RSB – ROUNDTABLE ON SUSTAINABLE BIOMATERIALS

RSB GHG Calculation Methodology

Version 2.3

Approved for certification

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Introduction

This standard specifies the provisions that shall be complied with by operators participating in the *RSB certification systems*.

The *participating operator* shall have control over and take full responsibility, accountability and liability for all operations, processes, activities and sites in relation to the implementation of and compliance with the *RSB standards* at all times.

This standard describes the methodology for the calculation of the lifecycle greenhouse gas emissions of biofuel production in the certification scheme of the Roundtable on Sustainable Biomaterials ("RSB GHG Calculation Methodology").

The RSB GHG Calculation Methodology is available for

- RSB Global Certification
- RSB EU RED Certification (compliance with the requirements of the EU Renewable Energy Directive)

Differences in the RSB GHG Calculation Methodology between the Global Certification and the EU RED Certification are described in this standard.

The methodology as described in this standard has been embedded into the RSB Greenhouse Gas Tool, the RSB calculator for life cycle assessment (LCA) of biofuels developed by RSB, in collaboration with the Swiss Federal Institute for Materials Testing (EMPA), Quantis and HTW Berlin.

Management of Change

Version / Date	Section(s)	Change
10.9.12	1.3	Added section 1.3: GHG Emissions calculation through the chain of production
10.9.12	1.4	Expanded the section on system boundary providing a more detailed explanation of all the inputs that need to be taken into consideration, and introducing the concept of materiality threshold.
2.2 / 3.5.16	Throughout the document	Included requirements of the European Commission for full compliance under the EU Renewable Energy Directive
2.3 / 08.08.17	3.2.4	The baseline date for land use change emissions was changed to January 2008 (consistent with the revision of the RSB Principles & Criteria)

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A. Intent of this standard

This standard is intended to define the GHG calculation methodology to be used by *participating operator*s in the *RSB certification scheme* when calculating GHG emissions for the scope of their operations. This standard describes the methodology for calculating GHG emissions as embedded in the RSB Greenhouse Gas Tool.

Furthermore, the intent of this standard is to ensure that all operators participating in the *RSB certification systems* use the same, standardized methodology to calculate GHG emissions.

B. Scope of this standard

This standard is an international standard and valid worldwide, and specifies the GHG calculation methodology to be used by RSB *participating operators* producing, converting, processing, trading, transporting, and distributing *biomass*/*biofuel*s in the *RSB certification systems*.

This standard applies to all *participating operators* in the *RSB certification systems*.

C. Status and effective date

The version 2.3 of the RSB GHG Calculation Methodology shall be effective on 15 August 2017.

D. Note on use of this standard

All aspects of this standard are considered to be normative, including the intent, scope, standard effective date, note on the use of this standard, references, terms and definitions, requirements and annexes, unless otherwise stated. Users implementing this standard shall ensure that the intent of this standard is met. To ensure that the intent of this standard is met users shall implement all of the requirements specified in this standard, and any and all additional measures necessary to achieve the intent of this standard.

E. References

Please see RSB-DOC-10-001 RSB List of documents and references for the full list of RSB Standards and references.

F. Terms and Definitions

For the purposes of this International Standard, the terms and definitions given in the EU Directive 2009/28/EC on the promotion of the use of energy from renewable sources (RED), and in RSB-STD-01-002 RSB Glossary of Terms shall apply.

G. GHG calculations for the Directive 2009/28/EC

For the calculations of greenhouse gas emissions according to the Directive 2009/28/EC of the European Parliament on the promotion of the use of energy from renewable sources (EU RED), the guidelines of the European Union are followed. The differences to the RSB methodology are the following:

- Allocation is based on energy content instead of economic value (according to Annex V, paragraph 17).
- The excess electricity from cogeneration in processing is taken into account using system expansion (according to Annex V, paragraph 16)
- The emission factors of the ecoinvent datasets were calculated without infrastructure (according to Annex V, paragraph 1) and by taking only CH_4, N_2O and CO_2 into account (according to Annex V, paragraph 5).
- The agricultural residues are not taken into account for allocation as they are assumed to have zero GHG emissions (according to Annex V, paragraph 18).
- The RSB methodology uses a more refined model for the calculation of ammonia and nitrate emissions (used in the calculation of indirect N_2O emissions).
- Differences in the calculation of greenhouse gas emissions from land use change are highlighted separately in Chapter 4.

H. Requirements

1. General Requirements

1.1. Functional Unit

The functional unit shall be one megajoule (MJ) of finished biofuel product. Results shall be reported on a Lower Heating Value (LHV) at 0% water (g CO_{2eq}/MJ.) Results for raw materials and intermediary products shall be reported in kg CO_{2eq}/kg dry-mass

Table 0-1: Lower Heating Values (LHV, see full list in Annex 6)

Biofuel	Source	LHV [MJ/kg]
Ethanol	Biograce[1]	26.81
Methanol	Biograce[1]	19.9
Fatty Acid Methyl Esters	Biograce[1]	37.2
Synthetic Diesel (BtL)	Biograce[1]	44.0
Hydrogenated vegetable oil	Biograce[1]	44.0
Pure vegetable oil	Biograce[1]	36.0
Dimethylether	Pacific Northwest Laboratory[2]	28.88

[1] BioGrace_GHG_calculations_-_version_4_-_Public.xls, sheet "standard values". Available on http://biograce.net/content/ghgcalculationtools/excelghgcalculations.

1.2. System Boundaries

The system boundary is from cradle (fossil fuel feedstock extraction and biofuel feedstock production, respectively, for fossil fuels and biofuels) up to, but not including, use of the fuel in an engine. However, theoretical (stoichiometric) emissions from fuel combustion are included.

Greenhouse gas emissions from the production and use of transport fuels, biofuels and bioliquids shall be calculated as:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee},$$

Where

E = total emissions from the use of the fuel;
e_{ec} = emissions from the extraction or cultivation of raw materials;
e_l = annualised emissions from carbon stock changes caused by land-use change;
e_p = emissions from processing;
e_{td} = emissions from transport and distribution;
e_u = emissions from the fuel in use;
e_{sca} = emission saving from soil carbon accumulation via improved agricultural management;
e_{ccs} = emission saving from carbon capture and geological storage;
e_{ccr} = emission saving from carbon capture and replacement; and
e_{ee} = emission saving from excess electricity from cogeneration.

RSB Global Certification: Infrastructure shall be included and the data come from the EcoInvent database. Infrastructure includes farm equipment (e.g., tractors), fossil feedstock production equipment (e.g., drilling equipment), fuel production equipment (e.g., refineries), and other.

RSB EU RED: Emissions from the manufacture of machinery and equipment shall not be taken into account.

Please note:

The calculation for e_{ccs} and e_{ccr} is currently not included in the RSB GHG tool. Please follow the methodology outlined in RSB-STD-11-001 *Standard for EU market access*.

1.3. Materiality threshold

All materials, chemicals and energy inputs into the system boundary must be taken into account in the calculations, with the exception of materials, chemicals and energy that are below a threshold of materiality of 0.1% in each category of: material, chemical, and energy. E.g.: if a particular chemical amounts to less than 0.1% of all chemicals used within the system boundary, it need not be included in the calculation.

[2] GREET Transportation Fuel Cycle Analysis Model, GREET 1.8b, developed by Argonne National Laboratory, Argonne, IL, released September 5, 2008. http://www.transportation.anl.gov/modeling_simulation/GREET/index.html

1.4. Integrated operations

Some processing plants can be integrated with other operations: for example, an ethanol plant can be integrated with the CHP plant. Two system boundaries are possible:

1) the system boundary is drawn as closely as possible around the biofuel operation. Inputs of the connected plant (e.g. electricity from CHP plant) are treated either with specific (delivered by the operator) data or with standard data (e.g. from ecoinvent).

2) the system boundary is drawn around the whole operation scope of the operator. The operator has to deliver data on the whole operation.

In practice, the boundary of the GHG calculation has to coincide with the scope of certification. The boundary should include all operations that are required for the production of the biofuel or the processing of co-products and waste.

1.5. Biofuel Feedstocks

The tool allows the calculation of operator's data for all biofuel pathways and feedstocks. However, RSB aims to include all relevant biofuel pathways and feedstocks in the tool. The current list of pathways and feedstocks is included in Annex 2- Pathways.

Broadly speaking, feedstocks include:

- Agricultural & forestry commodities (e.g., soybeans, wood);
- Agricultural & forestry by-products (e.g., wheat straw, waste wood);
- Animal husbandry by-products (e.g., tallow);
- Waste oil

1.6. Input data

The RSB Methodology requires that operators enter data relevant to their operations. Default values of material and energy usage are not employed; rather, operator-specific values (e.g., amount of fertilizer, amount and type of energy, etc.) are required. There are, however, default emission factors (such as the carbon intensity associated with materials and energy production). See next section.

1.7. Background (Default) data

The calculations of background data (carbon intensity of fertilizer production processes, etc.) rely on data from the ecoinvent database (www.ecoinvent.org).

1.8. Co-Products and waste

Greenhouse gas emissions shall be divided between the fuel or its intermediate product and the co-products in proportion to their

- Economic value (RSB Global Certification)
- Energy content determined by the lower heating value (RSB EU RED Certification): The *participating operator* shall determine the allocation factor for GHG emissions savings for co-products by applying actual values in the following formula:

$$allocation\ \ factor = \frac{energy\ yield_{main\ product}[MJ]}{energy\ yield_{main\ product}[MJ] + energy\ yield_{co-products}[MJ]}$$

No emissions should be allocated to agricultural crop residues and processing residues, since they are considered to have zero emissions until the point of their collection, nor to waste.

Note: Annex 5 provides a discussion on different co-product treatment methodologies, their advantages and disadvantages, and the reasoning behind the RSB's decision to use an economic allocation methodology.

1.9. Geographic Scope

This methodology is applicable to biofuel operations in any region of the world. Operators are required to enter actual data (material and energy usage, land use type, etc.) associated with their operations; hence, the tool does not include assumptions on data variability in different geographical areas.

1.10. GHG and GWP

The GHGs included in the calculation and their associated Global Warming Potentials are based on the ReCiPe method. ReCiPe includes more chemicals than IPCC (2007), but the latter includes 10 chemicals that are not included in ReCiPe. IPCC 2007 and ReCiPe GWP data are identical except for chloroform which has a higher value in IPCC (2007) than in ReCiPe (765 vs. 31 kgCO2). GHG and associated GWPs are included in Annex 1 – Global Warming Potentials. A comparison of ReCiPe and IPCC (2007) is included as well.

1.11. Calculating GHG emissions through the chain of custody

1.11.1. The emissions of a raw material or intermediate shall include the emissions of all inputs and raw materials including the emissions of the previous step in the chain. The operators along the chain of custody shall add the additional emissions from transport an/or

processing to e_P and/or e_{td} respectively (please see the formula for e_P in chapter H.8 and for e_{td} in chapter H.9).

In addition, the operators along the chain of custody shall apply a *feedstock factor* to all emissions to take energy losses into account.

Whenever a processing step yields co-products, emissions shall be allocated in proportion to the lower heating value of the products and co-products (*allocation factor*, see also point 18).

The following formula shall apply:

$$em_cum_{intermediate\ product}\left[\frac{gCO_2eq}{kg_{dry}}\right] = emissions_{\substack{actual \\ step}}\left[\frac{gCO_2eq}{kg_{dry}}\right] * AF + emissions_{previous\ step}\left[\frac{gCO_2eq}{kg_{dry}}\right] * FF * AF$$

Where:

$$Allocation\ factor\ AF: \left[\frac{Energy\ in\ intermediate\ product_a}{Energy\ in\ intermediate\ \ products\ +\ co-products}\right]$$

$Emissions_{actual\ step}$ *[g CO2-eq/kgdry]:* emissions per kg product of the participating operator for the process under his scope of operation

$Emissions_{previous\ step}$ *[g CO2-eq/kgdry]:* reported emissions per kg of product of the certified supplier, which include also emissions from previous steps up to cultivation

Feedstock factorFF:

$[Ratio\ of\ MJ\ feedstock\ required\ to\ make\ 1\ MJ\ of\ intermediate\ \ product]$

1.11.2. The final operator transforms the value in kg CO_{2eq}/MJ by using the lower calorific value as conversion factor (e.g. biodiesel: 37 MJ/kg, bioethanol: 27 MJ/kg).
The emissions of biofuels at the stage of the final product are therefore:

$$E\left[\frac{gCO_{2eq}}{MJ}\right] = \frac{em_cum_{\substack{final \\ product}}\left[\frac{gCO_{2eq}}{kg}\right]}{CF\left[\frac{MJ}{kg}\right]} + e_u\left[\frac{gCO_{2eq}}{MJ}\right]$$

Where:

$em_cum_{final\ product}$: Cumulated emissions up to the final product

CF: Conversion factor, here: lower calorific value

1.11.3. To receive information on emissions per dry-ton feedstock the following formula shall be applied:

$$e_{ec}feedstock_a\left[\frac{gCO_2eq}{kg_{dry}}\right] = \frac{e_{ec}\ feedstock_a\ \left[\frac{gCO_2eq}{kg_{moist}}\right]}{(1 - moisture\ content)}$$

Whereas the moisture content shall be the value measured upon delivery. If the moisture content is not known, the maximum value allowed per delivery contract shall be used.

1.11.4. Actual values shall only be transmitted to the customer if all relevant process and transport steps have been included. If the operator cannot guarantee that all relevant process and transport emissions are included in the calculation of an actual value, actual values must not be transmitted. The operator shall state on the delivery notes that the calculation of actual values is not feasible for downstream operators

1.11.5. Greenhouse gas emission saving from biofuels and bioliquids shall be calculated as:

SAVING = (EF – EB)/EF'

Where

EB = total emissions from the biofuel or bioliquid; and
EF = total emissions from the fossil fuel comparator.

For biofuels, the fossil fuel comparator E_F shall be the latest available actual average emissions from the fossil part of petrol and diesel consumed in the Community as reported under Directive 98/70/EC. If no such data are available, the value used shall be 83,8 gCO_{2eq}/MJ
For bioliquids used for electricity production, the fossil fuel comparator E_F shall be 91 gCO_{2eq}/MJ.
For bioliquids used for heat production, the fossil fuel comparator E_F shall be 77 gCO_{2eq}/MJ.
For bioliquids used for cogeneration, the fossil fuel comparator E_F shall be 85 gCO_{2eq}/MJ.

Please note : The RSB GHG Tool only covers the calculation of Greenhouse Gas emission savings for biofuels.

2. Modeling emissions from agriculture (eec)

2.1. The operator shall determine the GHG emissions resulting from primary production eec including all activities necessary for or related to the primary production of raw material. Calculations shall include the production of fertilizers and pesticides, the energy used for agricultural machines as well as emissions on the field (e.g. dinitrogen emissions in the palm oil production).

The GHG emissions from agriculture are calculated as follow:

$$e_{ec}\left[\frac{kgCO_{2eq}}{ha}\right] = \frac{E_{fertilizer}\left[\frac{kgCO_{2eq}}{ha}\right] + E_{pesticides}\left[\frac{kgCO_{2eq}}{ha}\right] + E_{\substack{agricultural\\machines}}\left[\frac{kgCO_{2eq}}{ha}\right] + E_{effluents}\left[\frac{kgCO_{2eq}}{ha}\right] + E_{electricity}\left[\frac{kgCO_{2eq}}{ha}\right] + E_{seed}\left[\frac{kgCO_{2eq}}{ha}\right]}{product\ yield_{\substack{main\\product}}\left[\frac{kg_{productyield}}{ha}\right]}$$

As a rule product yield shall be determined as:

- the actual product realized in a particular harvest in kg/ha averaged over the extent of the individual operation (production) site for crops which are harvested annually; or
- the actual product yield realized in the preceding 12 month period in kg/ha averaged over the extent of the individual operation (production) site for crops which are harvested more than once per year or which are harvested continuously.

2.2. $E_{fertilizers}$ shall be calculated as follows

$$E_{fertilizers}\left[\frac{kgCO_2}{ha}\right] = \sum fertilizer_type_i\left[\frac{kg}{ha}\right] * EF_fert_i\left[\frac{kgCO_2}{kg}\right]$$

EF_fert_i: emission factor of the fertilizer type (e.g. ammonium nitrate). The emission factors of the fertilizer type are taken from the ecoinvent database. The available fertilizers are shown in Table 0-2.

Table 0-2: Fertilizers in the RSB Tool

Fertilizers	Country	unit	nutrient
ammonium nitrate phosphate, as N	RER	kg	N
ammonium nitrate, as N	RER	kg	N
ammonium sulphate, as N	RER	kg	N
calcium ammonium nitrate, as N	RER	kg	N
calcium nitrate, as N	RER	kg	N
diammonium phosphate, as N	RER	kg	N
monoammonium phosphate, as N	RER	kg	N
potassium nitrate, as N	RER	kg	N
urea ammonium nitrate, as N	RER	kg	N
urea, as N	RER	kg	N
ammonium nitrate phosphate, as P2O5	RER	kg	P
diammonium phosphate, as P2O5	RER	kg	P
monoammonium phosphate, as P2O5	RER	kg	P
thomas meal, as P2O5	RER	kg	P
triple superphosphate, as P2O5	RER	kg	P
single superphosphate, as P2O5	RER	kg	P
potassium chloride, as K2O	RER	kg	K
potassium nitrate, as K2O	RER	kg	K
potassium sulphate, as K2O	RER	kg	K
lime, algae	RER	kg	CaO
lime, from carbonation	RER	kg	CaO

2.3. The GHG emissions of pesticide use ($E_{pesticides}$) are calculated as follow:

$$E_{pesticides}\left[\frac{kgCO_2}{ha}\right] = \sum pesticide_type_i\left[\frac{kg}{ha}\right] * EF_pest_i\left[\frac{kgCO_2}{kg}\right]$$

EF_pest_i: emission factor of the pesticide type (e.g. ammonium nitrate). The emission factors of the pesticide type are estimated with the value from the ecoinvent database for the dataset “pesticides, unspecified, RER”. The available pesticides are shown in Table 0-3.

Table 0-3: Available pesticides in the RSB tool and their category.

Category	Specific pesticide
[Sulfonyl]Urea-compounds	Chlorosulfuron, Diuron, Fluometuron, Linuron
[Thio]Carbamat-compounds	Carbofuran, Carbaryl, EPTC, Butylate
Acetamide-Anillid-compounds	Propanil, Alachlor, Propachlor, Metolachlor
Benzimidazol-compounds	Benomyl
Benzo[thia]diazol-compounds	Bentazon
Benzoic-compounds	Dicamba, Chloramben
Bipyridylium-compounds	Diquat
cyclic N-compounds	Methazol
Dinitroanilin-compounds	Trifluralin
Diphenylether-compounds	Fluazifop-butyl
Dithiocarbamat-compounds	Maneb, Ferbam
Nitrile compounds	Bromoxynil
Nitro compounds	Dinoseb
Organophosphorus compounds	Glyphosat, Phorat, Malathion, Parathion, Methylparathion
Phenoxy compounds	MCPA, 2,4-D, 2,4,5-T
Phtalamid- compounds	Captan
Pyretroid compounds	Cypermethrin
Pyridazin compounds	Norflurazon
Triazin compounds	Atrazine, Cyanazine, Chlorsulfuron

2.4. The GHG emissions of machine ($E_{agricultural\ machines}$) use are calculated as follow:

$$E_{\substack{agricultural \\ machines}}\left[\frac{kgCO_2}{ha}\right] = \sum machine_{type}\left[\frac{l}{ha}\right] * EF_machine\left[\frac{kgCO_2}{l}\right]$$

$EF_machine_i$: emission factor of the machine type (e.g. harvesting machine). The emission factors of the machine type are taken from the ecoinvent database (Annex 4 – Ecoinvent Emission Factors). The available agricultural machines are shown in Table 0-4.[3]

[3] The calculation of the EF_machine uses the fuel consumption of the machine in ecoinvent. The tool offers also the possibility to enter hours instead of fuel litres, and use the conversion factors of ecoinvent to calculate the carbon intensity of the machine.

Table 0-4: Agricultural machine use in the RSB Tool.

application of plant protection products, by field sprayer
Baling
chopping, maize
combine harvesting
fertilising, by broadcaster
fodder loading, by self-loading trailer
grain drying, high temperature
grain drying, low temperature
grass drying
harvesting, by complete harvester, beets
harvesting, by complete harvester, potatoes
haying, by rotary tedder
Hoeing
irrigating
loading bales
maize drying
Milking
mowing, by motor mower
mowing, by rotary mower
mulching
Planting
potato grading
potato haulm cutting
potato planting
slurry spreading, by vacuum tanker
solid manure loading and spreading, by hydraulic loader and spreader
Sowing
swath, by rotary windrower
tillage, cultivating, chiseling
tillage, currying, by weeder
tillage, harrowing, by rotary harrow
tillage, harrowing, by spring tine harrow
tillage, hoeing and earthing-up, potatoes
tillage, ploughing
tillage, rolling

tillage, rotary cultivator
transport, tractor and trailer

2.5. The GHG emissions due to effluents ($E_{effluents}$) are calculated as follows:

$$E_{effluents}\left[\frac{kgCO_2}{ha}\right] = \sum effluent_i\left[\frac{kg}{ha}\right] * EF_effluent_i\left[\frac{kgCO_2}{kg}\right]$$

The calculation of the different effluents is described in the following chapters (Table 0-5). Their specific emission factor (EF_effluent$_i$) is described in Annex 4 Ecoinvent Emission Factors.

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Table 0-5: Effluents and their description in this document.

Effluent	Chapter
CO_2 from land use	Chapter 3
Ammonia	Chapter 4
N_2O and NO_x	Chapter 5
Nitrate	Chapter 6
Emissions from fires (sugar cane)	Chapter 8

2.6. The GHG emissions due to electricity use ($E_{electricity}$) are calculated as follows:

$$E_{electricity}\left[\frac{kgCO_{2eq}}{ha}\right] = electricity\left[\frac{kWh}{ha}\right] * emission_factor_{electricity}\left[\frac{kgCO_{2eq}}{kWh}\right]$$

2.7. The GHG emissions due to seed production (E_{seed}) are calculated as follows:

$$E_{seed}\left[\frac{kgCO_{2eq}}{ha}\right] = seeds\left[\frac{kg}{ha}\right] * emission_factor_{production_seeds}\left[\frac{kgCO_{2eq}}{kg}\right]$$

3. Modeling CO2 emissions from land use (el)

3.1. Introduction

Land use activities in the agro forestry sector are one main source for anthropogenic greenhouse gas (GHG) emissions. The most important GHG emissions of concern are CO_2, N_2O (di-nitrogen

monoxide) und CH_4 (methane) (IPCC 2006). Approx. 30% of all anthropogenic GHG emissions between 1989 and 1998 could be allocated to land use activities (Carmenza and Blaser 2008). Land use changes, i.e. the transformation of one land use type to another, is responsible for approx. 2/3 of those emissions (Carmenza and Blaser 2008). In this context, optimization of land use activities and in particular land transformations plays a key role in reducing GHG emissions.

This standard establishes the framework for the calculation of land carbon stocks according to the methodology of the Roundtable on Sustainable Biomaterials (RSB) and provide all information required to calculate the CO_2 emissions associated with land use change.

3.2. Scope

3.2.1.Types

The land-use categories for greenhouse gas inventory reporting are:

(i) Forest Land

This category includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below, but *in situ* could potentially reach the threshold values used by a country to define the Forest Land category.

(ii) Cropland

This category includes cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.

(iii) Grassland

This category includes rangelands and pasture land that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastural systems, consistent with national definitions.

(iv) Wetlands

This category includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g., peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

(v) Settlements

This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with national definitions.

(vi) Other Land

This category includes bare soil, rock, ice, and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. If data are available, countries are encouraged to classify unmanaged lands by the above land-use categories (e.g., into Unmanaged Forest Land, Unmanaged Grassland, and Unmanaged Wetlands). This will improve transparency and enhance the ability to track land-use conversions from specific types of unmanaged lands into the categories above.

3.2.2.Strata

The broad land-use categories listed above may be further stratified by climate or ecological zone, soil and vegetation type, etc., as necessary, to match land areas with the methods for assessing carbon stock changes and greenhouse gas emissions and removals. Examples of stratifications that are used for Tier 1 emissions and removals estimation are summarized below. Specific stratification systems vary by land use and carbon pools.

Factor	Strata
Climate	Boreal Cold temperate dry Cold temperate wet Warm temperate dry Warm temperate moist Tropical dry Tropical moist Tropical wet
Soil	High activity clay Low activity clay Sandy Spodic Volcanic Wetland Organic

Biomass (Ecological zone)	Tropical rainforest Tropical moist deciduous forest Tropical dry forest Tropical shrubland Tropical desert Tropical mountain systems Subtropical humid forest Subtropical dry forest Subtropical steppe Subtropical desert Subtropical mountain systems Temperate oceanic forest Temperate continental forest Temperate steppe Temperate desert Temperate mountain systems Boreal coniferous forest Boreal tundra woodland Boreal mountain systems Polar
Management practice	Intensive tillage/Reduced till/No-till Long term cultivated Perennial tree crop Liming High/Low/Medium Input Cropping Systems Improved Grassland Unimproved Grassland

3.2.3.Types of Land Use Change

Tier 1 Land Use types in IPCC 2006 are used. Consequently, land use changes comprise managed ecosystem to managed ecosystem (e.g., cropland to cropland) and unmanaged ecosystem to managed ecosystem (e.g., forest to cropland). Palm oil plantations are treated as cropland, and concretely as a perennial crop/tree crop within the cropland category.

Figure 0-1 shows the types of land use transformations covered by the RSB-methodology. All land use categories refer to IPCC 2006 (IPCC 2006).

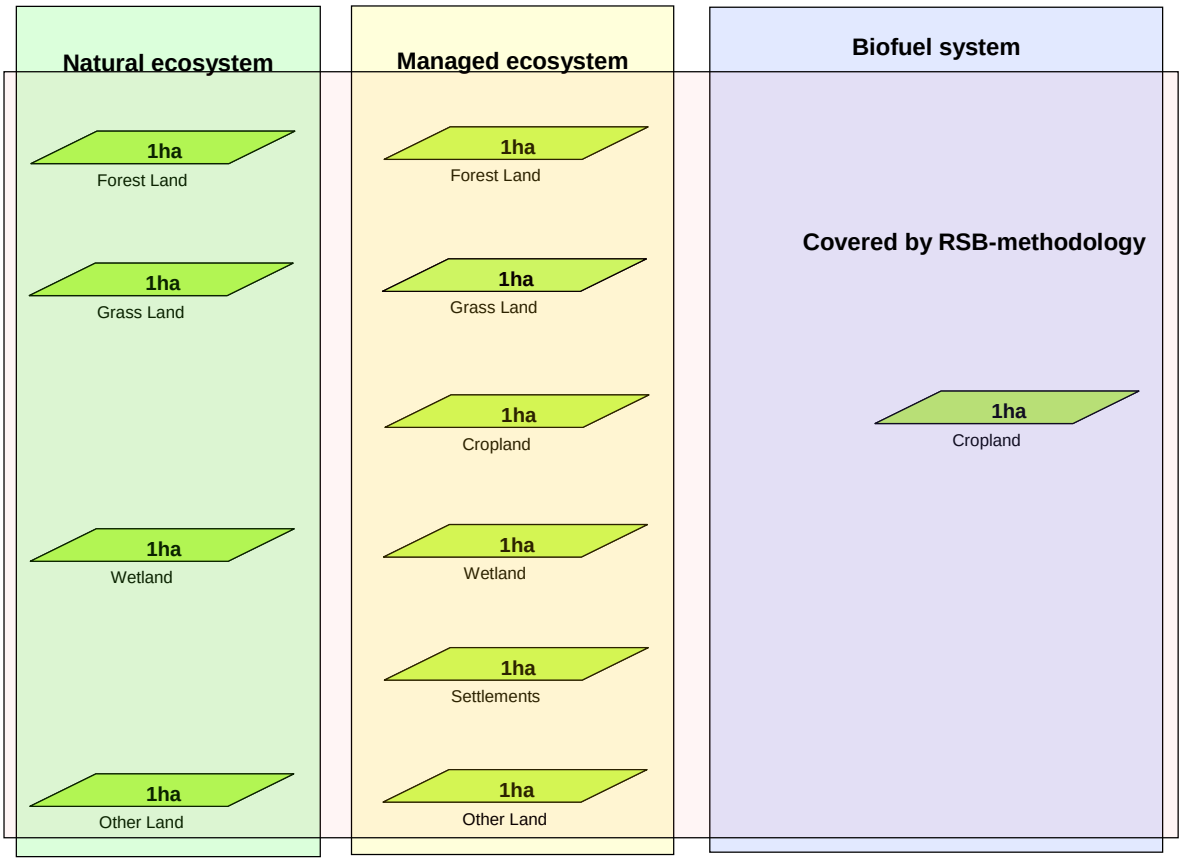

Figure 0-1: Land use changes, which can be calculated with the RSB Methodology. The categories are taken from the IPCC Guidlines 2006, p. 1.9. The RSB Methodology covers transformation of several natural and managed ecosystems to cropland.

In general, in order to calculate the CO_2 emissions from direct LUC, the carbon content of the implemented biofuel system (cropland) is subtracted from the carbon content of the land use at the reference date (01.01.2008). If a managed ecosystem is transformed to a biofuel system (a cropland), the carbon content of the baseline land use is calculated (i.e., the managed ecosystem) as that of a natural ecosystem.

The RSB methodology covers the transformation of natural ecosystems to biofuel systems as well as the transformation of managed ecosystems to biofuel systems. It covers only direct land use change emissions.

The user will be able to select the land use types that most appropriately define (a) their biofuel feedstock (“project land use type”), and (b) the “baseline land use type”.

3.2.4.Baseline and Project Land Use Type

The land use boundary comprises the total area affected by biofuel operations, including planted area, ecological corridors, buffer zones, etc.

- "Baseline land use type" is the land use type at the time of the baseline date. The baseline date is January 1, 2008 or earlier, if another sustainability standard (operational or currently under development) with an earlier cutoff date applied to the project.
- For RSB EU RED Calculations GHG emissions from any land use change that has occurred since 1 January 2008 shall be taken into account in the greenhouse gas calculation
    - "Project land use type" is as follows:
    - Annual crops: land use type at the time of maturity (after 1 year);
    - Perennial crops (life span more than a year): land use type at the time of evaluation (actual value).

3.2.5.Carbon pools taken into account

In order to determine the difference between the carbon content of the natural and the managed ecosystem three kind of carbon pools are taken into account:

(i) above ground biomass (AGB) and below ground biomass (BGB)

(ii) dead organic matter (DOM) and

(iii) soil organic carbon (SOC).

This corresponds to the tier 1 methodology determined in the IPCC 2006 (IPCC 2006). In the first step the carbon content of the baseline and use at the reference data is calculated. Starting from this carbon content, the carbon content of the projected land use is derived. Both carbon contents are calculated in dependence on (i) the ecozone, (ii) the land use category, (iii) the world region and (iiii) the cultivation practice. In the third step, the difference between both, i.e. the carbon content of the land use at the reference data and the biofuel land use is calculated and related to the functional unit. This include, the transformation of the calculated difference in carbon content to CO2 using the mol factor between C and CO2 (44/12).

3.2.6.Accounting Period and Annualization

Carbon emissions due to DLUC will be annualized over a 20-year period using a straight line discounting method. In other words, the accounting period refers to 20 years.

3.2.7.Carbon Stock (CS) Values

Carbon stock data, including above-ground biomass (AGB), soil organic carbon (SOC), and dead organic matter (DOM), are taken from IPCC 2006 (Tier 1 and 2[4]), except for Peat land, in which case such factors are based on Hooijer et al. (2006). Note that IPCC Tier 1 factors are built into the online

[4] Tier 2 uses the same methodological approach as Tier 1 but "applies emissions and stock change factors that are based on country- or region-specific data, for the most important land-use of regions…"

RSB Tool, but Tier 2 are not. The operator can enter CS data relevant to their operations if they have detailed knowledge of such data. Under IPCC 2006, this means using Tier 3[5] CS data.

3.2.8. Carbon Sequestration

The original land use biomass at baseline date can be harvested instead of discarded, and hence the embedded carbon would be effectively sequestered. For example, wood can be harvested and converted into wood or products, such as furniture or wood for construction, instead of being disposed of in a landfill.

One option could be to assign a carbon sequestration credit; this could be done based on the half life[6] of the product. However, carbon sequestration in biomass is *not* taken into account in the methodology because it would require, for consistency's sake, to assign carbon sequestration credits to all products in the system.

3.2.9. Differences to the Renewable Energy Directive (RED)

The RSB methodology differs with regard to the following aspects from the RED:

1. It takes account of forgone sequestration, i.e. carbon sequestration avoided by the land transformation.
2. It provides the possibility to take account of the GHG emissions associated with slashing and burning of the land use at reference date.
3. It considers N_2O emissions associated with a loss of soil organic carbon.

   For all other aspects RSB methodology uses the same assumptions and default values than the RED.

3.3. Calculation of Carbon Stocks

3.3.1. Central Equation

Equation 3-1: Equation for the computation of the annual CO_2 emissions from LUC in g CO_2 per kg crop (source: adapted from (IPCC 2006)

[5] Tier 3 "applies higher order methods, including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national level"

[6] RFS (2009), Table 2.4-28. Half-life for Forest Products in End Uses, p.366

$$\Delta CO_{2\,LUC_kgcrop} = \left[\frac{\left\{ \left(\Delta C_B - C_{SOILS} \right) * \left(\frac{44}{12} \right) * 1000 \right\} + L_{fire}}{\left(Y_{PLUC} * t \right)} \right] * 1000$$

Where

$\Delta CO_{2\,LUC_kgcrop}$ = annual CO_2 emissions from LUC **in g CO_2 per kg crop** at farm gate.

ΔC_B = change in carbon stocks in biomass on land converted to other land-use category, in tonne C ha-1 (use Equation 3-2 to determine ΔC_B).

C_{SOILS} = change in carbon stock in soil organic carbon, in tonne C ha-1.

$\left(\frac{-44}{12} \right)$ = Transformation of carbon to CO_2.

L_{fire} = amount of greenhouse gas emissions from fire, tonne of all GHG in kg CO_2 equiv. ha-1. Use Equation 3-4.

Y_{PLUC} = annual yield of the projected land use, in kg ha-1 fresh mass.

t = accounting period, 20 years

3.3.2. Calculation of carbon losses / gains from the difference in vegetation

Equations

In order to calculate the change in carbon stocks in biomass Equation 3-2 subtracts the net carbon accumulation by the projected land use from the carbon stored in the land use at the reference date. All terms in the equation refer to the given accounting period of 20 years, e.g. the decrease in biomass carbon stocks due to losses from harvesting reflect the amount of carbon harvested over 20 years.

Equation 3-2: Calculation of greenhouse gas emissions from biomass (source: adapted from (IPCC 2006), p. 2.20.)

$$\Delta C_B = \left[\left[AGB_{Total} + BGB_{Total} + DOM_{Total} + C_{Foregone} \right] - B_{fire} \right] - \left[\left(C_{G\,Total} - C_L \right) \right]$$

Where:

ΔC_B = change in carbon stocks in biomass on land converted to other land-use category, in tonne C.

AGB_{Total} = total carbon content of AGB per ha-1 in tons C. Determine AGB value of the former land use by means of the respective land use type and Table 2 -10.

BGB_{Total} = total carbon content of below ground biomass (BGB) per ha-1 in tons C. Determine BGB value of the former land use by means of the respective land use type and Table 2 -10.

DOM_{Total} = total carbon content of dead organic matter (DOM) per ha-1 in tons C. Only relevant if the former land use was forest land. Use Equation 3-3.

$C_{Foregone}$ = annual carbon sequestration avoided by the land use change, i.e. foregone sequestration in tonne C ha-1. Use Table 0-15.

B_{fire} = biomass carbon losses due to fire in tonne C per ha-1. Use Equation 3-5.

C_L = decrease in biomass carbon stocks due to losses from harvesting on the projected land use over the given accounting period in tonne C ha-1. See Equation **3-7**.

C_{GTotal} = gross increase in carbon stocks in biomass due to growth on the projected land use over the given accounting period, in tonne C ha-1. See Equation 3-6.

Dead organic matter (DOM) consists of dead wood and litter. IPCC 2006 (IPCC 2006) only provides default carbon values for litter in natural forests. Table 0-14 shows the available default values.

Equation 3-3: Annual change in carbon stocks in dead wood and litter due to land conversion (source: adapted from IPCC (2006).

$$DOM_{Total} = (C_{DW} + C_{LT})$$

Where:

DOM_{Total} = Total dead organic matter in a forest in tonne C yr-1.

C_{DW} = dead wood stock, tonne C ha-1.

C_{LT} = litter stock, tonne C ha-1. See Table 0-14 for default values.

The RSB does consider the greenhouse gas emissions caused by fires on the land use at reference date. The calculation in the brackets is done for each GHG separately, e.g., CH_4, N_2O, etc.

Equation 3-4: Calculation of greenhouse gas emissions from fire (source: adapted from IPCC (2006).

$$L_{fire} = \sum_i If_i * \left\{ \left[(AGB_{Total} + DOM_{Total}) * C_f \right] * \left(G_{ef} * 10^{-3} \right) \right\}_i$$

Where:

L_{fire} = Global Warming Potential (GWP) induced by fires, in kg CO_2 equiv. per ha-1;

If = impact factor of the fuel in terms of CO_2 equiv.; Use Table 0-19.

AGB_{Total} = carbon content of above ground biomass. Determine AGB value of the land use at reference date by means of the respective land use type and AGB values listed in Tables in this Chapter.

DOM_{Total} = carbon content of dead organic matter. Only relevant if land use at reference date is forest land.

C_f = combustion factor, dimensionless. To select the appropriate default value use Table 0-20.

G_{ef} = emission factor, g per kg-1 dry matter burnt; Use Table 0-18 to determine the appropriate value.

i = the respective greenhouse gas, e.g. methane.

The calculation of carbon losses induced by fires is done in order to avoid double counting.

Equation 3-5: Calculation of carbon losses induced by fires (source: adapted from IPCC (2006).

$$B_{fire} = \left[AGB_{Total} * C_f \right] + \left[DOM_{Total} * C_f \right]$$

Equation 3-6: Annual gross increase in biomass carbon stocks due to biomass increment in the projected land use (source: adapted from (IPCC 2006)).

$$C_{GTotal} = C_{Gn} + C_L$$

Where:

C_{GTotal} = average gross increase in biomass carbon stocks due to biomass growth over the given accounting period, tonne C per ha-1. For annual crops C_{GTotal} is assumed to be equal to C_L , i.e. C_{Gn}, the net increase in biomass carbon stocks is zero.

C_{Gn} = mean net increase in biomass carbon stocks due to biomass growth by vegetation type and climatic zone, tonne C per ha-1. For the growth rate of sugarcane, miscanthus, generic

or specific perennial crops use the default values given in the Tables in this chapter. For all other croplands use zero.

C_L = biomass carbon loss due to biofuel harvest over the assessed time period, ton carbon ha-1 over the accounting period.

3.3.3.Annual carbon losses on the projected land use induced by biofuel harvest

Equation 3-7: Annual carbon loss in biomass of biofuel removals (source: adapted from (IPCC 2006), p. 2.15).

$$C_L = t\left(Y_{Biofuel} * CF\right)$$

Where:

C_L = biomass carbon loss due to biofuel harvest over the assessed time period, tonne carbon ha-1 yr-1.

$Y_{Biofuel}$ = amount of biomass harvested over the given accounting period, tonne d. m. ha-1.

CF = carbon fraction of dry matter, tonne C per tonne d.m. Use Table ***0-17***.

t = time period, use 20 years as default.

3.3.4.Tables

As shown by Table 0-6, for annual crops the general assumption is that all of the AGB and BGB is harvested in the production period. In other words, the carbon harvested with the biomass is assumed to be equal to the carbon accumulated during the production period. Consequently, the mean annual net increase in biomass carbon stocks is zero.

Table 0-6: Vegetation values for annual cropland (general).

Climate region	**RSB**			**RED**
	AGB [tonne C per ha-1]	**BGB [tonne C per ha-1]**	**C_{Gn} [tonne C per ha-1]**	**CVeg [tonne C per ha-1]**
All	n.a.	n.a.	0	0

For perennial crops Table 0-7, Table 0-8, Table 0-9 and Table 0-10 give default values for C_{Gn}.

Table 0-7: Vegetation values for perennial crops (general). Only the carbon accumulation of the half production cycle is taken into account. Consequently, the sum of AGB and BGB (which reflect the carbon accumulated over 20 years) is multiplied with 0.5. Source: adapted from (Commission 2010).

Climate region	RSB			RED
	AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	C_{Gn} [tonne C per ha-1]	Cveg [tonne C per ha-1]
Temperate (all moisture regimes)	63	23.3	43.2	43.2
Tropical, dry	9	3.3	6.2	6.2
Tropical, moist	21	7.8	14.4	14.4
Tropical, wet	50	18.5	34.3	34.3

Table 0-8: Vegetation values for specific perennial crops. Values reflect literature data. The half cycle is taken into account, i.e. the amount of carbon accumulated after 10 years. Source: adapted from (Commission 2010).

Climate region	Croptype	RSB			RED
		AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	C_{Gn} [tonne C per ha-1]	CVeg [tonne C per ha-1]
All	Coconuts	n.a.	n.a.	75	75
Tropical, dry	Jatropha	n.a.	n.a.	17.5	17.5
Tropical, moist	Jojoba	n.a.	n.a.	2.4	2.4
Tropical, wet	Oil Palm	n.a.	n.a.	60	60

Table 0-9: Vegetation values for miscanthus (specific). Due to the annual harvest AGB is not taken into account. However, BGB, i.e. carbon accumulation due to roots, is accounted for. The carbon content per kg dry mass is assumed to be 50% Source: adapted from (Commission 2010).

Domain	Climate	Ecological	Continent	RSB	RED

	region	zone		AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	C_{Gn} [tonne C per ha-1]	CVeg [tonne C per ha-1]
Subtropical	Warm temperate dry	Subtropical dry forest	Europe	0	10	10	10
			North America	0.	14.9	14.9	14.9
		Subtropical steppe	North America	0	14.9	14.9	14.9

Table 0-10: Vegetation values for sugar cane (source: adapted from (Commission 2010)

Domain	Climate region	Ecological zone	Continent	RSB		RED
				AGB [tons C per hectare)	BGB [tonne C per ha-1]	CVeg [tonne C per ha-1]
Tropical	Tropical dry	Tropical dry forest	Africa	0	4.2	4.2
			Asia (continental, insular)	0	4	4
		Tropical shrub land	Asia (continental, insular)	0	4	4
	Tropical moist	Tropical moist deciduous forest	Africa	0	4.2	4.2
			Central and South America	0	5	5
	Tropical wet	Tropical rain forest	Asia (continental, insular)	0	4	4
			Central and South America	0	5	5
Subtropical	Warm temperate dry	Subtropical steppe	North America	0	4.8	4.8
	Warm tem-	Subtropical	Central and	0	5	5

	perate moist	humid forest	South America			
			North America	0	4.8	4.8

Table 0-11: Vegetation values for grassland (general). Source: adapted from (IPCC 2006; Commission 2010).

Climate region	RSB			RED
	AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	Total [tonne C per ha-1]	CVeg [tonne C per ha-1]
Boreal – Dry & Wet	0.79	3.51	4.3	4.3
Cool Temperate – Dry	0.79	2.51	3.3	3.3
Cool Temperate – Wet	1.13	5.67	6.8	6.8
Warm Temperate – Dry	0.75	2.35	3.1	3.1
Warm Temperate – Wet	1.27	5.53	6.8	6.8
Tropical – Dry	1.08	3.32	4.4	4.4
Tropical – Moist & Wet	2.91	5.19	8.1	8.1

Table 0-12: Vegetation values for scrubland namely land with vegetation composed largely of woody plants lower than 5 meter not having clear physiognomic aspects of trees. Source: adapted from (Commission 2010).

Domain	Continent	RSB			RED
		AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	Total [tonne C per ha-1]	CVeg [tonne C per ha-1]
Tropical	Africa	33	13	46	46

	North and South America	38	15	53	53
	Asia (continental)	28	11	39	39
	Asia (insular)	33	13	46	46
	Australia	33	13	46	46
Subtropical	Africa	33	10	43	43
	North and South America	28	12	50	50
	Asia (continental)	28	9	37	37
	Asia (insular)	33	10	43	43
	Australia	32	11	43	43
Temperate	Global	5	2	7	7

Table 0-13: Vegetation values for forest land – excluding forest plantations – having between 10% and 30% canopy cover. Values are calculated using 20% of the values of the AGB + BGB values of mature forest outlined by the IPCC (without DOM). Values are rounded Source: adapted from (Commission 2010).

Domain	Ecological zone	Continent	RSB (IPCC 2006)			RED
			AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	Total [tonne C per ha-1]	CVeg [tonne C per ha-1]
Tropical	Tropical rain forest	Africa	29	11	40	40
		North and South	28	10	39	39
		Asia (continental)	26	10	36	36
		Asia (insular)	33	12	45	45
	Tropical moist forest	Africa	24	6	30	30
		North and South	21	5	26	26
		Asia (continental)	17	4	21	21
		Asia (insular)	27	7	34	34
	Tropical dry forest	Africa	11	3	14	14
		North and South	20	6	25	25
		Asia (continental)	12	3	16	16
		Asia (insular)	15	4	19	19
	Tropical mountain sys-tems	Africa	21	8	13	13
		North and South	17	1	17	17
		Asia (continental)	27	12	16	16
		Asia (insular)	13	13	26	26
Subtropical	Subtropical humid forest	North and South	20	7	26	26
		Asia (continental)	12	9	22	22
		Asia (insular)	15	20	35	35
	Subtropical dry forest	Africa	8	9	17	17
		North and South	8	18	26	26
		Asia (continental)	6	10	16	16
		Asia (insular)	7	13	20	20
	Subtropical steppe	Africa	8	2	9	9
		North and South	8	2	10	10
		Asia (continental)	6	1	7	7
		Asia (insular)	7	2	9	9

Temperate	Temperate oceanic forest	Europe	11	3	14	14
		North America	62	17	79	79
		New Zealand	34	9	43	43
		South America	17	5	21	21
	Temperate continental forest	Asia, Europe	2	1	2	2
		Asia, Europe	11	3	14	14
		North and South	6	2	7	7
		North and South	12	3	16	16
	Temperate mountain systems	Asia, Europe	9	3	12	12
		Asia, Europe	12	3	16	16
		North and South	5	1	6	6
		North and South	5	1	6	6
Boreal	Boreal coniferous forest	Asia, Europe, North America	8	2	12	12
	Boreal tundra woodland	Asia, Europe,	0	0	0	0
		Asia, Europe,	2	0	2	2
	Boreal mountain system	Asia, Europe,	1	0	2	2
		Asia, Europe,	5	1	6	6

Table 0-14: Vegetation values for forest land – excluding forest plantations – having more than 30% canopy cover. Calculated on the basis of (IPCC 2006) using a carbon content of 0.47 kg C per kg d.m. DOM only includes litter, i.e. if specific values for the dead wood stock must be added separately.

Domain	Ecological zone	Continent	RSB				RED
			AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	DOM [tonne C per ha-1]	Total [tonne C per ha-1]	CVeg [tonne C per ha-1]
Tropical	Tropical rain forest	Africa	146	54	5	205	205
		North and	141	52	5	198	198
		Asia (conti-	132	49	5	185	185
		Asia (insu-	165	61	5	231	231
	Tropical moist for-	Africa	122	29	5	157	157
		North and	103	25	5	133	133
		Asia (conti-	85	20	5	110	110

	est	Asia (insu-	236	33	5	174	174
	Tropical dry forest	Africa	56	16	5	77	77
		North and	99	28	5	132	132
		Asia (conti-	61	17	5	83	83
		Asia (insu-	75	21	5	101	101
	Tropical mountain systems	Africa	56	15	5	77	77
		North and	71	19	5	95	95
		Asia (conti-	66	18	5	89	89
		Asia (insu-	99	27	5	131	131
Subtropical	Subtropical humid for- est	North and	103	25	4	132	132
		Asia (conti-	85	20	4	109	109
		Asia (insu-	136	33	4	173	173
	Subtropical dry forest	Africa	66	18	4	88	88
		North and	99	28	4	130	130
		Asia (conti-	61	17	4	82	82
		Asia (insu-	75	21	4	100	100
	Subtropical steppe	Africa	33	9	4	46	46
		North and	38	12	4	54	54
		Asia (conti-	28	9	4	41	41
		Asia (insu-	33	11	4	48	48
Temperate	Temperate oceanic forest	Europe	56	15	13	85	84
		North Amer-	310	84	13	407	406
		New Zea-	169	46	13	228	227
		South America	85	23	13	120	120
	Temperate continental forest	Asia, Eu-	9	3	16	28	28
		Asia, Eu-	56	15	16	88	88
		North and	28	8	16	52	52
		North and	61	16	16	94	94
	Temperate mountain systems	Asia, Eu-	47	13	16	76	76
		Asia, Eu-	61	16	16	94	94
		North and	24	6	16	46	46
		North and	61	16	16	94	94
Boreal	Boreal co-	Asia, Eu-	24	6	25	54	54
	Boreal tundra	Asia, Eu-	2	0	25	27	27
		Asia, Eu-	9	2	25	37	37
	Boreal	Asia, Eu-	7	2	25	34	34

	mountain	Asia, Eu-	24	6	25	54	54

Table 0-15: Foregone sequestration caused by deforestation of forest. Values are calculated on the basis of Table 4.9 (IPCC 2006) using a using a carbon content of 0.47 kg C per kg d.m.

Domain	*Ecological zone*	*Continent*	*Maturity*	*Foregone sequestration [tonne C per ha-1]*
Tropical	Tropical rain forest	Africa	<= 20 y	94
		Africa	> 20 y	29
		North America	n.a.	89
		South America	<= 20 y	109
		South America	> 20 y	29
		Asia (continental)	<= 20 y	66
		Asia (continental)	> 20 y	21
		Asia (insular)	<= 20 y	122
		Asia (insular)	> 20 y	32
	Tropical moist forest	Africa	<= 20 y	47
		Africa	> 20 y	12
		North and South America	<= 20 y	66
		North and South America	> 20 y	19
		Asia (continental)	<= 20 y	85
		Asia (continental)	> 20 y	19
		Asia (insular)	<= 20 y	103
		Asia (insular)	> 20 y	28
	Tropical dry forest	Africa	<= 20 y	23
		Africa	> 20 y	17
		North and South America	<= 20 y	38
		North and South America	> 20 y	9
		Asia (continental)	<= 20 y	56
		Asia (continental)	> 20 y	14
		Asia (insular)	<= 20 y	66
		Asia (insular)	> 20 y	19
	Tropical shrubland	Africa	<= 20 y	4
		Africa	> 20 y	8
		North and South America	<= 20 y	38

		North and South America	> 20 y	9
		Asia (continental)	<= 20 y	47
		Asia (continental)	> 20 y	12
		Asia (insular)	<= 20 y	19
		Asia (insular)	> 20 y	9
	Tropical mountain systems	Africa	<= 20 y	33
		Africa	> 20 y	12
		North and South America	<= 20 y	32
		North and South America	> 20 y	8
		Asia (continental)	<= 20 y	28
		Asia (continental)	> 20 y	7
		Asia (insular)	<= 20 y	71
		Asia (insular)	> 20 y	19
Subtropical	Subtropical humid forest	North and South America	<= 20 y	66
		North and South America	> 20 y	19
		Asia (continental)	<= 20 y	85
		Asia (continental)	> 20 y	19
		Asia (insular)	<= 20 y	103
		Asia (insular)	> 20 y	28
	Subtropical dry forest	Africa	<= 20 y	23
		Africa	> 20 y	17
		North and South America	<= 20 y	38
		North and South America	> 20 y	9
		Asia (continental)	<= 20 y	56
		Asia (continental)	> 20 y	14
		Asia (insular)	<= 20 y	66
		Asia (insular)	> 20 y	19
	Subtropical mountain system	Africa	<= 20 y	33
		Africa	> 20 y	12
		North and South America	<= 20 y	32
		North and South America	> 20 y	8
		Asia (continental)	<= 20 y	28
		Asia (continental)	> 20 y	7
		Asia (insular)	<= 20 y	81
		Asia (insular)	> 20 y	19
Temperate	Temperate oce-	Europe	n.a.	22

	anic forest	North America	n.a.	141
		New Zealand	n.a.	33
		South America	n.a.	53
	Temperate con-	Asia, Europe (<=20 y)	<= 20 y	38
	tinental forest	Asia, Europe (<=20 y)	> 20 y	38
		North and South America	<= 20 y	38
		North and South America	> 20 y	38
		North and South America	<= 20 y	38
	Temperate	Asia, Europe, North Ameri-	n.a.	28
Boreal	Boreal conifer-	Asia, Europe, North Ameri-	n.a.	10
	Boreal tundra	Asia, Europe, North Ameri-	n.a.	4
	Boreal mountain	Asia, Europe, North Ameri-	<= 20 y	12
	system	Asia, Europe, North Ameri-	> 20 y	10

Table 0-16: Vegetation values for forest plantations. The half cycle is used to assess the carbon accumulation within the accounting period, i.e. the total carbon accumulation is divided by two. Source: adapted from (IPCC 2006) and (Commission 2010).

Domain	Ecological zone	Continent	RSB			RED
			AGB [tonne C per ha-1]	BGB [tonne C per ha-1]	Total [tonne C per ha-1]	CVeg [tonne C per ha-1]
Tropical	Tropical rain forest	Africa broadleaf>20 y	141	34	87	87
		Africa broadleaf =<20 y	47	11	29	29
		Africa Pinus sp. >20 y	94	23	58	58
		Africa Pinus sp. =<20 y	28	7	17	17
		Americas Eucalyptus sp.	94	23	58	58
		Americas Pinus sp.	141	34	87	87
		Americas Tectona gran-	113	27	70	70
		Americas other broad-	71	17	44	44
		Asia broadleaf	103	25	64	64
		Asia other	61	15	38	38
Tropical	Tropcal moist de-	Africa broadleaf>20 y	71	17	44	44
	ciduous	Africa broadleaf =<20 y	38	9	23	23
		Africa Pinus sp. >20 y	56	14	35	35

	forest	Africa Pinus sp. =<20 y	19	5	12	12
		Americas Eucalyptus sp.	42	10	26	26
		Americas Pinus sp.	127	30	79	79
		Americas Tectona gran-	56	14	35	35
		Americas other broad-	47	11	29	29
		Asia broadleaf	85	20	52	52
		Asia other	47	11	29	29
Tropical	Tropical dry forest	Africa broadleaf>20 y	33	9	8721	8721
		Africa broadleaf =<20 y	14	4	9	9
		Africa Pinus sp. >20 y	28	8	18	18
		Africa Pinus sp. =<20 y	9	3	6	6
		Americas Eucalyptus sp.	42	12	27	27
		Americas Pinus sp.	52	14	33	33
		Americas Tectona gran-	42	12	27	27
		Americas other broad-	28	8	18	18
		Asia broadleaf	42	12	27	27
		Asia other	28	8	18	18
Tropical	Tropical shrubland	Africa broadleaf	9	3	6	6
		Africa Pinus sp. >20 y	9	3	6	6
		Africa Pinus sp. =<20 y	7	2	4	4
		Americas Eucalyptus sp.	28	8	18	18
		Americas Pinus sp.	28	8	18	18
		Americas Tectona gran-	24	6	15	15
		Americas other broad-	14	4	9	9
		Asia broadleaf	19	5	12	12
		Asia other	14	4	9	9
Tropical	Tropical mountain systems	Africa broadleaf>20 y	49	12	31	31
		Africa broadleaf=>20 y	33	8	20	20
		Africa Pinus sp. =<20 y	31	7	19	19
		Africa Pinus sp. =<20 y	12	3	7	7
		Americas Eucalyptus sp.	35	8	22	22
		Americas Pinus sp.	54	13	29	29
		Americas Tectona gran-	38	9	23	23
		Americas other broad-	26	6	16	16
		Asia broadleaf	45	11	28	28
		Asia other	25	6	15	15

Subtropical	Subtropical humid for- est	Americas Eucalyptus sp.	66	18	42	42
		Americas Pinus sp.	127	36	81	81
		Americas Tectona gran-	56	16	36	36
		Americas other broad-	47	13	30	30
		Asia broadleaf	85	24	54	54
		Asia other	47	13	30	30
Subtropical	Subtropical dry forest	Africa broadleaf>20 y	33	9	21	21
		Africa broadleaf =<20 y	14	5	9	9
		Africa Pinus sp. >20 y	28	9	19	19
		Africa Pinus sp. =<20 y	9	3	6	6
		Americas Eucalyptus sp.	52	17	34	34
		Americas Pinus sp.	52	17	34	34
		Americas Tectona gran-	42	14	28	28
		Americas other broad-	28	9	19	19
		Asia broadleaf	42	14	28	28
		Asia other	28	9	19	19
Subtropical	Subtropical steppe	Africa broadleaf	9	3	6	6
		Africa Pinus sp. >20 y	9	3	6	6
		Africa Pinus sp. =<20 y	7	2	5	5
		Americas Eucalyptus sp.	28	9	19	19
		Americas Pinus sp.	28	9	19	19
		Americas Tectona gran-	24	8	16	16
		Americas other broad-	14	5	9	9
		Asia broadleaf > 20 y	38	12	25	25
		Asia broadleaf =< 20 y	5	2	3	3
		Asia coniferous > 20 y	9	3	6	6
		Asia coniferous =< 20 y	52	17	34	34
Subtropical	Subtropical mountain systems	Africa broadleaf>20 y	49	12	31	31
		Africa broadleaf =<20 y	33	8	20	20
		Africa Pinus sp. >20 y	31	7	19	19
		Africa Pinus sp. =<20 y	12	3	7	7
		Americas Eucalyptus sp.	35	8	22	22
		Americas Pinus sp.	54	13	34	34
		Americas Tectona gran-	38	9	23	23
		Americas other broad-	26	6	16	16
		Asia broadleaf	45	11	28	28

		Asia other	25	6	15	15
Temperate	Temperate oceanic forest	Asia, Europe, broad-	94	25	60	60
		Asia, Europe, broadleaf	14	4	9	9
		Asia, Europe, coniferous	94	25	60	60
		Asia, Europe, coniferous	19	5	12	12
		North America	82	22	52	52
		New Zealand	118	32	75	75
		South America	49	13	31	31
Temperate	Temperate continental forest and mountain systems	Asia, Europe, broad-	94	25	60	60
		Asia, Europe, broadleaf	7	2	4	4
		Asia, Europe, coniferous	82	22	52	52
		Asia, Europe, coniferous	13	3	7	7
		North America	82	22	52	52
		South America	49	13	31	31
Boreal	Boreal coniferous forest and	Asia, Europe > 20 y	19	5	12	12
		Asia, Europe =< 20 y	2	1	1	1
		North America	21	5	13	13
Boreal	Boreal tundra woodland	Asia, Europe > 20 y	12	3	7	7
		Asia, Europe =< 20 y	2	1	1	1
		North America	12	3	7	7

Table 0-17: Default crop parameters. Carbon fraction of the respective crops can be used to determine C_L , the biomass carbon loss due to biofuel harvest. Only relevant if no default data for C_{Gn} (the mean net increase in biomass carbon stocks due to biomass growth) is available. Source: Ecoinvent (Jungbluth, Chudacoff et al. 2007)

Crop	Carbon fraction [kg C / kg crop fresh mass]	Moisture	Cultivation time [month]
Rape seed	0.732	6%	10.83
Soybeans	0.374	11%	6
Sugar beets	0.088	77%	7
Sugar cane	0.123	n.a.	10.8
Sweet sor-	0.115	73%	4.01

ghum stem			
Jatropha seed	0.575	5%	12
Potatoes	0.087	78%	5.67
Palm fruit bunches	0.313	47%	12

Table 0-18: Emission factors (g kg dry matter burnt) for various types of burning. Source: adapted from (IPCC 2006).

Category	CO2	CO	CH4	N2O	NOx
Savannah and grass-land	1613	65	2.3	0.21	2.9
Agricultural residues	1515	92	2.7	0.07	2.5
Tropical forest	1569	107	6.8	0.2	1.6
Extra trop-ical forest	1569	107	4.7	0.26	3.0
Biofuel burning	1550	78	6.1	0.06	1.1

Table 0-19: Impact factor (Global Warming Potential) for prominent greenhouse gases according to ReCiPe (Goedkoop, Heijungs et al. 2009).

Category	CO2	CO	CH4	N2O	NOx
Savannah and grassland	1	0	24	298	0

Table 0-20: Combustion factor values (proportion of pre-fire fuel biomass consumed) for fires in a range of vegetation types. Source: adapted from (IPCC 2006).

Vegetation type	Subcategory	Combustion factor
Primary tropical forest (slash and burn)	Primary tropical forest	0.32
	Primary open tropical forest	0.45
	Primary tropical moist forest	0.50
	Primary tropical dry forest	-
All primary topical forests		0.36
Secondary tropical forest (slash and burn)	Young secondary tropical forest (3-5 yrs)	0.46
	Intermediate secondary tropical forest (6-10 yrs)	0.6
	Advanced secondary tropical forest (14-17 yrs)	0.5
All secondary tropical forests		0.55
All tertiary topical forest		0.59
Boreal forest	Wildfire (general)	0.40
	Crown fire	0.43
	Surface fire	0.15
	Post logging slash burn	0.33
	Land clearing fire	0.59
All boreal forest		0.34
Eucalyptus forests	Wildfire	-
	Prescribed fire – (surface)	0.61
	Post logging slash burn	0.68
	Felled and burned (land clearing fire)	0.49

All Eucalyptus forest		0.63
Other temperate forests	Post logging slash burn	0.62
	Felled and burned (land-clearing fire)	0.51
All “other” temperate forests		0.45
Shrublands	Shrubland (general)	0.95
	Callina heath	0.71
	Fynbos	0.61
All shrublands		0.72
Savannah woodlands (mid/late dry season burns)	Savannah woodland	0.72
	Savannah parkland	0.82
	Tropical savannah	0.73
	Other savannah woodlands	0.68
All savannah woodlands (mid/late dry season burns)		0.74
Other vegetation types	Peatland	0.50
	Tropical wetlands	0.70
Agricultural residues	Wheat residues	0.90
	Maize residues	0.80
	Rice residues	0.80
	Sugarcane	0.80

3.3.5.Calculation of carbon losses / gains from soils

3.3.5.1. Equations

Equation 3-8: Annual change in carbon stocks in soil organic carbon (source: adapted from IPCC (2006).

$$C_{Soils} = \left[\Delta C_{Mineral} + L_{N_2O_mineral} - \left\{\left(L_{Organic} + L_{N_2O_organic}\right)\right\}\right]$$

Where

C_{Soils} = change in carbon stocks in soils, tonne C per ha-1 in 30 cm depth.

$\Delta C_{Mineral}$ = change in organic carbon stocks in mineral soils, tonne C per ha-1, use Equation 3-9.

$L_{N_2O_mineral}$ = loss of carbon stemming from N_2O emission, in tons C per ha-1, use Equation 3-10.

$L_{Organic}$ = annual loss of carbon stocks from drained organic soils, tonne C per ha-1 yr-1. For peat land the emission given by Hooijer are applied (Hooijer, Silvius et al. 2006), i.e. 469 tonne C per hectare (23.45 tonne C per hectare multiplied with 20 years, the accounting period). For all other organic soils no default data is available.

$L_{N_2O_organic}$ = annual loss of N_2O emission from organic soils expressed in tonne C per ha-1 yr-1, use Equation 3-11.

Equation 3-9: Annual change in organic carbon stocks in mineral soils (source: adapted from IPCC (2006).

$$\Delta C_{Mineral} = \left[\left(SOC_{(0-T)} - SOC_{0\ projected_nochange}\right) - \left(SOC_{(0-T)} - SOC_{0\ projected_biofuel}\right)\right]$$

$$SOC = SOC_{REF_{c,s,i}} * F_{LU_{c,s,i}} * F_{MG_{s,s,i}} * F_{I_{c,s,i}}$$

Where:

$\Delta C_{Mineral}$ = annual change in carbon stocks in mineral soils, tonne C.

$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time period, tonne C ha-1. Use the ecozone, the land use, the soil type and the soil characteristic to determine SOC(0-T) from Table 0-21.

SOC_0 = soil organic carbon stock in the last year of the time period, tonne C ha-1.

$SOC_{0\ projected_unchanged}$= soil organic carbon stock in the last year of the time period in tonne C ha-1, if no land use change would have occurred (Note: equivalent to $SOC_{REF_{c,s,i}}$ if the reference land use is Forest land).

$SOC_{0\ projected_biofuel}$ = soil organic carbon stock in the last year of the time period in tonne C ha-1, if the land use change to the biofuel system has occurred.

c = represents the climate zones, *s* the soil types, and *i* the set of management systems that are present.

$SOC_{REF_{c,s,i}}$ = the reference soil organic carbon stock, tonne C ha-1, i.e. equivalent to SOC(0-T). See Table 0-21.

$F_{LU_{c,s,i}}$ = stock change factor for land-use systems or sub-system for a particular land-use, dimensionless. Use Table 0-23, Table 0-24, Table 0-25, Table 0-26, Table 0-27 and Table 0-28 to determine the LU factor for cropland, grassland and forest land, respectively.

$F_{MG_{s,s,i}}$ = stock change factor for management regime, dimensionless. Use Table 0-23, Table 0-24, Table 0-25, Table 0-26, Table 0-27 and Table 0-28 to determine the LU factor for cropland, grassland and forest land, respectively.

$F_{I_{c,s,i}}$ = stock change factor for input of organic matter, dimensionless. Use Table 0-23, Table 0-24, Table 0-25, Table 0-26, Table 0-27 and Table 0-28 to determine the LU factor for cropland, grassland and forest land, respectively.

Equation 3-10: Carbon emissions associated with N mineralized in mineral soils as a results of loss of soil c through change in lad use or management (source: adapted from (IPCC 2006)).

$$L_{N_2O_mineral} = \frac{If * \left[Ef1 * (\Delta C_{Mineral} * \frac{1}{R}) \right]}{\left(\frac{44}{12} \right)}$$

Where:

$L_{N_2O_mineral}$ = N_2O emission expressed in tons C per ha-1.

If = impact factor of N_2O in terms of CO_2 equiv., use 298 as a default (Goedkoop, Heijungs et al. 2009).

$Ef1$ = emission factor N mineralised from mineral soil as a result of loss of soil carbon in kg N_2O–N (kg N)-1. Use 0.01 as default.

ΔCMineral = annual change in carbon stocks in mineral soils, tonne C. Use ΔCMineral from Equation 3-9.

R = C:N ratio of the soil organic matter. Determine R according to the land use at ref. date. If land use at ref. was forest or grassland set R =15, otherwise set R = 10.

$\frac{44}{12}$ = transformation factor from CO_2 to C.

Equation 3-11: Carbon emissions associated with N emitted by organic soils (source: adapted from (IPCC 2006)).

$$L_{N_2O_organic} = \frac{If * \left(Ef2 * \frac{44}{28} \right)}{\left(\frac{44}{12} \right)}$$

Where:

$L_{N_2O_organic}$ = N_2O emission expressed in tons C per ha-1 y-1.

If = impact factor of N_2O in terms of CO2 equiv., use 298 as a default (Goedkoop, Heijungs et al. 2009).

$Ef2$ = emission factor for N emitted by managed organic soils, in kg N_2O–N (kg N)-1. Use the ecozone and the projected land use to determine $Ef2$ from Table 0-22.

$\frac{44}{28}$ = transformation factor from N to N_2O.

3.3.5.2. Tables

Table 0-21: SOC_{REF}, i.e. standard soil organic carbon content in the 0-30 centimetre topsoil layer (source: (IPCC 2006))

Climate Region	High activity clay soil	Low activity clay soil	Sandy soil	Spodic soil	Volcanic soils	Wetland soils
Boreal	68	0	10	117	20	146
Cold temperate, dry	50	33	34		20	87
Cold temperate, moist	95	85	71	115	130	87
Warm temperate, dry	38	24	19		70	88

Warm temperate, moist	88	63	34		80	88
Tropical, dry	38	35	31		50	86
Tropical, moist	65	47	39		70	86
Tropical, wet	44	60	66		130	86
Tropical, montane	88	63	34		80	86

Table 0-22: Default emission factors to estimate direct N_2O emissions from managed soils (source: (IPCC 2006)).

Climate Region	Soil type	Default value [kg N2O-N ha-1]
Temperate	Organic crop and grassland soils	8
Temperate / Boreal	Organic nutrient rich forest soils	0.6
	Organic nutrient poor forest soils	0.1
Tropical	Organic crop and grassland soils	16
	Organic forest soils	8

Table 0-23: Factors for cropland (FLU_C) and for perennial crops (FLU_P), namely multi-annual crops whose stem is usually not annually harvested such as short rotation coppice and oil palm (source: adapted from (IPCC 2006))

Climate re-	Land use	Management	Input	FLU_C	FLU_P	FMG	FI
Temperate / Boreal, dry	Cultivated	Full-tillage	Low	0.8	1	1	0.95
			Medium	0.8	1	1	1
			High with manure	0.8	1	1	1.37
			High without ma-	0.8	1	1	1.04
		Reduced till-	Low	0.8	1	1.02	0.95
			Medium	0.8	1	1.02	1

		age	High with manure	0.8	1	1.02	1.37
			High without ma-	0.8	1	1.02	1.04
		No tillage	Low	0.8	1	1.1	0.95
			Medium	0.8	1	1.1	1
			High with manure	0.8	1	1.1	1.37
			High without ma-	0.8	1	1.1	1.04
Temperate / Boreal, moist/wet	Cultivated	Full-tillage	Low	0.69	1	1	0.92
			Medium	0.69	1	1	1
			High with manure	0.69	1	1	1.44
			High without ma-	0.69	1	1	1.11
		Reduced till- age	Low	0.69	1	1.08	0.92
			Medium	0.69	1	1.08	1
			High with manure	0.69	1	1.08	1.44
			High without ma-	0.69	1	1.08	1.11
		No tillage	Low	0.69	1	1.15	0.92
			Medium	0.69	1	1.15	1
			High with manure	0.69	1	1.15	1.44
			High without ma-	0.69	1	1.15	1.11
Tropical, dry	Cultivated	Full-tillage	Low	0.58	1	1	0.95
			Medium	0.58	1	1	1
			High with manure	0.58	1	1	1.37
			High without ma-	0.58	1	1	1.04
		Reduced till- age	Low	0.58	1	1.09	0.95
			Medium	0.58	1	1.09	1
			High with manure	0.58	1	1.09	1.37
			High without ma-	0.58	1	1.09	1.04
		No tillage	Low	0.58	1	1.17	0.95
			Medium	0.58	1	1.17	1
			High with manure	0.58	1	1.17	1.37
			High without ma-	0.58	1	1.17	1.04
Tropical, moist / wet	Cultivated	Full-tillage	Low	0.48	1	1	0.92
			Medium	0.48	1	1	1
			High with manure	0.48	1	1	1.44
			High without ma-	0.48	1	1	1.11
		Reduced till-	Low	0.48	1	1.15	0.92
			Medium	0.48	1	1.15	1

		age	High with manure	0.48	1	1.15	1.44
			High without ma-	0.48	1	1.15	1.11
		No tillage	Low	0.48	1	1.2	0.92
			Medium	0.48	1		1
			High with manure	0.48	1	1.22	1.44
			High without ma-	0.48	1	1.22	1.11
Tropical, montane	Cultivated	Full-tillage	Low	0.64	1	1	0.92
			Medium	0.64	1	1	1
			High with manure	0.64	1	1	1.44
			High without ma-	0.64	1	1	1.11
		Reduced till- age	Low	0.64	1	1.09	0.92
			Medium	0.64	1	1.09	1
			High with manure	0.64	1	1.09	1.44
			High without ma-	0.64	1	1.09	1.11
		No tillage	Low	0.64	1	1.16	0.92
			Medium	0.64	1	1.16	1
			High with manure	0.64	1	1.16	1.44
			High without ma-	0.64	1	1.16	1.11

Table 0-24: Guidance on management and input for cropland and perennial crops (source: adapted from (IPCC 2006))

Management / Input	Guidance
Full-tillage	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g.<30%) of the surface is covered by residues.
Reduced till- age	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion) and normally leaves surface with <30% coverage by resides at planting.
No till	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for wee control.
Low	Low residue return occurs when there is due to removal of resides (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g. vegetables, tobacco, cotton), no mineral fertilization or nitrogen-fixing crops.

Medium	Representative for annual cropping with cereals where all crop residues are returned to the filed. If residues are removed then supplemental organic matter (e.g. manure) is added. Also requires mineral fertilization or nitrogen-fixing crop in rotation.
High with manure	Represents significantly higher carbon input over medium carbon input cropping systems due to an additional practice of regular addition of animal manure.
High without manure	Represents significantly greater crop residues inputs over medium carbon input cropping systems due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied (see row above).

Table 0-25: Factors for grassland, including savannahs (source: adapted from (IPCC 2006))

Climate	Land use	Management	Input (FI)	FLU	FMG	FI
Temperate / Boreal, dry	Grassland	Improved	Medium	1	1.14	1
			High	1	1.14	1.11
		Nominally managed	Medium	1	1	1
		Moderately degrad-	Medium	1	0.95	1
		Severely degraded	Medium	1	0.7	1
Temperate / Boreal, moist / wet	Grassland	Improved	Medium	1	1.14	1
			High	1	1.14	1.11
		Nominally managed	Medium	1	1	1
		Moderately degrad-	Medium	1	0.95	1
		Severely degraded	Medium	1	0.7	1
Tropical, dry	Grassland	Improved	Medium	1	1.17	1
			High	1	1.17	1.11
		Nominally managed	Medium	1	1	1
		Moderately degrad-	Medium	1	0.97	1
		Severely degraded	Medium	1	0.7	1
Tropical, moist / wet	Grassland	Improved	Medium	1	1.17	1
			High	1	1.17	1.11
		Nominally managed	Medium	1	1	1
		Moderately degrad-	Medium	1	0.97	1
		Severely degraded	Medium	1	0.7	1
Tropical	Grassland	Improved	Medium	1	1.16	1

Montane, dry			High	1	1.16	1.11
		Nominally managed	Medium	1	1	1
		Moderately degrad-	Medium	1	0.96	1
		Severely degraded	Medium	1	0.7	1

Table 0-26: Guidance on management and input for grassland (source: adapted from (IPCC 2006))

Management / Input	Guidance
Improved	Represents grassland which is sustainably managed with moderate grazing pressure and that receive at least one improvement (e.g. fertilization, species improvement, irrigation).
Nominally managed	Represents non-degraded and sustainably managed grassland, but without significant management improvements.
Moderately degraded	Represents overgrazed or moderately degraded grassland, with somewhat reduced productivity (relative to the native or nominally managed grassland) and receiving no management inputs.
Severely degraded	Implies major long term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and/or severe soil erosion.
Medium	Applies where no additional management inputs have been used.
High	Applies to improved grassland where one or more additional management inputs/improvements have been used (beyond that is required to be classified as improved grassland)

Table 0-27: Factors for forests (source: adapted from (Commission 2010))

Climate region	Land use (FLU)	Management	Input (FI)	FLU	FMG	FI
All	Native forest (non	n/a*	n/a	1		
All	Managed forest	All	All	1	1	1
Tropical, moist / dry	Shifting cultivation – shortened fallow	n/a	n/a	0.64		
	Shifting cultivation – mature fallow	n/a	n/a	0.8		

Temperate/Boreal, Moist / dry	Shifting cultivation – shortened fallow	n/a	n/a	1		
	Shifting cultivation – mature fallow	n/a	n/a	1		

Table 0-28: Guidance on management and input for forest land(source: adapted from (IPCC 2006))

Management / Input	Guidance
Native forest (non degraded)	Represents native or long-term, non-degraded and sustainably managed forest.
Shifting cultivation	Permanent shifting of cultivation, where tropical forest or woodland is cleared for planning of annual crops for a short time (e.g. 3-5 years) period and then abandoned to regrowth.
Mature fallow	Represents situations where the forest vegetation recovers to a mature or near mature state prior to being cleared again for cropland use.
Shortened fallow	Represents situations where the forest vegetation recovery is not attained prior to re-clearing.

4. Agriculture: modeling of ammonia emissions

4.1. RSB EU RED Calculation

For RSB EU RED Certifications, the following formula shall be applied

NH_3 [kg NH_3/ha volatized]=(N_{min_fert}*0.1+N_{org_fert}*0.2)*17/14

With:

N_{min_fert}: kg N/ha in mineral fertilizer

N_{org_fert}: kg N/ha in organic fertilizer

0.1 is FracGASF = fraction of synthetic (mineral) fertiliser N that volatilises as NH3 and NOx, kg N volatilised (kg of N applied) (Table 11.3, IPCC 2006)

0.2 is FracGASM = fraction of applied organic N fertiliser materials that volatilises as NH3 and NOx, kg N volatilised / (kg of N applied) (Table 11.3, IPCC 2006)

The N-content of organic fertilizers is taken from the following table

N content of organic fertilizer for ammonia calculation

Animal category	Manure type	Unit	N soluble
Cattle	liquid manure	kg/m^3	2.3
	low-excrement liquid manure	kg/m^3	3.2
	stackable manure	kg/t	0.8
	solid manure from loose housing	kg/t	1.3
Pigs	liquid manure	kg/m^3	4.2
	solid manure	kg/t	2.3
Poultry	broiler manure	kg/t	10
	laying hen manure	kg/t	6.3
	laying hen litter	kg/t	7
	dried poultry litter	kg/t	9

4.3. RSB Global Calculation

4.3.1. Ammonia (NH_3) computation from mineral fertilizers

NH3 from mineral fertilizers

$NH_{3,\ mineral}$ [kg NH_3 /ha]= $Quantity_{N,\ mineral\ fertilizerX}$ * NH_3 –N fertilizerX * 17/14

$Quantity_{N,\ mineral\ fertilizerX}$ [kg /ha]: Entry quantity N from a specific fertilizer

NH_3 –N fertilizerX [kg NH_3 /kg fertilizer]: emission factor from Table 0-29

17/14: conversion factor from NH_3 –N to NH_3.

Table 0-29: NH_3-emissions from mineral fertilizers (% N emitted in form of NH_3).

Type of fertiliser	Emission factor for NH_3-N
ammonium nitrate, calcium ammonium nitrate	2 %
ammonium sulphate	8 %
urea	15 %
multinutrient fertilisers (NPK-, NP-, NK-fertilisers)	4 %
urea ammonium nitrate	8.5 %*)
ammonia, liquid	3 %

*) The average of ammonium nitrate and urea was taken, since no emission factor is given by Asman (1992).

4.3.2. Ammonia (NH3) computation from organic fertilizers

NH3 from organic fertilizer application

Here we follow the model Agrammon (www.agrammon.ch). The model structure and technical parameters can be found in Agrammon Group (2009a, b).

The overall formula is the following.

NH_3–N = TAN * (er + c_app) * cx

NH_3–N = nitrogen emissions in form of NH3 (kg N/ha)

TAN = Total ammoniacal nitrogen; this is considered equal to the soluble nitrogen content (Agrammon Group 2009b) and is calculated as the product of amount of farm manure (kg/ha) and the corresponding soluble nitrogen content (kg N/kg manure) according to Flisch et al. (2009) (kg N/ha)

er = emission rate; this is a fix emission rate for each type of farm manure (% of TAN) (Table 0-31**: Nitrogen emission rates (er) of different animal categories and manure types**)

c_app = correction factor that influences the emission rate; it refers to the amount of manure per application and its degree of dilution; applies only for liquid manure. We use here standard values as in the ecoinvent database

cx = correction factor x; this refers to various parameters of the crop production system; for the basic system assumed in Agrammon cx = 1; cx < 1 has a reducing effect on NH3–emissions, cx > 1 an increasing effect.

Formula for liquid organic fertilizer:

NH_3-N = TAN * (er+c_app) * c_x

TAN: see Table 0-30

er : see Table 0-31**: Nitrogen emission rates (er) of different animal categories and manure types**

C_app = -0.029

c_x = 0.97*0.96

Formula for solid organic fertilizer:

NH_3-N = TAN * (er) * c_x

c_x = 0.88 for cattle/pig, 0.82 for poultry.

Table 0-30: TAN Values

Animal category	Manure type	Unit	N soluble
Cattle	liquid manure	kg/m^3	2.3
	low-excrement liquid manure	kg/m^3	3.2
	stackable manure	kg/t	0.8
	solid manure from loose housing	kg/t	1.3
Pigs	liquid manure	kg/m^3	4.2
	solid manure	kg/t	2.3
Poultry	broiler manure	kg/t	10
	laying hen manure	kg/t	6.3
	laying hen litter	kg/t	7
	dried poultry litter	kg/t	9

Table 0-31: Nitrogen emission rates (er) of different animal categories and manure types

Animal category	manure type	er (% TAN)	c_x	c_app
Cattle	liquid	50	0.97*0.96	-0.029
	solid	80	0.88	-
Pigs	liquid	35	0.97*0.96	-0.029
	solid	80	0.88	-
Poultry	solid, from growers, layers and other poultry	30	0.82	-
	solid, from broilers and turkeys	65	0.82	-

Organic fertilizers in the RSB Tool:

Solid organic fertilizer:

Category	Drop-down name
Cattle	cattle, stackable manure
	cattle, solid manure from loose housing
Pigs	pigs, solid manure
Poultry	poultry, broiler manure
	poultry, laying hen manure (poultry)
	poultry, laying hen litterv (poultry)
	poultry, dried poultry litter

Liquid organic fertilizer:

Category	Drop-down name
Cattle	Cattle, liquid manure
	Cattle, low-excrement liq-uid manure
Pigs	Pigs, liquid manure

5. Agriculture: modeling of N2O and NOx emissions

5.1. N_2O emissions

The calculation of the N_2O emissions is based on the formula in Nemecek and Kägi (2007) and adopts the new IPCC guidelines from 2006 (IPCC 2006).

$$N_2O = 44/28 * (EF_1 * (N_{tot} + N_{cr}) + EF_4 * 14/17 * NH_3 + EF_5 * 14/62 * NO_{3-})$$

With:

N_2O = emissions of N_2O [kg N_2O/ha]

EF_1 = 0.01 (IPCC 2006, S. 11.11)

N_{tot} = total nitrogen input [kg N/ha]

N_{cr} = nitrogen contained in the crop residues [kg N/ha]

EF_4 = 0.01 (IPCC 2006, S. 11.24)

NH_3 = losses of nitrogen in the form of ammonia [kg NH_3/ha]; calculated according to chapter 4

14/17: conversion of kg NH_3 in kg NH_3-N

EF_5 = 0.0075 (IPCC 2006, S. 11.24)

NO_{3-} = losses of nitrogen in the form of nitrate [kg NO_{3-}/ha]; calculated according to chapter 6.

14/62: conversion of kg NO_{3-} in kg NO_3–N

5.2. NOx emissions

The calculation of the NO_x emissions is based on the formula in Nemecek and Kägi (2007).

$NO_x = 0.21 * N_2O$

.

6. Agriculture: modeling of nitrate emissions

The nitrate emissions from agricultural nitrogen inputs are modeled according to the models developed in the Sustainability Quick Check for Biofuels (Faist Emmenegger, Reinhard et al. 2009).

This methodology differs from IPCC (2006) in that IPCC (2006) Tier 1 uses a factor for humid regions (0.30 kg (NH3-N and NOx-N)/kg Napplied) and 0 for dryland regions.

6.1. Origin of model and model structure

The regression model used is described in (De Willigen 2000). This model relates the nitrate leaching to these parameters:

- Amount of fertilizer nitrogen
- Amount of nitrogen taken up by the crop

- Amount of nitrogen in soil organic matter
- Precipitations
- Percentage clay
- Layer thickness

The regression model is based on data within those ranges:

- Precipitation: 40-2000 mm
- Clay content: 3-54%
- Layer thickness: 0.25-2m

A regression equation such as in (De Willigen 2000) should be applied only for interpolation, i.e. within the ranges of the data used for the regression. We are in the range of the given data for the layer thickness (see 6.3.4). For precipitation, only one value is above the limit of the recommended values (see Table 0-32) and, for clay content, two minor soil types have lower clay contents (see 6.3.3).

Table 0-32: Mean annual precipitation for each ecozone

Ecozone	Mean annual precipitation [mm yr^{-1}]
Tar	2500
Tawa	1500
Tawb	1000
Tbsh	500
Tbwh	50
Scf	1200
Scs	700
Sbsh	400
Sbwh	200
TeDo	1500
TeDc	600
TeBsk	300
TeBWk	150
Ba	500
BB	400

These are not optimal conditions for applying this regression equation. It should however be sufficient for a quick assessment; no other simple method has been applied on a global scale.

6.1.1. Design of the nitrate loss model

The nitrate loss model and the data flows can be visualized in the following chart. The light blue elements refer to the inputs that have to be typed in by the user (or default value) and the output, nitrate loss, is outlined in green.

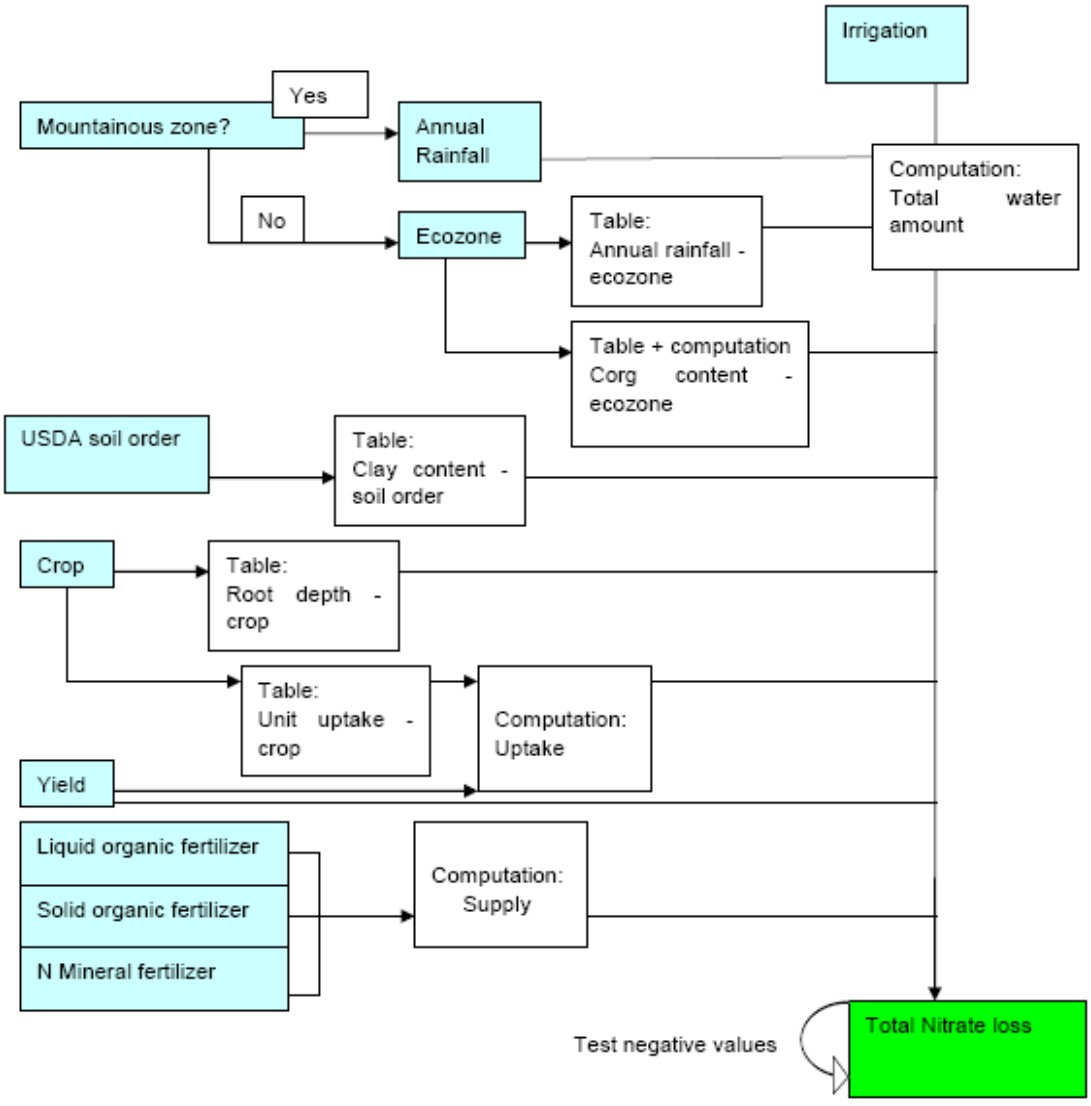

Figure 0-2. Structure of the nitrate model and data flows

6.2. Computation

There are some small differences between the equation given in (De Willigen 2000) and in (Roy 2003):

- Root depth is used instead of layer thickness in (Roy 2003)
- Organic carbon content is used instead of the amount of nitrogen in soil organic matter in (Roy 2003)
- Nitrogen fertilizer is restricted to mineral nitrogen fertilizer in (Roy 2003)

We compute the nitrate leaching according to (De Willigen 2000) and (Roy 2003) with small adaptations: $N = \left[21.37 + \frac{P}{c * L} \left[0.0037 * S + 0.0000601 * N_{org} - 0.00362 * U \right] \right] \frac{1}{y} \frac{1}{1000}$

$N =$ Nitrate loss through leaching [$kg_N\ kg_{product}^{-1}$]

$P =$ Annual precipitation and irrigation [$mm\ yr^{-1}$]

$c =$ Clay content [%]

$L =$ Root depth [m]

$S =$ Nitrogen supply [$kg_N\ ha^{-1}$]

$N_{org} =$ Organic nitrogen content [kg/ha]

$U =$ Nitrogen uptake [$kg_N\ ha^{-1}$]

$y =$ Yield [$tons_{product}\ ha^{-1}$]

Negative values are avoided by testing them:

$$N = \begin{cases} N & if \quad N \geq 0 \\ 0 & if \quad N < 0 \end{cases}$$

In the equation described in (Roy 2003), the annual precipitation amounts are considered without mentioning irrigation. We consider that the water amount supplied through irrigation also contributes to the nitrate leaching and is thus added to the precipitation amounts (see equation below).

$$P\left[\frac{mm}{yr}\right] = precipitation\left[\frac{mm}{yr}\right] + irrigation\left[\frac{m^3}{ha * yr}\right] * 0.1$$

Where the factor 0.1 represents the conversion from irrigation to mm/yr:

$$\frac{1m^3}{10'000m^2} * \frac{1000mm}{1m} = 0.1\left[\frac{mm}{m^3}\right]$$

In the same way as in (Roy 2003), the model uses the root depth (not the layer thickness) and the organic carbon content (not the amount of nitrogen in soil organic matter).

The model does not restrict the nitrogen fertilizer to the mineral fertilizer as in (Roy 2003), but we consider the nitrogen supplied through organic and mineral fertilizer.

The coefficient related to the yield is used in order to relate the nitrate loss to one kilogram of product.

Some parameter values are found in the tables or supplied by the operator: precipitation (operator), irrigation (operator), clay content (6.3.3) and root depth (6.3.4).

Some others require simple computations: nitrogen supply, organic carbon content and nitrogen uptake.

6.2.1. Nitrogen supply

The model considers the nitrogen supplied with the mineral fertilizers and with the liquid and solid organic fertilizers:

$$S = f + s * c_N^s + m * c_N^m$$

S = Nitrogen supply [kg_N ha^{-1}]

f = N Mineral fertilizer [kg_N ha^{-1}]

s = Liquid organic fertilizer (slurry) [m^3_{slurry} ha^{-1}]

c_N^s = Concentration of N in the slurry [kg_N m^{-3}_{slurry}]

m = Solid organic fertilizer (manure) [kg_{manure} ha^{-1}]

c_N^m = Concentration of N in the manure [kg_N kg_{manure}^{-1}]

The value of the applied amount of mineral fertilizer, liquid and solid organic fertilizer is supplied by the user (6.4).

The concentrations of N in slurry and manure are extracted from (Walther, Ryser et al. 2001).

6.2.2. Organic nitrogen content

The necessary organic nitrogen content can be calculated with the organic carbon content.

$$N_{org}\left[\frac{kg}{ha}\right] = \left(C_{org}\left[\frac{\%}{100}\right] * soil_volume\left[m^3\right] * bulk_density\left[\frac{kg}{m^3}\right]\right) / C/N_ratio * N_{org} / N_{tot}_ratio$$

The mean values for the organic carbon content are given per 3000 m^3 of soil in Table 0-33. We have to convert it to percent (mass fraction). We need the bulk density in order to carry out this conversion. As a rough approximation, a single value is taken for all soils. For a more precise assessment, we should consider a bulk density for each soil unit.

The conversion is computed in this way:

$$C_{org} = C_{org}^{EMPA} * \frac{1}{3000} * \frac{1}{1.3} * 100$$

C_{org} = organic carbon content [%]

C_{org}^{EMPA} = organic carbon content given in Table 0-33 [tons Corg 3000m^{-3}]

A bulk density of 1.3 tons of soil per cubic meter is assumed (average), based on the values found in (USDA 1999) and the values given by the American bulk density calculator[7].

Soil volume= 5000 m^3 (1 hectar * 50 cm thickness of upper soil)

Bulk density: 1300 kg/m^3 (see above)

C/N ratio: 11 (C_{org}/N_{tot}: assumption)

N_{org}/N_{tot}: 0.85 (ratio of organic N to total N in soil: assumption)

[7] http://www.pedosphere.com/resources/bulkdensity/worktable_us.cfm

Table 0-33: Default reference (under native vegetation) soil organic C stocks (SOC_{REF}) for mineral soils (tons C ha^{-1} in 0-30 cm depth). Source: (IPCC 2006)

Climate region	HAC soils	LAC soils	Sandy soils	Spodic soils	Volcanic soils	Wetland soils
Boreal	68	n.a.	10	117	20	146
Cold temperate, dry	50	33	34	n.a.	20	87
Cold temperate, moist	95	85	71	115	130	
Warm temperate, dry	38	24	19	n.a.	70	88
Warm temperate, moist	88	63	34	n.a.	80	
Tropical, dry	38	35	31	n.a.	50	86
Tropical moist	65	47	39	n.a.	70	
Tropical, wet	44	60	66	n.a.	130	
Tropical montane	88	63	34	n.a.	80	

6.2.3.Nitrogen uptake

The nitrogen uptake is computed as followed:

$$U = Unit_uptake * y$$

U = nitrogen uptake [kg_N ha^{-1}]

$Unit_uptake$ = unit uptake [kg_N $tons_{product}^{-1}$]

y = Yield [$tons_{product}$ ha^{-1}]

6.3. Tables

The tables contain the values of all the parameters needed in order to perform the assessment of nitrate loss and which are not supplied by the user. The input data typed in by the user are indeed used directly to compute nitrate loss but also indirectly to derive other parameters needed for this computation. The dataset of inputs is reduced as much as possible in order to ensure the use of the tool by a non-expert person.

6.3.1. Annual rainfall – ecozone

Annual rainfall is provided by the operator.

6.3.2. Organic carbon content – ecozone

A rough approximation of the organic carbon content in the soil is made in Table 0-33 for each climate region. It would be worthwhile using a more accurate organic carbon content by using more detailed data.

The values in (IPCC 2006) are given in tons of organic carbon per hectare in the first 30 cm of soil. This is equivalent to tons of organic carbon per 3000m^3.

6.3.3. Clay content – USDA soil order

The clay content was already used in order to determine the texture class and then the erodibility factor k of each USDA soil order (see 6.4.1. The values given in (USDA 1999) are:

Table 0-34: Clay content for each USDA soil order

USDA soil order	clay content %
Alfisol	28
Andisol	10.4
Aridisol	17.2
Entisol	3.5
Gelisol	23.7
Histosol	2
Inceptisol	4.9
Mollisol	21.1
Oxisol	53.9
Spodosol	1.8
Ultisol	12.3
Vertisol	49.0

For the histosol, no data is available in (USDA 1999). These soils are comprised primarily of organic material. The mineral material content should be minor and therefore a low clay content of 2% is assumed. This very rough approximation could lead to important errors in the nitrate leaching computation for these soils. The risk is however quite low since these soils cover less than 1% of the global ice free land surface and since they are usually not used for agriculture[8].

6.3.4.Root depth – crop

The FAO database crop water management (FAO) gives values for the rooting system depth for potato, sugar beet, sugar cane, sweet sorghum, soybean. There is unfortunately no data about rapeseed or palm. The FAO database ecocrop (FAO) gives one meter as standard depth for the oil palm rooting system. The Idaho University carried out a study about nitrogen removal with rapeseed and found that nitrogen was efficiently removed until a depth of three feet[9], which roughly corresponds to 0.9 meters. The root depth for cassava stems from (Boeni and Osses 2010), for castor bean from (Comar, Tilley et al. 2004).

[8] http://en.wikipedia.org/wiki/Histosols

[9] http://www.uiweb.uidaho.edu/wq/wqfert/cis785.html

Table 0-35: Root depth for each crop

Crop	Root depth [m]
Camelina	1.16[10]
Cassava	0.5
Castor bean	1.5
Corn	1.8[11]
Jatropha	1
Palm	1
Potato	0.45
Rapeseed	0.9
Soybean	0.65
Sugar beet	1
Sugar cane	1.5
Sunflower	1.3[12]
Sweet sor-ghum	1
Wheat	1.3[13]

The root depth can greatly vary according to the soil type, the maturation of the plant, the water availability, the concurrence with other plants, etc. These values are mean values and should not be considered as an absolute reference.

6.3.5.Unit uptake – crop

The regression equation used for calculating nitrate emissions needs the quantity of nitrogen that is taken up by the *whole plant*. The yield however refers to the main product in this project. We thus have to express the nitrogen uptake of the whole plant but expressed per ton of main product.

The FAO database ecocrop (FAO) gives values for oil palm, sweet sorghum and wheat:

- The oil palm (whole plant) takes up 6 kg nitrogen per ton of fruits
- The sweet sorghum (whole plant) takes up 50 kg nitrogen per ton of grains
- The wheat takes up 20-30 kg nitrogen per ton of wheat grains

[10] Personal communication, Camelina Company España, 01.06.2011
[11] http://www.extension.org/pages/Corn_Growth_&_Development
[12] {FAO, 2010 #233}
[13] http://www.fao.org/nr/water/cropinfo_wheat.html

The unit uptake of jatropha is 22 kg nitrogen per ton (Gmünder, Zah et al. 2010). We have to calculate the nitrogen uptake for the other crops, since no data has been found in (FAO). The results are:

Table 0-36: Unit uptake for each crop

Crop	Unit_uptake[kg N/tons]
Camelina	67[14]
Cassava	1.57
Castor bean	35.3
Corn	15.3
Jatropha	22.2
Potato	3.75
Sugar beet	4.5
Sugar cane	2.3
Sunflower	37
Sweet sorghum	50
Rapeseed	44.7
Soybean	77.1
Palm	6
Wheat	25[15]
	Unit uptake (kg/100 nuts)
Coconut	0.327

The calculations are described below.

Cassava

Information for cassava is provided below.

[14] Personal communication, Camelina Company España, 01.06.2011

[15] http://ecocrop.fao.org/ecocrop/srv/en/cropView?id=2114

Table 0-37: Nutrient uptake of cassava. Taken from (Howeler 2002)

Yield [t/ha]	Plant	[kg/ha]					
		N	P2O5	K2O	MgO	CaO	S
45	Fresh roots	62	23	197	36	17	3
	Whole plant	202	73	343	179	183	15
37	Fresh roots	67	38	122	14	22	7
	Whole plant	198	70	220	47	143	19
18	Fresh roots	32	8	41	6	7	1
	Whole plant	95	23	77	52	23	7
9	Fresh roots	13	2	5	3	4	0.2
	Whole plant	39	7	12	14	29	2
35.7	Fresh roots	55	13.2	112	-	-	-

As it can be seen from the table above, values for nutrition uptake vary considerably. For most substances, uptake increases with increasing yield. Therefore, the uptake is calculated for a yield of 21t/ha, as used in this study, by taking the average of 5 sources of N uptake fresh roots/ yield = 1.57kg N/t cassava. Multiplied with a yield of 21t, a final uptake of 33kg N/ha cassava roots results. This value is used to calculate NO3 emissions to water.

Castor bean

Table 0-38: Nutrition uptake (whole plant). Taken from (Embrapa 2006)

Yield [kg/ha/year]	Uptake [kg/ha/year]		
	N	P2O5	K2O
2000	74 to 80	15 to 18	13 to 24

The average value of N uptake (77kg/ha/year) is used to calculate NO3 emissions to water.

Coconut

(Magat) gives an average of 49 kg N uptake per ha, with an average of 150 trees and 100 nuts/tree (see also Table 0-39). The yield of copra is about 0.2 kg/nut (see Table 0-40).

Table 0-39: Nutrient demand/uptake/removal of coconut-macronutrients.

Nutrient demand/uptake/removal - Macronutrients									
Yield	Source	kg/ha							
		N	P2O5	K2O	Mg	Ca	S	Na	Cl
1.5 t copra	Copeland, 1931	93	41	138	-	17	-	-	-
25 nuts/palm	Cooke, 1950	29	9	26	-	-	-	-	-
60 nuts/palm	Nathaniel, 1969	72	39	108	-	-	-	-	-
100 nuts/palm:	Khanna and Nair, 1977								
nuts only		120	18	85	-	-	-	-	-
whole palm		157	28	346	-	-	-	-	-
100 nuts/palm	Ouvier and Ochs, 1978	49	16	115	8	5	4	11	64
6.7t copra:	Ouvier and Ochs, 1978								
nuts only		108	39	232	15	9	9	20	125
whole palm		174	46	299	39	70	30	54	249
1 t copra	Ashgar, 1988	16.2	5	36	2	1.4	1.3	2.5	19.7

Table 0-40 Copra yield per nut (Source: FAO / (Ohler 2000)).

Classification	Nuts/Palm	Copra/Palm	Copra/ha	Copra/nut (Calculated)
Very bad	0-10	0-2 kg	0-300 kg	0.2
Bad	11-20	2-4	300-600	0.2
Fair	21-30	4-6	600-900	0.2
Moderate	31-50	6-10	900-1,500	0.2
Good	51-70	10-14	1,500-2,100	0.2
Very good	71-90	14-18	2,100-2,700	0.2
Excellent	> 90	> 18	> 2,700	0.2

Corn

Following values can be found in (Eghball and Power 1999):

Table 0-41: N uptake for corn (Eghball and Power 1999).

Year	Grain yield	N uptake	N uptake per t crop
	t/ha	kg/ha	kg/t crop
1993	6.231	99	15.9
1994	7.49	94	12.6
1995	3.81	66	17.3
1996	5.44	84	15.4
Average			**15.3**

We use an average value of 15.3 kg N/t

Potato

(Walther, Ryser et al. 2001) gives those values:

- Tubers: Nitrogen uptake=135 kg N/ha; Harvest=45 tons/ha
- Crop residues: Nitrogen uptake=25 kg N/ha; Harvest=18 tons/ha

The nitrogen uptake of the whole crop expressed per ton of tuber (main product) is obtained by calculating: $\frac{135}{45}\left[\frac{kgN}{ha}\frac{ha}{t_{tubers}}\right]+\frac{25}{18}\left[\frac{kgN}{ha}\frac{ha}{t_{residues}}\right]*\frac{18}{45}\left[\frac{t_{residues}}{ha}\frac{ha}{t_{tubers}}\right]=3.6\left[\frac{kgN}{t_{tubers}}\right]$

The Bayerische Landesanstalt für Landwirtschaft[16] gives those values:

- Tubers: 3.5 kg N/t
- Crop residues: 2 kg N/t
- Proportion: 0.2 t residues/ 1 t tubers

Computing the nitrogen uptake of the whole crop expressed per ton of tuber (crop product) with these data leads to:

$$3.5\left[\frac{kgN}{t_{tubers}}\right]+2\left[\frac{kgN}{t_{residues}}\right]*0.2\left[\frac{t_{residues}}{t_{tubers}}\right]=3.9\left[\frac{kgN}{t_{tubers}}\right]$$

We consider the average of these 2 values: 3.75 kg N/t tubers.

Rapeseed

(Walther, Ryser et al. 2001) gives those data:

[16] http://www.lfl.bayern.de/iab/duengung/mineralisch/10536/

- Seed: Nitrogen uptake=105 kg N/ha; Harvest=3.5 t/ha
- Crop residues: Nitrogen uptake=49 kg N/ha; Harvest=6.5 t/ha

The nitrogen uptake of the whole crop expressed per ton of seed (crop product) is obtained by calculating: $\frac{105}{3.5}\left[\frac{kgN}{ha}\frac{ha}{t_{seeds}}\right]+\frac{49}{6.5}\left[\frac{kgN}{ha}\frac{ha}{t_{residues}}\right]*\frac{6.5}{3.5}\left[\frac{t_{residues}}{ha}\frac{ha}{t_{seeds}}\right]=44\left[\frac{kgN}{t_{seeds}}\right]$

The Bayerische Landesanstalt für Landwirtschaft gives those values:

- Seeds: 33.5 kg N/t
- Crop residues: 7 kg N/t
- Proportion: 1.7 t residues/ 1 t seeds

Computing the nitrogen uptake of the whole crop expressed per ton of seeds (crop product) with these data leads to:

$$33.5\left[\frac{kgN}{t_{seeds}}\right]+7\left[\frac{kgN}{t_{residues}}\right]*1.7\left[\frac{t_{residues}}{t_{seeds}}\right]=45.4\left[\frac{kgN}{t_{seeds}}\right]$$

The results differ only slightly and the average value is used for this study.

Soybean

(Walther, Ryser et al. 2001) provides the following data:

- Beans: Nitrogen uptake=150 kg N/ha; Harvest=2.5 t/ha
- Crop residues: Nitrogen uptake=88 kg N/ha; Harvest=2.5 t/ha

The nitrogen uptake of the whole crop expressed per ton of beans (crop product) is obtained by calculating: $\frac{150}{2.5}\left[\frac{kgN}{ha}\frac{ha}{t_{beans}}\right]+\frac{88}{2.5}\left[\frac{kgN}{ha}\frac{ha}{t_{residues}}\right]*\frac{2.5}{2.5}\left[\frac{t_{residues}}{ha}\frac{ha}{t_{beans}}\right]=95.2\left[\frac{kgN}{t_{beans}}\right]$

The Bayerische Landesanstalt für Landwirtschaft provides the following data:

- Beans: 44 kg N/t
- Crop residues: 15 kg N/t
- Proportion: 1 t residues/ 1 t beans

Computing the nitrogen uptake of the whole crop expressed per ton of beans (crop product) with these data leads to:

$$44\left[\frac{kgN}{t_{beans}}\right]+15\left[\frac{kgN}{t_{residues}}\right]*1\left[\frac{t_{residues}}{t_{beans}}\right]=59\left[\frac{kgN}{t_{beans}}\right]$$

These two results differ substantially. We take the average in this project but, for a more detailed and accurate assessment, some further investigations should be done in order to check if this value is appropriate as a mean value for the whole world.

Sugar beet

(Walther, Ryser et al. 2001) gives these values:

- Beet: Nitrogen uptake=137 kg N/ha; Harvest=65 t/ha
- Crop residues: Nitrogen uptake=150 kg N/ha; Harvest=50 t/ha

The nitrogen uptake of the whole crop expressed per ton of beet (crop product) is obtained by calculating:

$$\frac{137}{65}\left[\frac{kgN}{ha}\frac{ha}{t_{beets}}\right]+\frac{150}{50}\left[\frac{kgN}{ha}\frac{ha}{t_{residues}}\right]*\frac{50}{65}\left[\frac{t_{residues}}{ha}\frac{ha}{t_{beets}}\right]=4.4\left[\frac{kgN}{t_{beets}}\right]$$

The Bayerische Landesanstalt für Landwirtschaft gives those values:

- Beets: 1.8 kg N/t
- Crop residues: 4 kg N/t
- Proportion: 0.7 t residues/ 1 t beets

Computing the nitrogen uptake of the whole crop expressed per ton of beets (crop product) with these data leads to:

$$1.8\left[\frac{kgN}{t_{beets}}\right]+4\left[\frac{kgN}{t_{residues}}\right]*0.7\left[\frac{t_{residues}}{t_{beets}}\right]=4.6\left[\frac{kgN}{t_{beets}}\right]$$

We take the average: 4.5 kg N/t beets.

Sugar cane

Neither (Walther, Ryser et al. 2001) nor the Bayerische Landesanstalt für Landwirtschaft give some values for sugar cane, since it is not produced under European climate conditions.

Several values can be found in the literature for the nitrogen concentration in the different parts of the plant and for the ratio between the stalks and the residues (INRA, (Woytiuk 2006), (Hassuani 2005), (Kee Kwong 1987), (Rehm 1984)). They sometimes differ greatly. We combine them in all the possible ways in order to see how the results vary. The results for different combinations of the values found in the literature vary to up to 200%! Here, we chose to use the average value of all the possible combinations: 2.3 kg nitrogen per ton of stalk.

The differences between the values indicate that the unit nitrogen uptake can vary greatly and a more detailed assessment of this parameter should be done in order to improve the results.

Sunflower

(Merrien) gives an average N uptake of 131 kg/ha for a yield of 3.5 t/ha. We therefore assume a ratio of 37 kg/kg.

6.4. Inputs

The operator has to provide some information about the planned biofuel production in order to quantify the related nitrate emissions. A default value is available for some of the required inputs, but others are compulsory. The default values are presented in the next section.

The user has to be cautious regarding the units when typing in the inputs. The units are International System of Units (SI) units or derived units. All the input concerning resources are related to a surface of one hectare and to the period of cultivation.

- Duration of cultivation (see 6.4.9)

6.4.1.USDA soil order

The user finds the correct soil order related to his production zone by identifying his production zone in the soil order map. A soil order is the highest level of soil classification in the USDA classification system[17]. At this classification level, soils vary greatly within a given unit. Consequently, the utilization of these rough soil categories to derive other information (clay content for instance) can lead to inaccurate or wrong results. For a detailed assessment, a lower level of classification should be selected or field analyses should be carried out.

The possible answers are:

- Alfisol
- Andisol
- Aridisol
- Entisol
- Gelisol
- Histosol
- Inceptisol
- Mollisol
- Oxisol
- Spodosol
- Ultisol
- Vertisol

[17] http://www.uwsp.edu/geo/faculty/ritter/glossary/S_U/soil_order.html

6.4.2.Irrigation

The irrigation has to be supplied by the operator in [m^3ha^{-1}]. It corresponds to the water quantity supplied through irrigation to one hectare of the considered crop.

For annual crops (e.g. potato, sugar beet, sweet sorghum, rapeseed or soybean), it is the water amount supplied between sowing and harvest. For perennial crops, e.g. oil palm or sugar cane, it corresponds to the water amount supplied between two harvests. In case of perennial crops, we should consider the water and the fertilizers supplied during the first unproductive phase too. These amounts should be shared over all harvests. Consequently, the user has to know how much water and fertilizers he applied during this unproductive phase and he has to know how many harvests the trees will furnish before being cut. We do not consider the water and fertilizer amounts used in the first unproductive lifetime of the crop in SQCB. This is a simplification which will lead to a possible underestimation of the phosphorus emissions for perennial crops.

6.4.3.Ecozone

The user finds this information by locating his production zone in the corresponding ecozone map. The ecological zones, or ecozones, are defined as zones or areas with relatively homogeneous natural vegetation formations, and coinciding roughly with the Köppen-Trewartha climatic types (FAO 2001).

The possible answers are:

- Tar: Tropical rainforest
- Tawa: Tropical moist deciduous forest
- Tawb: Tropical dry forest
- Tbsh: Tropical shrublands
- Tbwh: Tropical desert
- TM: Tropical mountain systems
- Scf: Subtropical humid forest
- Scs: Subtropical dry forest
- SbSh: Subtropical steppe
- SBWh: Subtropical desert
- SM: Subtropical mountain systems
- TeDo: Temperate oceanic forest
- TeDc: Temperate continental forest
- TeBSk: Temperate steppe

- TeBWk: Temperate desert
- TeM: Temperate mountain systems
- Ba: Boreal coniferous forest
- Bb: Boreal tundra woodland
- BM: Boreal mountain systems

6.4.4.Annual rainfall

The ecozone concept is a relatively good indicator of the mean annual precipitations in flat regions.

In mountainous regions, the precipitation amount can be very different from one location to another according to the altitude, the mountainside orientation as well as other local effects. The ecozone concept is thus too rough in such regions and cannot provide information about the annual rainfall. The user has to provide the annual rainfall value for his production zone when it is located in a mountainous region (TM, SM, TeM or BM). The units are [mm yr^{-1}].

It is usually easy to find such information by consulting the regional or national meteorological office.

6.4.5.Liquid organic fertilizer

The liquid organic fertilizer (slurry) amount has to be supplied by the user in [m^3_{slurry} ha^{-1}]. It is the amount of slurry applied per hectare to the considered crop during the growth period. The possible types of slurry and their phosphorus content are described in Table 0-42. A dilution factor of 40:60 (slurry:water) is assumed if the user does not enter his dilution factor.

Table 0-42: Types of slurry and nitrogen content

Type of slurry		**Nitrogen conten**
		kg/m³
beef and dairy cattle	liquid	2.3
pigs	liquid	3.8
average liquid manure	liquid	3

The growth period is intended to be the period between sowing and harvest for annual crops (potato, sugar beet, sweet sorghum, rapeseed and soybean). The growth period for perennial crops (sugar cane and oil palm) is considered as the time period between two consecutive harvests. As mentioned for the irrigation, we should also take into account the slurry amount applied during the unproductive phase at the beginning of growth for the perennial crops and share this amount between all the harvests of the crop life.

6.4.6.Solid organic fertilizer

The solid organic fertilizer (manure) amount has to be supplied by the user in [kg_{manure} ha^{-1}]. It is the amount of manure applied per hectare to the considered crop during the growth period. The possible types of manure and their nitrogen content are described in Table 0-43.

Table 0-43: Types of manure and nitrogen content

Type of manure		**N-content**
		kg/t
beef and dairy cattle	solid	1.3
pigs	solid	2.3
hens (from deep pit)	solid	5
hens (from belts)	solid	3.6
broilers	solid	8
average solid manure	solid	**1.5**

The same remark as done in the previous section (liquid organic fertilizer) can be done here about the growth period.

6.4.7.N mineral fertilizer

The N mineral fertilizer amount has to be supplied by the user in [kg_N ha^{-1}]. It is the quantity of N mineral fertilizer applied per hectare to the considered crop during the growth period. The user types in detailed information about the N mineral fertilizers used. The possible N mineral fertilizers which can be selected by the user are shown in Table 0-2.

The growth period is intended to be the period between sowing and harvest for annual crops (potato, sugar beet, sweet sorghum, rapeseed and soybean). The growth period for perennial crops (sugar cane and oil palm) is considered as the time period between two consecutive harvests. We also take into account the N mineral fertilizer amount applied during the unproductive phase at the beginning of growth for the perennial crops and share this amount between all the harvests of the crop life.

6.4.8.Yield

The yield of product has to be supplied by the user in [tons ha^{-1}]. For perennial crops, the values represent the yield of one year on one hectare.

This quantity represents the amount of main product harvested per hectare. It is not the amount of whole crop (main product + co-products + residues) harvested per hectare. For potato, we consider the harvested amount of tubers per hectare for instance and, for soybean, the harvested amount of beans per hectare.

6.4.9.Duration of cultivation

The duration of the cultivation is needed for the calculation of nitrate emissions, which is designed for a certain cultivation period. If the operator performs two cultivation periods in one year, the data should be provided accordingly.

The default values are extracted from (Nemecek, A. Heil et al. 2004) for the “conventional” crops: 5 months for potato, 6.3 months for sugar beet, 10.6 months for rapeseed and 4.5 months for soybean. For the exotic crops, we use the FAO database ecocrop (FAO). For the sweet sorghum, it indicates that grains reach maturity between 90 and 120 days. We take the average of 3.5 months. It considers sugar cane and oil palm as perennial crop. We should take the time period between two consecutive harvests. Since this period is variable, we take an average of 12 months for these two crops.

Default values:

-5 months for potato

-6.3 months for sugar beet

-12 months for sugar cane

-3.5 months for sweet sorghum

-10.6 months for rapeseed

-4.5 months for soybean

-12 months for oil palm

-3.5 months for spring wheat (90-130 days)

-7 months for winter wheat (180-250 days)

-4 months for sunflower (120-160 days)

-12 months for jatropha

-12 months for coconut

-12 months for castor bean (Osses 2010)

-10 months for cassava (Boeni and Osses 2010)

-3 months for camelina [18]

[18] Personal communication, Camelina Company España, 01.06.2011

6.6. Modelling of nitrate for RED calculations

The nitrate calculations in the RSB EU RED adaptation of the calculator follow IPCC guidelines.

NO_3-N[kg N/ha leaching]=(N_{min_fert}+ N_{org_fert}+N_{cr})* $Frac_{LEACH}$

With:

N_{min_fert}: kg N in mineral fertilizer

N_{org_fert}: kg N in organic fertilizer

N_{cr}: kg N in crop residues

$Frac_{LEACH}$ = 0.3. Fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff, kg N/(kg of N additions) (Table 11.3 in IPCC 2006)

7. Field burning before harvest – sugarcane

The emissions of field burning before harvest related to sugar cane are calculated by multiplying each emission factor given in Table 0-18 with 0.20863 – this is the amount of dry mass burned per kg sugar cane moist harvested. The value is computed via Equation 7-12.

Equation 7-12: Amount of dry mass burned per kg sugar cane harvested (B_{burned})

$$B_{burned} = \frac{\left(Y_{Biofuel} * C_{DM} * CF\right)}{\left(Y_{Biofuel}\right)}$$

$Y_{Biofuel}$ = Sugarcane yield in kg moist mass, default yield according to ecoinvent is 66'300 kg sugarcane per hectare and year.

C_{DM} = Dry mass content per kg sugarcane, default value is 0.26 kg dry mass content per kg sugarcane harvested.

CF = Combustion factor, default value is 0.8 (see Table 0-17).

8. Modeling of fuel production and fuel refining

If operators calculate actual values for processing, all relevant processing steps shall be taken into account. In the case that no data are available for all processing steps of the supply chain, the use of calculated values for processing steps is not allowed

The calculations shall include the production of chemicals or products used in processing, the energy used for production, from waste and leakages as well as possible emissions from the process itself (e.g. methane emissions from ponds in the palm oil production).

Processing may be divided into several locally separate process steps, each producing a different product. e_p subsumes such different processing steps taking different conversion and allocation factors into consideration. The emissions shall be calculated for each processing step individually using the formula below and summed up.

The emissions of fuel use for electricity and heat are taken from the ecoinvent database.

The GHG emissions from fuel production and fuel refining shall be calculated as follow:

$$E_{Processing}\left[\frac{kgCO_2}{yr}\right] = \frac{E_{\substack{electricty\\consumption}}\left[\frac{kgCO_2}{yr}\right] + E_{\substack{heat\\production}}\left[\frac{kgCO_2}{yr}\right] + E_{\substack{operating\\material}}\left[\frac{kgCO_2}{yr}\right] + E_{effluent}\left[\frac{kgCO_2}{yr}\right]}{product\ yield_{\substack{main\\product(crop)}}\left[\frac{kg_{\ produc\ yield}}{yr}\right]} * Allocation_factor$$

With

$$E_{\substack{electricity\\consumption}}\left[\frac{kgCO_2}{yr}\right] = \sum Electricity_type_i\left[\frac{kWh}{yr}\right] * EF_elec_i\left[\frac{kgCO_2}{kWh}\right]$$

EF_elec_i: emission factor of the electricity type (e.g. hydropower). The emission factors of the electricity type are taken from the ecoinvent database (Annex 4 – Ecoinvent Emission Factors).

$$E_{\substack{heat\\consumption}}\left[\frac{kgCO_2}{yr}\right] = \sum Heat_type_i\left[\frac{MJ}{yr}\right] * EF_heat_i\left[\frac{kgCO_2}{MJ}\right]$$

EF_heat_i: emission factor of the heat type (e.g. natural gas). The emission factors of the heat type are taken from the ecoinvent database (Annex 4 – Ecoinvent Emission Factors

).

$$E_{\substack{operation\\material}}\left[\frac{kgCO_2}{yr}\right] = \sum material_type_i[kg] * EF_mat_i\left[\frac{kgCO_2}{kg}\right]$$

EF_mat_i: emission factor of the material type (e.g. chemical). The emission factors of the production of operating materials are taken from the ecoinvent database).

$$E_{effluent}\left[\frac{kgCO_2}{yr}\right] = \sum effluent_type_i\left[\frac{kg}{yr}\right] * EF_eff_i\left[\frac{kgCO_2}{kg}\right]$$

EF_eff$_i$: emission factor of the effluent (e.g. hexane).

The emission factor of the effluent is taken from point 5 for CO2, CH4 and N2O. For other effluents, these emission factors are the climate change factors of IPCC with a timeframe of 100 years (IPCC 2007).

The actual amount of energy and material requirements shall be provided by the operator.

Emission saving from excess electricity from cogeneration, e_{ee}, shall be taken into account in relation to the excess electricity produced by fuel production systems that use cogeneration except where the fuel used for the cogeneration is a co-product other than an agricultural crop residue. In accounting for that excess electricity, the size of the cogeneration unit shall be assumed to be the minimum necessary for the cogeneration unit to supply the heat that is needed to produce the fuel. The greenhouse gas emission saving associated with that excess electricity shall be taken to be equal to the amount of greenhouse gas that would be emitted when an equal amount of electricity was generated in a power plant using the same fuel as the cogeneration unit.

The *participating operator* determines the GHG emissions savings resulting from excess electricity from cogeneration e_{ee}, by applying actual values in the following formula:

$$e_{ee} = \frac{surplus_electricity\left[\frac{kWh}{yr}\right] * emissions_factor_{fuel}\left[\frac{kgCO_2eq}{kWh}\right]}{product_yield_{main_product(crop)}\left[\frac{kg_{\ produc\ yield}}{yr}\right]}$$

in [kg CO_{2eq} / kg of product]

The general allocation rule in point 17 does not apply for electricity from Combined Heat & Power (CHP) when the CHP runs on 1) fossil fuels; 2) bioenergy, where this is not a co-product from the same process; or 3) agricultural crop residues, even if they are a co-product from the same process. Instead, the rule in point 16 applies as follows:

a. Where the CHP supplies heat not only to the biofuel/bioliquid process but also for other purposes, the size of the CHP should be notionally reduced - for the calculation - to the size that is necessary to supply only the heat necessary for the biofuel/bioliquid process. The primary electricity output of the CHP should be notionally reduced in proportion.

b. To the amount of electricity that remains - after this notional adjustment and after covering any actual internal electricity needs - a greenhouse gas credit should be assigned that should be subtracted from the processing emissions.

c. The amount of this benefit is equal to the life cycle emissions attributable to the production of an equal amount of electricity from the same type of fuel in a power plant.

9. Modeling of transport and storage

If operators calculate actual value for transport, all relevant transport steps shall be taken into account. In the case that no data is available for all transport steps of the supply chain, the use of actual values for transport is not allowed.

Emissions from transport and distribution, e_{td}, shall include emissions from the transport of raw, semi-finished and finished materials (e_{tr}), from the storage of finished materials (e_{st}) as well as emissions from filling stations (e_{fl}). Transport may be divided into several locally separate transport steps. e_{td} subsumes all of the transport steps.

The emissions shall be calculated for each transport step individually using the formula below and summed up.

The *participating operator* determines the GHG emissions resulting from transport e_{td}, including all transport steps used by applying *actual values* in the following formula

$$e_{td} = e_{tr} + e_{st} + e_{fl}$$

$$e_{tr} = \frac{TD_{vehicle}[km] * TQ[kg] * EF_{transport}\left[\frac{kgCO_2}{tkm}\right]}{TQ\,[kg]}$$

$$e_{st} = \mathrm{E}_{storage}\left[\frac{\mathrm{MJ}}{\mathrm{MJ}_{\mathrm{fuel}}}\right] * \frac{1}{3.6}\left[\frac{\mathrm{kWh}}{\mathrm{MJ}}\right] * EF_{electricity}\left[\frac{kgCO_2}{kWh}\right] * ED\left[\frac{MJ_{fuel}}{kg}\right]$$

$$e_{fl} = E_{filling}\left[\frac{\mathrm{MJ}}{\mathrm{MJ}_{\mathrm{fuel}}}\right] * \frac{1}{3.6}\left[\frac{\mathrm{kWh}}{\mathrm{MJ}}\right] * EF_{electricity}\left[\frac{kgCO_2}{kWh}\right] * ED\left[\frac{MJ_{fuel}}{kg}\right]$$

in [kg CO_2 / kg of product]

With

TD: transport distance

TQ: transported quantity of biomass / bioliquid / biofuel

$EF_{transport}$: emission factor for transport; taken from the ecoinvent database (without infrastructure). They are specific for the different types of vehicle and take into account the average load of the vehicle.

$EF_{electricity}$: emission factor for eletricity at the location of storage or filling

ED: energy density of fuel

$E_{storage}$: electricity used at storage facilities: user-given actual value or, alternatively: standard value of 0.00084 MJ/MJ-fuel (JRC, 2008)

$E_{filling}$: electricity used at filling station: standard value of 0.0034 MJ/MJ-fuel (JRC, 2008)

Source for $E_{storage}$ and $E_{filling}$: JRC, “Input data relevant to calculating default GHG emissions according to RE Directive Methodology”, 2008

10. Fuel Combustion Emissions

Emissions associated with fuel combustion (i.e., use of final biofuel or fossil fuel product) are calculated based on the assumption that carbon is converted to CO2.

This assumption is highly idealized. Emissions for CH4 and N2O and other additional products of combustion are not calculated. This is because emission factors for such emissions are dependent on engine performance and efficiency. In addition, such emissions have been found to be very small in comparison with lifecycle GHG emissions.

Additionally, biogenic carbon emissions are assumed to be carbon neutral, as CO2 was taken up from the atmosphere to grow the biogenic material. Therefore, biogenic carbon is not assigned any CO2 emissions from fuel use; only fossil fuel is assigned CO2 emissions.

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Annex 1 – Global Warming Potentials

Comparison of IPCC 2007 and ReCiPe

	NAME (ReciPE)	GWP		Name IPCC	GWP
1	1-Propanol, 3,3,3-trifluoro-2,2-bis(trifluoromethyl)-, HFE-7100	297	0		
1	Butane, 1,1,1,3,3-pentafluoro-, HFC-365mfc	794	1	Butane, 1,1,1,3,3-pentafluoro-, HFC-365mfc	794
1	Butane, nonafluoroethoxy, HFE-569sf2	59	1	Butane, nonafluoroethoxy, HFE-569sf2	59
1	Butane, perfluoro-	8860	1	Butane, nonafluoromethoxy, HFE-7100	297
1	Butane, perfluorocyclo-, PFC-318	10300	1	Butane, perfluoro-	8860
0			1	Butane, perfluorocyclo-, PFC-318	10300
1	Carbon dioxide	1	1	Carbon dioxide	1
0			1	Carbon dioxide, biogenic	0
1	Carbon dioxide, fossil	1	1	Carbon dioxide, fossil	1
0			1	Carbon dioxide, in air	0
1	Carbon dioxide, land transformation	1	1	Carbon dioxide, land transformation	1
1	Chloroform	31	1	Chloroform	756
1	Dimethyl ether	1	1	Dimethyl ether	1
1	Dinitrogen monoxide	298	1	Dinitrogen monoxide	298
1	Ethane, 1-chloro-1,1-difluoro-, HCFC-142b	2310	1	Ethane, 1-chloro-1,1-difluoro-, HCFC-142b	2310
1	Ethane, 1-chloro-2,2,2-trifluoro-(difluoromethoxy)-, HCFE-235da2	350	1	Ethane, 1-chloro-2,2,2-trifluoro-(difluoromethoxy)-, HCFE-235da2	350
1	Ethane, 1,1-dichloro-1-fluoro-, HCFC-141b	725	1	Ethane, 1,1-dichloro-1-fluoro-, HCFC-141b	725
1	Ethane, 1,1-difluoro-, HFC-152a	124	1	Ethane, 1,1-difluoro-, HFC-152a	124
1	Ethane, 1,1,1-trichloro-, HCFC-140	146	1	Ethane, 1,1,1-trichloro-, HCFC-140	146
1	Ethane, 1,1,1-trifluoro-, HFC-143a	4470	1	Ethane, 1,1,1-trifluoro-, HFC-143a	4470
1	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	1430	1	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	1430
1	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	6130	1	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	6130
1	Ethane, 1,1,2-trifluoro-, HFC-143	353	0		
1	Ethane, 1,1,2,2-tetrafluoro-, HFC-134	1100	1	Ethane, 1,1,2,2-tetrafluoro-, HFC-134	1430
0			1	Ethane, 1,1,2,2-tetrafluoromethoxy-, HFE245cb2	708
1	Ethane, 1,2-dibromotetrafluoro-, Halon 2402	1640	0		
1	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	10000	1	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	10000
1	Ethane, 1,2-difluoro-, HFC-152	53	0		
1	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	609	1	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	609
1	Ethane, 2,2-dichloro-1,1,1-trifluoro-, HCFC-123	77	1	Ethane, 2,2-dichloro-1,1,1-trifluoro-, HCFC-123	77
0			1	Ethane, 2,2,2-trifluoromethoxy-, HFE245fa2	659
1	Ethane, chloropentafluoro-, CFC-115	7370	1	Ethane, chloropentafluoro-, CFC-115	7370
1	Ethane, fluoro-, HFC-161	12	0		
1	Ethane, hexafluoro-, HFC-116	12200	1	Ethane, hexafluoro-, HFC-116	12200
1	Ethane, pentafluoro-, HFC-125	3500	1	Ethane, pentafluoro-, HFC-125	3500
1	Ether, 1,1,1-trifluoromethyl methyl-, HFE-143a	756	0		
1	Ether, 1,1,2,2-Tetrafluoroethyl 2,2,2-trifluoroethyl-, HFE-347mcc3	575	0		
1	Ether, 1,1,2,2-Tetrafluoroethyl 2,2,2-trifluoroethyl-, HFE-347mcf2	374	1	Ether, 1,1,2,2-Tetrafluoroethyl 2,2,2-trifluoroethyl-, HFE-347mcf2	575
1	Ether, 1,1,2,2-Tetrafluoroethyl methyl-, HFE-254cb2	359	1	Ether, 1,1,2,2-Tetrafluoroethyl methyl-, HFE-254cb2	359

	NAME (ReciPE)	GWP		Name IPCC	GWP
1	Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356mec3	101	0		
1	Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcc3	110	0		
1	Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcf2	265	0		
1	Ether, 1,1,2,3,3,3-Hexafluoropropyl methyl-, HFE-356pcf3	502	0		
1	Ether, 1,2,2-trifluoroethyl trifluoromethyl-, HFE-236ea2	989	0		
1	Ether, 1,2,2-trifluoroethyl trifluoromethyl-, HFE-236fa	487	0		
1	Ether, 2,2,3,3,3-Pentafluoropropyl methyl-, HFE-365mcf3	11	0		
1	Ether, di(difluoromethyl), HFE-134	6320	0		
1	Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245cb2	708	0		
1	Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245fa1	286	0		
1	Ether, difluoromethyl 2,2,2-trifluoroethyl-, HFE-245fa2	659	0		
1	Ether, ethyl 1,1,2,2-tetrafluoroethyl-, HFE-374pc2	557	0		
1	Ether, pentafluoromethyl-, HFE-125	14900	0		
1	Hexane, perfluoro-	9300	1	Hexane, perfluoro-	9300
1	HFE-227EA	1540	0		
1	HFE-236ca12 (HG-10)	2800	1	HFE-236ca12 (HG-10)	2800
1	HFE-263fb2	11	0		
1	HFE-329mcc2	919	0		
1	HFE-338mcf2	552	0		
1	HFE-338pcc13 (HG-01)	1500	1	HFE-338pcc13 (HG-01)	1500
1	HFE-347pcf2	580	1	HFE-347pcf2	580
1	HFE-43-10pccc124 (H-Galden1040x)	1870	1	HFE-43-10pccc124 (H-Galden1040x)	1870
1	Hydrocarbons, chlorinated	10.6	0		
1	Methane	25	1	Methane	25
1	Methane, biogenic	25	1	Methane, biogenic	25
1	Methane, bromo-, Halon 1001	5	1	Methane, bromo-, Halon 1001	5
1	Methane, bromochlorodifluoro-, Halon 1211	1890	1	Methane, bromochlorodifluoro-, Halon 1211	1890
1	Methane, bromodifluoro-, Halon 1201	404	0		
1	Methane, bromotrifluoro-, Halon 1301	7140	1	Methane, bromotrifluoro-, Halon 1301	7140
1	Methane, chlorodifluoro-, HCFC-22	1810	1	Methane, chlorodifluoro-, HCFC-22	1810
1	Methane, chlorotrifluoro-, CFC-13	14400	1	Methane, chlorotrifluoro-, CFC-13	14400
1	Methane, dibromo-	1.54	0		
1	Methane, dichloro-, HCC-30	8.7	0		
1	Methane, dichloro-, HCC-30	8.7	1	Methane, dichloro-, HCC-30	8.7
1	Methane, dichlorodifluoro-, CFC-12	10900	1	Methane, dichlorodifluoro-, CFC-12	10900
1	Methane, dichlorofluoro-, HCFC-21	151	0		
1	Methane, difluoro-, HFC-32	675	1	Methane, difluoro-, HFC-32	675
1	Methane, fluoro-, HFC-41	92	0		
1	Methane, fossil	25	1	Methane, fossil	25
1	Methane, iodotrifluoro-	0.4	0		
1	Methane, monochloro-, R-40	13	1	Methane, monochloro-, R-40	13

	NAME (ReciPE)	GWP		Name IPCC	GWP
0			1	Methane, pentafluoromethoxy-, HFE-134	6320
1	Methane, tetrachloro-, CFC-10	1400	0		
1	Methane, tetrachloro-, CFC-10	1400	1	Methane, tetrachloro-, CFC-10	1400
1	Methane, tetrafluoro-, CFC-14	7390	1	Methane, tetrafluoro-, CFC-14	7390
1	Methane, trichlorofluoro-, CFC-11	4750	1	Methane, trichlorofluoro-, CFC-11	4750
0			1	Methane, trifluoro-(difluoromethoxy)-, HFE-125	14900
1	Methane, trifluoro-, HFC-23	14800	1	Methane, trifluoro-, HFC-23	14800
0			1	Methane, trifluoro-methoxy-, HFE-143a	756
1	Nitrogen fluoride	17200	1	Nitrogen fluoride	17200
1	Pentane, 2,3-dihydroperfluoro-, HFC-4310mee	1640	1	Pentane, 2,3-dihydroperfluoro-, HFC-4310mee	1640
1	Pentane, perfluoro-	9160	1	Pentane, perfluoro-	9160
1	PFC-9-1-18	7500	1	PFC-9-1-18	7500
1	PFPMIE	10300	1	PFPMIE	10300
1	Propane, 1,1,1,2,2,3-hexafluoro-, HFC-236cb	1340	0		
1	Propane, 1,1,1,2,3,3-hexafluoro-, HFC-236ea	1370	0		
1	Propane, 1,1,1,2,3,3,3-heptafluoro-, HFC-227ea	3220	1	Propane, 1,1,1,2,3,3,3-heptafluoro-, HFC-227ea	3220
1	Propane, 1,1,1,3,3,3-hexafluoro-, HCFC-236fa	9810	1	Propane, 1,1,1,3,3,3-hexafluoro-, HCFC-236fa	9810
0			1	Propane, 1,1,2,2,3,3, hexafluoromethoxy- HFE-356pcc3	110
1	Propane, 1,1,2,2,3-pentafluoro-, HFC-245ca	693	0		
1	Propane, 1,1,3,3-tetrafluoro-, HFC-245fa	1030	1	Propane, 1,1,3,3-tetrafluoro-, HFC-245fa	1030
1	Propane, 1,3-dichloro-1,1,2,2,3-pentafluoro-, HCFC-225cb	595	1	Propane, 1,3-dichloro-1,1,2,2,3-pentafluoro-, HCFC-225cb	595
1	Propane, 3,3-dichloro-1,1,1,2,2-pentafluoro-, HCFC-225ca	122	1	Propane, 3,3-dichloro-1,1,1,2,2-pentafluoro-, HCFC-225ca	122
1	Propane, perfluoro-	8830	1	Propane, perfluoro-	8830
1	Sulfur hexafluoride	22800	1	Sulfur hexafluoride	22800
1	Sulphur, trifluoromethyl pentafluoride	17700	1	Sulphur, trifluoromethyl pentafluoride	17700
96			**70**		

Annex 2 – Pathways

List of crops in the RSB Tool.

Crop
Camelina
Cassava
Castor bean
Corn
Corn Stover
Energy Tobacco
Jatropha
Palm
Potato
Rapeseed
Salicornia
Soybean
Sugar beet
Sugar cane
Sunflower
Sweet sorghum
Wheat Grains
Wheat Straw

List of conversion technologies included in the RSB Tool.

Biofuel production technologies → Biofuel product
(Hydrolysis &) Fermentation → Ethanol, Biogas
Methyl esterification → Methyl Ester
FT Synthesis → BTL, DME, Methanol
Hydrotreatment → Hydrotreated oils & fats

Annex 3 – Land Use Tables

AGB

Table A3-44: Above ground biomass in forests (source: (IPCC 2006), table 4.7 p. 4.53).

Domain	Ecological zone	Continent	Above-ground biomass (tonnes d.m. ha^{-1})	References
Tropical	Tropical rain forest	Africa	310 (130-510)	IPCC, 2003
		North and South America	300 (120-400)	Baker *et al.*, 2004a; Hughes *et al.*, 1999
		Asia (continental)	280 (120-680)	IPCC, 2003
		Asia (insular)	350 (280-520)	IPCC, 2003
	Tropical moist deciduous forest	Africa	260 (160-430)	IPCC, 2003
		North and South America	220 (210-280)	IPCC, 2003
		Asia (continental)	180 (10-560)	IPCC, 2003
		Asia (insular)	290	IPCC, 2003
	Tropical dry forest	Africa	120 (120-130)	IPCC, 2003
		North and South America	210 (200-410)	IPCC, 2003
		Asia (continental)	130 (100-160)	IPCC, 2003
		Asia (insular)	160	IPCC, 2003
	Tropical shrubland	Africa	70 (20-200)	IPCC, 2003
		North and South America	80 (40-90)	IPCC, 2003
		Asia (continental)	60	IPCC, 2003
		Asia (insular)	70	IPCC, 2003
	Tropical mountain systems	Africa	40-190	IPCC, 2003
		North and South America	60-230	IPCC, 2003
		Asia (continental)	50-220	IPCC, 2003
		Asia (insular)	50-360	IPCC, 2003
Subtropical	Subtropical humid forest	North and South America	220 (210-280)	IPCC, 2003
		Asia (continental)	180 (10-560)	IPCC, 2003
		Asia (insular)	290	IPCC, 2003
	Subtropical dry forest	Africa	140	Sebei *et al.*, 2001
		North and South America	210 (200-410)	IPCC, 2003
		Asia (continental)	130 (100-160)	IPCC, 2003
		Asia (insular)	160	IPCC, 2003
	Subtropical steppe	Africa	70 (20-200)	IPCC, 2003
		North and South America	80 (40-90)	IPCC, 2003
		Asia (continental)	60	IPCC, 2003
		Asia (insular)	70	IPCC, 2003
	Subtropical mountain systems	Africa	50	Montès *et al.*, 2002
		North and South America	60-230	IPCC, 2003
		Asia (continental)	50-220	IPCC, 2003
		Asia (insular)	50-360	IPCC, 2003

Table A3-45: Continued; Above ground biomass in forests (source: (IPCC 2006), table 4.7 p. 4.54).

Domain	Ecological zone	Continent	Above-ground biomass (tonnes d.m. ha^{-1})	References
Temperate	Temperate oceanic forest	Europe	120	-
		North America	660 (80-1200)	Hessl *et al.*, 2004; Smithwick *et al.*, 2002
		New Zealand	360 (210-430)	Hall *et al.*, 2001
		South America	180 (90-310)	Gayoso and Schlegel, 2003; Battles *et al.*, 2002
	Temperate continental forest	Asia, Europe (≤20 y)	20	IPCC, 2003
		Asia, Europe (>20 y)	120 (20-320)	IPCC, 2003
		North and South America (≤20 y)	60 (10-130)	IPCC, 2003
		North and South America (>20 y)	130 (50-200)	IPCC, 2003
	Temperate mountain systems	Asia, Europe (≤20 y)	100 (20-180)	IPCC, 2003
		Asia, Europe (>20 y)	130 (20-600)	IPCC, 2003
		North and South America (≤20 y)	50 (20-110)	IPCC, 2003
		North and South America (>20 y)	130 (40-280)	IPCC, 2003
Boreal	Boreal coniferous forest	Asia, Europe, North America	10-90	Gower *et al.*, 2001
	Boreal tundra woodland	Asia, Europe, North America (≤20 y)	3-4	IPCC, 2003
		Asia, Europe, North America (>20 y)	15-20	IPCC, 2003
	Boreal mountain systems	Asia, Europe, North America (≤20 y)	12-15	IPCC, 2003
		Asia, Europe, North America (>20 y)	40-50	IPCC, 2003

DOM

Table A3-46: Default Values for litter and dead wood (source: (IPCC 2006), table 2.2 p. 2.27).

Climate	Forest type			
	Broadleaf deciduous	Needleleaf evergreen	Broadleaf deciduous	Needleleaf evergreen
	Litter carbon stocks of mature forests		Dead wood carbon stocks of mature forests	
	(tonnes C ha^{-1})		(tonnes C ha^{-1})	
Boreal, dry	25 (10 - 58)	31 (6 - 86)	n.a.[b]	n.a
Boreal, moist	39 (11 - 117)	55 (7 - 123)	n.a	n.a
Cold Temperate, dry	28 (23 - 33)[a]	27 (17 - 42) [a]	n.a	n.a
Cold temperate, moist	16 (5 - 31) [a]	26 (10 - 48) [a]	n.a	n.a
Warm Temperate, dry	28.2 (23.4 - 33.0)[a]	20.3 (17.3 - 21.1)[a]	n.a	n.a
Warm temperate, moist	13 (2 - 31) [a]	22 (6 - 42)[a]	n.a	n.a
Subtropical	2.8 (2 - 3)	4.1	n.a	n.a
Tropical	2.1 (1 - 3)	5.2	n.a	n.a

Soil organic carbon

Table A3-47: Relative stock change factors (FLU, FMG, and FI) over 20 years) for different management activities on cropland (source: (IPCC 2006), table 5.5 p. 5.17).

CROPLAND		LAND USE				TILLAGE			INPUT			
Climate	Eco_code	FLU(Long_term)	FLU (Tree_crop)	FLU (Set_Aside)	FLU (Paddy_Rice	FULL	REDUCED	NO	LOW	MEDIUM	HIGH (without manure)	HIGH (with manure)
Tropical wet	Tar	0.48	1	0.82	1.1	1	1.15	1.22	0.92	1	1.11	1.44
Tropical moist	Tawa	0.48	1	0.82	1.1	1	1.15	1.22	0.92	1	1.11	1.44
Tropical dry	TAWb	0.58	1	0.93	1.1	1	1.09	1.17	0.95	1	1.04	1.37
Tropical dry	TBSh	0.58	1	0.93	1.1	1	1.09	1.17	0.95	1	1.04	1.37
Tropical dry	TBWh	0.58	1	0.93	1.1	1	1.09	1.17	0.95	1	1.04	1.37
Tropical montane	TM	0.64	1	0.88	1.1	1	1.09	1.16	0.94	1	1.08	1.41
Warm temperate moist	SCf	0.69	1	0.82	1.1	1	1.08	1.15	0.92	1	1.11	1.44
Warm temperate dry	SCs	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Warm temperate dry	SBSh	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Warm pemperate dry	SBWh	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Warm temperate moist or dry	SM	0.69	1	0.82	1.1	1	1.08	1.15	0.92	1	1.11	1.44
Cool temperate moist	TeDo	0.69	1	0.82	1.1	1	1.08	1.15	0.92	1	1.11	1.44
Cool temperate moist	TeDc	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Cool temperate dry	TeBSk	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Cool temperate dry	TeBWk	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Cool temperate moist or dry	TeM	0.69	1	0.82	1.1	1	1.08	1.15	0.92	1	1.11	1.44
Boreal moist	Ba	0.69	1	0.82	1.1	1	1.08	1.15	0.92	1	1.11	1.44
Boreal dry	Bb	0.8	1	0.93	1.1	1	1.02	1.1	0.95	1	1.04	1.37
Boreal moist and dry	BM	0.69	1	0.82	1.1	1	1.08	1.15	0.92	1	1.11	1.44

Table A3-48: Relative stock change factors for grassland management (source: (IPCC 2006), table 6.2 p. 6.16).

GRASSLAND		LAND USE	MANAGEMENT				INPUT	
Temperature	Eco_code	ALL	Nominally	Moderately	Severely	Improved	MEDIUM	HIGH
Tropical wet	Tar	1	1	0.97	0.7	1.17	1	1.11
Tropical moist	Tawa	1	1	0.97	0.7	1.17	1	1.11
Tropical dry	TAWb	1	1	0.97	0.7	1.17	1	1.11
Tropical dry	TBSh	1	1	0.97	0.7	1.17	1	1.11
Tropical dry	TBWh	1	1	0.97	0.7	1.17	1	1.11
Tropical montane	TM	1	1	0.96	0.7	1.16	1	1.11
Warm temperate moist	SCf	1	1	0.95	0.7	1.14	1	1.11
Warm temperate dry	SCs	1	1	0.95	0.7	1.14	1	1.11
Warm temperate dry	SBSh	1	1	0.95	0.7	1.14	1	1.11
Warm pemperate dry	SBWh	1	1	0.95	0.7	1.14	1	1.11
Warm temperate moist or dry	SM	1	1	0.95	0.7	1.14	1	1.11
Cool temperate moist	TeDo	1	1	0.95	0.7	1.14	1	1.11
Cool temperate moist	TeDc	1	1	0.95	0.7	1.14	1	1.11
Cool temperate dry	TeBSk	1	1	0.95	0.7	1.14	1	1.11
Cool temperate dry	TeBWk	1	1	0.95	0.7	1.14	1	1.11
Cool temperate moist or dry	TeM	1	1	0.95	0.7	1.14	1	1.11
Boreal moist	Ba	1	1	0.95	0.7	1.14	1	1.11
Boreal dry	Bb	1	1	0.95	0.7	1.14	1	1.11
Boreal moist and dry	BM	1	1	0.95	0.7	1.14	1	1.11

Annex 4 – Options for the treatment of co-products

Options for Treating Co-Products in the RSB GHG Lifecycle Calculation Methodology

8 December 2010

Executive Summary

This document is adapted from the backgrounder Note sent to the Steering Board for its meeting of April 15, 2010. Having considered the various options for treating co-products in GHG accounting, the RSB Secretariat proposes an *allocation* methodology. Furthermore, it is proposed that allocation be done based on economic value. This document discusses the different GHG accounting options for co-products and explains the choice of economic allocation.

Background

Attributional analysis involves the use of a methodology that assigns or attributes the environmental impacts to the biofuel and its co-products according a property, such as *mass, energy, economic* value, or other. .

Consequential analysis involves conducting a full assessment of the fate of the co-product, what products in the market it will likely replace, and what effects this *displacement* will have on other markets.

Example: Rapeseed

1. Consequential analysis (system expansion): Additional demand for rapeseed in Europe will generate extra rapeseed meal by-product, which will displace E.U. wheat and marginal U.S. soymeal as animal feed. This in turn results in creation of idle land in the E.U. and reduced export of soymeal from the U.S. to the E.U., which ends up resulting in increased export of soybean meal to Brazil/Argentina and avoided land expansion in those countries. This consequential analysis is called *system expansion* because the system analyzed is expanded beyond the borders strictly related to biofuel and its by-products.
2. Allocation: Rapeseed meal is a by-product of rapeseed oil production. For each 1 kilogram (or 1 megajoule) of rapeseed oil produced, X kg or Y MJ of rapeseed cake are produced. In addition, rapeseed oil has economic value of A and rapeseed meal has economic value of B. Using mass-based or energy-based allocation, the rapeseed meal would be allocated X% (or Y%) of the carbon emissions associated with producing the rapeseed. Using economic-based allocation, the rapeseed meal would be allocated B/A% of the carbon emissions. The carbon emissions associated with the rapeseed meal are then subtracted from those associated with the rapeseed oil.

A *multifunction process* is an activity that fulfils more than one function, such as a production process with more than one product. A methodological allocation problem arises in the LCI when a multifunctional process fulfils one or more functions for the product life cycle investigated and a different function, or set of functions, for other products. The problem is to decide what share of the environmental burdens of the activity should be allocated to the product investigated, i.e., included in the LCI of the product investigated (Ekvall & Finnveden, 2001).

The International Organisation for Standardisation (ISO) has presented a standard for LCI - ISO 14041, suggesting that the following procedure be used for allocation in multifunction processes[19]:

1. Allocation should be avoided, wherever possible, either through subdivision or system expansion, as follows:
    a. Subdivision of the multifunction process into sub-processes, and collection of separate data for each sub-process. Or,
    b. *Expansion of the systems* investigated until the same functions are delivered by all systems compared.
2. Where allocation cannot be avoided, the allocation should reflect the physical relationship between the environmental burdens and the functions, i.e. how the burdens are changed by quantitative changes in the functions delivered by the system. In other words, the environmental burdens should be partitioned among different functions of the system in a way that reflects the underlying physical causality. This could include allocation by mass or energy if these parameters reflect the physical relationship between the environmental burden and the biofuel/co-product.
3. Where such physical casual relationship alone cannot be used as the basis for the allocation, the allocation should reflect other relationships between environmental burdens and the functions. Allocation based on other causal relationships includes, e.g., allocation in proportion to the economic value of the products or functions. It can also include allocation by mass and energy when there is no physical relationship between the relative environmental burden of the biofuel–co-product system and its mass or energy; mass or energy can be used as a proxy of these burdens.

Consequential Analysis

Consequential analysis of by-products requires a multiple-step analysis of displacement/substitution effects of by-products and the products they displace. This method can be used provided that the conventional production process for the co-product or by-product can be clearly identified and that sufficient information is available to determine the GHG emissions intensity of the conventional process (CDM Meth Panel 35th meeting report). In addition, to perform a consequential analysis of by-product impacts, the fate of the by-products must be known, including displacement effects and effects on regional and global markets.

The assumptions made in performing a consequential analysis can change over time as the markets change and the analysis is dependent on geography, i.e., the effect of increased rapeseed meal production in the E.U. will have different effects on the market than increased rapeseed production in a different geographic region and hence the substitution analyses will differ. In addition, each assumption made on the fate of the co-product and its impact on regional and global markets has an uncertainty associated with it.

While most experts in the RSB GHG EG agree that system expansion is, in theory, a preferable approach to treating by-products, some experts argue that system expansion is ridden with uncertainties, is variable with time and geography, and is therefore not a preferable methodology; such experts propose allocation as a preferable method. In addition, an argument that has been made by some members of the GHG EG and by EMPA is that system expansion widens the boundaries of the system analyzed beyond the scope of what is under the control of the operator.

Allocation

[19] ISO (1998): Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis. ISO 14041:1998 (E). International Organisation for Standardisation, Geneva, Switzerland

One of the basic principles for allocation in ISO 14041 is that the sum of the allocated environmental burdens should equal the total, unallocated burdens. The allocation can then be expected to produce such additive results only for activities where the environmental burdens are linear and homogeneous function of the quantity of each of the different functions delivered by the activity (Ekvall & Finnveden, 2001).

Allocation based on physical properties of the products is the predominant allocation method in LCI practice because data on these properties are generally readily available and easily interpreted. In some cases, this allocation may coincide with allocation based on physical, causal relationships. However, when the allocation is not based on an accurate model of causal relationships, it will not provide reliable information on the consequences of the actions (Ekvall & Finnveden, 2001).

Allocation reflecting physical relationship between environmental burden and products

Allocation based on physical properties of the products can be done using, for example, mass, volume or energy content of products, although such bases for allocation need to be justified satisfactorily, and this is only likely to be a valid option in specific circumstances (CDM Meth Panel 35th meeting report). For example, in cases where all products and by-products are used for their energy content (e.g., if they are fuels), allocation by energy content can be regarded as appropriate. However, allocation by this means for products that are not used for their energy content cannot be said to be based on physical properties.

Some experts in the RSB GHG EG have stated that using allocation is an arbitrary method given that neither economic nor mass or energy values have a physical relationship to the environmental burden of a co-product and the biofuel. These experts therefore argue that using mass/energy content/ or economic allocation in the RSB methodology would fall under Option (3) above, where "a physical casual relationship cannot be used as the basis for the allocation".

Allocation reflecting other relationships between environmental burden and products

Allocation by *market value* has been proposed (CDM Meth Panel 35th meeting report) as one option. The disadvantage is that market prices often fluctuate and vary regionally, and in such cases the results of the LCA will change. However, the market price reflects the value of the by-product in proportion to the main product, and thus, it is a valid measure of the proportional value society places on each (CDM Meth Panel 35th meeting report). It should be noted that the choice of mass/energy/value will have a potentially large effect on the results (Winrock, 2009)[20].

Treatment of co-products in different methodologies

Different policy-oriented LCA methodologies, have different ways of dealing with co-products:

- The E.U. JRC methodology use system expansion as well; however, the JRC methodology uses a simplified one-step analysis. I.e., rapeseed meal is assumed to displace U.S. soybean meal, which has a calculated environmental impact, which is deducted from the impacts associated with the bio-

[20] From Winrock (2009): *"The impact of co-product treatment is well illustrated in the case of corn. At an average 2007-2008 US spot price of $468/t ethanol (FO Licht, 2009) and an illustrative DDGS price of $100/tonne, DDGS from a dry mill process represents 27% of the overall economic output and therefore 27% of total emissions are attributed to DDGS. If emissions from the same process are allocated on an energy basis the emissions attributed to DDGS represent 65% of the total. For corn ethanol and any process that yields co-products with a high energy value, energy allocation results in a substantially more favorable net calculated carbon intensity of corn ethanol than a system expansion approach or allocation by market value. As the percentage of emissions allocated to the co-product increases the emissions associated with the biofuel decrease. In the case of biodiesel, the choice of co-product treatment can also significantly affect the results of calculations.*

fuel. EMPA argues that the JRC methodology is not robust and consistent, and that the full consequential analysis methodology proposed by Bo Weidema (2009) and exemplified above for rapeseed meal should be employed;

- The E.U. RED GHG methodology uses energy-based allocation, except for electricity, where system expansion is used.
- The U.S. RFS2 LCA analysis of biofuels is a fully consequential analysis of the impact of increased biofuel production in the U.S. Hence, consequential system expansion is used to treat by-products (and all other system elements);
- The California Low Carbon Fuel Standard uses GREET as its GHG calculation methodology. GREET generally treats biofuel by-products using an allocation methodology, except for electricity, where system expansion is used.

In the GBEP "Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy", the user is asked how co- and/or by-products are considered in the LCA, whether co- and/or by-products originate from biomass or non-biomass, what falls under the definition of co- and/or by-products and the methodology to take them into account, i.e., system expansion (and assumptions used) or allocation (and type of allocation used). The document states that "this is an area where different approaches in LCAs can potentially produce quite different results and therefore clarity of the approach is important for useful comparison of LCAs".

Below is a summary of pros and cons of allocation vs. consequential analysis.

Table: Summary of pros and cons of co-product treatment using allocation vs. consequential analysis

Co-product treatment	Pros	Cons
Attributional (mass/energy/ economic value)	• Simpler analysis; • Implementation less time and resource intensive; • Sufficient to meet the needs for Study 1 and 2; • Includes factors that are under control of an operator.	• Not representative of real environmental impacts; • RSB risks being seen as having an overly simplistic LCA methodology.
Consequential analysis of system expansion	• More accurate portrayal of reality; • Assigns real environmental burden to biofuel & co products; • RSB LCA tool will arguable be regarded more highly; • Sufficient to meet the needs for Study 1 and 2.	• Uncertainty associated with assumptions on product displacement and effects on regional & international markets; • Results change over time and hence analysis would need to be reassessed every few years; • Results are dependent on geography, and hence for some pathways we would have to conduct various assessments (e.g., Brazilian and U.S. soy biodiesel); • Goes beyond the factors of control of an operator.

Implications for RSB Certification

The goal of Principle 3 is to cause a reduction in global GHG emissions through the use of biofuels that have significantly lower carbon footprints than the fossil fuels they replace. A second goal is to encourage individual producers to continuously improve their GHG performance.

Principle 3 requires to:

1. Requires calculation of the carbon footprint of a biofuel (Criterion 3b);
2. Requires calculation of the carbon footprint of baseline fossil fuels (Criterion 3b);
3. Sets a minimum GHG reduction threshold of the biofuel with respect to the fossil fuel (Criterion 3c);
4. Is meant to encourage individual producers to become better, i.e., to lower their GHG emissions, year by (not yet included in Principle 3, though continuous improvement is a requirement in Principle 2).

In order for Principle 3 to attain its goals, it can be said regarding the points above that:

1. The GHG calculation methodology should calculate the carbon footprint of a biofuel as accurately as possible;
2. The GHG calculation methodology should calculate the carbon footprint of baseline fossil fuels as accurately as possible;
3. The minimum GHG reduction threshold of the biofuel with respect to the fossil fuel should be ambitious enough to allow a *safety margin* for certain aspects that mitigate the positive effects of biofuel use, including, but not limited to: the rebound effect[21]; and other indirect effects (unless these will be addressed elsewhere in the P&C as a result of the analysis of the work on indirect impacts).
4. The GHG calculation methodology should reflect and credit GHG reduction measures implemented by the producer.

As a standard setting organization, the RSB is well advised to follow the ISO LCI - ISO 1404 procedure for allocation in multifunction processes:

1. **ISO Guidelines**: Allocation should be avoided, wherever possible, either through subdivision or system expansion.
    a. ***View of the RSB Secretariat****: According to EMPA, the subdivision methodology does not apply to biofuel LCA assessments. While some GHG EG members postulate that system expansion is the preferred and more accurate methodology, other members have highlighted some of the shortcomings of system expansion (such as potentially high uncertainty and system boundaries that go beyond what the operator can influence).The RSB Secretariat believes that system expansion is potentially a more accurate way of treating by-products than allocation. However, system expansion involves a very detailed assessment and numerous assumptions, leading to potentially high inaccuracy in the framework of a certification system, and additionally requiring substantial time and resources beyond what is currently available to the Secretariat. The Secretariat has requested a quote to conduct a system expansion analysis and has determined that at present, it does not have the resources to conduct such an analysis for all feedstock pathways. EMPA has estimated that it would*

[21] Rebound effect: Increased biofuel use causes fossil fuel prices to drop, which in turn causes increased fossil fuel use and subsequent GHG emissions.

take roughly 3 weeks per pathway to conduct a system expansion analysis. Hence, the RSB Secretariat does not have the time to conduct such an analysis by May 2010.

2. **ISO Guidelines**: Where allocation cannot be avoided, the allocation should reflect the physical relationship between the environmental burdens and the functions.
    a. ***View of the RSB Secretariat**: Mass and energy content only reflect a physical relationship between products and their environmental impacts in certain instances (see discussion above), for example, if all products and by-products are used for their energy content. However, neither mass nor energy content or any other parameter can be select that reflects a physical relationship between the products and their environmental impacts for all biofuel pathways and all by-products, and in most instances mass or energy content will not reflect such a physical relationship. Hence it can be said that no parameter has been identified that meets this criterion.*
3. **ISO Guidelines**: Where such physical casual relationship alone cannot be used as the basis for the allocation, the allocation should reflect other relationships between environmental burdens and the functions.
    a. ***View of the RSB Secretariat**: Mass, energy content, or economic value could be used as parameters that reflect a relationship (albeit not a direct, physical relationship) between environmental burden and the by-product and main product. The use of mass or energy makes only sense when the product and by-products have a value or a function that is related to their mass or energy content, respectively. This is only the case in some instances. Economic value reflects the value that society apportions to a specific product and can be used as a proxy of its impacts on the environment. However, economic value is time and geography-dependent.*

Cost & time implications for the RSB

In order to meet the schedule set by the Steering Board, the number of pathways included in Study 1 needs to be reduced compared to the 29 pathways contained in the proposal of EMPA. Actual costs will reflect the reduced number of pathways calculated.

EMPA has determined that a *consequential analysis* would take 3 weeks per pathway to conduct. This would clearly delay the development of the GHG RSB methodology and result in a much larger expense.

Rationale of the RSB decision regarding to the treatment of co-products

Taking into account the pros and cons of the different methodologies listed above, the RSB Secretariat recommended to the Steering Board to use an attributional approach with economic allocation.

The choice of the economic allocation allows taking into account all co-products, incl. such which have no mass (like electricity) or no energetic use (chemicals) in a consistent way. Furthermore, it creates an incentive for an optimal use of by-products and so reduce waste.

References

Winrock, 2009: "The Impact of Expanding Biofuel Production on GHG emissions, White paper #1: Accessing and interpreting existing data", April 2009.

Weidema (2009) Chapter for CALCAS deliverable D18, 2009

Ekvall & Finnveden (2001) Allocation in ISO 14041—a critical review, Journal of Cleaner Production 9 (2001) 197–208

CDM Meth Panel, 35th Meeting Report, "Draft Guidance on Apportioning of Emissions to Co-Products and By-Products", http://cdm.unfccc.int/Panels/meth/meeting/08/035/mp_035_an11.pdf

Annex 6 – Lower heating values

Source: Condensed list of standard values, version 2 – Public.doc, retrieved from http://www.biograce.net/content/ghgcalculationtools/standardvalues.

Diesel	43,1	MJ/kg (0% water)
Gasoline	43,2	MJ/kg (0% water)
HFO for marine transport	40,5	MJ/kg (0% water)
Ethanol	26,81	MJ/kg (0% water)
Methanol	19,9	MJ/kg (0% water)
FAME	37,2	MJ/kg (0% water)
Syn diesel (BtL)	44,0	MJ/kg (0% water)
HVO	44,0	MJ/kg (0% water)
PVO	36,0	MJ/kg (0% water)
n-Hexane	45,1	MJ/kg (0% water)
Hard coal	26,5	MJ/kg (0% water)
Lignite	9,2	MJ/kg (0% water)

Corn	18,5	MJ/kg (0% water)
FFB	24,0	MJ/kg (0% water)
Rapeseed	26,4	MJ/kg (0% water)
Soybeans	23,5	MJ/kg (0% water)
Sugar beet	16,3	MJ/kg (0% water)
Sugar cane	19,6	MJ/kg (0% water)
Sunflowerseed	26,4	MJ/kg (0% water)
Wheat	17,0	MJ/kg (0% water)
Animal fat	37,1	MJ/kg (0% water)
BioOil (byproduct FAME from waste oil)	21,8	MJ/kg (0% water)
Crude vegetable oil	36,0	MJ/kg (0% water)
DDGS (10 wt% moisture)	16,0	MJ/kg (10% water)
Glycerol	16,0	MJ/kg (0% water)
Palm kernel meal	17,0	MJ/kg (0% water)

Palm oil	37,0	MJ/kg (0% water)
Rapeseed meal	18,7	MJ/kg (0% water)
Soybean oil	36,6	MJ/kg (0% water)
Sugar beet pulp	15,6	MJ/kg (0% water)
Sugar beet slops	15,6	MJ/kg (0% water)

Annex 7 – Peer Reviewer Comments

The RSB Greenhouse Gas Calculation Methodology ("RSB GHG calculation methodology Draft for Peer Review", December 15, 2010) was submitted for peer review to the RSB GHG Expert Group. It was peer reviewed by individuals from these institutions and with the following areas of expertise:

- University of California, Berkeley – Experience: LCA, biofuels, land use
- National Wildlife Federation – Experience: Agricultural production & methods
- Michigan State University – Experience: Biofuels, land use, LCA
- Shell Oil – Experience: LCA, fossil fuels

The Secretariat received four reviewers' comments. The comments generally consist of suggestions for making the methodology more robust. The reviewers do not have any fundamental criticism of the methodology as a means to measure the direct GHG emissions of biofuel production using attributional LCA methodology. However, one reviewer does bring up the issue of uncertainty associated with calculating LCA emissions from biofuels without taking indirect land use change into account and without taking the rebound effect (increased used of fuel caused by a decrease in fuel prices caused by an increased supply of biofuels in the market) into consideration. ILUC and the rebound effect are examples of consequential LCA. In addition, one reviewer points out the lack of an uncertainty analysis, that is, the absence of a calculation of a margin of error.

The RSB Secretariat, together with EMPA, addressed each comment from the reviewers. All comments and the response to each comment are recorded in a summary document, which is included in this Annex.

Peer Reviewers:

Name	Title & Contact
Bruce Dale	Bruce E. Dale, PhD, Professor Department of Chemical Engineering and Materials Science DOE Great Lakes Bioenergy Research Center Editor in Chief: Biofuels, Bioproducts and Biorefining Michigan State University 3815 Technology Boulevard, Lansing, MI 48910 Website: www.everythingbiomass.org Office phone: 517-353-6777 Fax 517-337-7904
Rick Malpas	Project Leader, Greenhouse Gas Intensity Analysis Team Projects & Technology Retail Fuels Technology Shell International Petroleum Company Limited
Richard Plevin	Energy & Resources Group University of California Berkeley
Eliav Bitan	Agriculture Advisor Climate and Energy Program National Wildlife Federation

Peer reviewer: Rick Malpas

Feedback (R. Malpas)	RSB Response
· As an overall comment there are several areas where the RSB has taken a different approach to all others in this field and I would question the need for this, as it is likely to confuse and add complexity. Things have moved on somewhat since our last GHG telecom and I would suggest taking developments, particularly in Europe, into account in the methodology, which would make the calculations simpler while not altering the results materially. Some of these issues are addressed below	na
· I don't see the need to quote results based on HHV. LHV is accepted and adding HHV can confuse.	This change has been made.
· The system boundary appears to include infrastructure (tractors, buildings etc). This is inconsistent with other methodologies. It is not clear how emissions associated with such infrastructure will be amortised and the contribution is likely to be extremely low if this is done over the infrastructure's useful life. This seems a lot of effort for little added value and I suggest removing this element.	Chemical production, e.g., includes infrastructure. This is also true for use of machinery (entered as practices such as harvesting, tilling, etc.) For the chemical plant, it is included in the chemical use, but not in the equipment, only building of the plant. In agriculture, machinery is important. In the chemical plant, it is less relevant.
· It is mentioned in section 2.4 that the tool will not provide default values for material and energy usage. I would recommend providing conservative values as options. Some biofuel producers, for example, could purchase raw material (e.g. vegetable oil) from a range of different suppliers and entering actual data would be difficult, if not impossible.	Each supplier will enter data pertaining to their own operations. We are not providing defaults for energy and chemical usage because it requires defining conservative values and they are pathway-dependent.
· The GHGs included are much wider than the typical CO2/CH4/N2O considered by others (and by regulations). While academically this may be correct, it adds to complexity – does it make much difference to the final result?	All the GHGs are included (embedded) in the EcoInvent factors and it is not possible to take them out. These GHGs are embedded in EcoInvent factors related to chemicals, energy, and machinery (materials) production. SF6 can indeed make a difference, and it shows up in electricity as it is used in electrical transmission. This said, the *direct* emissions calculated by the methodology are restricted to CH4, N2O and CO2 (and in the case of fires, NOX and CO as well).

Feedback (R. Malpas)	RSB Response
· One of your reasons for choosing allocation for co-product treatment is the attributional nature of the methodology. However, you have then included foregone sequestration, which is a very consequential consideration (e.g. how long would the trees have remained if biofuels were not grown?) I think you should be consistent in your approach here and, for an attributional methodology, you should exclude foregone sequestration.	FS looks at the difference in the carbon accumulation rates between the original and transformed land used. FS is indeed a consequential perception. EMPA's opinion is that it is *not* consistent from a methodological point of view. In principle we agree with this comment so the decision is to eliminate FS.
· I agree with your use of allocation for co-product treatment on the grounds of simplicity, but question use of allocation by economic value rather than by energy. These are, after all, fuels, and other methodologies and regulatory requirements all use allocation by energy – so why be different?	Co-products, even more in refineries, are not always used for energy purposes (e.g. glycerine in pharma/cosmetics). In this case, energy does not make any sense, whereas economic allocation at least can be used in a consistent way over all products which leave a facility.
· The LUC section follows the IPCC Guidelines extremely closely (please check the equation numbers in this section – p 17 in particular seems to have IPCC numbers). However, the IPCC Guidelines are really intended as a carbon inventorisation method and in some places I don't think it is clear how these translate into the calculation of LUC emissions. For example, how does a producer predict what the net carbon stock growth or loss will be over the 20 years amortisation period due to a perennial biofuel crop such as oil palm? I would like more discussion on this.	Oil palm and coconut are indeed the only bioenergy crop that are assigned a net growth over 20 years. The net growth was determined from average data from IPCC. Peatland is treated in a special way as well
· Likewise the methodology includes the IPCC carbon stock tables but these only cover some cases (IPCC does not consider energy crops for example) and some of the entries have ranges – which is not very useful. If these have been modified or augmented in the tool (as seems to be implied by section 4.1.6) then, again, more discussion would help. The EU methodology has now made some pragmatic modifications and simplifications to the IPCC methodology including filling the gaps in the carbon stock tables for relevant biofuel crops and I suggest making use of this in your methodology.	The RSB methodology follows generally the modified LUC methodology described in the last LUC Guideline document.
· Following on from this, I find the section on carbon sequestration in harvested wood products confusing. Again this is relevant to an IPCC inventorisation but how do you decide how long furniture (for example) will last and continue to sequester carbon? More discussion would again help.	As stated in the methodology "carbon sequestration in biomass is not taken into account in the methodology"
In general I suspect that some of these points have been addressed in the GHG tool if it is to be practically useable, but, if this is so, it would be good to see the document reflect what has been done.	The methodology, esp. The land use portion, has been rewritten to provide more transparency about the calculations done in the Tool and comparison with EU RED.

Peer reviewer: Eliav Bitan

Feedback (E. Bitan)	RSB Response
First, land management practices are the most important determinant of GHG impacts, if land use change is not allowed. Therefore, I think a greater focus on land management is appropriate in this tool, as it is meant (I think) to distinguish among biofuels that have not caused land use change.	This is certainly true, and accurately incorporating ag management practices in the methodology is a way to promote good practices. There is a resource and time constraint limit and hence not all ag management practices have been incorporated into the calculations.
Second, this tool uses IPCC tier 1 methodology (tier 1= global or national emissions factors) for land management (the table on page 70). While this methodology may be appropriate in the developing world, where regionally or locally specific data is not available, in the developed world tier 2 or 3 is appropriate (Tier 2= local or regionally derived emissions factors. Tier 3= local measurements, calibrated process based models, or a combination). IPCC chapter 2 figure 2.4 directs developers of GHG inventories to use the highest tier possible, and in the USA (the place I know most about) Tier 2 is always possible, and Tier 3 is generally possible.	The methodology allows for the use of Tier 2 or 3 as well.
Third, attached please find a comprehensive literature review USA ghg impacts of various practices. Based on that data, I would submit that cover crops and crop rotation should give you a land management factor of about 1.2 EACH. (about 1 metric ton per year, times 20 years= 20 metric tons, with an average of about 75 metric tons of SOC already present.) This is about the same size factor as tillage.	Cover crops and tillage are taken into account as having an impact on carbon emissions , but not crop rotation. It would be good to integrate crop rotation.
Fourth, Nitrogen application is over simplified in the tool. Timing of N application makes a difference just as big as N type (which is included in the tool). Similarly, injecting N vs. surface applying it makes a difference that is the same order of magnitude. Both timing and method of application are questions farmers know the answer to, and science knows that there is a significant GHG reduction possible by moving timing closer to crop needs and application deeper into the soil.	For the moment we will not integrate these considerations but it would be a good idea to integrate these in the future in order to make the cultivation calculations more accurate, which would also better incentivize good practices.

Peer Reviewer: Richard Plevin

Feedback (R. Plevin)	RSB Response
I understand that for the sake of simplicity, RSB would choose to use allocation. I disagree with this, but I understand it. However, the Annex has a few statements that really should be adjusted for the sake of clarity and scientific honesty.	It should be noted that the "Optional for Addressing Co Product Treatment" originally included in the Annex was an older document that had been drafted as a Steering Board backgrounder to talk about this issue, and before the choice of an allocation method was used. The RSB agrees that the document should be updated in order for it to be more relevant. Hence, the document was modified and updated in December.
1. "Some experts in the RSB GHG EG have stated that using allocation is an arbitrary method given that neither economic nor mass or energy values have a physical relationship to the environmental burden of a co-product and the biofuel."	Please note that "some experts" refers only to the RSB GHG EG. It is generally accepted by LCA practitioners that allocation is an arbitrary allocation method to a degree.
Saying "some experts" implies that this point is disputed. Can anyone show that these methods are predictive of environmental burdens? Of course not: it's easy to show the opposite. The only honest justification for allocation is expediency.	
2. "However, the market price reflects the value of the by-product in proportion to the main product, and thus, it is a valid measure of the proportional value society places on each (CDM Meth Panel 35th meeting report)."	Economic value is used in this methodology as an allocation method for the following reason: Products with high value tend to drive production, i.e., be the reason for the production process and it makes sense to attribute more impact to them. This said, like any attributional method, the economic allocation method has important limitations, like all other allocation methods. We agree that conducting a consequential analysis of co products is a more accurate analysis.
With all due respect to the meth panel, LCA is not a measure of the value society places on a product; it's a tool to estimate environmental burdens. Is there any evidence that the environmental burdens associated with co-products relate to their relative prices? No, this method is just as arbitrary as using energy or mass. That it uses prices suggests market analysis, but it's nothing of the sort.	

Feedback (R. Plevin)	RSB Response
3. The table lists uncertainty as a "Con" for consequential analysis. Uncertainty is a feature of the problem, not of the method. If we agree that system expansion, in theory, correctly estimates the environmental effect of a co-product, and we recognize that this is uncertain, then we must accept that the environmental burden of the main product is uncertain. Substituting a method that produces crisp results that are demonstrably unrelated to the environmental effects does not reduce this uncertainty, it merely submerges it.	The uncertainty that we referred to, as it applies to consequential analysis, is the uncertainty about the fate of the co product. In many instances, this fate is not known to the operator. The RSB built a Tool for operators to use to calculate their emissions; allowing system expansion and consequential analysis means that the Tool would have to be able to accommodate all possible fates of the product (one of which would be selected by the operator). At least in the initial version of the Tool and the methodology, this was seen as an impractical and resource intensive option which was not possible to implement.
Also, some of the "Cons" listed for consequential analysis also apply to economic value: prices also vary regionally and temporarily.	This is true; however, the Tool asks the operator the actual economic data that are relevant to them (the price they have paid/received).
4. Economic allocation is said to create "an incentive for an optimal use of by-products". How is this? (For that matter, optimal for *what?* Profits? GHG reduction?)	Note that we are only saying that economic allocation "creates an incentive", not that it actually leads to better use of resources. If a coproduct has low economic value then the burden is allocated to the

Feedback (R. Plevin)	RSB Response
Presumably biofuel producers are price takers, so price provides incentives only to processes for which co-product ratios are flexible, i.e. the producer can make more biofuel and less co-product, or vice-versa (e.g., cellulosic ethanol and electricity). For cases with fixed co-product ratios (e.g., DDGS, glycerin, soybean meal) what incentives are provided by price that affect optimality? The environmental benefits of exported electricity are clearly a function of what is displaced from the grid, which varies regionally and temporally. It is as clearly *not* a function of the relative price of ethanol and electricity. The price of ethanol rises with the price of oil, increasing its value relative to electricity. Does this mean the environmental benefit of co-produced electricity is getting lower? The environmental benefits of glycerin depend on what it displaces in the market, not its market value. Methods that credit biodiesel producers for the actual avoided GHG provide incentives to avoid those GHGs. Price-based allocation offers no incentive to find high GHG displacement opportunities.	main production process and the operator has an incentive to lower the GHG emissions associated with their operations. We do agree that economic allocation (and any allocation method) has important limitations in attributing impact to coproducts.
If RSB decides to go this way, so be it. But don't justify the decision with nonsensical arguments. The statement in the table that allocation is "not representative of real environmental impacts" is key. Let's be clear that allocation (in any of its forms) trades environmental relevance for expediency. That's the bottom line.	Allocation was indeed chosen for practical reasons, as explained in the Annex, and it was understood consequential analysis is, if all (co)product fates are known, a more accurate way to treat coproducts.

Peer Reviewer: Bruce Dale

Was in general agreement with the methodology.