Greenhouse Gas Balances for the German Biofuels Quota Legislation

Methodological Guidance and Default Values

Prepared for the

Federal Environment Agency Germany

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Content

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1 Background of the GHG calculations

1.1 Legal background

On the 1st of January 2007 the law of a mandatory biofuel quota (Biokraftstoff-quotengesetz) became effective in Germany. It requires from mineral oil companies that an increasing share of fuels on a biomass basis has to be admixed to gasoline and diesel or sold as genuine biofuel as such.

This law follows the EU Directive 2003/30/EG from the year 2003 for the use of biofuels. The Directive strives for using a share of 5.75 percent of biofuels compared to the total fuel use.

The German legislation requires that from 2007 on at least 4.4 percent of Diesel has to be of biomass origin. For gasoline a biofuel share of 1.2 % is required in 2007. The regulation for gasoline foresees an increase of the admixture for 2008 of 2 %, for 2009 of 2.8 % and finally of 3.6 % from 2010 on.

Despite these specific shares for gasoline and diesel a quota for biofuel for the total of all fuels sold in Germany has to be fulfilled in the following way:

- 6.25 % in 2009
- 6.75 % in 2010
- 7.0 % in 2011
- 7.25 % in 2012
- 7.5 % in 2013
- 7.75 % in 2014
- 8.0 % from 2015 on

The quota will be counted at an energy level. The federal government is authorised to introduce a multiplication factor for the quota depending on the GHG savings of the different biofuels.

Furthermore the government may introduce requirements concerning

- the sustainable cultivation of agricultural land
- the protection of natural habitats
- a minimal level of CO_2 savings for the biofuels

Details shall be established in the Biomass Sustainability Ordinance (Biomasse-Nachhaltigkeitsverordnung) under the Biofuel Quota Law. It shall include the evidence of a proper execution of the requirements and its monitoring.

For this purpose the methodological guidance for accounting the greenhouse gases laid down in this document.

1.2 Application of the GHG balance

One of the main objectives of the Biofuel Quota Law is the reduction of the emission of greenhouse gases. Therefore the legal framework enables the Government to establish two types of requirements concerning the GHG balance:

- a minimum value of GHG savings for biofuels
- a multiplication factor for the GHG savings for the different types of biofuels for their contribution to the total quota

Both applications need a fixed and comprehensible value for greenhouse gas savings. Ranges cannot be applied.

Greenhouse gas savings are calculated on the basis of greenhouse gas balances (GHG balances) figuring out the emission of all greenhouse gases to produce and use a biofuel and the emission of all greenhouse gases to produce and use the equivalent energy amount of the respective fossil fuel.

The emission of greenhouse gases shall be calculated in the unit:

kg CO_2 equivalent / GJ of fuel.

The value of **30 % saving** (**40 %** from 2011) compared to the substituted fossil based reference system is defined to be the minimum requirement for a “significant reduction”.

The Biofuel quota act authorises the government to introduce a multiplication factor for accounting different biofuels to the quota based on their GHG savings.

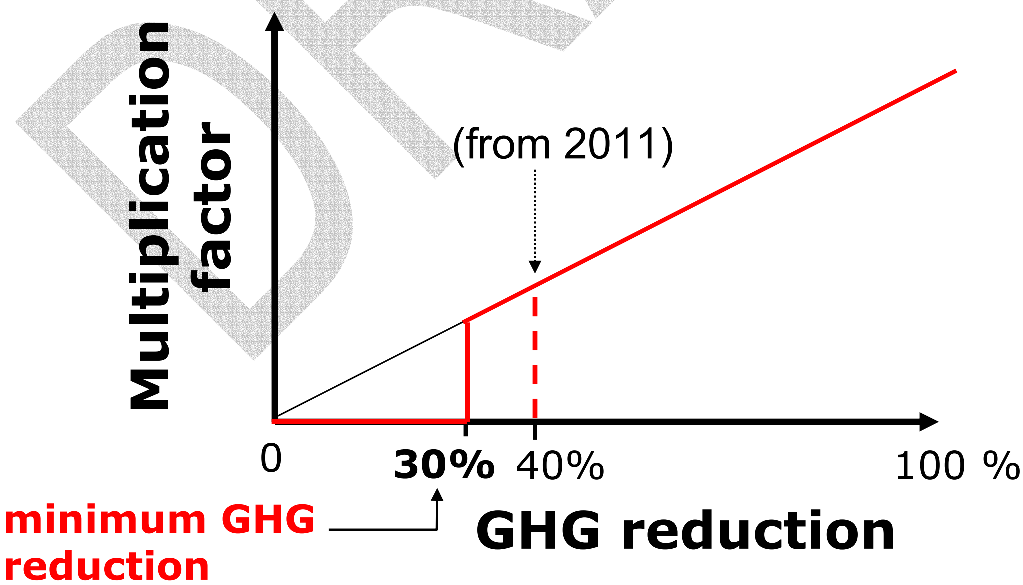


Figure 1 Scheme showing the relation between GHG reduction and multiplication factor

The methodology described here is designed specifically for the purpose of the regulation to the Biofuel Quota Law respectively the Biomass Sustainability Ordinance. Other objectives may require other approaches.

1.3 Implementation strategy and default values

A differentiation has to be made for using default values and using singular case values. For the fossil reference system only default values shall used. Default values will be given in this document. They have to be applied if no certified singular case values are available.

The default values for the biomass systems are based on **conservative** but **realistic** cases for biofuels used in Germany. They reflect the situation closest in time to their implementation based on the availability of information.

The default values should be updated on a regular basis (e.g. every 2 years). The update can be positive or negative according to the real development.

Default values shall be available for different steps of the biofuel production system and a sufficiently comprehensive set of types of biofuels (given in section 4.3, see Table 2 and Table 3).

As long as no procedures for the certification of singular cases are in place only the default values shall be applied. The procedure for deriving values for singular cases must include at least the following items: way of application, quality control, third party review, monitoring, etc..

A singular case can encompass the entire production chain from biomass production to admixture or can be only for a specific production step of the biofuel production chain where the default values for the other production steps are maintained.

1.4 General principles

In cases of disagreement with methodological procedures a competent administrative institution (to be fixed) will exist. Complaints can be made before this competent institution.

In case of doubt the specifications of the Kyoto Protocol are valid. For any greenhouse gas balance regarding the Biofuel Quota Law only the greenhouse gases as mentioned in the Kyoto protocol are relevant. The CO_2 equivalents will be derived using the conversion factors laid down in the Kyoto Protocol. They listed in Table 1.

Table 1 Greenhouse gases and conversion factors according to the Kyoto Protocol considered within this method.

Greenhouse gas	Conversion factor
Carbon dioxide (CO_2)	1
Methane (CH_4) fossil [a)]	21
non fossil [b)]	18.25
Nitrous oxide (N_2O)	310

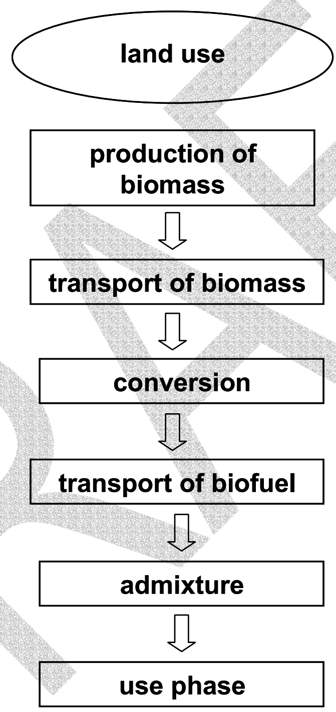
a) includes the impact of CO_2 after CH_4 has been oxidized in the atmosphere
b) does not include the impact of CO_2 after CH_4 has been oxidized

2 Biofuel and fossil fuel reference system

The emission of the greenhouse gases (see Table 1) has to be accounted for any process of the biofuel system and added for all processes and for all greenhouse gases according to their radiative forcing potential.

2.1 The Biofuel system

The biofuel system encompasses the production of the biomass, all conversion processes, waste treatment, any transportation of goods and the use of the biofuels. The production of ancillary material is included. Also all downstream processes like effluent and waste treatment is included. The production of capital goods and infrastructure is excluded.



A cut-off criteria for including the production of ancillary material in the system shall be limited to 1 % of the total mass input of the system step (as detailed above). If there is knowledge about GHG intensive production of such cut-off material it shall be included in a consistent way.

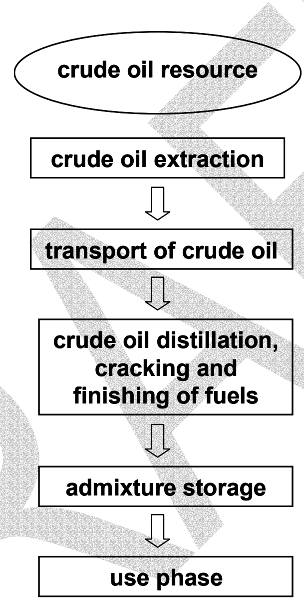
The point of balancing is the point of admixture which has to be reported to the authorities. The reference is the energy equivalent of the biofuel to the fossil fuel at the admixture storage tank.

For reasons of simplification the handling of the fuel from the point of admixture to the final use is treated equally. Differences caused by different ratios of energy content to mass (relevant for transport processes) and similar effects are neglected. Additives are disregarded.

The use phase is included with the assumption that all carbon is released as carbon dioxide. In the case of biofuel the CO_2 emissions are accounted for with the value "zero" if the biofuel is 100% from biomass. If this is not the case a corresponding calculation has to be applied.

2.2 Fossil fuel reference system

The fossil fuel reference system encompasses the extraction of crude oil, the transportation to the refinery, all refinery processes to produce gasoline and diesel and the use of the fuels. The production of ancillary material is included. Also all downstream processes like effluent and waste treatment is included. The production of capital goods and infrastructure is excluded as well. A cut-off criterion is considered analogously to the biofuel system.



The point of balancing is the point of admixture which has to be reported to the authorities. The reference is the energy equivalent of the fossil fuel at the admixture storage tank. For reasons of simplification the handling of the fuel from the point of admixture to the final use is treated equally. Differences caused by different ratios of energy content to mass (relevant for transport processes) and similar effects are neglected. Additives are disregarded.

The use phase is included with the assumption that all carbon is released as carbon dioxide.

Future developments like exploitation of more effort consuming mineral oil resources (e.g. tar sands) or an increasing use of natural gas as fossil fuel has to be observed and potentially included.

Note: Specific GHG calculations for fossil systems are not performed at this stage. As concretized in chapter 4.1 data from JRC/Eucar/Concawe (2006) are preliminary laid down to facilitate accordance in terms of data at a European scope.

3 Specific requirements

3.1 GHG accounting for direct land use

Biofuel systems interact directly with the land they are cultivated on. This interaction has two implications:

- On the one hand the type of land use is connected with storage of carbon in the soil and above ground. (carbon storage aspect)
- On the other hand the type of land use change may also result in constant emissions of greenhouse gases like methane and nitrous oxides (N_2O) which is not covered by the C-balance. (permanent emission aspect)

The direct land use and respective land use change (direct LULUC) has to be taken into account for the biofuel GHG balance.

For the carbon storage aspect a carbon account of all carbon above and below ground has to be taken into consideration. The difference of the system before and after the change to the biofuel system has to be calculated. The difference whether it is positive or negative has to be attributed to the biomass and as a consequence to the biofuel.

The effect shall be distributed over a time span of **20 years**.

It is difficult to obtain reliable information on carbon storage above and below ground. Therefore values IPCC 2006 GHG Reporting Guidelines (vol. 4) values shall be applied if no specific information is available (see section 4.4). If permanent emissions of methane and nitrous oxides have changed considerably caused by the land use change (e.g. wetland) it has to be taken into account.

Taking the date of enforcement of the Biofuel Quota Act into account a direct land use change shall be recognized as such if the change is not happened after the 1st of January 2005.

The direct land use and land use change can be regarded for singular cases. An entry into the default value matrix is set on a country/regional specific level (see section 4.4).

Note: This methodology is only related to GHG balances. Other aspects e.g. the biodiversity connected to LULUC have to be treated separately.

3.2 Modelling of agricultural systems

Modelling agricultural systems for GHG accounting is not always straightforward because of widely varying parameters and complex system interactions. Therefore some conventions are needed.

Agricultural systems are often composed of various cultivations and shifts of cultivations. For simplicity reasons the cultivation of biofuels shall be cut out of the total period of the agricultural system with varying cultivations. But interactions with the shifting cultivations (e.g. fertilizer interactions) shall be taken into account.

Biomass left on the agricultural land or brought back to the land has to be taken into account for balancing the fertilizer demand or carbon storage calculations. (direct biomass loop)

Secondary biomass (e.g. straw, leaves, etc.) being used for non-energy purposes and brought back to the agricultural land has to be taken into account for balancing the fertilizer demand or carbon storage calculations. This shall be done even if it is not the original land (indirect biomass loop).

N-fixation for subsequent cultivations (e.g. legumes like soy plants) and N-release from previous cultivations have to be taken into account. Therefore an N-balance has to be calculated which serves as the basis for the mineral fertilizer demand. This interaction with cultivation shifts shall be considered.

Manure is not considered as a co-product of another system (e.g. meat production, milk production). It is modelled from the moment of its generation until its end use on the land.

All agricultural activities shall be modelled as they occur in reality. This includes machine work, pesticide application, fertilizer application, biomass burning, etc.

3.3 Co-product allocation

Many processes in the biofuel systems have one or more co-products. All inputs and outputs shall be **allocated** to the co-products by their share of the **lower heating value** (= net calorific value).

The lower heating value has been chosen to minimize the arbitrariness for the objective of the Biofuel Quota Law because it provides a clear and measurable figure to be used as a rule for allocation.

The lower heating value as an energy figure is appropriate for allocation in this context because the Biofuel Quota Law is about the substitution of fossil energy. Therefore all energy uses of co-products but also the material use of co-products (e.g. animal feed, etc.) can be analysed according to their energy content. A consistent table of lower heating values shall be used (see further below in Table 15).

Biomass which stays on the land or is returned to it (directly or indirectly) is not treated as co-product but modelled in a closed loop. Cross compliance demands for the carbon content of the soil has to be taken into account. Biomass with no use or no defined use is treated as it stayed on the agricultural land.

3.4 Biofuels from waste material

Biobased waste material is a source for biofuels which is included in the application of the Biofuel Quota Act. Such materials enter the GHG balancing system without up-chain emissions and input. Only the point of handing over the waste from its original system to the biofuel system – the system boundaries – must be clearly defined.

Biobased waste material must be declared explicitly as waste. This is the case if the waste material is defined as waste according to national and international legislation and being reported under waste reporting requirements, etc. If biobased material does not fulfil these requirements the biomass has to be considered as co-product of another system and will be charged with GHG emissions from the other system according to given allocation rules.

The production of a biofuel from the waste material might compete with other recycling or recovery options. These options shall be analyzed and possible misguided developments in the waste management regime be avoided. Such an assessment can be based on a LCA in waste management.

4 Default values

4.1 Reference system

As noted at the end of section 2.2 the GHG emissions for the fossil reference system are adopted from JRC/EUCAR/Concawe (2006). They add up to:

- 86.2 kg CO_2-eg. per GJ of diesel
  (adding together: crude oil extraction: 3.3; transport 0.8; refinery: 8.6; use: 73.5)

- 85 kg CO_2-eq. per GJ of gasoline
  (adding together: crude oil extraction: 3.3; transport 0.8; refinery: 6.5; use: 74.4)

4.2 Conservative character of the default values

The default values are used as references for greenhouse gases within the framework of the Sustainability Directive for the Biofuel Quota Act, in as far as the manufacturer of a biofuel does not present any greenhouse gas balance for his product. For this reason, the default values are derived on a **conservative** basis and represent a comparatively unfavourable case for each system. The intention is to give the biofuel manufacturer an incentive to achieve a better practice.

Conservatism is not an absolute quantifiable stipulation/regulation/measure. It can be pronounced on various levels in quite varying manners. In the definition used here, it does not necessarily describe the worst possible case. If numerous input data is available, the determination was made according to the principle illustrated in Figure 2. If only little input data is available, then generally the most unfavourable value was chosen. It must be noted that only single values were available for many processes and thus this value was taken.

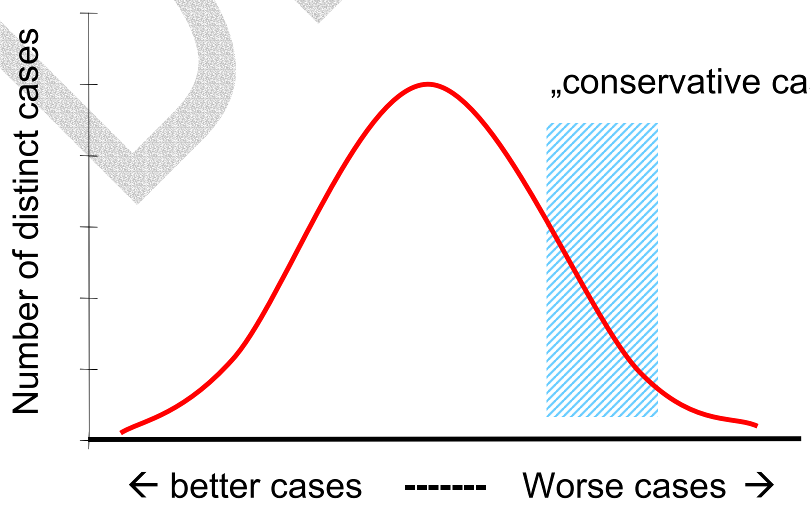


Figure 2 Definition range for “conservative cases” with extensive data basis

It cannot be ruled out that in reality individual cases may occur that could correspond to a more unfavourable situation than the default value for the corresponding scenario. In Section 4.4 to 4.7 when exemplifying the calculation processes and input data, attention is invited to the question as to whether and to which extent the calculations were conservative.

4.3 Selection of biofuel systems

The articles selected correspond to the global standards, i.e. the systems most relevant for the German biofuel market. These are listed below:

- **Ethanol:**
  1. from wheat through fermentation and distillation,
     origin of biomass and production in Europe
  2. from maize through fermentation and distillation, origin of biomass and production in North America
  3. from sugarcane through sugar extraction, production in Latin America
  4. from sugar beet through sugar extraction, production in Europe
- **fatty acid methyl ester (FAME):**
  1. from rapeseed through pressing, extraction and transesterification,
     origin of biomass and production in Europe
  2. from soybeans through pressing, extraction and transesterification,
     origin of biomass and production of oil in Latin America, transesterification in Germany
  3. from soybeans like above but origin of biomass and production of oil in North America, transesterification again in Germany
  4. from palm oil through pressing, extraction and transesterification,
     origin of biomass and production of oil in Southeast Asia, transesterification in Germany
- **straight vegetable oils** (rape seed oil, soybean oil and palm oil[1]):
- **hydrogenated vegetable oils** (rape seed oil, soybean oil and palm oil)

[1] Straight palm oil (respectively crude palm oil, CPO) is not appropriate for biofuel (Biodiesel) use. Its consideration within this selection is exemplary purposes informational intents.

Table 2 Set of proposed default values for examples of bioethanol and FAME; all figures given in kg CO_2-equivalents per Gigajoule.

Biofuel	**Ethanol**				**Biodiesel (FAME)**			
Biomass	**Wheat**	**Maize** (corn)	**Sugarcane**	**Sugar beet**	**Rapeseed**	**Soybean**		**Palm oil**
origin **step of production chain**	Europe	North America	Latin America	Europe	Europe	Latin America	North America	Southeast Asia
direct land use change	*26.2* [a)]	*19.8* [a)]	*158.8* [a)]	*15.6* [a)]	*32.8* [a)]	*289.6* [a)]	*54.5* [a)]	*112.8* [a)]
production of biomass	22.3	17.8	19.5	11.3	29.1	12.9	15.2	6.6
transport of biomass	0.7	0.7	1.5	1.7	0.4	0.5	0.5	0.1
conversion step I	-	-	0.8	6.6	7.6	7.3	9.2	6.90
transport between conversion steps	-	-	-	-	0.2	3.8	3.4	4.3
conversion step II	34.3	25.0	1.0	48.9	7.6	7.7	7.7	7.7
transport to fuel storage for admixture	0.4	4.8	5.5	0.4	0.3	0.3	0.3	0.3
Total without LUC	**57.7**	**48.2**	**28.3**	**68.8**	**45.3**	**32.4**	**36.3**	**25.9**
Total with direct LUC	*83.9* [a)]	*68.0* [a)]	*187.1* [a)]	*84.4* [a)]	*78.1* [a)]	*322* [a)]	*90.7* [a)]	*138.7* [a)]

a) worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

Table 3 Set of proposed default values for examples of straight and hydrogenated vegetable oils; all figures given in kg CO_2-equivalents per Gigajoule.

Biofuel / Biomass / origin — step of production chain	straight vegetable oil: rapeseed oil Europe	straight vegetable oil: soybean oil Latin America	straight vegetable oil: soybean oil North America	straight vegetable oil: palm oil Southeast Asia	Hydrogenated vegetable oil: rapeseed oil Europe	Hydrogenated vegetable oil: soybean oil Latin America	Hydrogenated vegetable oil: soybean oil North America	Hydrogenated vegetable oil: palm oil Southeast Asia
direct land use change	*34.2*[a)]	*298.8*[a)]	*56.2*[a]	*117.4*[a)]	*33.2*[a]	*293.4*[a]	*55.2*[a]	*114.3*[a]
production of biomass	30.4	13.1	15.5	6.9	29.5	13.0	15.4	6.7
transport of biomass	0.5	0.6	0.6	0.1	0.4	0.8	0.5	0.1
conversion step **I**	7.6	6.9	9.0	7.4	7.3	6.8	8.6	7.2
transport between conversion steps	-	-	-	-	0.2	3.8	3.5	4.3
conversion step **II**	-	-	-	-	9.7	9.7	9.7	9.7
transport to fuel storage for admixture	0.2	3.9	3.5	4.4	0.7	0.7	0.7	0.7
Total without LUC	**38.6**	**24.5**	**28.5**	**18.8**	**47.9**	**34.8**	**38.3**	**28.7**
Total with direct LUC	***72.8***[a)]	***323.3***[a)]	***84.7***[a]	***136.2***[a)]	***81.1***[a)]	***328.2***[a)]	***93.5***[a]	***143.1***[a)]

a) worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

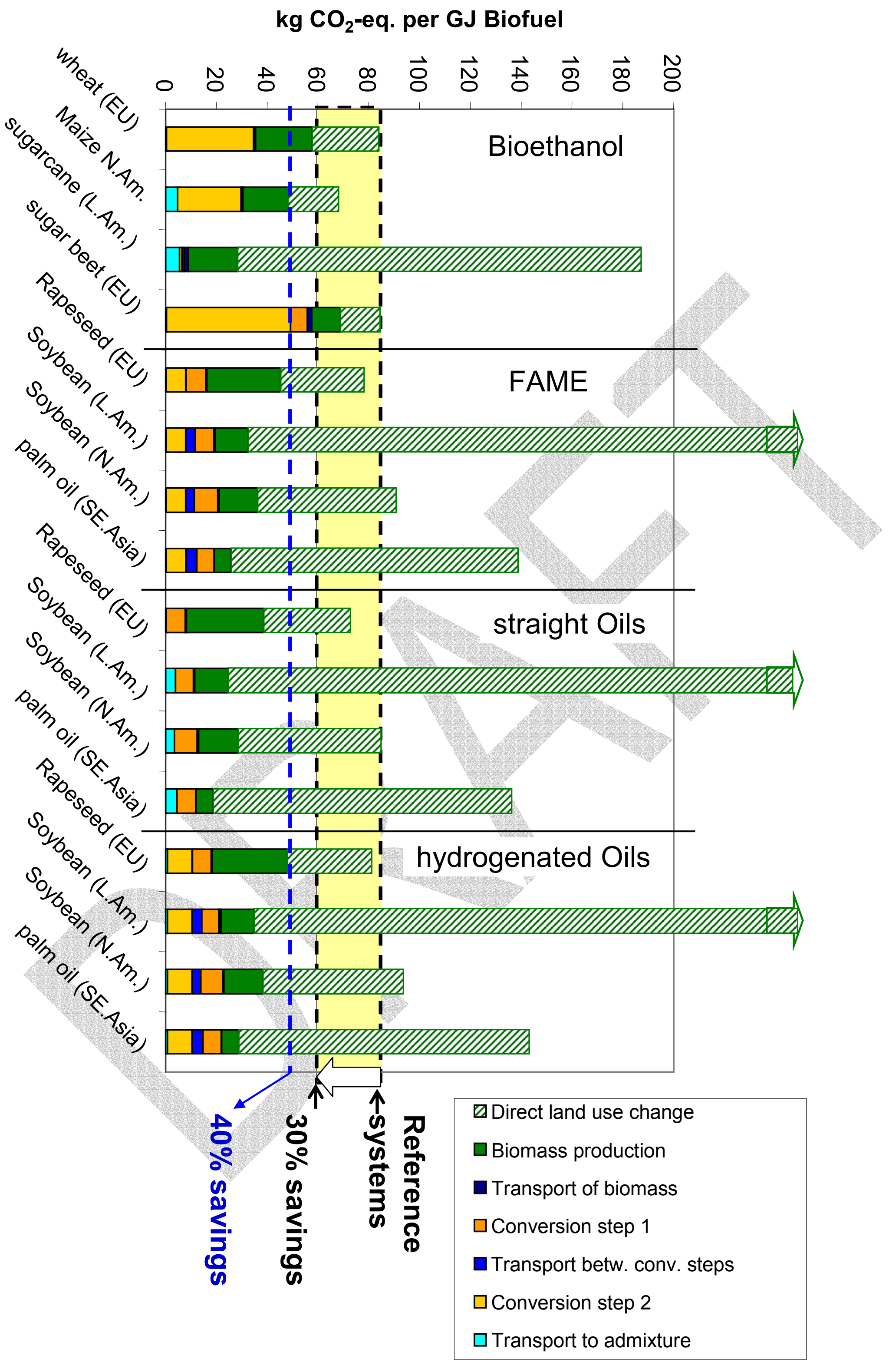


Figure 3 The proposed default values for the selected examples as measured by the reference systems and the minimum value of 30 % saving.

4.4 Default values for direct land use change effects

Data basis for the calculation method/model used here mainly by the method suggested by the Intergovernmental Panel on Climate Change (IPCC) [1] This is partially supplemented in the case of palm oil by research done by IFEU (2007)[2]

For following selection of biofuels the default values were determined on the assumption of the following changes in land usage:

a) **Ethanol from wheat, Europe**
In the year 2007, the available area of set-aside fallow land or similar areas was considerably reduced. Contrarily, a tendency to convert grasslands into croplands can be observed.[3] This is why a change of land from **grassland to cropland** was chosen as a conservative basis case.

b) **Ethanol from maize, North America**
In the year 2007, the maize production in North America was considerably increased, which can be accounted for by the increase in biofuel production. Currently there are various shifts to be observed between croplands (e.g. a current decrease of soybean production). Since an increase in crops for oilseeds is probable based on market development for the short term, a change from grasslands to croplands is also to be expected here. This is why a change of land from **grassland to cropland** was chosen as a conservative basis case.

c) **Ethanol from sugarcane, Latin America**
The expansion of sugarcane crops remains, particularly in Brazil. This inevitably also includes unspoiled nature. Mainly affected are humid tropical and sub-tropical climatic zones with grass and scrubs (grasslands, scrubwood, savannahs, hardwood forests). Thus a land use change from **humid subtropic savannahs with high carbon content to croplands** is assumed as a conservative basis.
In certain cases tropical rainforests and wetlands are also affected. In order to change these areas, sustainability is ruled out due to further criteria. Thus these cases are not included in the calculation of default values.[4]

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1 IPCC Guidelines for National Greenhouse Gas Inventories, 2006, Tables 4.3, 4.4, 4.7, 6.4: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm
IPCC's calculation tool for carbon storage in soil: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/annex4a1.htm

2 Wuppertal Institut, IFEU, FUER: Social-ecological evaluation of the stationary energetic use of imported biofuel materials for the example of palm oil, commissioned by the BMU, 2007.

3 IE: Monitoring for the effect of the amended Erneuerbare-Energien-Gesetzes (EEG = Sustainable Energy Law) on the development of power generation from biomass, a study commissioned by the BMU, 2007.

4 Basic literature on these subjects, among others:
de Almeida, E.F. et al., (2007): The performance of Brazilian biofuels; an economic, environmental and social analysis; CEMT/OCDE/JTRC/TR(2007)
Guerreiro, A. (2006). *The technological dimension of biofuels*. EPE/Ministry of Mines and Energy. Powerpoint presentation at the Seminar *Expert Meeting on Participation of Developing Countries in New Dynamic Sectors of World Trade: Review of the Energy Sector Adjusting to the New Energy Economy.* Geneva, UNCTAD.

d) **Ethanol from sugar beet, Europe**
Here the same process is used as for wheat. Thus a land use change from **grasslands to croplands** is assumed as a conservative basis.

e) **FAME from rapeseed, Europe**
Again the process is used as for wheat. Thus a land use change from **grasslands to croplands** is assumed as a conservative basis.

f) **FAME from soybeans, Latin America:**
Soy beans are raised in all five greater regions in Brazil, as well as in Argentina and Paraguay. In certain cases Brazilian regions with tropical rainforest are also affected. In more frequent cases, climatic zones as we listed above for sugarcane are affected.[5]

g) **FAME from soybeans, North America:**
Next to Brazil the USA are the biggest producer of soy beans. Analogously to maize a change of land from **grassland to cropland** was chosen as a conservative basis case.

h) **FAME made from palm oil, Southeast Asia:**
It is inevitable that unspoiled natural areas will be affected by the expansion of palm oil crops in this greater area (especially Indonesia). Even if the change of tropical rainforests and wetlands can be exempted due to further criteria for sustainability, it has to be assumed that this case in Southeast Asia describes the standard situation (in contrast to the case described above for soybeans). Until a functioning certification system comes into effect, the conservative basis case is thus a land use change from **tropical rainforest to plantation crops** is assumed.

The default values for land use change given in Table 4 were determined on the basis of the IPCC information and calculation models.

Supplementary to the values listed in Table 4 for the carbon content of various systems, values for further systems in which individual cases can be used alternately are listed in Table 5.

[5] Basic literature on these subjects, among others:
de Almeida, E.F. et al., (2007*The performance of Brazilian biofuels; an economic, environmental and social analysis*; CEMT/OCDE/JTRC/TR(2007)
Morton, D. et al. (2007), Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. PNAS Early Edition. www.amazonia.org.br

Table 4 Determining the default values for land use change for seven cases of generating biofuels. Source: IPCC 2006

		wheat Europe	**Maize / corn North America**	**Sugar cane trop. Latin America**	**Sugar beet Europe**	**rapeseed Europe**	**soybean trop. Latin America**	**soybean North America**	**Palm oil South East Asia**
previous use		**grassland**	**grassland**	**Savannah**	**grassland**	**grassland**	**savannah**	**grassland**	**trop. rain forest**
Change of C-storage									
biomass total	**t C/ha**	**70**	**70**	**134.0**	**70**	**70**	**134.0**	**70**	**265**
above ground	t C/ha	6.3	6.3	66.0	6.3	6.3	66.0	6.3	165
below ground	t C/ha			21.0			21.0		40
Soil	t C/ha	63.0	63.0	47.0	63.0	63.0	47.0	63.0	60
Use		**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**plantation**
biomass total	**t C/ha**	**55**	**55**	**55**	**55**	**55**	**53**	**55**	**110**
above + below ground	t C/ha	5	5	7.5	5	5	5	5	50
Soil	t C/ha	50	50	47.5	50	50	48	50	60
Changement [a]	**t C/ha**	**-15**	**-15**	**-79**	**-15**	**-15**	**-81**	**-15**	**-155**
time span	a	20	20	20	20	20	20	20	20
	t C/(ha*a)	0.75	0.75	3.95	0.75	0.75	4.05	0.75	7.75
Result (emission) t CO_2 /(ha*a)		**2.75**	**2.75**	**14.5**	**2.75**	**2.75**	**14.8**	**2.75**	**28.4**
required area									
not allocated	ha/GJ	0.0174	0.0131	0.0121	0.0089	0.0200	0.0607	0.0632	0.0079
Allocated	ha/GJ	0.0095	0.0072	0.0107	0.0057	0.0107	0.0168	0.019	0.0038
emission referring to biofuel									
not allocated	**kg CO_2-**	**47.8**	**36.1**	**175.5**	**24.5**	**54.9**	**901.1**	**173.8**	**223.9**
allocated	**eq./GJ**	26.2	19.8	154.7	15.6	32.8	282.4	54.5	106.6

a) negative values are given in case of a loss of carbon storage

b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

Table 5 Basic data concerning carbon stock in diverse natural areas and land use types; source: IPCC 2006

previous use		**C storage total**	biomass above ground	biomass below ground	Soil organic carbon
Grassland moderate zone	**t C/ha**	**70**	6.3		63
Savannah Latin America (high carbon content)	t C/ha	**134**	66	21	47
Trop. secondary forest	t C/ha	**165** [a)]	65	45	60
Trop. rainforest SE Asia (mineral soil)	t C/ha	**265**	165	40	60
Trop. rainforest SE Asia (wetland)	t C/ha	1,400 [a,b)]	165	40	1,200 [a,b)]
Degraded land SE Asia	t C/ha	40 [a,c)]	10		30

supplementary sources:
- a) Wuppertal-Inst., IFEU, FUER (2007)
- b) Hoijer, A. et al. (2006)
- c) Lasco, R.D. et al (2002)

The land use change is linked to slash-and-burn in some cases. This is assumed for cases in the savannah and secondary woodland. The emissions of N_2O and CH_4 occurring in such cases are calculated according to IPCC and included. The contributions to the default values are listed in Table 6. Table 7 combines the carbon stock changes and the slash-and-burn emissions.

Table 6 Calculation of default values for emissions from the slash-and-burn due to land use change; Source: IPCC 2006, UNFCCC 2007

		sugar cane Latin America	**soybean Latin America**	**Palm oil SE Asia**
previous use		**savannah**	**savannah**	**trop. rainforest**
Biomass total [a)]	**t C/ha**	**134**	**134**	**265**
biomass above ground	t C/ha	66	66	165
Emission factor für burning [b)]				
Methane (CH_4)	t/t biomass	0.0023	0.0023	0.0068
Laughing gas (N_2O)	t/t biomass	0.00021	0.00021	0.0002
emission per area [c)]				
Methane (CH_4)	t /ha	0.161	0.161	1.194
	t CO_2-eq./ha	2.9	2.9	21.8
Laughing gas (N_2O)	t /ha	0.015	0.015	0.035
	t CO_2-eq./ha	4.6	4.6	10.9
time span	Years	20	20	20
emission referring to biofuel				
not allocated	kg CO_2-eq./GJ	**4.56**	**22.8**	**12.87**
allocated [d)]	kg CO_2-eq./GJ	4.02	7.1	6.13

- a) conversion factor biomasse to carbon: 0,47; according to IPCC Guidelines 2006, Volume 4, Chapter 4, Table 4.3; see Table 5 this report
- b) data from IPCC Guidelines 2006, Volume 4, Chapter 2, Table 2.5;
- c) 50% taken into account
- d) allocation according to heeting value along the complete production chain

Table 7 The combination of carbon stock changes and the slash-and-burn emissions

kg CO_2-eq./GJ	Wheat Europe	Maize North America	Sugarcane trop. Latin America	Sugar beet Europe	Rapeseed Europe	Soybean trop. Latin Am.	Soybean North America	Palm oil South East Asia
emission from carbon stock changes								
not allocated	**47.8**	**36.1**	**175.5**	**24.5**	**54.9**	**901.1**	**173.8**	**223.9**
allocated [a)]	26.2	19.8	154.7	15.6	32.8	282.4	54.5	106.6
slash-and-burn emissions								
not allocated	-	-	4.56	-	-	22.8	-	12.87
allocated [a)]	-	-	4.02	-	-	7.1	-	6.13
Sum								
not allocated	**47.8**	**36.1**	**180.1**	**24.5**	**54.9**	**923.9**	**173.8**	**236.7**
allocated [a)]	26.2	19.8	158.8	15.6	32.8	289.6	54.5	112.8

a) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

4.5 Default values for production of biomass

In this section of production the emissions of the agricultural processes are calculated. The emissions are divided into the following categories,

- emissions that come from the agricultural area (particularly N_2O from fertilizer),
- emissions that are caused by agricultural machinery (diesel fuels, including the pre-chain),
- emissions that are caused by the production of agricultural auxiliary aids (fertilizer, pesticides).

From case to case the cost of irrigation (here in the case of maize from the U.S.A.) and the drying of the crops (grain, soybeans) were included.

The input data for the calculation of default values are listed in Table 8.

There is no allocation added for co-products straw and other harvest residue in the basic case, as there is no use for these materials that would nearly be comparable to the energy content (in ratio to the crops) – e.g. stable litter. The materials remaining on the field are accounted to the stabilization of the organic content of the soil. For the proven case of an energetic (or comparable) use of these materials, an allocation can be applied.

The soy plant provides the soil with an excess of nitrate. It is allocated with the initial fertilization (5 kg/(ha*a), see Table 8) and allowed for as a byproduct. The direct application of the concept of the lower heating value is not applicable here, yet the energy value of the production of N-fertilizer (49 MJ/kg N) may alternatively be applied.

For the input of N fertilizer into the soil, laughing gas emissions are also calculated (N_2O). The value of 1% N_2O-N of the N-fertilizer is assumed according to IPCC [2006]. According to Macedo (2004)[1] methane emission factors for sugarcane crops are applied.

The origin of the data is listed in Table 9 again. The applied data are divided into categories under the aspect of conservatism.

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[1] Macedo, Isaias *at al.* (2004), *Greenhouse Gas Emissions in the production and use of ethanol in Brazil*: present situation (2002). Secretaria de Meio-Ambiente do Estado de São Paulo.

Table 8 Calculation of default values for production of biomass

		Wheat Europe	Maize North America	Sugarcane trop. Latin America	Sugar beet Europe	Rapeseed Europe	Soybean trop. Latin Am.	Soybean North America	Palm oil South East Asia
core biomass		grains	grains	cane	beets	rapeseeds	soy beans	soy beans	oil fruits
Yield	t/(ha*a)	7.31	8.77	68.7	56	3.5	2.5	2.4	10.5
co-products		straw	straw	harvest residues	harvest residues	straw	Legum.-N [a)]	Legum.-N [a)]	Empty fruit benches
allocation applied		no	no	no	no	no	yes	yes	no
emission from land									
N_2O	kg/(ha*a)	2.25	2.1	2.02	2.04	2.67	1.18	1.18	1.375
CH_4	kg/(ha*a)	0	0	19.7	0	0	0	0	0
Diesel consumption	kg/(ha*a)	48.9	81.5	56.4	90.8	54.7	48.9	48.9	167
fertilizer consumption									
N	kg/(ha*a)	143	132	58.3	130	170	5	4	87.5
P_2O_5	kg/(ha*a)	58.5	70	36.7	56	63	10	11.9	10.5
K_2O	kg/(ha*a)	43.9	44	100	95	35	20	22	131.3
CaO	kg/(ha*a)	7.3	11	367	27	22.2	0	275	26.2
Pesticides	kg/(ha*a)	4.5	3.0	2	2.1	1.23	1.25	1.25	1.23
Irrigation		no	for 25%	no	no	no	no	nein	no
Diesel	kg/(ha*a)		10						
Drying									
Electricity	kWh/kg grains	0.011	0.011	-	-	0.0117	0.0072	0.0072	-
fuel oil	MJ/kg grains	0.4	0.4	-	-	0.4	0.17	0.17	-

Table 8 Calculation of default values for production of biomass (continued)

		Wheat Europe	Maize North America	Sugarcane trop. Latin America	Sugar beet Europe	Rapeseed Europe	Soybean trop. Latin Am.	Soybean North America	Palm oil South East Asia
Emission									
Field	kg CO_2-eq. /(ha*a)	698	643	986	633	828	366	366	426
Diesel use		186	310	215	346	208	186	186	636
fertilizer prod.		1,038	981	601	990	1,219	58	58	681
PSM-prod.		56	37.11	25	26	15	15	15	15
Diesel irrigation			38						
electricity drying		51	82	0	0	26	5	15	0
fuel oil drying		314	376	0	0	150	46	44	0
SUM		**2,342**	**2,468**	**1,826**	**1,995**	**2,447**	**676**	**763**	**1,759**
Emission by biofuel									
not allocated	kg CO_2-eq./GJ	**40.7**	**32.4**	**22.1**	**17.8**	**48.8**	**41.0**	**48.2**	**13.9**
Allocated	kg CO_2-eq./GJ	**22.3**	**17.8**	**19.5**	**11.3**	**29.1**	**12.9**	**15.1**	**6.6**

a) Nitrogen produced during soybean growing and accumultaed in the soil (70 kg/ha) is considered to be a co-product and allocated by the energetic value of N fertilizer (49 MJ/kg N).

b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

Table 9 Origin of data on biomass production and categorization of the conservatism when producing biomass

		Data source	Category of conservatism
Crops and co-products		Calculations by IFEU, basis of various LCAs	Median value, no conservatism
Field emissions	N_2O	IPCC (2006)	International standard value, based on newer studies possibly highly underestimated
	CH_4	for sugarcane Macedo (2004)	single literature value, no conservatism
Diesel consumption		Calculations by IFEU, basis of various LCAs	Median value, no conservatism
Fertilizer consumption		Calculations by IFEU, basis of various LCAs	Upper value range (approach analogue to Figure 2)
Pesticides		Calculations by IFEU, basis of various LCAs	Upper value range (approach analogue to Figure 2)
Energy for irrigation		Calculations by IFEU, basis of various LCAs	Median value, no conservatism
Energy for drying		Calculations by IFEU, basis of various LCAs	Median value, no conservatism

4.6 Default values for conversion processes

In this section of production the emissions of the conversion processes are calculated. Depending on the system, the processes are summarized into one to two steps and are defined for the calculation of default values as follows:

a) **Ethanol from wheat, Europe**
The individual steps of the process such as grinding, fermentation, distillation of the ethanol and drying of the distiller's wash are summarized into one complete step (see Conversion step 2 in Table 11).
The electricity/power and process heat needed are supplied by a combined heat and power plant (CHP) fired by lignite.
In addition to the main product ethanol, DDGS is produced.

b) **Ethanol from maize, North America**
The modelling of the process steps is analogue to ethanol from wheat. The power needed is drawn from the general power network (in this case USA), process heat is provided by facilities fired with natural gas and fuel oil (50 % each). In addition to the main product ethanol, DDGS is produced.

c) **Ethanol from sugarcane, Latin America**
Conversion step 1:
This includes the processes up the production of molasses (45% saccharose), these are: Extraction of the sugarcane juice and its thickening, as well as pressing the co-product bagasse.
The electricity/power and process heat needed are supplied by a combined heat and power plant (CHP) using bagasse.
Part of the bagasse is used for supplying energy to the 2nd conversion step. For the excess, no utilization is assumed for the basic case. For the proven case of a complete energetic utilization of bagasse (export of power from the network), an allocation can be applied.
Conversion step 2:
It includes the processes of fermentation and distillation of the ethanol as well as pressing the co-product vinasse (used for energy supply like bagasse).
The electricity/power and process heat needed are supplied by a combined heat and power plant (CHP) using bagasse (see above).

d) **Ethanol from sugar beet, Europe**
Conversion step 1:
The modelling of the process steps is analogue to ethanol from sugarcane. The electricity/power and process heat needed are supplied by a combined heat and power plant (CHP) fired by lignite. In addition to the main product ethanol, beet slices are produced.
Conversion step 2:
Modelling again is to ethanol from sugarcane. Energy supply corresponds to conversion step 1. In addition the co-product vinasse is considered by allocation.

e) **FAME from rapeseed (RME), Europe**
Conversion step 1:
It includes the processes of pressing and the extraction of rapeseed oil as well as its refining. Rapeseed extraction cakes are a co-product.
The power needed is drawn from the general power grid (in this case Germany). Process heat is produced from heating plants fired by natural gas and fuel oil.

Hexane is used as a means of extraction. A sodium hydroxide solution and citric acid are used for the refining process.

Conversion step 2:

It includes the processes of transesterification using methanol, sodium hydroxide solution and hydrochloric acid.

The need for power and process heat is covered the same as in step 1.

f) **FAME from soybeans (SYME), Latin America**

Conversion step 1:

It includes the processes of pressing and the extraction of soy oil as well as its refining. Soy extraction cakes are a co-product.

The power needed is drawn from the general power grid (in this case Brazil). Process heat is produced from heating plants fired by natural gas and fuel oil. The application/use of auxiliary aids for extracting and refining is the same as for RME.

Conversion step 2:

Is the same as for RME.

g) **FAME from soybeans (SYME), North America**

Conversion step 1:

The processes are the same as above.

The power needed is drawn from the general power grid (in this case USA). Process heat is produced from heating plants fired by natural gas and fuel oil. The application/use of auxiliary aids for extracting and refining is the same as for RME.

Conversion step 2:

Is the same as for RME. .

h) **FAME made from palm oil (PME), Southeast Asia:**

Conversion step 1:

It includes the processes of pressing and the extraction of palm oil as well as its refining. Palm nuts are one of the co-products (further processed into palm nut oil as well as palm fibre cake (not included in the calculation).

The electricity/power and process heat needed are supplied by a combined heat and power plant (CHP) using palm fibre cakes.

For the excess, no utilization is assumed for the basic case. For the proven case of a complete energetic utilization of palm fibre cakes (export of power from the network), an allocation can be applied.

The oily waste water from the pressing (POME) is not treated specially according to the basic case. For this reason, methane emissions from the POME ponds are taken into account for the balance. This is not the case when the waste water is treated with BAT.

Conversion step 2:

This is the same as for RME – in regard to the energy requirement and supply, as it is assumed that it will be processed in Germany.

i) **Straight vegetable oils:**

The process data for these materials (rapeseed oil, soybean oil, palm oil) are yet covered by conversion step 1 modelling under e), f) and g).

j) **Hydrogenated vegetable oils:**

The model data for feedstock oils are covered by e) and g) conversion step 1.

Conversion step 2:

Rough and aggregated data are taken from a published study performed by IFEU on behalf of Neste Oil. Due to confidentiality only aggregated data can be applied here (see Table 11).

Table 10 Calculation of the default values on emissions from Conversion Step 1

		Sugarcane, Latin America	Sugar beet Europe	Rapeseed oil, Europe	Soybean oil, Latin and North America	Palm oil, Southeast Asia
Step 1		Sugar production	Sugar production	Oil mill + refinery	Oil mill + refinery	Oil mill + refinery
Input		**Cane**	**Beets**	**Rapeseed grains**	**Soy beans**	**Palm fruits**
Core product		Sugar (in 45% molasses)	Sugar (in 16% molasses)	Rapeseed oil	Soybean oil	Palm oil
Output Sugar/Oil		10.0%	16.8%	38.9%	18.0%	33.3%
Output bagasse/oil fibers		33.8%				26.4%
Output extraction cake			26.5%	58.5%	80.4%	
Output palm nuts						43.9%
Power consumption						
Electricity Mill/Sugar production	kWh/kg core product	0.105	0.071	0.0953	0.332	0.093
Power refinery	kWh/kg core product			0.0063	0.0063	0.0063
Thermic/Heat, Mill/ Sugar production	kWh/kg core product	3.4	0.54	3.25	5.54	2.71
Thermal, refinery	MJ/kg core product			0.302	0.315	0.303
Fuel		Bagasse		fuel oil	fuel oil	Oil fibres
Excess power	kWh/kg core product	1.08				0.679
Resources						
Hexane	g/kg Oil			0.367	1.11	1.11
Citric acid	g/kg Oil			0.367	1.11	1.11
Fuller's Earth	g/kg Oil			6	6	6

Table 10 Calculation of the default values on emissions from Conversion Step 1 (continued)

		Sugarcane, Latin America	**Sugar beet Europe**	**Rapeseed oil, Europe**	**Soybean oil, Latin America**	**Soybean oil, North America**	**Palm oil, Southeast Asia**
Emissions							
Electricity Mill/Sugar production	$kg\ CO_2$-eq./kg core product	0.003	0.045	0.060	0.092	0.283	0.003
power refinery				0.004	0.002	0.005	0.0002
Excess power		0.029					0.0183
Thermal: mill/ sugar prod.		0.008	0.057	0.349	0.594	0.594	0.006
Thermal: refinery				0.032	0.034	0.034	0.001
Resources				0.002	0.002	0.002	0.003
TOTAL		***0.0395***	***0.102***	***0.447***	***0.724***	***0.918***	***0.031***
POME pond emissions	$kg\ CH_4$/ kg Oil						0.028
	$kg\ CO_2$-eq./kg Oil						0.511
Total	**$kg\ CO_2$-eq./kg** core product	**0.04**	**0.102**	**0.447**	**0.724**	**0.918**	**0.5421**
Total without refinery		0.01		0.411	0.688	0.879	0.523
Refinery				0.036	0.036	0.039	0.001
Excess power		0.029					0.018
Emission based on GJ							
Refinery	$kg\ CO_2$-eq./GJ			1.0	1.0	1.1	0.023
Excess	$kg\ CO_2$-eq./GJ	2.44					0.51
Total							
not allocated	$kg\ CO_2$-eq./GJ	**3.32**	**8.6**	**12.1**	**19.8**	**25.1**	**14.96**
allocated	$kg\ CO_2$-eq./GJ	**0.78**	**5.47**	**7.64**	**7.34**	**9.199**	**6.9**

a) DS: Molasses; percentage is based on dry sugar bulk
b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

Table 11 Calculation of the default values on emissions from Conversion Step 2

		Ethanol wheat, Europe	**Ethanol maize, North America**	**Ethanol sugarcane, Latin America**	**Ethanol sugar beet, Europe**	**FAME rapeseed oil, Europe**	**FAME soybean oil, Latin + N. America**	**FAME Palm oil, Southeast Asia**	**Hydro-genated vegetable oil**
Step 2		Fermentation	Fermentation	Fermentation	Fermentation	Transesterif.	Transesterif.	Transesterif.	Hydrogenation
Core product		Ethanol:	Ethanol	Ethanol	Ethanol	RME	SYME	PME	
Output core product a)	kg/GJ Hu	37.45	37.45	37.45	37.45	26.88	27.03	27.32	
	% of input	29.50%	32.50%	44.60%	44.60%	99%	99%	99%	
Output DDGS, vinasse a)	% of input	40.60%	44.70%	10.40%	10.40%				
Output Glycerin a)	% of input					9.30%	9.30%	9.30%	
Input Methanol a)	% of input					10.90%	10.90%	10.90%	
energy consumption									
Electricity	kWh/kg core pr.	0.402	0.402	0.345	0.1	0.046	0.046	0.046	
thermal energy	MJ/kg core pr.	9.76	9.76	9.16	9.76	1.36	1.36	1.36	
Fuel		lignite	gas/fuel oil	Bagasse	lignite	gas/fuel oil	gas/fuel oil	gas/fuel oil	
surplus electricity	kWh/kg EtOH								
Total electricity prod.	*kWh/kg EtOH*			*0.345*					
Auxillaries									
NaOH (g/kg)	g/kg					6	6	6	
HCl (g/kg)	g/kg					5	5	5	
Emission									
Methanol	kg CO_2-Eq./kg core prod.					0.1364	0.136	0.136	
electricity		0.2534	0.2436	0.0093	0.063	0.0290	0.0290	0.0290	
heat/steam		1.418	0.8756	0.0206	0.876	0.122	0.122	0.122	
auxiliaries		0	0	0		0.00849	0.00849	0.00849	
SUM		**1.671**	**1.119**	**0.0299**	**0.939**	**0.296**	**0.296**	**0.296**	
Emission related on GJ									
not allocated	kg CO_2-Eq./GJ	**62.6**	**45.6**	**1.12**	**35.2**	**7.95**	**8.0**	**8.08**	**10.5**
allocated b)	kg CO_2-Eq./GJ	**34.3**	**25.0**	**0.99**	**31.0**	**7.63**	**7.67**	**7.75**	**9.7**

a) Sum of output mass flows does not match with input mass flow because of losses due to CO_2 creation (fermentation), evaporation and effluent discharge.
b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

The origin of the data is listed in Table 12 again. The applied data are divided into categories under the aspect of conservatism.

Table 12 Origin of data on biomass production and categorization of the conservatism for the conversion processes

	Data source	Category of conservatism
Crops and co-products	Calculations by IFEU, basis of various LCAs	Median value, no conservatism
Power and resource consumption	Calculations by IFEU, basis of various LCAs	Median value, no conservatism
Selection of fuels		Assumption of a typical case of unfavourable energy source (Europe: lignite as the case for Germany) → conservative
Treatment of any possible energy excess		Neglect of potential excesses when applying biomass (by-products) → conservative
Emission factors	GEMIS as well as calculations by IFEU	Upper heating value → conservative (approach analogue to Figure 2)

4.7 Default values for transport systems

There are three transport steps investigated:

- Transport of the agriculturally produced biomass to Conversion Step 1
- Transport of the semi-manufactured product (here only vegetable oil) to Conversion Step 2
- Transport of the biofuel for admixture (refinery)

The distances chosen (see Table 13) are based on estimated median values as they have been applied in various LCAs. The long-distance sea voyages are based on information from studies of the distances from the manufacturing countries to the harbour in Hamburg.

The means of transportation are categorized as follows

- three different classes of trucks/lorries:
    - dump trucks for biomass transport for short distances
    - medium-sized trucks for intermediate products for medium distances
    - tank trucks for biofuels and far distances
- inland vessels for partial routes on rivers, especially in the U.S.A. and Brazil
- Open sea travel for routes from the U.S.A., Brazil and Southeast Asia

The data are flexible and easy to adjust to individual cases. For transports within Germany, inland navigation vessels as well as railroad transport is possible.

The basic data for the greenhouse gas calculation for the individual mode of transport are based on TREMOD. A discussion referring to the conservatism of the data and assumptions is to be taken from Table 14.

Table 13 Calculation of the default values on emissions from transportation processes (GHG emission factor taken from TREMOD)

Good to be transported	means of transport	**Ethanol** wheat Europe km	kg CO_2-eq./GJ	**Ethanol** maize North Am. km	kg CO_2-eq./GJ [a)]	**Ethanol** sugarcane Lat. Am. km	kg CO_2-eq./GJ [a)]	**Ethanol** sugar beet Europe km	kg CO_2-eq./GJ [a)]
Biomass	Truck	100	**1.336**	100	**1.213**	20	**1.75**	50	**2.63**
Biofuel	Truck	150	0.383	300	0.766	500	1.277	150	0.383
	Ship (overseas)			9,500	3.199	11,000	3.704		
	Barge (inland)			500	0.403	200	0.161		
	Truck			150	0.383	150	0.383		
	Total Biofuel		**0.383**		**4.751**		**5.525**		**0.383**
TOTAL									
not allocated			**1.72**		**5.96**		**7.28**		**3.01**
allocated [b)]			1.12		5.42		7.07		2.06

Good to be transported	means of transport	**FAME** Rapeseed Europe km	kg CO_2-eq./GJ [a)]	**FAME** Soybean Latin Am. km	kg CO_2-eq./GJ [a)]	**FAME** Soybean North Am. km	kg CO_2-eq./GJ [a)]	**FAME** palm oil SE Asia km	kg CO_2-eq./GJ [a)]
Biomass	Truck	100	**0.735**	100	**1.600**	100	**1.600**	20	**0.174**
Oil	Truck	100	0.213	500	0.931	500	0.931	300	0.648
	Ship (overseas)			11,000	2.700	9.500	2.332	14,000	3.474
	Barge (inland)			200	0.118	200	0.118	200	0.119
	Truck			100	0.186	100	0.186	100	0.216
	Total Oil		**0.213**		**3.934**		**3.566**		**4.458**
Biofuel	Truck	150	0.275	150	0.276	150	0.276	150	0.279
	Total Biofuel		**0.275**		**0.276**		**0.276**		**0.279**
TOTAL									
not allocated			**1.22**		**5.81**		**5.44**		**4.91**
allocated [b)]			0.92		4.59		4.24		4.63

a) Based on 1 GJ biofuel as the final product
b) Taking the allocation into consideration according to the lower heating value via the production chain up to the final product (ethanol, FAME)

Table 14 Origin of data on biomass production and categorization of the conservatism for the transport processes

	Data source	Category of conservatism
Distances	Calculations or estimates by IFEU	Median value, no conservatism
Efficiency and consideration of return transport	Calculations or estimates by IFEU	Full efficiency of the transports is assumed → no conservatism Empty return transports for biomass transport assumed → conservatism No empty return transport for ships assumed → no conservatism
Fuel consumption and emission factors	TREMOD	Median standard values, no conservatism

4.8 Allocation method and default values according to the lower heating values

Allocating the emissions for co-products occurs via allocation according to the lower heating value. The reasons for the assumed heating values are listed in Table 15. Here it must be taken into consideration that the data on the water contents can fluctuate in reality.

To ensure the utmost completeness, the table also includes materials that are not allocated/assigned an allowance within the default value calculation as by-products – e.g. straw (also see Section 4.5).

The allocation is carried out within each process step in which co-products occur. The allocation is carried out as in the following example:

The transesterification of rapeseed oil produces 0.307 kg CO_2-eq. / kg RME
(see Table 11).
This provides 0.092 kg of glycerine.
The energy content of 1 kg RME amounts to 37.2 MJ, the one of 0.092 kg glycerine to 1.56 MJ (s. Table 15).
Therefore the emission due to the transesterification process is allocated by 96 %
(= 37.2 / 38.76) to RME and by 4 % (= 1.23 / 38.76) to glycerine.
1 kg RME causes: 0.2947 kg CO_2-eq.
1 kg glycerine causes: 0.1228 kg CO_2-eq. (0.307 kg CO_2-eq. x 4 % / 0.092 kg)

Table 16 resumes the GHG balance results for each biofuel system without considering allocation of any co-product (these values are identical with the data given in the rows labelled „not allocated“ within Table 4 to Table 13). Each value in this table is allocated according to the described methodology. The allocated values can be found within the lowest rows of Table 4 to Table 13 (labelled “allocated”) as well as in Table 2 and Table 3.

Table 15 Lower heating values of the material investigated.

		Lower heating value Hu		Water content.
		MJ/kg DS	MJ/kg OS	%
Agricultural products				
Wheat	Complete plant	17.1	13.5	18.4%
	Grains	17.0	13.7	16.9%
	Straw	17.2	13.3	19.8%
Maize	Complete plant	16.5	14.3	11.6%
	Grains	21.4	17.4	16.7%
	Straw	17.7	13.7	19.8%
Sugarcane	Complete plant	17.0	11.0	30.8%
	Crop harvest	17.0	11.0	30.8%
Sugar beet	Complete plant			
	beet	17.0	2.1	76.4%
	Crop harvest			
Rapeseed	Complete plant	21.8	17.0	19.6%
	Grains	26.5	21.8	16.2%
	Residue	17.0	14.7	11.8%
Soybeans	Complete plant	18.0	14.5	17.1%
	Beans/seed	20.0	17.0	13.3%
	Residue	17.0	13.0	20.5%
Palm oil	Seed head	24.6	22.3	8.5%
	Fruits	31.7	31.5	0.6%
	empty seed heads	17.5	14.0	17.5%
Semi-manufactured products				
Destiller's dried grains (DDGS)		21.8	16.0	23.9%
Molasses (45% sucrose)		19.0	7.2	55%
Bagasse (50% DS)		16.6	7.1	50%
Extracted beet slices		16.3	2.1	75.5%
Melasse, vinasse		17.0	7.2	50%
Rapeseed oil		37.2	-	0%
Soybean oil		36.6	-	0%
Palm oil		36.5	-	0%
Rapeseed extraction cakes		19.0	15.0	18.6%
Soy extraction cakes		19.0	15.0	18.6%
Oil fibers		17.5	14.0	17.5%
Palm nuts		28.0	28.0	0%
Glycerine (un-processed)		17.0	13.4	18.5%
Final product				
Ethanol		26.7	-	0%
RME		37.2	-	0%
SYME		37.0	-	0%
PME		36.6	-	0%
Hydrogenated vegetable oil		44.0	-	0%

DS: dry substance
OS: original substance with consideration to the given (default) water content

Table 16 GHG balance results per system without allocation of co-products for ethanol and FAME; all figures given in kg CO_2-equivalents per GJ.

Biofuel / Biomass / origin — step of production chain	Ethanol				Biodiesel (FAME)			
	Wheat Europe	**Maize** (corn) North America	**Sugarcane** Latin America	**Sugar beet** Europe	**Rapeseed** Europe	**Soybean** Latin America	**Soybean** North America	**Palm oil** Southeast Asia
direct land use change	*47.8* [a)]	*36.1* [a)]	*180.1* [a)]	*24.5* [a)]	*54.9* [a)]	*923.9* [a)]	*173.8* [a)]	*236.7* [a)]
production of biomass	40.7	32.4	22.1	17.8	48.8	41.0	48.2	13.9
transport of biomass	1.3	1.2	1.8	2.6	0.7	1.6	1.6	0.2
conversion step I	-	-	3.3	8.6	12.1	19.8	25.1	15.0
transport between conversion steps	-	-	-	-	0.2	3.9	3.6	4.5
conversion step II	62.6	45.6	1.1	35.2	8.2	8.3	8.3	8.4
transport to fuel storage for admixture	0.4	4.8	5.5	0.4	0.3	0.3	0.3	0.3
Total without LUC	**105.0**	**84.0**	**33.8**	**64.6**	**70.4**	**74.9**	**87.0**	**42.1**
Total with direct LUC	***152.7*** [a)]	***120.2*** [a)]	***213.9*** [a)]	***89.1*** [a)]	***125.3*** [a)]	***998.8*** [a)]	***260.8*** [a)]	***278.8*** [a)]

a) Worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

Table 17 GHG balance results per system without allocation of co-products for straight and hydrogenated vegetable ; all figures given in kg CO_2-eq. per GJ.

Biofuel / Biomass / origin — step of production chain	straight vegetable oil				Hydrogenated vegetable oil			
	rapeseed oil	**soybean oil**		**palm oil**	**rapeseed oil**	**soybean oil**		**palm oil**
	Europe	Latin America	North America	Southeast Asia	Europe	Latin America	North America	Southeast Asia
direct land use change	54.9 [a)]	913.9 [a)]	171.9 [a)]	236.1 [a)]	57.6 [a)]	970.1 [a)]	182.5 [a)]	248.6 [a)]
production of biomass	48.8	40.1	47.2	13.8	51.3	43.1	50.6	14.5
transport of biomass	0.7	1.6	1.6	0.2	0.8	1.7	1.7	0.2
conversion step I	12.1	19.5	25.3	14.9	12.7	20.8	26.3	15.7
transport between conversion steps	-	-	-	-	0.2	4.1	3.7	4.7
conversion step II	-	-	-	-	10.5	10.5	10.5	10.5
transport to fuel storage for admixture	0.2	3.9	3.5	4.4	0.7	0.7	0.7	0.7
Total without LUC	**61.9**	**65.2**	**77.6**	**33.3**	**76.2**	**80.8**	**93.6**	**46.3**
Total with direct LUC	***116.8*** [a)]	***979.1*** [a)]	***249.6*** [a)]	***269.4*** [a)]	***133.9*** [a)]	***1.051*** [a)]	***276.1*** [a)]	***294.9*** [a)]

a) Worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

In Figure 4 the modular derivation/deduction of the allocated default value is illustrated for the case of RME. Assuming the reference value of 1 GJ biofuel, the material flow/chain is calculated back to the land use change. In this calculation, the information on the THG emissions is listed in the upper line of the complete emission of the respective module, under it the heating value of the allocation factor for the target product is listed and below it the allocated emission share/ratio/percentage for the biofuel can be found. This form of presentation is chosen to clearly indicate that the allocation factors increasingly multiply when looking back at the process chain. The share of 4% for glycerine during transesterification continues along the whole chain up to the land use change.

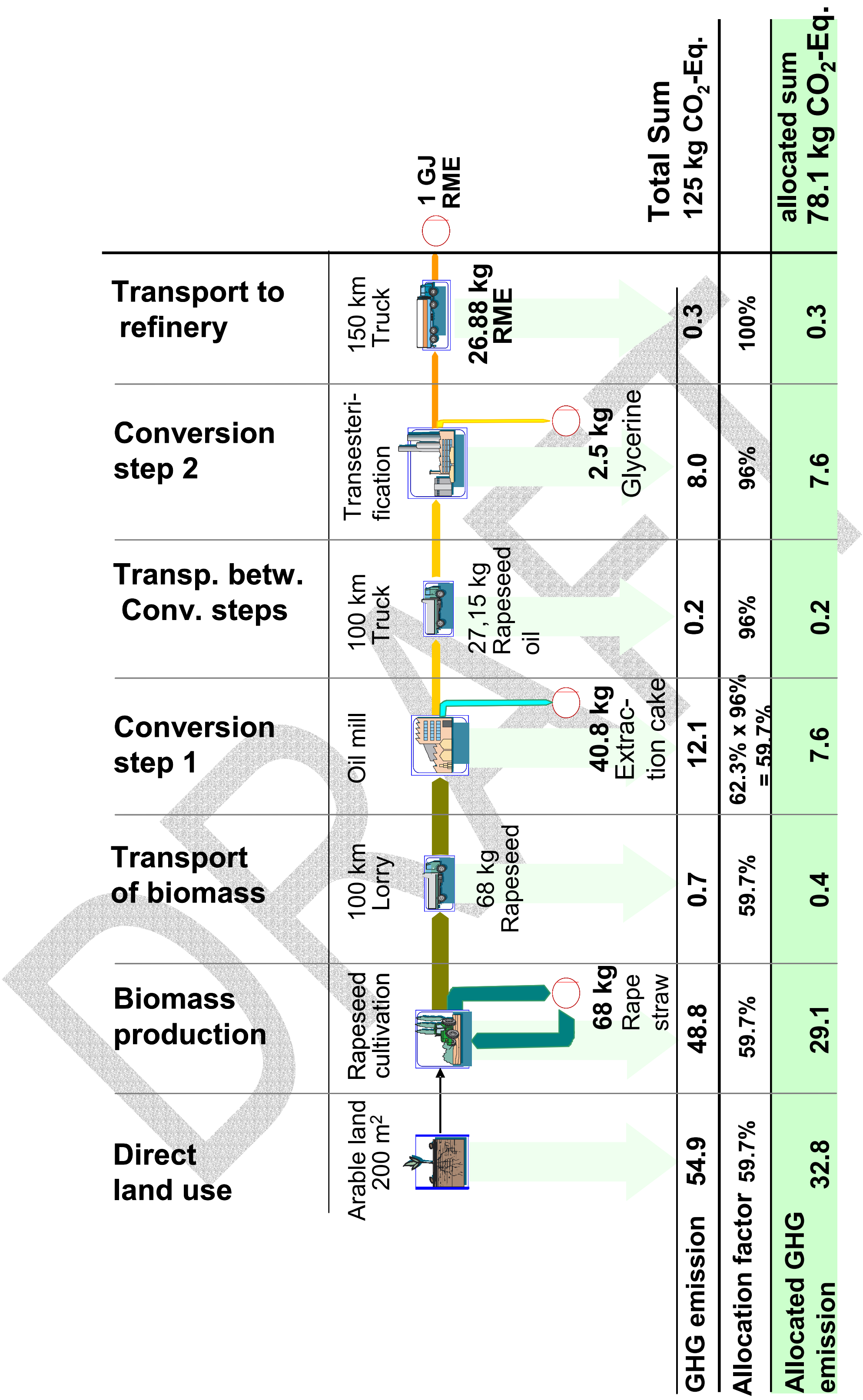

Figure 4 Allocation scheme for the example of RME

5 Glossary

CO_2	Carbon dioxide
CO_2-eq.	Carbon dioxide equivalents
CH_4	Methane
N_2O	Nitrous oxide; laughing gas
DDGS	Dried Distiller's Grains with Solubles
EtOH	Ethanol
LUC	Land use change
LULUC	Land use and land use change
IPCC	Intergovernmental Panel on Climate Change
Hu	Lower heating value, net calorific value
GHG	Greenhouse gas
FAME	Fatty acid methylester
PME	Palm oil methylester
RME	Rapeseed oil methylester
SYME	Soybean oil ethylester

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