SUSTAINABLE RESOURCES
Verification Scheme GmbH

Technical guidance for greenhouse gas calculation

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Contents

1 Requirements for greenhouse gas emission saving

Directive (EU) 2018/2001 stipulates that the greenhouse gas emission saving from the production of electricity and heat from biomass fuels in installations that became operational from 2021 onwards must be 70%. The greenhouse gas emission saving (GHG) is the savings of greenhouse gas (GHG) emissions expressed as a percentage from the use of biomass fuels compared to fossil fuels for the production of electricity or heat[1]. This limit for the greenhouse gas emission savings increases to at least 80% for installations starting operation from 1 January 2026.

An installation is deemed to be operational if it generates electricity and/or heat for the first time in accordance with its intended use after technical readiness for operation has been established. The date the installation became operational does not change if the generator or other technical or structural parts are replaced after the initial start-up. An installation is any device that generates electricity and/or heat, including those that temporarily store energy and convert it into electricity and/or heat. It is important in this case to validate whether the installation starts production after the respective cut-off date.

Mitigating greenhouse gases is part of the SURE scheme requirements. The last interface that converts biomass fuels into electricity and/or heat must provide information on the date the installation became operational.

2 Scheme principles for greenhouse gas calculation

2.1 Methodology for greenhouse gas calculation

The calculation of the total GHG emissions and the greenhouse gas emission saving resulting from the use of biomass fuels must be calculated as specified in the European regulations.[2] The provisions listed here for biofuels apply to biomass fuels as well.

GHG emissions from the production of biomass fuels and the production of electricity and/or heat must be calculated as follows[3]:

$$E = e_{ec} + e_{l} + e_{p} + e_{td} + e_{u} + e_{sca} + e_{ccs} + e_{ccr}$$

where:

E = *total emissions from the production of the biomass fuel before energy conversion*

e_{ec} = *emissions from the extraction of raw materials, in particular from the cultivation and harvesting of the biomass used to produce the biomass fuels; CO_2 fixation during cultivation is not taken into account*

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 savings from soil carbon accumulation via improved agricultural management*

e_{ccs} = *emission savings from CO_2 capture and geological storage*

e_{ccr} = *emission savings from CO_2 capture and replacement*

Greenhouse gas emissions from biomass fuels are expressed as gCO_2eq/MJ (grams of CO_2 equivalent per MJ of biomass fuel); the total greenhouse gas emissions for the final energy commodity (electricity or heat) produced from biomass fuels ($EC_{h,el}$) are expressed as gCO_2eq/MJ (grams of CO_2 equivalent per MJ of electricity or heat). Greenhouse gas emissions from raw materials and intermediate products are expressed in terms of grams of CO_2 equivalent per kilogram of dry matter of raw materials and intermediate products [gCO_2eq/kg]. If heat is produced at the same time as electricity, emissions are divided between heat and electricity, regardless of whether the heat is actually used for heating or cooling.

Emissions from the manufacture of machinery and equipment are not taken into account. CO_2 emissions during combustion of the fuel (e_u) are set to zero for the biomass fuels. Emissions of non-CO_2 greenhouse gases (CH_4 and N_2O) from the fuel in use must be included in the e_u factor.

Economic operators must provide the auditor with all relevant information on the calculation of the actual GHG emissions prior to the planned audit. All data measured and recorded on site that is relevant for the calculation of actual values must be documented and submitted to the auditor for verification.

GHG emissions data must include accurate data on all relevant elements of the emission calculation formula (if relevant) under Directive (EU) 2018/2001.[4]

The auditor must document the greenhouse gas emissions (after allocation) generated in the inspected operation and, if necessary, the savings in the audit report or in accompanying documents to show that the calculation has been thoroughly verified and understood.

If these emissions deviate significantly from the typical value[5] (e.g. more than 10%), the reasons why should be included in the audit report.

The greenhouse gas emission saving of biomass fuels or electricity and/or heat from biomass fuels must be determined using one of the following alternatives pursuant to Directive (EU) 2018/2001:

- ✓ using the default values (last interface)
- ✓ based on actual values calculated in accordance with the methodology in Directive (EU) 2018/2001 (see the requirements below)
- ✓ using disaggregated default values
- ✓ using a combination of disaggregated and actual values

2.2 Calculation using default values

Economic operators may use the default value for the greenhouse gas emission saving to provide proof of compliance with the greenhouse gas saving requirement if

- ✓ the production pathway and raw material in Annex VI of Directive (EU) 2018/2001 applies
- ✓ the GHG emissions resulting from carbon-stock changes caused by land-use change (e_l value) are less than or equal to “0”
- ✓ and – if distance-dependent default value classes are used – corresponding transport distances along the supply chain have been specified.

Default values are to be taken from Annex VI of Directive (EU) 2018/2001. The European Commission may update the default values. Any updates will immediately enter into force in the SURE-EU system.

If a default value is used, it is determined by the last interface. In this case, it is sufficient that upstream economic operators simply inform the downstream economic operator to “use default value” or similar and of the transport distance (where relevant).

The same applies to disaggregated default values. They can only be applied to certain elements in the supply chain (e_{ec}, e_p, e_{td} and e_u). When economic operators use the disaggregated default values up to the last interface, this must be indicated on their shipping documents, e.g. “Disaggregated default value used for e_{ec}” or “Disaggregated default value used for e_{td}” and for the respective transport distance (if relevant).

Data for the individual calculation of greenhouse gas emissions only has to be included in the documentation if actual values are applied.

The default values listed in Annex VI to the Directive can only be applied if the process technology used to produce the biomass fuel is employed, the raw materials used consistent with their description and volume and, in the case of solid biomass, the transport distances correspond. If a specific technology is specified, the default values can only be used if this technology has actually been applied. If necessary, both the process technology and the raw materials used must be specified.

2.3 Calculation using actual values

Actual values can be used for each phase in the chain of custody regardless of whether there is a default value or not. Actual values of emissions can only be determined at the point when they arise in the value chain (e.g. the actual values of emissions from cultivation (e_{ec}) can only be determined at the beginning of the value chain). Similarly, economic operators can only determine the actual values for transport if emissions from all relevant transport steps are taken into account. Actual emissions for processing can only be determined if the emissions of all processing steps are recorded and passed along through the value chain. Actual values are to be calculated in accordance with the methodology described in Directive (EU) 2018/2001.

The greenhouse gases to be included in the GHG calculation are CO_2, N_2O and CH_4. To calculate the CO_2 equivalence, these gases are weighted as follows in accordance with Directive (EU) 2018/2001 (as of 10/2020):

Greenhouse gas	CO_2 equivalence
CO_2	1
N_2O	298
CH_4	25

If these values change in Directive (EU) 2018/2001, the new values apply in the SURE-EU system with immediate effect.

All GHG emissions (if relevant) associated with the incoming feedstock (upstream emissions e_{ec}, e_l, e_p and e_{td}) must be adjusted to the respective intermediate product using the feedstock factor.

The feedstock factor can be calculated as follows:

$$\text{feedstock factor}_a = \frac{\text{feedstock}_a\left[\text{kg}_{dry}\right]}{\text{intermediate product}_a\left[\text{kg}_{dry}\right]}$$

In addition to the upstream emissions, the emissions generated at the recipient's premises must also be taken into account.

If by-products result from a processing step, the emissions must be allocated (see section 3.9 "Allocation of greenhouse gas emissions").

An example of how the feedstock factor and the allocation factor for the intermediate product are applied to emissions from cultivation is provided below (e_{ec}).

$$e_{ec}\text{intermediate product}_a\left[\frac{gCO_2eq}{kg_{dry}}\right]_{ec} =$$

$$e_{ec}\text{feedstock}_a\left[\frac{gCO_2eq}{kg_{dry}}\right] \times \text{feedstock factor intermediate product}_a \times \text{allocation factor intermediate product}_a$$

The upstream emissions for the processing stage from e_{ec}, e_l, e_p and e_{td} and the emissions to be included for the interface (if relevant) must be converted into the unit CO_2eq/MJ of the final biomass fuel using the feedstock factor for biomass fuel, the allocation factor for biomass fuel and the lower calorific value(H_i).

The feedstock factor for biomass fuel in relation to the biomass fuel can be calculated as follows:

$$\text{feedstock factor biomass fuel}_a = \frac{\text{feedstock}_a[MJ]}{\text{biomass fuel}_a[MJ]}$$

Ratio from the energy, how many MJ of raw product (feedstock) is required for 1 MJ biomass fuel.

If by-products result from a processing step, the emissions must be allocated (see section 3.9 "Allocation of greenhouse gas emissions").

An example of how the feedstock factor for biomass fuel and the allocation factor for biomass fuel are applied to emissions from cultivation is provided below (e_{ec}).

$$e_{ec}\text{biomasse fuel}_a\left[\frac{gCO_2eq}{MJ_{\text{biomass fuel}}}\right]_{ec} =$$

$$\frac{e_{ec}\text{feedstock}_a\left[\frac{gCO_2eq}{kg_{dry}}\right]}{\text{lower calorific value}_a\left[\frac{MJ_{\text{feedstock}}}{kg_{\text{feedstock dry}}}\right]} \times \text{feedstock factor biomass fuel}_a \times \text{allocation factor biomass fuel}_a$$

To perform this calculation, feedstock factors must be determined on the basis of installation data. For the calculation of the feedstock factor biomass fuel, the lower calorific value, which relates to the dry matter, must be used, whereas for the calculation of the allocation factor, the lower calorific value for the whole product must be used. This approach was also used to calculate the default values. The lower calorific value in relation to the dry matter therefore does not take into account the energy needed to cause the water in the wet material to evaporate. No emissions are allocated for products with a negative energy content.[6]

Once the last interface has determined the total GHG emissions for all elements (if relevant) of the formula in gCO_2eq/MJ of biomass fuel pursuant to Directive (EU) 2018/2001, Annex VI, Part 5, No 1, further or subsequent emissions for conversion to electricity and/or heat must be included. See section 3.5 "Requirements for the calculation of greenhouse gas emissions from transport and distribution (e_{td})". For information on the calculation of the greenhouse gas emission saving by the last interface, see section 3.10 "Calculating the greenhouse gas reduction by the last interface".

It is not necessary to include inputs in the calculation which have little or no effect on the result, e.g. low quantities of chemicals used in processing.[7] Inputs with little or no effects are those with a calculated share of less than 0.5% of the total emissions of the production unit.

All information on actual GHG emissions must be taken into account in the individual greenhouse gas calculation for all elements of the formula under Directive (EU) 2018/2001[8] and passed on throughout the value chain (if applicable). It is therefore necessary to separately report the greenhouse gas emissions of e_{ec}, e_l, e_{sca}, e_p, e_{td}, e_{ccs} and e_{ccr} where relevant. This also applies to the elements of the formula for which there are no default values e_l, e_{sca}, e_{ccr} and e_{ccs}. If information on greenhouse values of individual formula elements required for greenhouse gas calculation is missing, the corresponding (disaggregated) default values must be used. This must be clearly identified and evident in the report. As an alternative to the default values, scientific literature sources or a scientifically recognised database (e.g. BioGrace, ECOINVENT database, etc.) can be used if no default values are available or can be applied. If emissions are not recorded along the production pathway and the result is that downstream operators can no longer calculate actual emissions consistently, this must be clearly indicated in the delivery documents at the phase where this gap occurred, taking into account the accompanying documents.

The values such as emission factors, calorific values, etc. should be taken from the European Commission's list to calculate the actual greenhouse gas emissions.[9]

If alternative values are used, appropriate reasons must be provided and clearly indicated in the economic operator's documentation to facilitate verification by the auditor.

2.4 Calculation using disaggregated default values and actual values

Directive (EU) 2018/2001 also provides disaggregated default values in accordance with Parts A, C and D of Annex VI, which can be used in combination with actual values to calculate GHG emissions. The disaggregated default values may then also be used if the main production took place in a region which is listed in the reports of the member states as a NUTS level 2 region in the Common classification of territorial units for statistics" (NUTS-2) or a region at a more disaggregated NUTS level[10], and in which the GHG emissions from cultivation correspond to the disaggregated default value stipulated in Annex VI, Parts C and D of Directive (EU) 2018/2001.

NUTS-2 values are to be indicated in the unit gCO_2eq/kg of dry matter along the entire production chain. These values are alternatives to the individually calculated values. They are published on the website of the European Commission and are not default values. Consequently, they can only be considered input values to calculate and adjust individual cultivation emissions of the downstream interfaces. They are not suitable for specifying emissions from the cultivation phase in gCO_2eq/MJ of biomass fuel.

It is important to note here that there are no default values for the component "land-use changes" (e_l). If disaggregated default values are used for cultivation, GHG emissions from land-use changes always have to be added to them (for information on the methodology to calculate greenhouse gas emissions due to land-use change, see section 3.2).

Disaggregated default values are to be taken from Annex VI of Directive (EU) 2018/2001. The list of (disaggregated) default values can be updated by the Commission. Any changes made by the European Commission to the (disaggregated) default values immediately enter into force in the SURE scheme.

The (disaggregated) default values in Annex VI of Directive (EU) 2018/2001 are to be expressed in gCO_2eq/MJ of biomass fuel. The values are based on the background data of the Joint Research Center (JRC).

For every phase in the production and supply chain, the use of (disaggregated) default values and/or all details used to determine the actual values (methodology, measurements, data sources for non-measured values) must be documented.

When information on greenhouse gas emissions is passed on to the downstream interface, only actual values can be transferred, as otherwise it is not possible to determine whether this is a default value or an actual value for downstream phases. If a default value is to be used, this should be indicated by “use default value” or similar and the transport distance should be specified (if relevant). It is the responsibility of the last interface to provide information on the (disaggregated) default values for the final biomass fuel or commodity.

3 Requirements for calculating GHG emissions based on actual values

3.1 Requirements for calculating GHG emissions based on actual values (e_{ec})

The GHG emissions from the production of raw materials (e_{ec}) include the GHG emissions resulting from the cultivation and harvesting of the raw materials and the GHG emissions resulting from the production of the chemicals and other relevant substances used in cultivation. To calculate e_{ec}, the following data is collected on site at a minimum, i.e. the respective values are taken from, e.g. company documents:

- ✓ quantity of P_2O_5, K_2O, CaO, mineral and organic N fertilisers as well as crop residues in case of agricultural biomass [kg/(ha*year)] – total quantity used annually (in the year of cultivation
- ✓ quantity of chemicals (e.g. pesticides) [kg/(ha*year)] – total quantity used annually (in the year of cultivation)
- ✓ fuel consumption [l/(ha*year)] – total quantity of fuel used annually for, e.g. tractors, harvesters and water pumps per hectare in the year of cultivation – as a measured value or as an estimate based on documented, reliable data (distance, consumption, etc.)
- ✓ electricity consumption [kWh/(ha*year)] – total electricity consumption per hectare in the year of cultivation
- ✓ quantity and type of raw materials used [kg/(ha*year)] (e.g. seeds)
- ✓ harvest yield [kg harvest yield dry/(ha*year)] – quantity of the main/by-product in kg of dry matter per hectare in the year of cultivation. If drying took place, the dry matter content of the dried product must be included

The method for collecting measured data and the measured data for the calculation of the GHG emissions must be documented so that the calculations are also transparent. Actual emissions from cultivation can only be determined if greenhouse gas emissions relevant to the interface are recorded and consistently passed along through the production chain.

It must be kept in mind that the requirements above for calculations and formulas are examples. 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 economic operator responsible calculates the GHG emissions for raw material production (e_{ec}) taking into account the GHG emissions from cultivation and harvest of the raw material as well as the GHG emissions from production of chemicals or products used in cultivation by applying actual values to the following formula (EM = emissions):

$$e_{ec}' = \frac{EM_{fertiliser}\left[\frac{kgCO_2eq}{ha \times year}\right] + EM_{pesticides}\left[\frac{kgCO_2eq}{ha \times year}\right] + EM_{fuel}\left[\frac{kgCO_2eq}{ha \times year}\right] + EM_{electricity}\left[\frac{kgCO_2eq}{ha\ x\ year}\right] + EM_{N2O}\left[\frac{kgCO_2eq}{ha \times year}\right]}{yield_{main\ procuct}\left[\frac{kg_{yield}}{ha \times year}\right]}$$

specified in mass units in relation to the dry harvest yield or dry main product ($kgCO_2eq/kg$ dry). The harvest yield relates to the dry matter content.

The formula below is to be used to specify the emissions of the dry matter in kg:

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

The moisture content is based on the delivery details. If it is missing or not known, it is based on the maximum value allowed in the supply contract.

$$EM_{fertiliser}\left[\frac{kgCO_2eq}{ha \times year}\right] = fertiliser\left[\frac{kg}{ha\ x\ year}\right] \times \left(Ef_{production\ fertiliser}\left[\frac{kgCO_2eq}{kg_{fertiliser}}\right] + Ef_{field}\left[\frac{kgCO_2eq}{kg_{fertiliser}}\right]\right)$$

$$EM_{PSM}\left[\frac{kgCO_2eq}{ha \times year}\right] = PSM\left[\frac{kg}{ha \times year}\right] \times Ef_{production\ PSM}\left[\frac{kgCO_2eq}{kg}\right]$$

$$EM_{fuel}\left[\frac{kgCO_2eq}{ha\ x\ year}\right] = fuel\left[\frac{l}{ha\ x\ year}\right] \times Ef_{fuel}\left[\frac{kgCO_2eq}{l}\right]$$

$$EM_{electricity}\left[\frac{kgCO_2eq}{ha\ x\ year}\right] = electricity\left[\frac{kWh}{ha\ x\ year}\right] \times Ef_{electricity\ mix}\left[\frac{kgCO_2eq}{kWh}\right]$$

Formula components in detail (EM = emissions; Ef = emission factor):

$Ef_{production\ fertiliser}$ = *emission factor fertiliser production [kgCO₂eq/kg fertiliser]*

Ef_{field} = *emission factor laughing gas (N_2O) [kgCO_2eq/kg N fertiliser]*

$Ef_{pesticide\ production}$ = *emission factor pesticide production [kgCO_2eq/kg pesticides]*

Ef_{fuel} = *emission factor fuel in agricultural or forestry machinery [kgCO_2eq/l fuel]*

$Ef_{electricity\ mix}$ = *emission factor EU electricity mix [kgCO_2eq/kWh]*

The values (emission factors, calorific values, etc.) should be taken from the European Commission's list to calculate e_{ec}.[11]

Alternatively a scientific literature source or scientifically recognised database (e.g. BioGrace, ECOINVENT database) can be used.

In the production of agricultural biomass, N_2O field emissions must be calculated for plant residues remaining on the field and for mineral or organic nitrogen fertilisers.

An appropriate way to take into account N_2O emissions from soils is the IPCC methodology, including what are described there as both direct and indirect N2O emissions N_2O emissions[12]. All three IPCC tiers can be used by economic operators. Tier 3 is based on detailed measurement and/or modelling. The BioGrace calculation tool provides details on the calculation of the N_2O emissions from the cultivation of the crop using IPCC Tier 1 (http://www.biograce.net/home). Another way to include these direct and indirect N_2O emissions is the Global Nitrous Oxide Calculator (GNOC) developed by the Joint Research Center for the biomass types not included in the BioGrace calculator (http://gnoc.jrc.ec.europa.eu/).

The data has to be placed in the formula accordingly. The source must be cited (in particular, the author, title, magazine, volume, year) for values taken from scientific literature sources or scientifically recognised databases. The values taken from literature sources or databases must be based on scientific and peer-reviewed work – with the condition that the data used lies within the commonly accepted data range when available.

The life-cycle greenhouse gas emissions of agricultural and forestry waste, harvest residues and production residues including wood from thinning, crown material, non merchantable wood, so-called forest residues, straw, and waste and residues from processing stages in the value chain, are taken to be "zero" until such time as these materials are collected.[13] Materials can be classified as waste, residues or by-products using the Communication from the European Commission COM(2007) 59 and/or can be taken from the SURE scheme principles for the production of biomass fuels from waste and residues.

3.2 Requirements for calculating greenhouse gas emissions resulting from land-use change (e_l)

In the case of land-use changes (converted areas), which have taken place since 1 January 2008 and on which biomass production is permitted under Article 29 of Directive (EU) 2018/2001, the accumulated GHG emissions resulting from the land-use changes must be calculated and added to the other emissions.[14] GHG emissions must be calculated for any land-use change. Land-use change should be understood as changes to land cover between the six land categories used by the IPCC (forest land, grassland, cropland, wetlands, settlements and other land) plus a seventh category of perennial crops, i.e. multi-annual crops whose stem is usually not annually harvested such as short rotation coppice and oil palm (because such land has features of both cropland and forest land).

Directive (EU) 2015/1513, Annex I, therefore stipulates that “cropland” and “perennial cropland” must be regarded as one land use. For all land which according to the definition laid down in Article 1 of 1307/2014 (EU) was grassland in January 2008 or has become grassland in the meantime, it needs to be established whether the grassland would remain or cease to be grassland in the absence of human intervention. This can be natural or non-natural highly biodiverse grassland, which may not be used for the production of biomass fuels (see “Scheme principles for the production of biomass fuels from agricultural biomass”).

This means, for example, that a change from forest land or grassland to cropland is a land-use change, while a change from one crop (e.g. maize) to another (e.g. rapeseed) is not a land-use change. Cropland includes fallow land (i.e. land set at rest for one or several years before being cultivated again). A change of management activities, tillage practice or manure input practice is not considered land-use change.[15] GHG emissions from changes in carbon stocks resulting from land-use change (e_l) are to be calculated in accordance with the Commission Decision of 10 June 2010.[16]

The Commission Decision provides details on the calculation of emissions from changes in carbon stock resulting from land-use change, which can be accessed online.[17]

Annualised GHG emissions from carbon stock changes caused by land-use change (e_l) are calculated by dividing total emissions equally over 20 years.

These emissions are calculated as follows:

$$e_l = (CS_R - CS_A) \times 3{,}666 \times \frac{1}{20} \times \frac{1}{P} - e_B \; ^{18(*)}$$

(*) The quotient obtained by dividing the molecular weight of CO_2 (44.010 g/mol) by the molecular weight of carbon (12.011 g/mol) is equal to 3.664.

e_l = *annualised greenhouse gas emissions from carbon stock change due to land-use change (measured as mass of CO_2-equivalent per unit biomass fuel energy); cropland and perennial cropland shall be regarded as one land use*

CS_R = *the carbon stock per unit area associated with the reference land use (measured as mass (tonnes) of carbon per unit area, including both soil and vegetation). The reference land use shall be the land use in January 2008 or 20 years before the raw material was obtained, whichever was the later*

CS_A = *the carbon stock per unit area associated with the actual land use (measured as mass (tonnes) 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 CSA shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever the earlier*

P = *the productivity of the crop (measured as biomass fuel energy per unit area per year)*

e_B = *bonus of 29 g CO_2eq/MJ biomass fuel if biomass is obtained from restored degraded land under the conditions laid down in Annex VI, Part B, Number 8*

"Severely degraded land" means land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded. If e_l is not zero, the annualised greenhouse gas emissions from carbon stock changes due to land use must be transferred to the next economic operator as the value of e_l in gCO_2eq/kg of dry matter biomass. The biomass producer must therefore use the same formulas as above, where the productivity of the plant (P) is expressed in kg dry matter content of biomass per hectare per year for the calculation.

For converted land where cultivation or silvicultural growing is permitted[19], the accumulated GHG emissions resulting from changes in land use must be calculated and added to the other emission values. The land-use category the cultivated land falls into as of 1 January 2008 therefore has to be determined.

If evidence is provided that the cropland was categorised as "cropland" on 1 January 2008, or the forestry as "forest" on the cut-off date 1 January 2008, and no change in land use took place after the cut-off date 1 January 2008, e_l equals "0".

3.3 Requirements for the use of aggregated and measured values for the management of agricultural and forested areas

Measured or aggregated values (e_{ec} and e_l) can be used for the management of agricultural and forested areas. The following must be kept in mind when using aggregated values:

- ✓ Aggregated GHG values can be calculated for farms operating as a group in a specific region and on the condition that this is done at a more detailed level than at NUTS 2 or similar level.
- ✓ The aggregated values for cultivation must be calculated according to the methodology for e_{ec} as described in section 3.1 "Requirements for calculating greenhouse gas emissions from the production of raw materials (e_{ec})".
- ✓ Input data should be primarily based on official statistical data from government authorities if available and of good quality. Otherwise statistical data published by independent agencies can be used. As a third option, the data can also be taken from literary sources or databases based on scientific and peer-reviewed work – with the condition that the data used lies within the commonly accepted data range when available.
- ✓ The informational material must be based on the most recent data available from the sources above. Typically, data should be updated over time unless it does not vary significantly over time.
- ✓ With respect to fertiliser use, the type and quantity of fertiliser typical for the crops in the respective region must be used.
- ✓ If a measurement for yield (and not an aggregated value) is used for the calculations, a measurement also has to be used for the fertiliser input. The reverse is also true.
- ✓ Economic operators must specify the methods and sources used to determine the input data (e.g. average values based on representative yields, fertiliser input, N_2O emissions and changes in the carbon stock).

3.4 Requirements for the calculation of emissions savings as a result of improved agricultural management (e_{sca})

"Improved agricultural management practices" can contribute to emission savings through soil carbon accumulation. These include (examples):

- ✓ shifting to reduced or zero-tillage
- ✓ improved crop rotations and/or cover crops, including crop residue management

- ✓ improved fertiliser or manure management
- ✓ use of soil improver (e.g. compost, manure/slurry fermentation digestate)

Emissions savings resulting from these improvements in agricultural management practices can be taken into account only if solid and verifiable evidence is provided that the soil carbon has increased or that it is reasonable to expect to have increased over the period in which the raw materials concerned were cultivated.

Measurements of soil carbon can constitute such evidence, e.g. by a first measurement in advance of the cultivation and subsequent measurements at regular intervals several years apart. In this case, the increase in carbon stocks in the soil before the second measurement is available would be estimated on the basis of a relevant scientific basis. From the second measurement onwards, the measurements would constitute the basis for determining the existence of an increase in soil carbon stocks and its magnitude.

Similarly, the use of manure/slurry as a substrate for the production of biogas and biomethane is regarded as improved agricultural manure/slurry management, which contributes to emission reduction by preventing diffuse field emissions and can therefore be counted towards e_{sca} with a credit of 45 gCO_2eq/MJ of manure/slurry.

The emission savings from soil carbon accumulation in gCO_2eq/MJ biomass fuel can be calculated using a formula like the one in point 7, Part B of Annex VI to Directive (EU) 2018/2001, where the divisor "20" is replaced by the period (in years) of the rotation cycle of the respective crops.

$$e_{sca} = (CS_R - CS_A) \times 3{,}666 \times \frac{1}{20} \times \frac{1}{P} - e_B \;^{(*)}$$

(*) The quotient obtained by dividing the molecular weight of CO_2 (44.010 g/mol) by the molecular weight of carbon (12.011 g/mol) is equal to 3.664.

CS_R = *the carbon stock per unit area associated with the reference land-use (measured as mass (tonnes) of carbon per unit area, including both soil and vegetation); the reference land-use shall be the land-use in January 2008 or 20 years before the raw material was obtained, whichever was the later*

CS_A = *the carbon stock per unit area associated with the actual land use (measured as mass (tonnes) 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 CSA shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever the earlier*

P = *the productivity of the crop (measured as biofuel or bioliquid energy per unit area per year)*

e_B = *bonus of 29 g CO_2eq/MJ biofuel or bioliquid if biomass is obtained from restored degraded land under the conditions laid down in point 8, Annex VI, Part B*

"Severely degraded land" means land that, for a significant period of time, has either been significantly salinated or presented significantly low organic matter content and has been severely eroded.

In addition to emission savings from soil carbon accumulation due to improved agricultural management practices, the avoidance of GHG emissions, for example by substituting fermentation residues for mineral fertilisers, can also be counted as emission savings from improved agricultural management practices as e_{sca}. The reference value is the avoided quantity of mineral fertilisers multiplied by their emission factor.

The use of manure and slurry as a substrate for the production of biogas and biomethane can also be counted with a bonus of 45 gCO_2eq/MJ of slurry toward e_{sca}.

Emission savings from e_{sca} are only applicable if the measure to improve agricultural management was implemented after January 2008.

3.5 Requirements for calculating greenhouse gas emissions from transport and distribution (e_{td})

Emissions from transport and distribution/supply include the emissions from the transport of the biomass (e_{td}) and from the storage of the biomass fuels. Economic operators along the production and supply chain for biomass fuels that receive biomass calculate the GHG emissions from transport using the following formula (e_{td}):

$$e'_{td}\left[\frac{\text{kgCO}_2\text{eq}}{\text{kg}}\right] = \frac{(d_{loaded}[\text{km}] \times K_{loaded}\left[\frac{\text{l}}{\text{km}}\right] + d_{empty}\,[\text{km}] \times K_{empty}\left[\frac{\text{l}}{\text{km}}\right] \times Ef_{fuel}\left[\frac{\text{kgCO}_2\text{eq}}{\text{l}}\right]}{m_{product\ dry}\,[\text{kg}]}$$

specified in mass units in relation to the dry matter content of the transported biomass (kgCO_2eq/kg dry). This formula applies analogously to all biomass transport options and the energy consumed for them.

It must be kept in mind that this formula only applies for a single transport step. If there are more transport steps, the corresponding emissions must be calculated individually. Actual transport emissions can only be determined if the information for the transport steps is recorded and consistently passed along through the production chain. If not, the actual value cannot be accepted. The GHG emissions already included for production and cultivation do not have to be included again in the calculation. Other emissions from transport and distribution have to be added to e_{td}.

The values (emission factors, calorific values, etc.) should be taken from the European Commission's list[20] to calculate e_{ec}, which can be accessed online.

Alternatively a scientific literature source or scientifically recognised database (e.g. BioGrace, ECOINVENT database) can be used.

d_{loaded} [km]	=	transport distance across which the biomass or biomass fuel was transported
d_{empty} [km]	=	*transport distance when the transport vehicle was empty (if the transport vehicle is not empty upon return, it does not have to be included)*

means of transport used (e.g. 40 t diesel truck)

$m_{product}$ [kg dry]	=	*measured mass of the transported biomass or biomass fuel*
Ef_{fuel} [kgCO_2eq/l]	=	*emission factor fuel*
K_{loaded} [l/km]	=	*fuel consumption of the means of transport used per km when loaded*
K_{empty} [l/km]	=	*fuel consumption of the transport vehicle used per km when empty*

When calculating transport emissions, the actual GHG emissions must be divided by the dry matter of the biomass transported. Treatment plants calculate the respective upstream transport emissions in gCO_2eq/kg of the dry matter content of the transported biomass. The upstream transport emissions, linked to the raw product (feedstock), must be adjusted by applying the feedstock factor and allocation factor to the corresponding product (intermediate or final product) (see section 2.3 "Calculation using actual values").

The last interface is responsible for calculating emissions from transport and distribution for biomass fuels.

The GHG emissions associated with the storage of biomass fuels must also be taken into account.

3.6 Requirements for calculating greenhouse gas emissions from processing (e_p)

Every processing plant must ensure that all GHG emissions from processing (e_p) are included in the calculation of the GHG emissions. This includes emissions from processing itself, from waste and leakage and from the production of chemicals or products used in processing, including CO_2 emissions corresponding to the carbon contents of fossil inputs, whether or not actually combusted in the process. The following formula is used for this purpose, which applies to one processing step at a time:

$$e_p'\left[\frac{kgCO_2eq}{kg}\right] = \frac{EM_{electricity}\left[\frac{kgCO_2eq}{year}\right] + EM_{heat}\left[\frac{kgCO_2eq}{year}\right] + EM_{inputs\ production}\left[\frac{kgCO_2eq}{year}\right] + EM_{wastewater}\left[\frac{kgCO_2eq}{a}\right]}{yield_{main\ product\ dry}\left[\frac{kg_{main\ product\ dry}}{year}\right]}$$

specified in mass units in relation to the dry matter content of the main product ($kgCO_2eq/kg$ dry).

Formula components in detail (EM = emissions[21]; Ef = emission factor):

$$EM_{electricity}\left[\frac{kgCO_2eq}{year}\right] = \text{electricity consumption}\left[\frac{kWh}{year}\right] \times Ef_{electricity}\left[\frac{kgCO_2eq}{kWh}\right]$$

$$EM_{heat}\left[\frac{kgCO_2eq}{year}\right] = \text{fuel consumption}\left[\frac{kg}{year}\right] \times Ef_{fuel}\left[\frac{kgCO_2eq}{kg}\right]$$

$$EM_{inputs\ production}\left[\frac{kgCO_2eq}{year}\right] = \text{inputs production}\left[\frac{kg}{year}\right] \times Ef_{inputs\ production}\left[\frac{kgCO_2eq}{kg}\right]$$

$$EM_{wastewater}\left[\frac{kgCO_2eq}{year}\right] = \text{wastewater}\left[\frac{l}{year}\right] \times Ef_{wastewater}\left[\frac{kgCO_2eq}{l}\right]$$

$$Yield_{main\ product}\left[\frac{kg_{yield}}{year}\right] = \text{yield of the main product in kg per year}$$

The annual yield of the main product relates to the dry matter content.

The formula below is to be used to specify the emissions of the dry matter in kg:

$$e_p product_a\left[\frac{gCO_2eq}{kg_{dry}}\right] = \frac{e_p product_a\left[\frac{gCO_2eq}{kg_{moist}}\right]}{(1 - \text{moisture content})}$$

To calculate the GHG emissions from processing (e_p), the following data at a minimum must be collected on site, i.e. the respective values are taken from, e.g. company documents:

- ✓ electricity consumption [kWh/year] – annual total electricity consumption

- ✓ heat generation – type of fuel/combustible used to produce steam (e.g. heating oil, gas, agricultural crop residues)
- ✓ fuel consumption [kg/year] – total annual consumption of fuel for heat production, e.g. heating oil [kg], gas [kg], bagasse [kg]
- ✓ production of inputs [kg/year] – quantity of chemicals or additional products (inputs) used in processing
- ✓ wastewater quantity [l/year] – quantity of wastewater per year
- ✓ yield main product [kg/year] – annual harvest of the main product

Input data for calculating the processing emissions in the production chain must be measured or based on technical specifications of the processing plant. If the range of emissions for a group of processing plants (which the respective plant belongs to) is known, the most conservative emission value (highest) for this group is to be used. Actual emission values for processing can only be determined if all of the information about emissions relevant to the interface is recorded and consistently passed along through the production chain. Other emissions from processing have to be added to e_p.

The values (emission factors, calorific values, etc.) should be taken from the European Commission's list to calculate e_p which can be accessed online[22]:

Alternatively a scientific literature source or scientifically recognised database (e.g. BioGrace, ECOINVENT database) can be used.

Ef_{fuel} [kgCO_2eq/kg]	=	*emission factor fuel*
$Ef_{wastewater}$ [kgCO_2eq/l]	=	*emission factor wastewater*
$Ef_{EU\ electricity\ mix}$ [kgCO_2eq /kWh]	=	*emission factor EU electricity mix*
$Ef_{production\ input}$ [kgCO_2eq/kg]	=	*emission factor chemicals or additional products (inputs) used for production*

The source must be cited for values taken from scientific literature sources or scientifically recognised databases. If there are different values from producers, the most conservative value is to be used. It is also important to include the emissions arising from chemicals and energy that are also indirectly linked to the production of biomass fuels.

In accounting for the consumption of electricity not produced in the biogas plant itself, it is assumed that the GHG emission intensity of the production and transmission of this electricity is equal to the average emission intensity of the production and distribution of electricity in a specific, clearly defined region:

- ✓ In the case of the EU as a defined region, the average EU emission intensity is the reference value.
- ✓ In the case of third countries, where grids are often less linked-up across borders, the national average could be the appropriate choice.[23]
- ✓ In the case of locally produced electricity or heat, individual emission values may be used where appropriate. The prerequisite for this is that the plant in question is not connected to the electricity or heat grid and that the quantity can be validated using a suitable meter.
- ✓ If electricity from renewable energy sources (e.g. wind turbine, biogas plant) is consumed either off-grid or independently of the grid, and the quantity can be validated by a suitable electricity meter, the emission factor for the type of renewable electricity may be set to zero.

An average value may be used for the electricity produced by an individual electricity power plant if that plant is not connected to the electricity grid. Emissions from processing include emissions from drying intermediate products and materials, where appropriate. Guarantees of origin for electricity from renewable energy sources or other certificates are not applicable to reduce greenhouse gas emissions.

3.7 Requirements for calculating the emission saving from CO_2 capture and replacement (e_{ccr})

The definition of this emissions saving in accordance with Annex VI Part B No. 15 of Directive (EU) 2018/2001 is:

"Emission savings from CO_2 capture and replacement (e_{ccr}) shall be related directly to the production of biomass fuel they are attributed to, and shall be limited to emissions avoided through the capture of CO_2 of which the carbon originates from biomass and which is used to replace fossil-derived CO_2 in production of commercial products and services."

Compliance with the requirement that carbon of fossil origin be replaced by carbon from biomass in the production of commercial products and services is assumed to be satisfied if it is common commercial practice to use only carbon of fossil origin in these commercial products and services.

In this case, there is no need for the certifying company to provide evidence of the actual (end) use of the biogenic CO_2 to replace fossil-derived CO_2 on a case-by-case basis. However, verifiable objective evidence on the CO_2 quantities produced from biogenic carbon in defined time periods must be kept, whereby only those quantities can be credited that are actually sold on the market as directly commercially usable CO_2 or those that are used directly.

The following parameters are to be considered when calculating the emission saving (e_{ccr}):

- ✓ produced quantity of biomass fuel
- ✓ produced quantity of biogenic CO_2

The following are also to be determined in relation to the processing of CO_2 (compression and liquefaction to carbon dioxide):

- ✓ consumed quantity of energy (electricity, heat, etc.)
- ✓ consumed quantity of auxiliary materials
- ✓ other process-specific, energy-related input variables are included here

as well as the respective greenhouse gas emissions values for these consumed quantities.

The emission savings e_{ccr} [g CO_2eq/MJ biomass fuel] are calculated as follows:

$$e_{ccr} = \frac{\text{quantity produced } CO_2\,[t] - \text{energy consumed [MWh]} \times EF\left[t\,\frac{CO_2eq}{MWh}\right] - \text{auxiliary materials consumed } [t] \times EF\left[t\,\frac{CO_2eq}{t}\right]}{\text{produced quantity of biomass fuels } [t] \times \text{lower calorific value biomass fuel}\left[\frac{GJ}{t}\right]} \times 1000$$

The balancing period of the emissions saving (e_{ccr}) must be linked to the greenhouse gas balancing period of the respective production pathway of the main product (biomass fuel). If the CO_2 is not captured continuously, it may make sense to allocate different quantities of savings to biomass fuel from the same processes.

However, higher savings of CO_2 should never be allocated to a given batch of biomass fuel per MJ than the savings from the average quantities of CO_2 in a hypothetical process which captures the total CO_2 from the process.

For example, it would not be justified to allocate different quantities of savings to different biomass fuels that relate to the same process. All biomass fuels from the same process are treated equally in this respect.

All emissions and information related to CO_2 capture and savings must be included in the greenhouse gas calculation and documentation, and must be verifiable by the auditor: These include:

- ✓ purpose for which the captured carbon is used
- ✓ origin of substituted carbon
- ✓ origin of carbon from fossil sources
- ✓ information on the amount of emission saved though substitution

3.8 Requirements for calculating the emission savings from CO_2 capture and geological storage (e_{ccr})

Emission saving from carbon capture and geological storage e_{ccs}, that has not already been accounted for in e_p are limited to emissions prevented by the capture and sequestration of CO_2 emissions directly linked to the extraction, transport, processing and distribution of biomass fuel.

The following parameters are to be considered when calculating the emission saving (e_{ccs}):

- ✓ produced quantity of biomass fuel
- ✓ produced quantity of biogenic CO_2

The following are also to be determined in relation to the processing of CO_2 (compression and liquefaction to carbon dioxide):

- ✓ consumed quantity of energy (electricity, heat, etc.)
- ✓ consumed quantity of auxiliary materials
- ✓ other process-specific, energy-related input variables are included here

as well as the respective greenhouse gas emissions values for these consumed quantities.

The emissions saving e_{ccs} [gCO_2eq/MJ biomass fuel] is calculated as follows:

$$e_{ccs}=$$

$$\frac{\text{quantitiy produced } CO_2\,[t] - \text{energy consumed }[MWh] \times EF\left[t\,\frac{CO_2eq}{MWh}\right] - \text{auxiliary materials consumed }[t] \times EF\left[t\,\frac{CO_2eq}{t}\right]}{\text{produced quantity of biomass fuel }[t] \times \text{lower calorific value biomass fuel }\left[\frac{GJ}{t}\right]} \times 1000$$

The emission saving from carbon capture and geological storage (e_{ccs}) can only be taken into account if there is valid evidence that CO_2 has actually been captured and reliably stored. If the CO_2 is stored directly, it must be checked that the storage facility is in good condition and does not leak (according to Directive 2009/31/EC).

The emission saving from carbon capture and geological storage (e_{ccs}), which has not already been taken into account in e_p, is limited to the emissions prevented by the capture and storage of CO_2 emissions directly associated with the production, transport, processing and distribution of biofuel/bioliquids, provided that the storage is in compliance with Directive 2009/31/EC on the geological storage of carbon dioxide.

The balancing period of the emissions saving (e_{ccs}) must be linked to the greenhouse gas balancing period of the respective production pathway of the main product (biomass fuel). If the

CO_2 is not captured continuously, see section 3.7 "Requirements for calculating the emission saving from CO_2 capture and replacement (e_{ccr})".

3.9 Allocation of greenhouse gas emissions

If by-products or excess useful energy are produced during the production of biomass fuels, their greenhouse gas intensity can be deducted from the greenhouse gas intensity of the biomass fuel:

- ✓ In the case of by-products other than electricity and heat, allocated based on their energy content (lower calorific value)
- ✓ In case of excess electricity or excess heat, by determining the greenhouse gas intensity, the amount of heat or electricity delivered to the production process for biomass fuel. This calculated value may be deducted from the greenhouse gas intensity of the biomass fuel.

3.9.1 Allocation of greenhouse gases to by-products

Allocation takes place in every process step that the main product passes through in which a by-product is produced (except electricity or heat). All GHG emissions up to this process step are to be distributed to the main and by-product proportional to their energy content. The portion of GHG emissions allocated to the elements of the formula according to Directive (EU) 2018/2001, Annex VI, Part B, No. 1 is to be calculated using the following formula (if applicable):

$$e'_{allocated} = \text{total GHG} \times \text{allocation factor}$$

The variable total GHG in the formula above is the sum of all GHG gas emissions that are produced up to and including the process step in which the by-product is produced. The allocation relates to the formula elements $e_{ec} + e_l + e_{sca}$ + the shares of e_p, e_{td}, e_{ccs} and e_{ccr} up to and including the process step in which a by-product is produced. If GHG emissions were already allocated to by-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 (total GHG). To calculate the allocation factor for intermediate products and biomass fuels, the following data is collected at a minimum on site, i.e. the respective values are taken from, e.g. company documents:

- ✓ Mass of the intermediate product/biomass fuel [kg dry]
- ✓ Mass of the by-product [kg dry]

The formula for calculating the allocation factor for the intermediate product is as follows:

$$\text{allocation factor intermediate product}_a = \left[\frac{\text{Energy in intermediate product}_a}{\text{Energy in intermediate product}_a \text{ and by-product}_a}\right]$$

The formula for calculating the allocation factor for biomass fuel is as follows:

$$\text{allocation factor biomass fuel}_a = \left[\frac{\text{Energy in biomass fuel}_a}{\text{Energy in biomass fuel}_a \text{ and by-product}_a}\right]$$

where:

$$\text{energy content}_{\textit{intermediate product}}[\text{MJ}] = \text{yield}_{\textit{intermediate product}}\left[\text{kg}_{\textit{dry}}\right] \times \text{lower calorific value}_{\textit{main product}}\left[\frac{\text{MJ}}{\text{kg}}\right]$$

$$\text{energy content}_{\textit{biomass fuel}}[\text{MJ}] = \text{yield}_{\textit{biomass fuel}}\left[\text{kg}_{\textit{dry}}\right] \times \text{lower calorific value}_{\textit{main product}}\left[\frac{\text{MJ}}{\text{kg}}\right]$$

$$\text{energy content}_{\textit{by-product}}[\text{MJ}] = \text{yield}_{\textit{by-product}}\left[\text{kg}_{\textit{dry}}\right] \times \text{lower calorific value}_{\textit{by-product}}\left[\frac{\text{MJ}}{\text{kg}}\right]$$

The energy content is determined using the lower calorific value and the yield. The lower calorific value used in applying this rule must be that of the entire (by-) product (not the value for only the dry part of it). In many cases, however, notably in relation to nearly-dry products, the latter could give a result that is an adequate approximation. Because heat does not have a lower calorific value, no emissions can be allocated to it on this basis.

No emissions should be allocated to waste, agricultural crop residues and processing residues, since they are considered to have zero emissions until the point of their collection[24].

Allocation should be applied directly after a by-product (a substance that would normally be storable or tradable) and biomass fuel/intermediate product are produced at a process step. This can be a process step within a plant after which further "downstream" processing takes place for either product. However, if downstream processing of the (by-) products concerned is interlinked (by material or energy feedback loops) with any upstream part of the processing, the system is considered a "refinery" and allocation is applied at the points where each product has no further downstream processing that is interlinked by material or energy feedback loops with any upstream part of the processing.

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

3.9.2 Determination of the greenhouse gas intensity of usable excess heat and electricity

Heat and electricity, which are not the main product, are generally excluded from allocation. The defined lower calorific values of both energy forms (1 kWh/kWh) mathematically exclude an allocation based on the calorific heating value. The GHG intensity of excess usable heat and electricity is therefore equal to the GHG intensity of the heat or electricity supplied for the production of biomass fuels.

The greenhouse gas intensity of the supplied quantity of electricity and heat not generated in the biomass plant itself is determined as described in section 3.6 “Requirements for the calculation of greenhouse gas emissions from processing (e_p)”

If the energy (electricity or heat) supplied for the production of biomass fuels is generated in the production facility itself, the greenhouse gas intensity is determined as described in section 3.10 “Calculating the greenhouse gas emission saving by the last interface”

3.10 Calculating the greenhouse gas emission saving by the last interface

The last interface determines the GHG emissions “E” caused by the biomass fuel expressed in gCO_2eq/MJ of biomass fuel in accordance with the method described in section 2.1 “Methodology for greenhouse gas calculation” and calculates the GHG emissions in gCO_2eq/MJ of final energy commodity (electricity, heat) for heat and/or electricity production from the biomass fuels.

Greenhouse gas emissions, which are available in the unit gCO_2eq/t of dry feedstock, can be converted into the unit gCO_2eq/MJ of biomass fuel using the following formula:

$$e_{ec}\text{biomass fuel}_a \left[\frac{gCO_2eq}{MJ_{\text{biomass fuel}}}\right]_{ec} =$$

$$\frac{e_{ec}\text{feedstock}_a \left[\frac{gCO_2eq}{t_{dry}}\right]}{\text{lower calorific value}_a \left[\frac{MJ_{\text{feedstock}}}{t_{\text{feedstock dry}}}\right]} \times \text{feedstock factor biomass fuel.} \times \text{allocation factor biomass fuel.}_a$$

For information on how to calculate GHG emissions of biogas by co-digestion of different substrates to electricity and heat, see section 3.11 “Balancing of GHG emissions from co-digestion in biogas plants”.

The greenhouse gas saving from the use of biomass fuels to produce heat and electricity compared to the respective fossil reference value can be calculated using the following formula:

$$\text{GHG emission savings} = (EC_{F(h\&c,\ el)} - EC_{B(h\&c,\ el)}) / EC_{F(h\&c,el)}$$

where:

$EC_{B(h\&c,el)}$ = *total emissions from the heat or electricity from biomass fuels*

$EC_{F(h\&c,el)}$ = *total emissions from the fossil fuel comparator for useful heat or electricity*

Greenhouse gas emissions from biomass plants that deliver only heat are to be calculated as follows:

$$EC_h = \frac{E}{\eta_h}$$

Greenhouse gas emissions from biomass plants that deliver only electricity are to be calculated as follows:

$$EC_{el} = \frac{E}{\eta_{el}}$$

$EC_{h,el}$ = *total greenhouse gas emissions from the final energy commodity*

E = *total greenhouse gas emissions of the fuel before end-conversion*

η_h = *the electrical efficiency, defined as the annual electricity produced divided by the annual fuel input, based on its energy content*

η_{el} = *the heat efficiency, defined as the annual useful heat output divided by the annual fuel input, based on its energy content*

For biomass fuels used for useful heat production and for heating and/or cooling, the comparator is fossil fuel:

$$EC_{F(h)} = \frac{80\ gCO_2\ eq}{MJ_{heat}}$$

If it can be clearly demonstrated that coal is directly physically substituted by biomass fuels for useful heat production, the comparator for fossil fuels is:

$$EC_{F(h)} = \frac{124\ gCO_2\ eq}{MJ_{heat}}$$

For biomass fuels used to generate electricity, the comparator is fossil fuel:

$$EC_{F(el)} = \frac{183\ gCO_2\ eq}{MJ_{electricity}}$$

or for the outermost regions

$$EC_{F(el)} = \frac{212\ gCO_2\ eq}{MJ_{electricity}}$$

Outermost regions are those regions defined in the Treaty on the Functioning of the EU (TFEU) whose energy sector is often characterised by isolation, limited supply and dependence on fossil fuels while those regions benefit from significant local renewable sources of energy.

Useful heat means heat generated to satisfy an economical justifiable demand for heat, for heating and cooling or for production processes such as the provision of steam and pressure, as opposed to unused waste heat. “Economically justifiable demand” means the demand that does not exceed the needs for heat or cooling and which would otherwise be satisfied at market conditions.

When heating and cooling are co-generated with electricity in a single process, emissions are allocated between useful heat and generated electricity. GHG emissions for electricity or mechanical energy are calculated as follows:

$$EC_{el} = \frac{E}{\eta_{el}} \left[\frac{C_{el} \cdot \eta_{el}}{C_{el} \cdot \eta_{el} + C_h \cdot \eta_h}\right]$$

The GHG emissions of useful heat produced in co-generation are calculated as follows:

$$EC_h = \frac{E}{\eta_h} \left[\frac{C_h \cdot \eta_h}{C_{el} \cdot \eta_{el} + C_h \cdot \eta_h}\right]$$

where:

$EC_{h,el}$	=	*total greenhouse gas emissions from the final energy commodity*
E	=	*total greenhouse gas emissions of the fuel before end-conversion*
η_{el}	=	*the electrical efficiency, defined as the annual electricity produced divided by the annual fuel input, based on its energy content*
η_h	=	*the heat efficiency, defined as the annual useful heat output divided by the annual fuel input, based on its energy content*
C_{el}	=	*fraction of exergy in the electricity, and/or mechanical energy, set to 100% (C_{el} = 1)*

C_h = *Carnot efficiency (fraction of exergy in the useful heat)*

Exergy is the fraction of the total energy of a system or material flow that can do work when it is brought into thermodynamic equilibrium with its environment. In the case of the generation of electricity or mechanical energy, the SURE-EU system assumes that the energy share is 100%, i.e. that there is no energy loss during transmission through the grid until electricity is removed from the grid.

The Carnot efficiency is the highest theoretically possible efficiency in converting thermal energy into useful heat. It describes the ratio of useful heat to the amount of heat absorbed and is higher the greater the temperature difference between the useful heat at the point of delivery and its ambient temperature. Since neither absolute zero nor infinitely high temperatures can be reached, a Carnot efficiency of 100% is impossible.

Accordingly, the Carnot efficiency for useful heat is defined as follows:

where:

T_h = *temperature, measured in absolute temperature (kelvin) of the useful heat at point of delivery*

T_0 = *temperature of surroundings, set at 273.15 kelvin (0 °C)*

If excess heat is generated in the co-generation process and used to heat buildings, at a temperature below 150°C, C_h (423.15 kelvin) can be set at 0.3546.

If the reference values for fossil fuels change or are implemented by the EU Commission, for example by means of delegated acts, modified values or methods, these also apply in the SURE-EU system with immediate effect.

3.11 Balancing of GHG emissions from co-digestion in biogas plants

GHG emissions may only be offset in the case of the production of biogas for the production of electricity or heat or biomethane. GHG emissions resulting from processes that deviate from this may only be balanced if the GHG values to be offset are identical. Individual substrate-specific GHG emission values can be balanced using the formulas explained below. Typical values or default values are balanced as follows:

$$E = \sum_{1}^{n} S_n \times E_n$$

where:

E = *greenhouse gas emissions per MJ biogas or biomethane produced from co-digestion of the defined mixture of substrates*

S_n = *share of feedstock n in energy content*

E_n = *emission in g CO_2/MJ for pathway n as provided in Part D of Annex VI of Directive (EU) 2018/2001*

The share of feedstock n in the energy content is calculated as follows:

$$S_n = \frac{P_n \times W_n}{\sum_1^n \times W_n}$$

where:

P_n = *energy yield [MJ] per kilogram of wet input of feedstock n*(*)

W_n = *weighting factor of substrate n defined as:*

$$W_n = \frac{I_n}{\sum_1^n I_n} \times \left(\frac{1 - AM_n}{1 - SM_n}\right)$$

where:

I_n = *annual input to digester of substrate n [$tonne_{fresh\ matter}$]*

AM_n = *average annual moisture of substrate n [$kg_{water}/kg_{fresh\ matter}$]*

SM_n = *standard moisture for substrate n*(**)

(*) To calculate the typical values and the default values, the following values are used for P_n:

P_{maize} = *4.16 [$MJ_{biogas}/kg_{wet\ maize\ at\ 65\%\ moisture}$]*

$P_{manure/slurry}$ = *0.50 [$MJ_{biogas}/kg_{slurry\ at\ 90\%\ moisture}$]*

$P_{biowaste}$ = *3.41 [$MJ_{biogas}/kg_{biowaste\ at\ 76\%\ moisture}$]*

(**) The following values of the standard moisture for substrate SM_n are used:

SM_{maize} = *0.65 [$kg_{water}/kg_{fresh\ matter}$]*

$SM_{manure/slurry}$ = *0.90 [$kg_{water}/kg_{fresh\ matter}$]*

$SM_{biowaste}$ = *0.76 [$kg_{water}/kg_{fresh\ matter}$]*

Changes to these values or calculation methods originating from the EU Directive (EU) 2018/2001, for example due to delegated acts of the EU Commission to review and, if necessary, adjust the methods and values of Annex VI of the Directive (EU) 2018/2001, will take effect immediately in the SURE system.

The actual emissions of the biogas or biomethane can also be balanced as follows:

$$E = \sum_{1}^{n} S_n \times (e_{ec,n} + e_{td,\,feedstock,n} + e_{l,n} - e_{sca,n}\ ) + e_p + e_{td,product} + e_u - e_{ccs} - e_{ccr}$$

E	=	*total emissions from the production of the biogas or biomethane before energy conversion*
S_n	=	*share of feedstock n, in fraction of input to the digester*
$e_{ec,n}$	=	*emissions from the extraction or cultivation of feedstock n*
$e_{td,feedstock,n}$	=	*emissions from transport of feedstock n to the digester*
$e_{l,n}$	=	*annualised emissions from carbon stock changes caused by land-use change, for feedstock n*
e_{sca}	=	*emission savings from improved agricultural management of feedstock n*
e_p	=	*emissions from processing*
$e_{td,product}$	=	*emissions from transport and distribution of biogas and/or biomethane*
e_u	=	*emissions from the fuel in use, that is greenhouse gases emitted during combustion*
e_{ccs}	=	*emission savings from CO_2 capture and geological storage*
e_{ccr}	=	*emission savings from CO_2 capture and replacement*

4 Relevant documents

With regard to the documentation (scheme documents) in the SURE-EU system, reference is made here to the document “Scope and basic scheme requirements”.

SURE reserves the right to create and publish additional supplementary scheme principles if necessary.

The legal EU regulations and provisions for sustainable biomass and biomass fuels including other relevant references that represent the basis of the SURE documentation are published separately on SURE's website at www.sure-system.org. References to legal regulations always relate to the current version.

5 References

1

Heat or waste heat is also used to generate cooling with absorption chillers. "Heat" in this case therefore also encompasses "cooling" or "refrigeration", regardless of whether the end use of the heat is actual heating or cooling via absorption machines.

2

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according to Directive 2018/2001/EC (for more information, see [2 I]).

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according to Directive 2018/2001/EC, Annex VI, Part B, No.1 (for more information, see [2 I]).

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according to Annex VI, Part A and C and D of Directive 2018/2001/EC (for more information, see [2 I]).

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for more information, see [7].

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pursuant to Article 29 of Directive 2018/2001/EC (for more information, see [2 l]).

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for more information, see [9].

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The term “EM” = emissions refers to the total emissions and not only to the emissions of the main product.

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for more information, see [9].

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Similarly, if these materials are used as raw materials, they start with zero emissions at the collection point.

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