



REDcert

System principles for
GHG calculation

under the Biomass Sustainability Ordinances
(BioSt-NachV and Biokraft-NachV)

Version 04

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1 Definitions

1.1 Greenhouse gas emission savings

The greenhouse gas emission saving denotes the percentage of greenhouse gas emissions that could be saved by using liquid biomass instead of fossil fuels.

1.2 Default values

The default value is a value that can be used if the conditions outlined in the BioSt-NachV have been met instead of a value that has actually been calculated. The GHG emission saving can thus be calculated using the default values shown in Annex 2 of the Biokraft-NachV or BioSt-NachV.

The standard values stated there for pure palm oil and pure soy oil which are brought to market as biofuels or are used for electricity production may no longer be used for calculating the greenhouse gas reduction potential starting 1 January 2011.

1.3 Partial default values

The partial default value is a value defined in Annex 2 of the Biokraft-NachV or BioSt-NachV that relates to one part of production.

If partial default values are used, the partial default value can only be used for the cultivation e_{ec} from Annex 2 no 1 (a) and the standard values from Annex 2 no 1 (e) of the Biokraft-NachV or BioSt-NachV if:

- the biomass was produced in a third country or in a region of the European Union that is listed in Art. 19 para. 2 of the 2009/28/EG Directive (list of the NUTS2 regions) or
- the liquid biomass was produced from waste or residues and the residues do not originate from agriculture, forestry, and fishing or aquacultures

For all values that are missing or are not consistent with the specifications of the list stipulated in 2009/28/EC, the interfaces have to calculate the individual greenhouse gas emissions.

Neither the Biokraft-NachV/BioSt-NachV nor the Directive makes provisions for using individual NUTS2 values.

1.4 NUTS2 values

For biomass types from EU member states, the NUTS2 values may be used for those biomass types that are specified in the reports of the member states (if available) in accordance with Article 19, para. 2 of Directive 2009/28/EC from 23 April 2009 instead of the partial default values for farming stipulated in 1.3. For biomass farmed in Germany, the NUTS tool developed by REDcert can be used to determine the applicable NUTS2 values depending on the farming region and biomass type. The tool can be accessed on REDcert's website at <http://www.redcert.de> under Documents/NUTS tool.

1.5 Estimates

The GHG emissions for farming can also be calculated if necessary using regional estimates for farming as long as these values are published.

Estimates can be used if they are based on a methodology based on which the NUTS2 values were also calculated and that is recognised by the Commission, e.g. the estimated values of the German NUTS2 regions for barley, rye and triticale. Estimates which do not meet these requirements are not recognised. The German estimates for barley, rye and triticale can be found on REDcert's website at <http://www.redcert.de> under Documents/Material.

2 Greenhouse gas emission savings

2.1 Calculating the greenhouse gas emission savings

The greenhouse gas emission saving is calculated by the last interface using the formula below:

$$\text{Treibhausgas – Minderungspotenzial(\%)} = \frac{E_F - E_B}{E_F} * 100$$

where:

E_B = total emissions in the use of liquid biomass

E_F = total emissions of the reference value for fossil fuels

The following values are used as reference values for fossil fuels when calculating the greenhouse gas emission savings of liquid biomass:

- 91 g CO₂eq/MJ for use in electricity production
- 85 g CO₂eq/MJ for use in heat-and-power generation plants
- 83.8 g CO₂eq/MJ for use as fuel
- 77 g CO₂eq/MJ for use in heat production

2.2 Minimum requirements for the greenhouse gas emission savings

According to Article 8 of the Sustainability Ordinances, the liquid biomass/biofuel used has to have a greenhouse gas emission savings of **at least 35%**.

This saving shall increase

- on 1 January 2017 to **at least 50%** and
- on 1 January 2018 to **at least 60%** in interfaces in which production started on or after 31 December 2016

3 Greenhouse gas emissions

3.1 Calculating the greenhouse gas emissions

Each operation involved in the production and supply chain is required to calculate the GHG emissions incurred during the respective step. The GHG emissions incurred when producing the raw materials, particularly during the cultivation and harvesting of the biomass, can be calculated by the first gathering point using the default values listed in Annex 2 of the Biokraft-NachV. In this case, the farmer has to confirm to the first gathering point in writing that the default value should be used for the calculation of the incurred GHG emissions prior to or upon delivery of the biomass.

Every interface, every operation and every operating site calculates the GHG emissions produced in his own area. He adds this value to the GHG emissions incurred with the upstream interfaces, operations, operating sites and gives this figure to the downstream interface, the downstream operations or the downstream operating site.

The total emissions are calculated using one of the generally binding formulas described below. It comprises emissions and emission savings.

The individual components of the formula can be calculated:

- using precisely measured data
- using partial default values for the emissions that are specified in the ordinance or
- using the total default values for the emissions that are specified in the ordinance if the interface/processing operation is the last one

It is important to note here that there are no default emission values for the component "land-use changes" (e_l). If default values or partial default values are used for cultivation, values that can be attributed to land-use changes always have to be added to them.

To help calculate the GHG emissions, the calculation tool BioGrace approved by the EU Commission or the calculation tool ENZO2 approved by the BLE can also be used. Both calculation tools make it possible to calculate the GHG emissions across the entire production and supply chain although the ENZO2 tool was adapted to German production conditions while the BioGrace tool offers more flexibility with respect to input values and calculation formulas.

3.2 Calculation the cumulative greenhouse gas emission

Every interface, every operation and every operating site calculates the greenhouse gas emissions incurred on its premises [in kg CO₂/ton] for the production and delivery of the biomass before it is forwarded to the downstream interfaces, operations or operating sites, using the following formula:

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

3.2.1 Meaning of the variables

E = *total emissions in the use of the liquid biomass*

e_{ec} = *emissions from production of the relevant raw materials, and especially in cultivation and harvesting of the biomass from which the bioliquids are produced*

e_l = *annualised emissions resulting 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 use of the liquid biomass*

e_{sca} = emissions savings from soil carbon accumulation via improved agricultural management

e_{ccs} = emissions savings from capture and geological storage of carbon dioxide

e_{ccr} = emissions savings from carbon dioxide capture and replacement

e_{ee} = emissions savings from excess electricity from cogeneration. GHG emissions from the manufacture of machinery and equipment shall not be taken into account.

The unit of the e variables above is [g CO₂/MJ final product]

When calculating the values for the intermediate steps, it is, however, recommended calculating the GHG emissions (e') in relation to the intermediate product produced in the respective process step based on the allocation (taking into account co-products) in subsequent process steps.

e': greenhouse gas emissions per mass of the intermediate product. This value is not yet allocated up to the respective production step.

$$\left[\frac{g \text{ CO}_2}{kg \text{ Vorprodukt}} \right]$$

3.2.2 Data for calculating the GHG emissions

Data that is necessary for calculating the GHG emissions can be sub-divided into two categories:

- **data affecting the results** that has to be gathered anyway (e.g. quantity of nitrogen fertiliser)
- **other data** that is necessary for the calculation but the work required to determine it precisely is disproportionately high (e.g. emission factor of nitrogen fertiliser, i.e. the quantity of CO₂ released in the production of the fertiliser) or that would hardly impact the overall result (e.g. quantity of pesticides)

The following data is only considered precisely measured when it is gathered on-site:

- quantity of primary and co-products
- quantity of chemicals (e.g. pesticides, methanol, NaOH, HCl, hexane, citric acid, Fuller's earth, alkali),

- quantity of P₂O₅, K₂O, CaO and N fertilisers,
- diesel consumption, electricity consumption
- consumption of thermal energy
- process energy source

The following data is considered precisely measured if it is taken from a recognised scientific source:

- calorific values of the primary and co-products
- emission factors of e.g. fertiliser, diesel in agricultural machinery, chemicals, electricity, Palm Oil Mill Effluent (POME), thermal energy and
- emission factor of laughing gas (N₂O)

Precisely measured data must be documented for the calculation of the GHG emissions to be transparent. The source must be cited (in particular, the author, title, magazine, volume, year) for values taken from literary sources or databases.

The method for collecting precisely measured data must be transparent so that the calculations are also transparent.

3.2.3 Calculating the greenhouse gas emission savings for raw material production (e_{ec})

The first gathering point calculates the GHG emissions for raw material production e_{ec} including the GHG emission for cultivation and harvesting of the raw materials as well as the GHG emissions for production of the inputs used for production or cultivation on the basis of exactly measured data in the following formula:

$$e_{ec} \left[\frac{kgCO_2}{kgErnteertrag} \right] = \frac{Em_{Dünger} \left[\frac{kgCO_2}{ha * yr} \right] + Em_{Diesel} \left[\frac{kgCO_2}{ha * yr} \right] + Em_{Strom} \left[\frac{kgCO_2}{ha * yr} \right] + Em_{Input} \left[\frac{kgCO_2}{ha * yr} \right]}{Ertrag_{Haupterzeugnis} \left[\frac{kgErnteertrag}{ha * yr} \right]}$$

The primary product is the intermediate product originating from a step in the production chain from which the liquid biomass is produced in subsequent steps of the production chain for use in electricity production or as fuel.

An input is material or energy added to a process. Formula components in detail:

$$Em_{Dünger} \left[\frac{kgCO_2}{ha * yr} \right] = Dünger \left[\frac{kg}{ha * yr} \right] * \left(Ef_{Herstellung} \left[\frac{kgCO_2}{kgDünger} \right] + Ef_{Feld} \left[\frac{kgCO_2}{kgDünger} \right] \right)$$

$$Em_{Diesel} \left[\frac{kgCO_2}{ha * yr} \right] = Diesel \left[\frac{l}{ha * yr} \right] * Ef_{Diesel} \left[\frac{kgCO_2}{l} \right]$$

$$Em_{Strom} \left[\frac{kgCO_2}{ha * yr} \right] = Strom \left[\frac{kWh}{ha * yr} \right] * Ef_{NationaleStrommix} \left[\frac{kgCO_2}{kWh} \right]$$

The GHG emissions that are produced in the following steps must be included:

- production and cultivation process
- collection of the raw materials and
- chemicals and other products used (e.g. diesel)

To calculate e_{ec} , at least the following data must be collected on-site, i.e. the respective quantities are taken from, e.g. company documents:

- fertiliser [kg/(ha*yr)] - total quantity of the N, P₂O₅, K₂O, CaO fertiliser per hectare used annually in the year of cultivation
- diesel [l/(ha*yr)] - total quantity of diesel used annually for, e.g. tractors and water pumps per hectare in the year of cultivation
- electricity consumption-total electricity consumption - e.g. for drying and water pumps per hectare in the year of cultivation
- harvest yield - primary/co-product [kg harvest yield/(ha*yr)] - annual harvest of the primary/co-product in kg per hectare in the year of cultivation. If drying took place, the mass of the dried product is to be specified

If other emissions are incurred, they must be recorded and included in the calculation. The data has to be placed in the formula accordingly.

The following emission factors can be taken from a literature source or database (e.g. GEMIS, GREET) to calculate e_{ec} : (see also Annex 1, Table 2):

- Ef_{Diesel} – emission factor diesel [kg CO₂/l diesel]
- $Ef_{Production}$ – emission factor fertiliser production [kg CO₂/kg N fertiliser]

- E_{Field} – emission factor fertiliser field emission [kg CO₂/kg N fertiliser]
- $E_{\text{NationalElectricityMix}}$ – emission factor national electricity mix [kg CO₂/kWh]

The data has to be placed in the formula accordingly.

All data on greenhouse gas emissions is expressed in mass units in relation to the primary product (e.g. diesel [kg]/rape seed [kg]).

The GHG emissions for cultivation can also be calculated if necessary using regional estimates for cultivation as long as these values are published.

Estimates can be used if they are based on a methodology based on which the NUTS2 values were also calculated and that is recognised by the Commission, e.g. the estimated values of the German NUTS2 regions for barley, rye and triticale. The BLE does not recognise estimates for which these requirements are not satisfied.

3.2.4 Calculating greenhouse gas emissions resulting from land-use change (e_l)

E_l are the annualised greenhouse gas emissions from carbon stock change due to land-use changes.

If the carbon stock of the cultivated area has changed since the reference date, it has to be included in the calculation of the GHG emissions as a land-use change.

This is the case in particular if, after the reference date:

- grasslands that are not highly biodiverse grasslands are converted to areas with annual or permanent crops
- continuously forested areas with a canopy cover of 10 to 30% are converted to areas with annual or permanent crops
- areas with permanent crops are converted to areas with annual crops
- continuously forested areas that feature a high degree of canopy cover over the long run as a result of the type of forest management (e.g. >80%) is converted through a change in management to areas that will have significantly lower canopy cover (e.g. 40%) over the long term (land-use change within the category of continuously forested areas with more than 30% canopy cover). A significant change is defined as a reduction in the canopy cover of more than 20%
- permanently saturated wetlands for cultivating biomass are drained to the extent that they are only saturated with water for a considerable part of the year

The interface, the operation or the operating site determines the annualised GHG emissions as a result of land-use changes (e_l) by evenly distributing the greenhouse gas emissions

produced as a result over 20 years using the data provided by the farm in the following formula:

$$e_{ec} \left[\frac{kgCO_2}{kgErnteertrag} \right] = \frac{CS_R \left[\frac{kgC}{ha} \right] - CS_A \left[\frac{kgC}{ha} \right]}{Ernteertrag_{Hauptprodukt} \left[\frac{kg}{ha * yr} \right] \cdot 20[yr]} \cdot 3,664 - \frac{e_B}{AF * KF}$$

AF, KF = product-specific conversion factor to calculate the mass-related value of the greenhouse gas emissions (AF = allocation factor; KF conversion factor)

e_B = bonus of 29 g CO₂eq/MJ of liquid biomass when cultivating on restored areas that were previously degraded

e_B - to be entitled to the bonus e_B for cultivation on restored areas that were previously degraded, the farm documents that the area in question

- was not used for agricultural or other purposes as of the reference date and
- is a heavily degraded area or
- a heavily contaminated area

The bonus e_B applies for a period of up to 10 years starting when the area is converted to agricultural land if

- there is a continuous increase in the carbon stocks and a notable decrease in erosion on heavily degraded areas and
- the soil contamination on heavily contaminated areas decreases

Heavily contaminated areas are areas that are unfit for cultivation of food and animal feed due to the soil contamination.

Carbon stocks of the area are defined as the mass of carbon in the soil and vegetation per land unit.

CS_R the carbon stock per unit area associated with the reference land use (measured as mass of carbon per unit area, including both soil and vegetation) as of the reference date or 20 years before the raw material was obtained, whichever came later.

CS_A is the carbon stock per unit area associated with the actual land use (measured as mass of carbon per unit area, including both soil and vegetation). In cases where the carbon stock accumulates over more than one year, the value attributed to CS_A shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever comes first.

Areas where cultivation is permitted pursuant to Articles 4 to 7 of the Sustainability Ordinances can be converted if the accumulated GHG emissions resulting from changes in

land use are calculated and added to the other emission values. It must be determined which land-use category the cultivation area belongs to as of the reference date (for sample background data, see Annex 1, Table 3).

If evidence is provided that no changes in land use have occurred since the reference date, this means that $e_l = \text{zero}$ if the cultivation area belongs to the land-use category "cropland" as of the reference date.

Severely degraded areas

Severely degraded areas are areas that were salinated over a longer period of time, that contain a lot of pollutants, to which very few organic substances have been added and areas that are heavily eroded. Areas that were previously used for agricultural purposes are also severely degraded areas.

Salinated soils as defined in the BioSt-NachV include soils with excess salt and sodium (sodium fortification) and are present if

- soil layers that lie at or within 100 cm under the soil surface and contain secondary fortifications of salts, that are more soluble than gypsum and produce electrical conductivity in a soil saturation extract $>4 \text{ dS m}^{-1}$ and
- the total salinated layers have a minimum thickness of 15 cm or when
- soil layers that lie at or within 100 cm below the soil surface and have an exchangeable sodium percentage (ESP) of at least 15% and
- the total layers with excess sodium have a minimum thickness of 15 cm

These areas are also eligible for the bonus if they were recognised as severely damaged or severely contaminated pursuant to a decision of the Commission of the European Communities based on Article 18 para. 4 section 4 of the EU Directive 2009/28/EC.

3.2.5 Calculating the greenhouse gas emissions including transport (e_{td})

The operation or the operating site calculates the GHG emissions for the transport e_{td} of biomass including all transport steps using the following formula:

$$e_{td} \left[\frac{\text{kgCO}_2}{\text{kg}} \right] = \frac{\left(d_{beladen} [\text{km}] * K_{beladen} \left[\frac{\text{l}}{\text{km}} \right] + d_{leer} [\text{km}] * K_{leer} \left[\frac{\text{l}}{\text{km}} \right] \right) * Ef_{Kraftstoff} \left[\frac{\text{kgCO}_2}{\text{l}} \right]}{m_{Zwischenprodukt} [\text{kg}]}$$

The GHG emissions already taken into account in producing the raw material and cultivation are not included in the calculation.

To calculate e_{td} , the following must be documented:

- d [km] – transport distance across which the biomass was transported (e.g. the distance between the farm and the oil mill) and
- m [kg] – measured mass of the transported biomass (e.g. 40 t) and
- the means of transport used (e.g. diesel truck 40 t)

To calculate e_{td} , the following must be documented:

- emission factor fuel [kg CO₂/l],
- K_{Loaded} [l/km] – fuel consumption of the means of transport used per km when loaded and
- K_{Empty} [l/km] – fuel consumption of the means of transport used per km when empty (return journey)

measured or taken from a scientific source of literature.

Scientific publications serve as sources for emission factors (for sample background data, see Annex 1, Table 2).

Reference unit for transport of intermediate products is kg of the intermediate product.

3.2.6 Calculating the greenhouse gas emissions including processing (e_p)

Every processing operation ensures that all GHG emissions caused by processing – this contains greenhouse gas emissions from waste (wastewater) and the GHG emissions caused by production of all inputs – are included in the calculation of the GHG emissions. The following formula is used:

$$e_p \left[\frac{kgCO_2}{kgErtrag} \right] = \frac{Em_{Strom} \left[\frac{kgCO_2}{yr} \right] + Em_{Wärme} \left[\frac{kgCO_2}{yr} \right] + Em_{Betriebsmittel} \left[\frac{kgCO_2}{yr} \right] + Em_{Abwasser} \left[\frac{kgCO_2}{yr} \right]}{Ertrag_{Haupterzeugnis} \left[\frac{kgErtrag}{yr} \right]}$$

Meaning of the variables:

$$Em_{Strom} \left[\frac{kgCO_2}{yr} \right] = Stromverbrauch \left[\frac{kWh}{yr} \right] * Ef_{Strom} \left[\frac{kgCO_2}{kWh} \right]$$

$$Em_{Wärme} \left[\frac{kgCO_2}{yr} \right] = Brennstoffverbrauch \left[\frac{kg}{yr} \right] * Ef_{Brennstoff} \left[\frac{kgCO_2}{kg} \right]$$

$$Em_{Abwasser} \left[\frac{kgCO_2}{yr} \right] = Abwasser \left[\frac{l}{yr} \right] * Ef_{Abwasser} \left[\frac{kgCO_2}{l} \right]$$

$$Em_{Betriebsmittel} \left[\frac{kgCO_2}{yr} \right] = Betriebsmittelverbrauch \left[\frac{kg}{a} \right] * Ef_{Betriebsmittel} \left[\frac{kgCO_2}{kg} \right]$$

To calculate the emissions from processing (e_p), the following data must be collected on-site at a minimum, i.e. the respective quantities are taken from, e.g. company documents: Alternative reference sizes (month, kg of the primary product, etc.) are possible.

- electricity consumption [kWh/yr] – total external electricity purchased per year (i.e. not produced in one's own cogeneration plant)
- heat production – type of fuel/combustible used to produce steam e.g. heating oil, gas, harvest residues
- fuel consumption [kg/yr] – total annual consumption of fuel for heat production, e.g. heating oil [kg], gas [kg], bagasse [kg],
- yield_primary/co-product [kg /yr] – yield of the primary/co-product per year, e.g. rape seed oil and
- wastewater quantity [l/yr] – quantity of wastewater per year (e.g. POME) per year. For more information, see the section on methane capture at the oil mill.

The GHG emissions that are produced by waste are included in the calculation for e_p .

To calculate e_p , the following emission factors can be taken from recognised scientific sources:

- Ef_{Fuel} – emission factor fuel [kg CO₂/kg]
- $Ef_{Wastewater}$ – emission factor wastewater [kg CO₂/l]
- $Ef_{Electricity}$ – emission factor national electricity mix [kg CO₂/kWh] and
- $Ef_{Means\ of\ production}$ – emission factor means of production [kg CO₂/kg]

Scientific publications serve as sources for emission factors (for sample background data, see Annex 1, Table 2).

3.2.7 Greenhouse gas savings through excess electricity

The greenhouse gas emission savings through excess electricity from cogeneration (e_{ee}) is calculated using the following formula:

$$Em_{ee} \left[\frac{kgCO_2}{yr} \right] = \frac{Stromüberschuss \left[\frac{kWh}{yr} \right] * Ef_{Brennstoff} \left[\frac{kgCO_2}{kWh} \right]}{Ertrag_{Haupterzeugnis} \left[\frac{kg}{yr} \right]}$$

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It is assumed for the calculation that the size of the cogeneration plant is consistent with the minimum size that is required to supply the heat necessary for production of the liquid fuel.

The reduction in GHG emissions that results from the excess electricity is the quantity of GHG emissions that would be emitted in the production of a corresponding quantity of electricity in a power station that uses the same fossil fuel as the cogeneration plant.

To calculate e_{ee} , the following data is measured on-site:

- excess electricity [kWh/yr] – electricity fed into an external grid per year that was produced in one's own cogeneration plant
- type of fuel that is used in the cogeneration plant (e.g. heating oil, gas, coal)
- yield of the primary product per year, e.g. rape seed oil [kg/yr] and
- type of cogeneration plant (e.g. combined heat and power plant (CHP), steam and heat plant (DHKW), gas and turbine plant (gas and steam/combined power plants)).

To calculate e_{ee} , the following emission factors can be taken from recognised scientific sources (see also Annex 1, Table 2):

- E_{Fuel} – emission factor of the fuel [kgCO₂/kWh] consistent for the respective type of cogeneration plant

Possible greenhouse gas reduction through capture and geological storage or replacement of carbon dioxide is taken into account pursuant to Annex 1 nos. 14 and 15 of the Sustainability Ordinances (Biokraft-NachV/BioSt-NachV).

3.2.8 Allocation and calculation of the allocation factor

The GHG emissions incurred up to the respective step in the production of the liquid fuel are divided between the liquid fuel and/or its intermediate products and the co-products.

A co-product is one of several products that stem from the same production process and for which an allocation is carried out. No allocation is carried out for waste.

The allocation is performed by energy content. The following formula is used:

$$e'_{alloziert} = \text{SummeTHG} * \text{Allokationsfaktor}$$

TotalGHG is created from all of the greenhouse gas emissions incurred up to the respective production step, i.e. the cumulative greenhouse gas emissions across all upstream operations (e.g. $e'_i + e'_{ec}$). If greenhouse gas emissions were already allocated to co-products in an earlier process step, the portion of these greenhouse gas emissions that was assigned

to the respective intermediate product in the last process step is used for the total (*TotalGHG*).

The formula for calculating the allocation factor is as follows:

$$\text{Allokationsfaktor} = \frac{\text{Energiegehalt}_{\text{Haupterzeugnis}}[\text{MJ}]}{\text{Energiegehalt}_{\text{Haupterzeugnis}}[\text{MJ}] + \text{Energiegehalt}_{\text{Nebenerzeugnis}}[\text{MJ}]}$$

where

$$\text{Energiegehalt}_{\text{Haupterzeugnis}}[\text{MJ}] = m_{\text{Haupterzeugnis}}[\text{kg}] * H_{u,\text{Haupterzeugnis}} \left[\frac{\text{MJ}}{\text{kg}} \right]$$

$$\text{Energiegehalt}_{\text{Nebenerzeugnis}}[\text{MJ}] = m_{\text{Nebenerzeugnis}}[\text{kg}] * H_{u,\text{Nebenerzeugnis}} \left[\frac{\text{MJ}}{\text{kg}} \right]$$

The energy content is determined for other co-products as electricity using the lower heating value H_l and the mass. The lower heating value is the maximum usable quantity of heat for combustion that does not result in condensation of the water vapour contained in the exhaust in relation to the quantity of fuel used (for sample background data, see Annex 1, Table 4).

All co-products are taken into account in the calculation.

Harvest residues, the straw, bagasse, husks, corn cobs and nutshells are not included in the calculation.

The energy content of co-products with negative energy content is set to zero.

When calculating the allocation factor, the lower heating values that relate to the dry mass are multiplied by the yield of dry mass.

When calculating the allocation factor, the lower heating values that relate to the original substance are multiplied by the yield of original substance.

At least the following data must be measured on-site to calculate the allocation factor:

- mass of primary and co-products [kg]

3.2.9 Calculating the greenhouse gas emission savings by the last interface

The last interface calculates the sum of the GHG emissions in g CO₂eq/MJ and calculates the GHG savings potential as a % compared to the respective fossil fuel.

If the partial default value for transport (e_{td}) was not already used to calculate the GHG emissions of the upstream operations, the last interface calculates which regions the liquid biomass can be transported to without falling below the respective GHG emission savings.

The last interface calculates the greenhouse gas emission savings using the following formula:

$$\text{Treibhausgas – Minderungspotenzial(\%)} = \frac{E_F - E_B}{E_F} * 100$$

where:

E_B = total emissions in the use of liquid biomass

E_F = total emissions of the reference value for fossil fuels

When calculating the greenhouse gas emissions savings of liquid biomass that is used to produce electricity, $E_F = 91 \text{ g CO}_2\text{eq/MJ}$ is set as the reference value for fossil fuels.

When calculating the greenhouse gas emissions savings of liquid biomass that is used to produce electricity in cogeneration plants, $E_F = 85 \text{ g CO}_2\text{eq/MJ}$ is set as the reference value for fossil fuels.

When calculating the greenhouse gas emissions savings of liquid biomass that is used to produce heat, $E_F = 77 \text{ g CO}_2\text{eq/MJ}$ is set as the reference value for fossil fuels.

When calculating the greenhouse gas emissions savings of liquid biomass that is used as fuel, $E_F = 83.8 \text{ g CO}_2\text{eq/MJ}$ is set as the reference value for fossil fuels.

3.2.10 Balancing the greenhouse gas emissions

Balancing the greenhouse gas emissions before the last interface

Operations and operating sites before the last interfaces that mix quantities of sustainable biomass with different GHG emissions may only carry out balancing pursuant to Article 16 para. 2 sentence 2 (b) of the Biokraft-NachV / BioSt-NachV if every individual quantity of biomass added to the mixture has already satisfied the requirements of the Biokraft-NachV / BioSt-NachV prior to mixing and has demonstrated the value defined for the respective production step. These values are defined by the Commission of European Communities or by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The Commission of the European Communities publishes these values in the Official Journal of the European Union and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety publishes the respective values in the electronic Federal Gazette.

Balancing the greenhouse gas emissions after the last interface

Pursuant to Article 16 para. 2 sentence 2 (a) of the BioSt-NachV, operations and operating sites after the last interface that mix the individual quantities of liquid biomass for which a sustainability certificate has already been issued may only perform balancing of the GHG emissions if all components of the mixture have the GHG emissions savings required by the Biokraft-NachV / BioSt-NachV. Consequently, the operations and operating sites after the last interface may only currently balance biomass with a GHG emissions savings of at least 35%. Balancing is carried out as a weighted average of the greenhouse gas emission savings. Biomass that does not fulfil this requirement may not be included in the balance.

3.3 Conversion between e' and e

The operation uses the conversion factors (CF) that correspond to the intermediate product to convert the partial default values in relation to the energy content (e) to (e') (partial default values in relation to the intermediate product mass). Sample conversion factors for rape seed and rape seed oil are listed in Annex 1, Table 1. The conversion is performed using the following formula:

Emissions are allocated proportionally to the primary and co-product using the **allocation factor** (AF). Because the partial default values listed already factors in the allocation, the allocation factor must be included again for conversion in relation to the intermediate product.

$$e' \left[\frac{kgCO_2}{kgZwischenprodukt} \right] = \frac{e \left[\frac{kgCO_2}{MJ} \right]}{AF \left[\frac{MJ}{MJ} \right] * KF \left[\frac{kgZwischenprodukt}{MJ} \right]}$$

To convert the reference quantity MJ to the reference quantity kg, the Conversion Factor CF is still needed. As an example for the production of pure rape seed oil, this means that the conversion factor for e_{ec} indicates the quantity of rape seed (in kg) that is needed for 1 MJ of pure rape seed oil. Accordingly, the conversion factor for e_p indicates the quantity of raw rape seed oil necessary for 1 MJ of pure rape seed oil.

Annex 1: Conversion factors and sample background data

Table 1: Conversion factors of default values (in relation to the final product MJ) to mass-related values for intermediate products

Biomass	Partial default value BioSt-NachV [g CO ₂ eq./MJ]	Allocation Factor AF [MJ/MJ]	Conversion Factor CF [kg inter.prod./MJ final product]	Partial default value e_{ec}' e_p' adjusted to [g CO ₂ eq./kg inter.product]
Cultivation e_{ec}				
Rape seed	30	0.61	0.0714	688
Processing e_p				
Rape seed oil	5	0.61	0.0289	283

Source for AF and CF: "JRC (2008) Update on Data on pathways for RED Directive.XLS"

Table 2: Sample background data for calculating e_{ec} , e_p , e_{td} and e_{ee}

	Value	Unit	Source:
Cultivation e_{ec}			
E-factor diesel (production and use)	2.1	kg CO ₂ eq./l diesel	TREMOD
E-factor N fertiliser (production)	6.41	kg CO ₂ eq./kg N fertiliser	IFEU
E-factor P ₂ O ₅ fertiliser (production)	1.18	kg CO ₂ eq./kg P ₂ O ₅ fertiliser	IFEU
E-factor K ₂ O fertiliser (production)	0.663	kg CO ₂ eq./kg K ₂ O fertiliser	IFEU
E-factor CaO fertiliser (production)	0.297	kg CO ₂ eq./kg CaO fertiliser	IFEU
E-factor field emission N fertiliser	4.87	kg CO ₂ eq./kg N fertiliser	IPCC
National electricity mix (D)	0.633	kg CO ₂ eq./l electricity	IFEU/GEMIS

Processing e_p			
E-factor: natural gas (production and use)	0.0722	kg CO ₂ eq./MJ	IFEU
E-factor: heating oil (production and use)	0.1072	kg CO ₂ eq./MJ	IFEU
E-factor: lignite (production and use)	0.1452	kg CO ₂ eq./MJ	IFEU
E-factor: biomass (use)	0.0028	kg CO ₂ eq./MJ	IFEU
E-factor: methanol (use)	1.25	kg CO ₂ eq./kg methanol	IFEU
E-factor: Isobutane (production)	1.27	kg CO ₂ eq./kg isobutane	IFEU
E-factor: NaOH (production)	1.12	kg CO ₂ eq./kg NaOH	IFEU
E-factor: HCl (production)	0.35	kg CO ₂ eq./kg HCl	IFEU
E-factor: Citric acid (production)	0.43	kg CO ₂ -Äq./kg citric acid	IFEU
E-factor: Fuller's earth (production)	0.24	kg CO ₂ -Äq./kg Fuller's earth	ECOINVENT
E-factor wastewater (from palm oil mill POME)	0.511	kg CO ₂ eq./kg palm oil	IFEU
National electricity mix (D)	0.599	kg CO ₂ eq./l electricity	IFEU

Transport e_{td}			
E-factor diesel (production and use)	2.1	kg CO ₂ eq./l Diesel	TREMOD
Fuel consumption (loaded)	0.49	Litre / km	TREMOD (truck with max. 24 t load)
Fuel consumption (empty)	0.25	Litre / km	

	Value	Unit	Source:
Excess electricity e_{ee}			
Gas-fired power plant (boiler)	0.5	kg CO ₂ eq./l electricity	DEHSt/GEMIS/IFEU
Gas-fired power plant (gas and steam)	0.41	kg CO ₂ eq./l electricity	DEHSt/GEMIS/IFEU
Heating oil power plant	0.71	kg CO ₂ eq./l electricity	DEHSt/GEMIS/IFEU
Coal power plant	0.87	kg CO ₂ eq./l electricity	DEHSt/GEMIS/IFEU
Lignite power plant	0.88	kg CO ₂ eq./l electricity	DEHSt/GEMIS/IFEU

Table 3: Sample background data for calculating e_l (Source IPCC)

Type of land	Climate zone	Carbon stock (above-ground/underground biomass + SoilC) [t C/ha]
Carbon stocks of various potential reference areas CS_R		
Bushland	Tropical Africa	94
	North/South America	99
	Asia (continent)	87
	Asia (islands)	110
Pastureland	Tropical Tropical, dry	39
	Tropical, moist	55
	Tropical, wet	68
	Moderate Cold dry	36
	Cold wet	92
	Warm dry	27
	Warm wet	70
Forest (also includes areas with canopy cover of 10-30%)	Tropical	265
Carbon stocks of various potential cultivation areas CS_A		
Cropland annual	Tropical Dry	35
	Moist	46
	Wet	57
	Moderate Cold dry	34
	Cold wet	79
	Warm dry	26
	Warm wet	60
Permanent cropland	Tropical Dry	33
	Moist	48
	Wet	72
	Moderate	-

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Table 4: Sample heating values for primary, intermediate and co-products

Material	Lower heating value (MJ/kg)	Source
Rape seed oil, soy oil, palm oil (raw, refined)	37	Annex III Renewable Energy Ordinance
Rape seed extraction residue	15.0	JRC
Soy extraction residue	15.0	JRC
Palm fruit expeller cake	14.0	IFEU
Palm seeds	28.0	IFEU
Palm seeds expeller cake	17.0	JRC

Annex 2: Sample calculation

A sample calculation of greenhouse gas emissions is provided with precisely measured data in a bioethanol facility in the following section. The bioethanol facility operates on the basis of wheat and produces DDGS as a co-product. The process energy is natural gas.

Emissions from agriculture (e'_{ec} and e')

Delivery of 2,800 t of wheat. The supplier (primary distributor) has calculated the GHG emissions arising from cultivation:

a) Fertiliser

	Measured on-site [kg/ha/a]	Literature value [kg CO _{2eq} /kg fertiliser]	Sum Un _{fertilised} [kg CO _{2eq} /ha/a]
N fertiliser	148	Production: 6.41 Field: 4.87	(148*6,41)+(148*4,87) 1,669
P fertiliser	48	Production: 1.18	57
K fertiliser	40	Production: 0.663	27
Lime fertilizer	575	Production: 0.297	171

The total of all fertiliser emissions $Em_{Fertiliser}$ produces a value of 1,923 kg CO_{2eq}/ha/a.

b) Diesel

	Measured on-site [l/ha/a]	Literature value [kg CO _{2eq} /l]	Sum Em _{Diesel} [kg CO _{2eq} /ha/a]
Diesel	70	2.1	148

c) Electricity

	Measured on-site [kWh]	Literature value	Sum Em _{Electricity}

	electricity/ha/a]	E_f^{Regional electricity mix} [kg CO₂eq/kWh]	[kg CO₂eq/ha/a]
Electricity	9	0.633	6

d) Yield

7,620 kg of wheat/ha/a was harvested.

e) Total emissions from agriculture e'_{ec} and e'_i

The sum of all emissions (Em_{Fertiliser} + Em_{Diesel} + Em_{Electricity}) produces 2,077 kg CO₂eq/ha/a. This is related to the yield:

$$\frac{2077 \text{ kg CO}_{2\text{eq}}}{7620 \text{ kg Weizen}} = 0,273 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Weizen}}$$

As a result, the first gathering point provides the bioethanol facility with a value of 0.273 kg CO₂eq/kg of wheat.

The value for e'_i = 0 because the cropland was already used for agriculture before 1.1.2008.

Emissions from transport

Other emissions were produced from the transport of the biomass. These are calculated using the formula:

$$e_{td} = \frac{\left(\text{Distanz}[\text{km}] \times \text{KV}_{\text{beladen}} \left[\frac{1}{\text{km}} \right] + \text{Distanz}_{\text{leer}}[\text{km}] \times \text{KV}_{\text{leer}} \left[\frac{1}{\text{km}} \right] \right) \times \text{Emissionsfaktor}_{\text{Kraftstoff}} \left[\frac{\text{kgCO}_2}{1} \right]}{\text{transportierte Biomasse}[\text{kg}]}$$

Some of the data to be inserted in this formula is measured exactly, some is weighted; other data originates from literature sources.

Precisely measured data:

- Transported quantity: 2,800t
- Journey with load 35 km
- Empty journey 35 km
- Diesel consumption loaded 0.49 l/km
- Diesel consumption empty 0.25 l/km

Data taken from literature sources:

Emission factor_{Diesel}: 2.1 kg CO₂eq/l

The GHG emissions arising from transport can be reliably calculated by inserting this data into the formula:

$$e_{td}' = \frac{35\text{km} \times 0,49 \frac{\text{l}}{\text{km}} + 35\text{km} \times 0,25 \frac{\text{l}}{\text{km}} \times 2,1 \frac{\text{kgCO}_{2\text{eq}}}{\text{l}}}{24.000 \text{ kg}} = 0,0023 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Weizen}}$$

Emissions from biofuel production e'_p

The bioethanol facility calculates its own data for a specific accounting period (e.g. one year) based on company documents

- input wheat (processed quantity)
- bioethanol yield (in the time period above)
- DDGS yield (accumulation of dry co-product from mash in the time period above)
- electricity consumption of the mill and distillery
- fuel consumption for process heat production (type and quantity)

Precisely measured data:

	Quantity	Mass unit	Comments
Input wheat	2,800	t	
bioethanol yield	790	t	
DDGS yield	950	t	
Electricity consumption	0	kWh	No grid-electricity reference because own code generation plant with excess electricity
Heat consumption	12.000 GJ (=3333.33 MWh)	GJ	$\frac{12 \text{ GJ/m}^3 \text{ EtOH} * 790 \text{ t EtOH}}{0,79 \text{ t/m}^3}$
Wastewater	3.000 m ³	m ³	$\frac{3 \text{ m}^3 \text{ Abwasser /m}^3 \text{ EtOH} * 790}{0,79 \text{ t/m}^3}$
Excess electricity	500 MWh	MWh	$\frac{0,5 \text{ MWh/m}^3 \text{ EtOH} * 790}{0,79 \text{ t/m}^3}$

Data taken from literature:

Emission factors for

- electricity: 0.599 kg CO₂eq/kWh electricity
- heat: 0.0722 kg CO₂eq/MJ natural gas
- wastewater¹: 0 kg CO₂-eq/l wastewater

The GHG emissions of the bioethanol facility per kg of bioethanol are calculated using the formula below:

$$e_p = \frac{\text{Emission}_{\text{Strom}} [\text{kg CO}_{2\text{eq}}] + \text{Emission}_{\text{Wärme}} [\text{kg CO}_{2\text{eq}}] + \text{Emission}_{\text{Abwasser}} [\text{kg CO}_{2\text{eq}}]}{\text{Ertrag}_{\text{Bioethanol}} [\text{kg}]}$$

The emissions for energy consumption are to be calculated using the following formulas:

$$\text{Emission}_{\text{Strom}} = \text{Stromverbrauch} [\text{kWh}] \times \text{Emissionsfaktor}_{\text{regionalesStrommix}} \left[\frac{\text{kgCO}_{2\text{eq}}}{\text{kWh}} \right]$$

$$\text{Emission}_{\text{Wärme}} = \text{Brennstoffverbrauch} [\text{MJ}] \times \text{Emissionsfaktor}_{\text{Heizöl}} \left[\frac{\text{kgCO}_{2\text{eq}}}{\text{MJ}} \right]$$

¹ Explanation for combined anaerobic and aerobic treatment: anaerobic treatment is technically closed, i.e. no methane losses. The biogas is used in the cogeneration plant.

$$\text{Emission}_{\text{Abwasser}} = \text{Abwasseranfall [l]} \times \text{Emissionsfaktor}_{\text{Abwasser}} \left[\frac{\text{kgCO}_{2\text{eq}}}{1} \right]$$

When the data that has been collected and taken from literature sources is inserted into the formula, the result is as follows:

$$e_p = \frac{0 \text{ kWh} \times 0,599 \frac{\text{kgCO}_{2\text{eq}}}{\text{kWh}} + 12.000.000 \text{ MJ} \times 0,0722 \frac{\text{kgCO}_{2\text{eq}}}{\text{MJ}} + 3.000.000 \text{ l} \times 0 \frac{\text{kgCO}_{2\text{eq}}}{\text{l}}}{790.000 \text{ kg Bioethanol}} = 1,097 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}}$$

Production of excess electricity e'_{ee}

$$e'_{ee} \left[\frac{\text{kgCO}_2}{\text{kgHaupterzeugnis}} \right] = \frac{\text{Stromüberschuss} [\text{kWh}] \times E_{f \text{ Brennstoff}} \left[\frac{\text{kgCO}_2}{\text{kWh}} \right]}{\text{Ertrag}_{\text{Haupterzeugnis}} [\text{kg}]}$$

By inserting the individual values, the following results:

$$= \frac{500.000 \text{ kWh Stromüberschuss} * 0,5 \text{ kg CO}_{2\text{eq}}/\text{kWh Strom}}{790.000 \text{ kg Bioethanol}} = 0,316 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}}$$

Total emissions (before allocation)

The individual emissions are merged using the following formula:

$$\text{Gesamtsumme} = \frac{\left(e_{ec} \left[\frac{\text{kgCO}_{2\text{eq}}}{\text{kg Vorprodukt}} \right] + e'_{id} \left[\frac{\text{kgCO}_{2\text{eq}}}{\text{kg Vorprodukt}} \right] \right) \times \text{Input}_{\text{Vorprodukt}} [\text{kg}]}{\text{Bioethanol} [\text{kg}]} + e_p - e'_{ee}$$

The GHG emissions are calculated by inserting the individual values that have already been calculated:

$$\text{Gesamtmission} = \frac{(0,273 + 0,0023) \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Weizen}} \times 2.800.000 \text{ kg Weizen}}{790.000 \text{ kg Bioethanol}} + 1,097 - 0,316 = 1,757 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}}$$

Total emissions of the biofuel after allocation

Before this value can be passed along, it still has to be allocated because the co-product DDGS was also produced in the production of the bioethanol. The emissions incurred up to now are allocated according to the energy content of the mass flows.

This is calculated using the formula:

$$\text{Emmission}_{\text{alloziert}} \left[\frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}} \right] = \frac{\text{Gesamtmission} \left[\frac{\text{gCO}_{2\text{eq}}}{\text{kg Bioethanol}} \right] \times \text{Bioethanol} [\text{kg}] \times H_{u \text{ Bioethanol}} \left[\frac{\text{MJ}}{\text{kg}} \right]}{\text{Bioethanol} [\text{kg}] \times H_{u \text{ Bioethanol}} \left[\frac{\text{MJ}}{\text{kg}} \right] + \text{DDGS} [\text{kg}] \times H_{u \text{ DDGS}} \left[\frac{\text{MJ}}{\text{kg}} \right]}$$

Precisely measured company data is:

- bioethanol yield 790 t
- DDGS yield 950 t
- total emission (see above) 1,749 $\frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}}$

The following data is taken from literature sources:

- lower heating value (HV) for bioethanol 26.6 GJ/t
- lower heating value (HV) for DDGS 17 GJ/t

The allocation is calculated by inserting the values

$$\text{Emission}_{\text{alloziert}} = \frac{1,757 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}} \times 790 \text{ t Bioethanol} \times 26,6 \frac{\text{GJ}}{\text{t}}}{790 \text{ t Bioethanol} \times 26,6 \frac{\text{GJ}}{\text{t}} + 950 \text{ t DDGS} \times 17 \frac{\text{GJ}}{\text{t}}} = 0,993 \frac{\text{kgCO}_{2\text{eq}}}{\text{kg Bioethanol}}$$

The allocated value totalling 0.989 kg CO_{2eq} per kg of bioethanol is needed by the bioethanol facility because, as the last interface, it must indicate the GHG savings.

It is converted to MJ bioethanol as follows:

$$\frac{993 \frac{\text{gCO}_{2\text{eq}}}{\text{kg Bioethanol}}}{26,6 \frac{\text{MJ}}{\text{kg}}} = 37,3 \frac{\text{gCO}_{2\text{eq}}}{\text{MJ Bioethanol}}$$

Greenhouse gas emissions savings

The value EB of 37.2 g CO_{2eq} /MJ bioethanol results in a GHG savings according to the formula

$$\text{Treibhausgas – Minderung} = \frac{E_F - E_B}{E_F} \times 100 [\%]$$

as follows:

$$\frac{83,8 \frac{\text{gCO}_{2\text{eq}}}{\text{MJ Benzin}} - 37,3 \frac{\text{gCO}_{2\text{eq}}}{\text{MJ Bioethanol}}}{83,8 \frac{\text{gCO}_{2\text{eq}}}{\text{MJ Benzin}}} \times 100 = 55 \%$$

Thus bioethanol based on wheat with natural gas for process energy in a cogeneration plant and the co-product DDGS result in a GHG savings of 56% vis-à-vis fossil fuel.