanol	significant	some variability	Yes	Provided default value based on UK ORFA report.
Potassium Hydroxide (Sodium Hydroxide)	low significance	some variability	Yes	Provided default value based on UK ORFA report.
Biodiesel yield from rapeseed oil	significant	some variability	Yes	Provided default value based on UK ORFA report.
Total amount of Glycerine produced	low significance	some variability	Yes	Provided default value based on UK ORFA report.



## Emission factors

This chapter outlines the emission factors necessary to estimate the GHG emissions associated with individual production processes and raw material use (activity level data). Conversion factors are also used to calculate the market value of input products and energy content of fuel.

Emission factors are a type of conversion factor used to convert a unit of an activity (e.g. 1 litre of diesel) into a unit of greenhouse gas emissions (e.g. 1 kilogram carbon dioxide equivalent or kgCO<sub>2</sub>e). As part of the earlier stages of this project, URS undertook a desktop review of New Zealand and international emission factors outlined by EECA. Section 4.2.5 of the first report (URS, 2009) contains a more detailed description of the desktop review.

**Table 4-1** below contains the emission factors provided in the emission models. Where possible conservative emission factors were chosen, i.e. the end result has a bias towards overestimation of emissions rather than underestimation. Section 4.2.5 of the first report provides a justification of the choice of emission factors used.

**Table 4-1 Default emission factor table**

Parameter	Emission factor	Unit	Source
Diesel	0.0865	kg CO <sub>2</sub> e/MJ	Barber, 2008
Diesel	3.59	MJ/t-km	EECA, 2009
Diesel	3.11	kg CO <sub>2</sub> e/L	Barber, 2008 & MED, 2008
Petrol (regular)	0.0841	kg CO <sub>2</sub> e/MJ	Barber, 2008
Petrol (premium)	0.0831	kg CO <sub>2</sub> e/MJ	Barber, 2008
International shipping	0.0163	kgCO <sub>2</sub> /t-km	CE Delft, 2006 and DEFRA, 2008
Fertiliser - Nitrogen	3	kg CO <sub>2</sub> /kg N	Wells, 2001 p26
Fertiliser - Phosphorus	0.90	kg CO <sub>2</sub> /kg P	Wells, 2001. p27
Fertiliser Potassium	0.6	kg CO <sub>2</sub> /kg elemental K	Wells, 2001 p27
Fertiliser - Lime	0.4	kg CO <sub>2</sub> /kg lime	Wells, 2001, p29

Please note that the emission factor for international shipping has changed from the first report from 0.03176 kg CO<sub>2</sub>/t-km to 0.0163 kg CO<sub>2</sub>/t-km, due to an overestimate of the maximum/minimum emission for international shipping (small ships).

## 4 Emission factors

In addition to the emission factors provided in the previous report (URS, 2009) **Table 4-2** outlines a range of additional factors not previously identified that are also necessary for the emission calculations. A copy of the complete emission factor matrix, including comments, is provided in **Appendix C**.

**Table 4-2 Additional emission and conversion factors**

Parameter	Factor	Unit	Source
Nitrous oxide (soil emissions)	6.21	kg CO <sub>2</sub> e/kg N fertiliser applied	Kelliher & de Klein, 2006 cited in MfE, 2009
Pesticides	13	kg CO <sub>2</sub> /kg pesticide	Wells, 2009. p30
Electricity	0.0458	kg CO <sub>2</sub> e/MJ	Adapted from MfE, 2008
Coal	0.09681	kgCO <sub>2</sub> e/MJ	Barber et al, 2007
Carbon intensity of rape meal	-504	kgCO <sub>2</sub> e/tonne rape meal	ORFA, 2009
Market value of glycerine	897	£345 = \$NZ 897.00 assuming exchange rate of £1 = \$NZ 2.6	ORFA, 2009
Market value of sodium hydroxide	1.0	\$NZ/kg	URS survey
Market value of potassium hydroxide	3.5	\$NZ/kg	URS survey
Market value of biodiesel	884	£340 = \$NZ 884.00 assuming exchange rate of £1 = \$NZ 2.6	ORFA, 2009
Market value of potassium sulphate	195	£75 = \$NZ 195 assuming exchange rate of £1 = \$NZ 2.6	ORFA, 2009
Methanol	2.75	kgCO <sub>2</sub> e/kg	ORFA, 2009
Potassium hydroxide	2.43	kgCO <sub>2</sub> e/kg	ORFA, 2009
Sodium hydroxide		No value identified yet	

## Emission estimates for New Zealand biodiesels

URS populated the three emission models with the activity data gained from the industry survey (or the agreed default values) and then used the emission and conversion factors provided in Chapter 4 to calculate the GHG emissions for each production step (e.g. transport and biodiesel conversion). The emissions resulting from biodiesel production in New Zealand are outlined below.

**Table 5-1 GHG emissions associated with New Zealand rapeseed biodiesel production**

	[kg CO <sub>2</sub> e/t biodiesel]
Crop production	1,325
Drying and storage <sup>1</sup>	0
Emissions from rapeseed transport	84
Emissions from conversion (oil)	147
Emissions from rapeseed oil transport <sup>2</sup>	0
Emissions from conversion (biodiesel)	645
Emissions from biodiesel transport <sup>3</sup>	0
<b>Total Emissions</b>	<b>2,201</b>

The main emission sources from rapeseed biodiesel production are N<sub>2</sub>O emissions from soil, emissions associated with the production of nitrogen based fertiliser and lime, methanol use and energy input into biodiesel conversion.

<sup>1</sup> Emissions from drying are included in oil conversion stage, based on figures provided in CRL (2008) report.

<sup>2</sup> All biodiesel processes are currently undertaken at the same facility; therefore, no rapeseed oil is transported.

<sup>3</sup> Based on the survey information no biodiesel is transported to blending facilities at the time of writing.

## 5 Emission estimates for New Zealand biodiesels

**Table 5-2 GHG emissions associated with New Zealand tallow biodiesel production**

	[kg CO <sub>2</sub> e/t biodiesel]
Emissions from tallow transport	18
Emissions from conversion (biodiesel)	787
Emissions from biodiesel transport <sup>4</sup>	0
<b>Total Emissions</b>	<b>804</b>

Methanol use is the single largest emission source for tallow biodiesel production; however, these figures are based on pilot scale plant and will change once full scale plants are implemented.

**Table 5-3 GHG emissions associated with New Zealand used cooking oil biodiesel production**

	[kg CO <sub>2</sub> e/t biodiesel]
Emissions from used cooking oil transport	32
Emissions from conversion (biodiesel)	795
Emissions from biodiesel transport <sup>5</sup>	0
<b>Total Emissions</b>	<b>827</b>

The largest emission sources for used cooking oil are methanol use and energy input into the biodiesel conversion process.

The calculated GHG emissions for rapeseed-based biodiesel are significantly greater than those calculated for either tallow or used cooking oil based biodiesel. This is because emissions arising from crop production were included in the rapeseed result. By contrast emissions arising from the upstream production stages of tallow and used cooking oil were not included in the model calculations. The approach taken for this study reflected the approach previously adopted by ORFA 2009 – on the basis that both tallow and used cooking oil are “waste” products which would have been manufactured regardless of their use as a raw material for biodiesel. This approach is currently being widely discussed and the latest international guidance (BSI British Standards 2008 - *PAS 2050: How to assess the carbon footprint of goods and services*) requires all “processes used in the transformation of raw material” be included in a full life cycle boundary.

The boundaries for each of the three biodiesel products investigated through this study should be evaluated further in future updates of the GHG model.

<sup>4</sup> Ibid

<sup>5</sup> Ibid

## Model limitations

### 6.1 Emission model limitations

A Life Cycle Assessment (LCA) is a model of a physical system so it, therefore, contains a number of simplifications and assumptions. Furthermore, the physical system is dynamic; changing over both time and scale, so the model can quickly become unrepresentative. The limitations and uncertainties that exist with regard to this model are discussed below.

#### *Activity data limitations*

The biodiesel industry in New Zealand is small but evolving quickly. Data provided in an industry survey was limited due to both the small number of participants in the industry, concerns over the commercial sensitivity of the data, and the timeframes of the project. As a result, no statistical analysis of responses was possible because of the small sample size. New Zealand survey data was supplemented by data taken from New Zealand and international literature. In these cases, the most representative and most recent data was used. These should be updated with new information as it becomes available.

#### *Emission model limitations*

As indicated in this section, there are a variety of uncertainties associated with the emission models, the activity data and the emissions factors, all impacting on the uncertainty of the final result. As a rule of thumb it should be considered, that:

- the model will only be as good as the activity data that the producers provide
- any uncertainties that exist with activity data entered, plus the emission figures (see below) need to be clearly indicated when reporting on any resulting emissions
- the results need to be communicated together with the boundary used for the calculations.

### 6.2 Uncertainty in emission factors

The emission factors used in the model are derived from a number of different New Zealand and overseas sources. In some cases the emission factors will be very reliable (e.g. for CO<sub>2</sub>e emissions from New Zealand electricity production). In other cases the emission factors will be less reliable. We have discussed whether or not there is a way to analyse the uncertainty within the different emission factors to provide the users of the model with some understanding of the uncertainty in the final result. This would, however, be a difficult exercise, as in many cases the reported emission factors do not include sufficient accompanying information, in particular the assumptions used and the likely variability. The reported emission factor for methanol, for example, does not include information on the type and amount of energy consumed during the manufacturing process or the kilometres travelled/vehicle type and, therefore, fuel consumed for raw material collection and product distribution. In addition, it is not evident whether or not "embodied emissions" (for example emissions arising from manufacturing the raw materials used to make the methanol) are included in some of the reported emission factors.

## 6 Model limitations

To date, there has been very little scrutiny on the technical validity of different emission factors being used in life cycle studies - either in New Zealand or overseas. We anticipate that this situation will change in the future as the life cycle study results (environmental emissions per unit of product manufactured) have a greater influence on business outcomes such as access to markets and market share. In other words as the stakes become higher then the technical evaluation underpinning conclusions about the environmental credentials of different products will be more closely scrutinised. In the interim, this GHG inventory model includes a qualitative description of possible sources of uncertainty in the emission factors, as opposed to a more quantitative approach attempting to measure uncertainty/sources of variability underpinning each emission factor. Given the lack of available information, this qualitative approach will alert the model users to potential inadequacies in the result and will ensure that the model is credible and appropriately qualified.

A detailed discussion of the uncertainty in the model emission factors is found in Section 4.2.5 and Appendix E of the first report.

Emission factors provided in the emissions model should be updated at least annually to reflect changes in the emissions profile and to use more recent and more accurate emissions factors for the emissions calculations.

### 6.3 Comparability to UK model

The UK model was developed by ORFA to implement the Renewable Transport Fuels Obligation. The model was developed based on UK industry characteristics, including a high degree of imported biofuels or biofuel feedstocks. A collaborative approach was used, with the agency working with the industry to ensure that data collection and reporting requirements were both practical and robust. As UK producers become more familiar with the system, reporting requirements are likely to become more rigorous. New Zealand does not currently have mandatory emission reporting, however, a similar approach to the UK is applied here, and data collection requirements are designed to be practical.

Both the New Zealand and UK models use similar process boundaries (e.g. excluding upstream emissions from tallow and used cooking oil production) and emission estimates are, therefore, comparable (only like with like, e.g. tallow NZ with tallow UK).

### 6.4 New Zealand biodiesel estimate limitations

The following sections outline the limitations with regards to the emissions calculated for New Zealand biodiesel production processes (refer Chapter 7).

#### *Data values*

URS relied on the data provided by the industry survey and only used published data or overseas (UK ORFA) data to overcome data gaps. Where possible URS calculated a weighted average default figure for each data point based on the data provided, using the total amount of biodiesel produced by individual biodiesel producers.

## 6 Model limitations

### *Energy inputs into biodiesel conversion*

Most biodiesel production processes in New Zealand at the time of writing were still at a pilot plant scale. Changes to the total amount of energy required during the biodiesel production processes are expected once biodiesel producers implement full scale plants. For some of the producers this will reduce the energy required per tonne of biodiesel whereas for others it might increase the energy requirements, based on the design of their pilot plants (current energy inputs range from 255 MJ to over 12,000 MJ/t biodiesel produced).

Reductions in energy use are expected from efficiency gains using continuous biodiesel production, i.e. by reducing the start up energy requirements, energy recovery due to continuous production and economy of scale energy gains.

Energy increases are expected as a result of the introduction of additional production stages, such as glycerine refining to increase the value of the by-products as well as recovery processes for catalysts, alcohols and alkalis.

The wide range of energy inputs into the biodiesel conversion process also outlines the large amount of uncertainty attached to the activity data collected in the industry survey. Default values provided with the model should, therefore, only be used to overcome data gaps and as a guideline. Biodiesel producers need to provide actual production data for the emission estimates to become more accurate.

Some of the energy input data used for this study is based on national and international publications, rather than actual energy usage from biodiesel producers; actual production data should be used once it becomes available.

### *Sulphuric acid*

Overseas biodiesel production processes generally use sulphuric acid to neutralise the reaction process resulting in potassium sulphate as a by-product. However, some of the producers contacted in New Zealand are not using this technique and it is, therefore, not clear if other biodiesel producers will use this process in the future. If sulphuric acid is used during the production, then this needs to be added into the emissions calculations. Similarly, the generation of potassium or sodium sulphate as a by product would need to be considered for the emissions calculations.

### *Sodium hydroxide*

Sodium hydroxide is used by some New Zealand biodiesel producers as a catalyst instead of potassium hydroxide. URS could not obtain a publically available relevant emission factor for sodium hydroxide. Sodium hydroxide has the potential to be a material emission source, depending on its emissions intensity. It is unknown whether sodium hydroxide accounts for greater or fewer emissions than potassium hydroxide, as this would depend on the quantity of catalyst required, and their emission factor.

### *Glycerine*

It appears that, at the time of writing, none of the glycerine produced as a by-product of the biodiesel production is sold to other users. Several biodiesel producers have indicated that they are stockpiling the glycerine or are using it as a fuel source for the biodiesel conversion process. The model enables

## 6 Model limitations

entry of glycerine value if sales occur. If glycerine is used as a fuel source a glycerine emission factor should be added to the model.

### *Emission comparisons*

The emissions calculated by the emission models are based on the boundaries outlined in the previous report (URS, 2009). It is important that emission estimates are only compared with others that have been made using similar boundaries and process assumptions. Caution should be used for example, when comparing biodiesel made from rapeseed with biodiesel made from tallow, or conversely when comparing biodiesel with fossil diesel.

### *Assumptions*

The underlying assumptions made as part of the emission calculations are outlined below:

#### **Tallow Biodiesel**

- Tallow emission estimates are based on URS survey results from 1 source.
- Energy inputs are based on URS survey results, but are expected to increase as tallow producers currently do not use glycerol recovery and also do not have to melt tallow as they receive liquid tallow from the rendering plant.

#### **Used Cooking Oil**

- Used cooking oil estimates are based on URS survey results from 3 different sources.
- Energy inputs are expected to decrease due to continuous production and efficiency gains due to economy of scale.
- At least one producer is potentially going to use up to 20% of the glycerine produced as a heat source for biodiesel conversion process.
- One of the three producers uses sodium hydroxide instead of potassium hydroxide. URS was unable to identify an emissions factor for sodium hydroxide and have thus excluded this from the emissions calculations.

#### **Rapeseed Biodiesel**

- Rapeseed emission estimates are based on URS survey results from one producer and several data gaps had to be overcome by using nationally published data (e.g. CRL, 2008)
- The producer was in the first year of production; some data was not available at the time of writing and other data was not provided due to confidentiality concerns.

#### **General**

- Some UK data points were used for all three models to overcome data gaps, these are market values for glycerine, potassium sulphate and biodiesel
- Biodiesel is currently not blended into regular fuels on a large scale; therefore, no emissions from transporting fuel to blending facility were calculated.
- Emission figures are the same as provided in the template emission models and are based on New Zealand factors where possible and UK factors where required to overcome lack of New Zealand factors.

## Recommendations

This report outlines the development of the life cycle GHG emission models for the production of biodiesel, how the models work and the limitations that exist within the models and their data. EECA's objective for this project is to provide robust and comparable models to enable producers of tallow, used cooking oil and rapeseed biodiesel to calculate the life cycle greenhouse gas emissions of their products.

We have outlined below in Section 7.1 how we envisage the models can be used to achieve EECA's objective and in Section 7.2 how the models should be used to achieve this objective. Also, through the work completed to date we have identified areas for further improvement in the models going forward, these areas are outlined in Section 7.3.

### 7.1 What the models can currently deliver

Despite the limitations and areas of uncertainty discussed in this, and the first study report, the models provide a useful tool for both EECA and biodiesel manufacturers. Biodiesel manufacturers will be able to use the models to:

- Identify their most significant GHG emission sources (e.g. methanol use, fertiliser use and energy input into biodiesel conversion) and, therefore, be able to prioritise actions to reduce and manage those sources in the future
- Understand the activity data requirements for preparing a robust GHG emission result and investigate mechanisms for collecting activity data for parameters where default values were initially used
- Compare emissions from other biodiesel sources where the same boundaries are used (e.g. tallow with tallow or tallow with used cooking oil).

EECA will be able to use the models to:

- Evaluate the emission estimates of individual producers, based on their specific activity data
- Generally compare New Zealand biodiesel GHG emissions with international figures – with the proviso that a detailed comparison should only be made once more accurate New Zealand activity data becomes available (especially for rapeseed biodiesel)
- Generally compare tallow, used cooking oil and rapeseed biodiesel GHG emissions with fossil fuel diesel GHG emissions – with the proviso that boundary decisions would need to be checked to assess comparability (in particular whether or not emissions from activities upstream of the manufacturing stage are included or not included);

Overall, the models have been developed in a robust and defensible way and will enable EECA to estimate biodiesel emissions based on current and future data sources.

## 7 Recommendations

### 7.2 How the models should be used

- The biodiesel producers should use primary activity data wherever possible in the model and this requirement should be emphasised. Use of the default values will decrease the accuracy of the emission estimates. The limitations that are inherent in the default values are summarised in Chapter 6.
- We suggest that the emissions models are provided to the biodiesel producers with empty cells for activity data and that a look up table (e.g. current assumptions table) is provided for the producers to overcome data gaps. This should help discourage the use of default values except where absolutely necessary.
- The models provided are based on specific production boundaries agreed for each process. There are limitations and uncertainties that exist within the model. A reference to the boundary and to the limitations and uncertainties should be made alongside any statement or claim made in relation to the life cycle GHG emission of any biodiesel product using these models.
- The emission models should be provided to the biodiesel producers for primary activity data entry and returned to EECA for review. At that stage EECA could compare the specific values generated by each producer against the emission estimates provided in this report as a method of checking the likely accuracy of each figure generated and to continue to firm up their understanding of biodiesel production emissions in New Zealand.
- There may be some value in EECA assisting biodiesel producers with the data collection, data entry and use of the model to facilitate the data entry and to minimise data omissions.

Note that the life cycle GHG emissions estimated using this model do not comply with the PAS 2050: 2009 standard or the emerging ISO standard on carbon footprinting for products, primarily due to incomplete boundaries. For this reason considerable caution should be used prior to using the information generated by the models in the public arena. At the very least, the boundary plus all limitations and uncertainties should be made available and comparisons between different types of biodiesel should be avoided.

### 7.3 Recommendations for future updates

For future updates of these initial models, URS recommends that EECA:

- Regularly updates activity data default values and the GHG emission factors – at a minimum frequency of once every two years.
- Consider reviewing default values which have a high level of uncertainty attached to them, and those where the underlying activity levels are likely to change significantly in the future. This is especially the case for activities which are likely to be significant sources of emissions. Examples of values which fall into these categories are: methanol use (default value is partly based on studies rather than activity data); level of nitrogen fertiliser application (unknown level of variability); energy input into the biodiesel and rapeseed oil conversion stages (wide range of energy inputs provided); plant yield for rapeseed oil extraction (currently based on studies not on activity data); and finally the quantity of rapemeal produced and type of animal feed it replaces (currently no information available for New Zealand).
- Revises the boundaries to remain in line with international best practice as it evolves. For example revision of the boundaries for the tallow and used cooking oil emission models to include emissions

## 7 Recommendations

related to the generation of raw material, e.g. including farming emissions from animal farming or from collection of used oil.

- Includes changes in land use as a source of GHG emissions from the manufacture of the biodiesel. This can be included as a module for those producers wishing to comply with PAS 2050, and be consistent with the UK Renewable Fuels Agency (2008) guidelines. The omission of land use change emissions should be transparently documented.
- Consider (when larger volumes of biodiesel are produced) adding storage energy requirements to the transport sections.
- Consider adding a qualitative description of possible sources of uncertainty in the emission factors to alert the model users to potential inadequacies in the result and to help ensure that the model is credible and appropriately qualified.

The model is currently designed in a “static” way (Microsoft Excel). To facilitate the use of the model and to provide internet access, it might be useful to develop a web based model using drop down menus (e.g. for default values) and built in checks e.g. highlighting sections that have not been filled in and only letting a producer progress through the model if all relevant fields have been completed. Currently if data is omitted this is not shown in the emissions calculations.



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## Limitations

URS New Zealand Limited (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use by Energy Efficiency and Conservation Authority and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 07 April 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 07 April 2009 and 19 November 2009 and is based on the information review at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.



# Appendix A Emission model template



## Used Cooking Oil Biodiesel

### Introduction

The tables in this excel file calculate the greenhouse gas emissions associated with each of the biodiesel production process steps for used cooking oil biodiesel.

Each table outlines the main process steps to produce biodiesel and the activity data associated with these processes. These are for example: fuel use, electricity consumption and material consumption related emissions.

The used cooking oil biodiesel production steps have been separated into: used cooking oil transport, conversion (biodiesel) and biodiesel transport. Each emission source worksheet provides a data entry table calculating the greenhouse gas emissions associated with each production step.

The assumptions tab at the end outlines all the activity data provided, the assumptions made for the data points and the data source. The table also provides the relevant emission factors, assumptions made and data source for each emission factor.

### Instructions

To estimate the biodiesel production related emissions, please:

- 1) in each tab (except totals and assumptions) enter your own activity data in place of the default values (where possible) in each white cell.
- 2) where no activity data is available, please retain the default values provided which are automatically populated via the assumptions tab.
- 3) white fields containing 0 entries do not have default values and require specific activity data.

### NOTE

In general, all activity data necessary for the emissions calculations should be provided by biodiesel producers when estimating their production related emissions. Default values provided by URS should only be used when no actual data is available or as an indication for what the actual data values might be.

The data collection survey by URS indicated that several biodiesel producer use biodiesel as a heat source for the conversion stages. Biodiesel was assumed to have a 0 emission factor as part of the emissions calculations.

## Used Cooking Oil Biodiesel - Used Cooking Oil Transport

From used cooking oil collection to conversion plant

Data categories	Data points	Factors	Calculations
<b>Basic data</b>			
Total used cooking oil collected	[t] 0		
	or		
	[L]		Used cooking oil [t] 0
<b>Transport mode</b>	[% of used cooking oil transported by transport mode]		Total transported [t]
By truck	100%		0
By ship			0
<b>Transport distance</b>	[km]		[t-km]
Transport distance by truck	0		0
Transport distance by ship			0
<b>Fuel consumption</b>		[MJ/t-km]	[MJ]
Truck (diesel)		3.59	0.0
<b>Emissions</b>		[kgCO <sub>2</sub> e/MJ]	[kgCO <sub>2</sub> e]
Truck (diesel)		0.0865	0
Ship		[kgCO <sub>2</sub> e/t-km] 0.0163	0
<b>Totals</b>			[kg CO <sub>2</sub> e]
Total emissions			0
Contribution to fuel chain			[kg CO <sub>2</sub> e/t biodiesel] 0.00



## Used Cooking Oil Biodiesel - Biodiesel Transport

From biodiesel conversion plant to blending facility

Data categories	Data points	Factors	Calculations
<b>Basic data</b>			
Total biodiesel	[t] 0		
	or		
	[L] 0		Total biodiesel [t] 0
<b>Transport mode</b>	[% of biodiesel transported by transport mode]		Total transported [t]
By truck	100%		0
By ship	0%		0
<b>Transport distance</b>	[km]		[t-km]
Transport distance by truck	0		0
Transport distance by ship	0		0
<b>Fuel consumption</b>		[MJ/t-km]	[MJ]
Truck (diesel)		3.59	0.0
<b>Emissions</b>		[kgCO <sub>2</sub> e/MJ]	[kgCO <sub>2</sub> e]
Truck (diesel)		0.0865	0
Ship		[kgCO <sub>2</sub> e/t-km] 0.0163	0
<b>Totals</b>			[kg CO <sub>2</sub> e]
Total emissions			0
Contribution to fuel chain			[kg CO <sub>2</sub> e/t biodiesel] 0.0

## Used Cooking Oil Biodiesel - Totals

Emissions from used cooking oil transport	[kg CO <sub>2</sub> e/t biodiesel] 0.00
Emissions from conversion (biodiesel)	[kg CO <sub>2</sub> e/t biodiesel] 622.97
Emissions from biodiesel transport	[kg CO <sub>2</sub> e/t biodiesel] 0.00
<b>Total Emissions</b>	[kg CO <sub>2</sub> e/t biodiesel] 622.97

## Used Cooking Oil Biodiesel - Default Values, Emission Factors and Assumptions

Category	Unit	Quantity	Assumptions (document any assumptions made in calculating the quantity)	Data Source (where did you get the quantity data from)	Unit	Emission factor	Assumptions (document any assumptions made in calculating the emissions factor)	Data Source (where does the emissions factor come from)
<b>Transport</b>								
Total used cooking oil collected	[t]							
Transport distance by truck	[km]							
Transport distance by ship	[km]				[kgCO <sub>2</sub> e/t-km]	0.0163		Average of (CE Delft, 2006) and (UK DEFRA, 2008)
Truck (diesel)	[MJ/t-km]	3.59	NZ data for general truck freight	(EECA, 2009)	[kgCO <sub>2</sub> e/MJ]	0.0865		(Barber, 2008)
Ship	[MJ/t-km]				[kgCO <sub>2</sub> e/t-km]	0.0163		Average of (CE Delft, 2006) and (UK DEFRA, 2008)
<b>Conversion (Biodiesel)</b>								
Yield	[t biodiesel/t used cooking oil]	0.875		(ORFA, 2009)				
Electricity purchased	[MJ/t biodiesel]	335		(ORFA, 2009)	[kgCO <sub>2</sub> e/MJ]	0.0458		(MFE, 2008)
Biodiesel	[MJ/t biodiesel]				[kgCO <sub>2</sub> e/MJ]	0		
Diesel	[MJ/t biodiesel]				[kgCO <sub>2</sub> e/MJ]	0.0865		(Barber, 2008)
Steam	[MJ/t biodiesel]	1690	Based on UK data for energy input (natural gas)	(ORFA, 2009)	[kgCO <sub>2</sub> e/MJ]	0.0968	Assumes emission factor from burning coal	(Barber et al, 2007)
Methanol	[kg/t biodiesel]	162		URS survey	[kgCO <sub>2</sub> e/kg]	2.75	Based on UK emissions factor	(ORFA, 2009)
Potassium hydroxide	[kg/t biodiesel]	25.4		URS survey	[kgCO <sub>2</sub> e/kg]	2.43	Based on UK emissions factor	(ORFA, 2009)
Sodium hydroxide	[kg/t biodiesel]				[kgCO <sub>2</sub> e/kg]		No value identified yet	
Sulphuric acid	[kg/t biodiesel]				[kgCO <sub>2</sub> e/kg]		No value identified yet	
Glycerine	[t glycerine/t biodiesel]	0.1	Necessary for emission calculations	(ORFA, 2009)				
Potassium sulphate/t biodiesel	[t potassium sulphate/ t biodiesel]		Only generated as a by product when using sulphuric acid					
Market value Glycerine	[\$/t glycerine]	897	£345 = \$NZ 897 assuming exchange rate of £1 = \$NZ 2.6	(ORFA, 2009)				
Market value potassium sulphate	[\$/t potassium sulphate]	195	£75 = \$NZ 195 assuming exchange rate of £1 = \$NZ 2.6	(ORFA, 2009)				
Market value Biodiesel	[\$/t biodiesel]	884	£340 = \$NZ 884 assuming exchange rate of £1 = \$NZ 2.6	(ORFA, 2009)				
<b>Biodiesel Transport</b>								
Total biodiesel transported	[t]							
Transport distance by truck	[km]							
Transport distance by ship	[km]				[kgCO <sub>2</sub> e/t-km]	0.0163		Average of (CE Delft, 2006) and (UK DEFRA, 2008)
Truck (diesel)	[MJ/t-km]	3.59	NZ data for general truck freight	(EECA, 2009)	[kgCO <sub>2</sub> e/MJ]	0.0865		(Barber, 2008)
Ship	[MJ/t-km]				[kgCO <sub>2</sub> e/t-km]	0.0163		Average of (CE Delft, 2006) and (UK DEFRA, 2008)

## Appendix B Default value matrix



## EECA Life Cycle GHG Emission default values matrix

### Introduction

EECA have tasked URS to prepare an emissions calculation model that will provide EECA with a robust and comparable method of calculating GHG emissions from tallow, used cooking oil and rapeseed biodiesel production.

The aim of the following tables is to screen the EECA parameter list with regards to their significance to generating greenhouse gas emissions and the variability of the data collected. Based on this analysis we determined which data points require default values and which are more appropriate as individual entry, and for those that are default values, what our proposed next steps would be for creating the values. In addition, URS will also develop a range of emission factors to allow EECA or biodiesel producer to calculate the emissions associated with biodiesel production once more detailed data becomes available (using the emissions model currently developed by URS).

Please note:

Where only one data point exists, variability has been checked against the UK ORFA model.

Default values (e.g. amount of fertiliser used or km travelled) will be based on NZ data where more than 2 data points exist (this is to protect the confidentiality of the data provided by biodiesel producers). Where it is not possible to generate a NZ based default value (2 or less data points), URS aims to identify an appropriate international default value. We will compare these international default values with the data collected as part of the survey to ensure it is relevant to NZ conditions.

## EECA Life Cycle GHG Emission default values matrix

### Tallow biodiesel

The table below outlines the operational data from producing tallow based biodiesel. The default value column identifies if a default operational value will be provided for the emissions calculations model. For information on the emissions factors to be used for the emissions calculations please refer to the emission factor tab below.

Parameter	Data points	Unit	Significant	Variability	Default	Comments	Default value	Unit	Source	Comments
Proportion that tallow makes from the total output from meat processing	5 data points	%	unknown	some variability	No	Outside current emissions boundary.	n/a	%		Outside current emissions boundary.
Transportation distance (km) of tallow from the point of production (i.e. the rendering plant) to the biodiesel plant	2 data points	km	low significance	high variability	No	Default value not applicable, producer activity data required	n/a	km		Provide emission factor to allow producers to calculate their own emissions.
Heat (type, and amount )	1 data point	MJ	very significant	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the energy use. Alternatively, also provide emission factors for energy inputs to allow producers to calculate their own emissions.	1690	MJ Natural gas/t biodiesel	ORFA, 2009	Default same for Denmark, UK and USA
Electricity use	1 data points	kWh	significant	some variability	Yes	Provide emission factor to allow producers to calculate their own emissions.	345	kWh	ORFA, 2009	Default same for Denmark, UK and USA
Methanol	1 data point	kg/t biodiesel	high significance	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the methanol use.	113	kg/t biodiesel	ORFA, 2009	Default same for Denmark, UK and USA
Potassium hydroxide (Sodium hydroxide)	1 data point	kg/t biodiesel	low significance	some variability	Yes	Also provide emissions factor to allow producers to calculate their own emissions.	26	kg/t biodiesel	ORFA, 2009	Potassium hydroxide Default same for Denmark, UK and USA
Plant yield	1 data point	n/a	some significance	some variability	Yes		0.875	t biodiesel/t UCO or tallow	ORFA, 2009	Default same for Denmark, UK and USA
Total amount of Glycerine produced	1 data point	kg/t biodiesel	low significance	some variability	yes	Allows allocation of some emissions to a secondary product	0.1	kg/t biodiesel	ORFA, 2009	Default same for Denmark, UK and USA

## EECA Life Cycle GHG Emission default values matrix

### Used cooking oil biodiesel

The table below outlines the operational data from producing used cooking oil based biodiesel. The default value column identifies if a default operational value will be provided for the emissions calculations model. For information on the emissions factors to be used for the emissions calculations please refer to the emission factor tab below.

Parameter	Data points	Unit	Significant	Variability	Default	Comments	Default value	Unit	Source	Comments
Transportation distance (km) of used cooking oil from the point of collection to the biodiesel plant	3 data points	km	low significance	high variability	No	Provide emission factor to allow producers to calculate their own emissions.	n/a			
Heat (type, and amount )	3 data point	MJ	high significance	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the energy use. Alternatively, also provide emission factors for energy inputs to allow producers to calculate their own emissions.	1690	MJ Natural gas/t biodiesel	ORFA, 2009	
Electricity use	3 data points	kWh	significant	high variability	yes	Provide emission factor to allow producers to calculate their own emissions.	345	kWh	ORFA, 2009	ORFA provide only one default option
Methanol	3 data point	kg/t biodiesel	high significance	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the methanol use.	162	kg/t biodiesel	URS survey	average across three biodiesel producer
Potassium hydroxide (Sodium hydroxide)	3 data point	kg/t biodiesel	low significance	low variability	Yes	Also provide emissions factor to allow producers to calculate their own emissions.	18.8	kg/t biodiesel	URS survey	average across three biodiesel producer
Plant yield	2 data point	n/a	some significance	some variability	Yes		0.875	t biodiesel/t used cooking oil	ORFA, 2009	
Total amount of Glycerine produced	2 data point	kg/t biodiesel	low significance	some variability	Yes	Allows allocation of some emissions to a secondary product	0.1	kg/t biodiesel	ORFA, 2009	Default same for Denmark, UK and USA

## EECA Life Cycle GHG Emission default values matrix

### Rapeseed oil biodiesel

The table below outlines the operational data from producing rapeseed based biodiesel. The default value column identifies if a default operational value will be provided for the emissions calculations model. For information on the emissions factors to be used for the emissions calculations please refer to the emission factor tab below.

Parameter	Data points	Unit	Significant	Variability	Default	Comments	Default value	Unit	Source	Comments
Yield and destination of rape straw	0 data points	n/a	low significance	unknown	No	Not currently a commercial product. Producer activity data required	n/a			No direct impact on emissions.
Yield of rapeseed	1 data point	(t/ha-a)	significant	unknown	Yes		3.00	t/ha-a	ORFA, 2009	Used UK figure, Range - Lowest yield: Ukraine, highest yield: Germany. At traded moisture content 9%. Consistent with NZ figures from Johnson & Gallacher (2008) and Andrwe & Forgie (2008).
Traded moisture content of rapeseed	1 data point	%	no impact	no variability	No	Provides an indication of the applicability of drying default activity data.	n/a			No direct impact on emissions.
Fertiliser - nitrogen	1 data point	kg N / ha-a	most significant	unknown	Yes	Also provide emissions factor to allow producers to calculate their own emissions. Soil related emissions are potentially the largest emission source so accuracy is important.	150.00	kgN/ha-a	Ravensdown, 2009	Pers.comm Ravensdown. NZ estimate for Mackenzie Country, with reasonable existing soil fertility (e.g. pH5.8-6.2, Olsen P 20-30, Sulphate 10-15, Quick Test K 6≤). These estimates are broadly consistent with application rates in URS survey and with other published NZ sources, and are at the higher end of default application rates in the ORFA report.
Fertiliser - phosphorous	1 data points	kg P / ha-a	low significance	some variability	Yes	Also provide emissions factor to allow producers to calculate their own emissions.	30.00	kgP <sub>2</sub> O <sub>5</sub> /ha-a		
Fertiliser - potassium	1 data points	kg K / ha-a	low significance	some variability	Yes		30	kgK <sub>2</sub> O/ha-a		
Fertiliser - lime	1 data points	kg CaO / ha a	some significance	high variability	Yes		271	kgCaO/ha-a	ORFA, 2009	NZ can be significantly higher, e.g. application rates for pasture in Wells vary from 0kg/ha to 1,900kg/ha, but no other relevant application rates could be identified.
Pesticides (type and application rate)	1 data point	kg Pesticide / ha-a	low significance	some variability	Yes		0.28	kg/ha-a	ORFA, 2009	NZ can be significantly higher, but no other generic application rate could be identified
Diesel consumption in cultivation and harvesting	1 data point	L/ha-a	low significance	high variability	No	Provide emission factor to allow producers to calculate their own emissions.	n/a			

**Rapeseed oil biodiesel**

Transportation distance (km) of rapeseed crop from farm to drying and storage facility	1 data point	km	low significance	high variability	No		n/a			Provide emission factor to allow producers to calculate their own emissions
Transportation distance (km) of rapeseed crop from the drying and storage facility to the oil extraction facility	1 data point	km	low significance	low variability	No		n/a			Provide emission factor to allow producers to calculate their own emissions
Transportation distance (km) of rapeseed crop from the oil extraction facility to the biodiesel plant	1 data point	km	low significance	low variability	No		n/a			Provide emission factor to allow producers to calculate their own emissions
Fuel use for (heat) drying and storage of rapeseed crop	1 data point	MJ	low significance	low variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the energy use. Also provide emissions factor to allow producers to calculate their own emissions.	318.00	MJ/ tonne OSR	ORFA, 2009	For all default countries except Australia where 0 MJ/tonne.
Electricity use drying & heating	0 data points	kWh	low significance	low variability	yes	Provide emission factor to allow producers to calculate their own emissions.	35.00	MJ/t rapeseed	ORFA, 2009	For all default countries except Australia where 0 MJ/tonne
Grown rotationally	1 data point	n/a	unknown	unknown	No	Provides an indication of the applicability of drying default activity data.	n/a			No direct impact on emissions.
Moisture removed	1 data point	%	no impact	low variability	No		n/a			
Oil extraction plant yield	1 data point	t rapeseed oil/t rapeseed	significant	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the plant yield.	0.43	t rapeseed oil/t OSR	ORFA, 2009	Same for all default countries
Heat (type, amount) oil extraction	1 data point	MJ	significant	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the energy use. Also provide emissions factor to allow producers to calculate their own emissions.	1986	MJ natural gas/t rapeseed oil	ORFA, 2009	Same for all default countries
Electricity use oil extraction	1 data points	kWh	low significance	some variability	Yes	Provide emission factor to allow producers to calculate their own emissions.	337.00	MJ/t biodiesel	ORFA, 2009	Same for all default countries
Quantity of rape meal produced	0 data points	t	unknown	unknown	No	Need to follow up with producer to understand significance and potential emission credits.	1.32	t rape meal /t rapeseed	ORFA, 2009	Same for all default countries (substitutes US soy meal with soybeans crushed in EU)
Carbon intensity of animal feed being replaced by rape meal	0 data points	t CO <sub>2</sub> /t animal feed replaced	unknown	unknown	No	So far it is seems that no animal feed is being replaced by rape meal. Need to follow up with producer to understand what happens to rape meal produced.	-504	kgCO <sub>2</sub> e/t rape meal	ORFA, 2009	Same for all default countries (substitutes US soy meal with soybeans crushed in EU)

**Rapeseed oil biodiesel**

Heat (type, amount) transesterification	1 data points	MJ	significant	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the energy use. Also provide emission factors for energy inputs to allow producers to calculate their own emissions.	1690.00	MJ/t biodiesel	ORFA, 2009	
Electricity use transesterification	0 data points	kWh	significant	unknown	Yes	Provide emission factor to allow producers to calculate their own emissions.	335.00	MJ/t biodiesel	ORFA, 2009	Same for all default countries
Methanol	1 data point	kg/t biodiesel	significant	some variability	Yes	Need to follow up with Biodiesel sector to get a better understanding of the methanol use.	113	kg/t biodiesel	ORFA, 2009	
Potassium hydroxide (Sodium hydroxide)	1 data point	kg/t biodiesel	low significance	some variability	Yes	Also provide emission factor to allow producers to calculate their own emissions.	26	kg/t biodiesel	ORFA, 2009	
Biodiesel plant yield	1 data point	n/a	significant	some variability	Yes		0.95	t biodiesel/t used cooking oil	ORFA, 2009	
Total amount of Glycerine produced	1 data point	kg/t biodiesel	low significance	some variability	Yes	Allows allocation of some emissions to a secondary product	0.1	kg/t biodiesel	ORFA, 2009	Default same for Denmark, UK and USA

# Appendix C Emission factor matrix



## EECA Life Cycle GHG Emission factors matrix

The table below outlines the emissions factors to be used for the emissions calculations. For

Parameter	Default emission factor	Emission factor	Unit	Source	Comments
Diesel	Yes	0.08650	kg CO <sub>2</sub> e/MJ	Barber, 2008	Conservative emission factor. Life cycle approach including emissions from foreign extraction, NZ refineries and domestic transportation. Energy values provided do not indicate if gross or net calorific values have been used.
Diesel	Yes	3.59	MJ/t-km	EECA, 2009	UK Model uses MJ/t-km conversion factor to estimate fuel based emissions. For comparability URS has also used this figure but has modified it to EECA estimates for NZ. This figure is approximately twice as intense as ORFA default values.
Diesel	Yes	3.11	kg CO <sub>2</sub> e/L	Barber, 2008 & MED, 2008	Used Barber, 2008 Diesel emissions factor (0.0865 kg CO <sub>2</sub> e/MJ) and MED 2008 calorific value for Diesel (35.95 MJ/L) 0.0865 * 35.95 = 3.11 kg CO <sub>2</sub> e/L
Petrol (regular)	Yes	0.08405	kg CO <sub>2</sub> e/MJ	Barber, 2008	Conservative emission factor. Life cycle approach including emissions from foreign extraction, NZ refineries and domestic transportation (primary and secondary energy). Energy values provided do not indicate if gross or net calorific values have been used.
Petrol (premium)	Yes	0.08313	kg CO <sub>2</sub> e/MJ	Barber, 2008	Conservative emission factor. Life cycle approach including emissions from foreign extraction, NZ refineries and domestic transportation (primary and secondary energy). Energy values provided do not indicate if gross or net calorific values have been used.
International shipping	Yes	0.01634	kgCO <sub>2</sub> /t-km	CE Delft, 2006 and DEFRA, 2008	Used average of the CE Delft and the UK DEFRA figures for small tankers Conservative emission factor. 1 nautical mile = 1.85200 kilometres. Chemical Tanker, average GT 20,311, based on sample of 49 ships in class. Study seems to indicate an almost linear relationship between the average index value and average ship size for ships carrying dry or liquid bulk cargos (Chemical tanker, Crude oil tanker and Dry bulk). However in general, variations in index performance within a ship category is significant and dependent on ship size.
Coal	Yes	0.09681	kgCO <sub>2</sub> e/MJ	Barber et al, 2007	Conservative life cycle emission factor for sub-bituminous coal combusted in an industrial boiler. Includes an allowance for upstream emissions.
Fertiliser - nitrogen	Yes	3	kg CO <sub>2</sub> /kg N	Wells, 2001 p26	Emissions embodied in fertiliser only ( i.e. energy required to manufacture material). Does not include emissions from use (i.e. N <sub>2</sub> O emissions from soils). Assumes that fertiliser type is urea
		65	MJ/kg	Wells, 2001 p27	Nitrogen (N)
N emissions from soil	Yes	6.21	kgCO <sub>2</sub> e/kg N fertiliser	MfE, 2009	The EECA RFP specifically asked for the fertiliser emissions factor to EXCLUDE nitrogen emissions from soil. However, from the UK ORFA report it became obvious that nitrogen emissions from soils are a significant emissions source. URS decided that a emissions factor was necessary to complete the emissions calculations. Emission factor taken from Kelliher FM, de Klein CAM. 2006. Review of New Zealand's fertiliser nitrous oxide emission factor (EF1) data. A Report for the Ministry for the Environment (April 2006): New Zealand cited in MfE, 2009 New Zealand GHG Inventory, 1990 - 2007. Nitrogen emissions from soils are a significant greenhouse gas source. Emission factor is obtained from the New Zealand national inventory as reported to the UNFCCC. It includes both direct (1%) and indirect (0.01% volatilisation and 0.02% leaching) emissions. Conversion of N <sub>2</sub> O-N emissions to N <sub>2</sub> O emissions for reporting purposes is performed by using the following equation: N <sub>2</sub> O = N <sub>2</sub> O-N • 44/28. N <sub>2</sub> O is considered to have a GWP of 310 in accordance with the NZ annual national greenhouse gas report.
Fertiliser - phosphorus	Yes	15	MJ/kg	Wells, 2001. p27	Phosphorus (P)
		0.90	kg CO <sub>2</sub> /kg P	Wells, 2001. p27	Phosphorus (P). Assume reactive rock phosphate (RPR)
Fertiliser - potassium	Yes	10	MJ/kg	Wells, 2001 p27	Potassium (K)
		0.6	kg CO <sub>2</sub> /kg elemental K	Wells, 2001 p27	
Fertiliser - lime	Yes	0.6	MJ/kg	Wells, 2001	Lime
		0.4	kg CO <sub>2</sub> /kg lime	Wells, 2001, p29	Assumes limestone of 90 percent purity
Pesticides	Yes	13	kg CO <sub>2</sub> /kg active ingredient (ai)	Wells, 2009. p30	For all agri-chemicals the carbon dioxide emission factor was taken to be 0.06 kgCO <sub>2</sub> /MJ assuming that all energy used in production, packaging and distribution is derived from fossil fuels. This is the default factor for "Other chemicals" which assumes energy requirement of 220MJ/kg.ai. and 50% concentration
		17.3	kgCO <sub>2</sub> e/kg active subs	ORFA, 2009	
Electricity	Yes	0.04583	kg CO <sub>2</sub> e/MJ	MfE, 2007	
Carbon intensity or rape meal	Yes	-504	kgCO <sub>2</sub> e/tonne rape meal	ORFA, 2009	
Market value of glycerine	Yes		\$NZ		Based on survey
Market value of sodium hydroxide	Yes	1.0	\$NZ/kg		Based on survey
Market value of potassium hydroxide	Yes	3.5	\$NZ/kg		Based on survey
Market value of biodiesel	Yes	1.3	\$NZ/L		Based on survey



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