BIOGRACE II

Harmonised Greenhouse Gas Calculations for Electricity, Heating and Cooling from Biomass

May 2015

BioGrace II
Calculation rules

Version 3

www.biograce.net

Co-funded by the Intelligent Energy Europe Programme of the European Union

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Contents

1 Introduction

The BioGrace-II greenhouse gas (GHG) calculation tool allows the reproduction of the calculation of the default values presented in the JRC report *Solid and gaseous bioenergy pathways: input values and GHG emissions*[1] as well as the possibility to perform actual calculations. The calculations use the BioGrace-II list of standard values and follow the methodology laid down in the two European Commission reports on sustainability of electricity, heat and cooling from solid and gaseous biomass: COM(2010)11[2] and SWD(2014)259[3].

Bioliquid pathways such as sunflower oil and used cooking oil have also been included in the BioGrace-II Excel tool. These pathways follow the calculation methodology set up in the Renewable Energy Directive (RED)[4] and hence for the bioliquid pathways the BioGrace-I GHG calculation rules must be used. When RED Annex V has been updated (see section 1.1) these pathways will be updated and follow the same methodology as the solid and gaseous pathways.

The calculation rules apply for adapted calculations in the BioGrace-II Excel tool, when calculating new pathways, new processes or for new inputs in the tool. The calculation rules form integral part of this Excel tool; when using the tool the calculation rules must be respected. The BioGrace-II User Manual gives detailed explanations on the functions of the Excel tool. For explanation on methodological choices made by the European Commission, please refer to the BioGrace-II Methodological background document.

Most of the calculation rules in this document are very similar to versions 4c and 4d of the BioGrace-I calculation rules for biofuels. However, a few rules have been updated and some new rules have been added.

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1 Solid and gaseous bioenergy pathways: input values and GHG emissions. JRC: EUR 27215 EN

2 Report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling [COM/2010/11]

3 State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU [SWD (2014)259]

4 Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

1.1 Update of this document

We expect the European Commission to update the GHG accounting methodology for biofuels (RED, Annex V) in 2015. It is expected that once the updated Annex V has been published, all methodological aspects that currently are different for solid biomass as compared to biofuels will have been harmonised. The BioGrace-I and the BioGrace-II calculation rules will then be updated and be merged into one document. Also the BioGrace-I and BioGrace-II lists of standard values will then be replaced by one list.

2 General

2.1 Compliance with national sustainability criteria

The following rules apply when the BioGrace-II Excel tool is used to show compliance with sustainability criteria of solid and gaseous biomass for electricity, heating and cooling purposes, as defined in national legislation.

2.1.1 BioGrace-II calculation rules are binding

If the BioGrace-II Excel tool is used, the BioGrace-II calculation rules shall be respected. An auditor checking actual calculations shall not approve the calculations when the calculation rules were not respected.

2.1.2 Actual calculations shall be audited and shall be made with the "for Compliance" version of the Excel tool

When actual calculations are made to show compliance with GHG reduction targets or maximum GHG emission levels in national legislation the calculations shall:

- be subject to third party independent auditing; and
- be made with the version “for Compliance”[5] of the Excel tool in which the "track changes" option is always turned on. This will allow an auditor that will check the calculations to easily find the actual input numbers that were used for the calculation.

2.1.3 Actual calculations shall be made using Global Warming Potentials of 1, 25 and 298

Actual calculations shall be made with the Global Warming Potentials of 1 for CO_2, 25 for CH_4 and 298 for N_2O. These are pre-defined standard values in the Excel tool.

2.1.4 Units of input numbers shall not be changed

The units of the input numbers shall not be changed. Therefore the user of the BioGrace-II Excel tool must convert actual data collected into the units of the BioGrace-II Excel tool. Auditors checking actual

[5] The “Version for Compliance” is the version of the tool that is opened after it has been downloaded from www.BioGrace.net. The “Version for Testing” is the version that is created after pressing the orange button “Track changes” causing that track changes is turned off. Please note that track changes cannot be turned on again after turning it off.

calculations shall make sure that the actual input numbers have been converted into the right units, and that the units in the BioGrace-II Excel tool have not been changed.

2.2 Standard Values

2.2.1 BioGrace-II harmonised list of standard values

Standard values are values needed to convert input data into GHG emissions[6]. Standard values shall be taken from the BioGrace-II harmonised list of standard values[7] unless:

1. For inputs, (by-/co-)products, process related emissions and transport modes not listed on the harmonised list of standard values,
   - reliable information[8] (literature, database) is given showing where these standard values were obtained; and auditors are allowed and are able to verify this information.
2. For inputs, (by-/co-)products, process related emissions and transport modes that are listed[9] on the harmonised list of standard values
   - these standard values are explicitly named together with the result of the calculation; and reliable information is documented[7], showing how these values were determined; and it is

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6 Examples are Lower Heating Values and values to convert 1 kg synthetic N-fertiliser or 1 MJ of natural gas into CO_2, CH_4 and N_2O emissions. Some of the standard values have also been calculated using LCA analysis of both the processes that supply the inputs (like synthetic N-fertiliser and natural gas) and their emissions at combustion

7 The list of standard values is available on the sheet "Standard values" in the BioGrace II GHG Excel tool.

8 Data used shall lie within the commonly accepted data range.
In case of
(a) Densities and lower heating values (LHV’s),
(b) Fuel efficiencies and (CH_4 and N_2O) transport exhaust gas emissions,
(c) CH_4 and N_2O emissions (also called “emission coefficients” in the BioGrace list of standard values) from boilers, CHP’s, machinery operation, steam or heat provision,
reliable information shall consist of reports of analyses following suitable ISO, CEN or ASTM standards or other commonly accepted methods, or public scientifically sound articles or reports that include or refer to such analyses or methods.
In case of
(d) Emission coefficients other than those mentioned under (a), (b) and (c),
reliable information shall consist of (references to) peer reviewed or scientifically sound LCA analysis on the provision of the input material. In case of reference, the LCA analysis shall be public. The LCA study shall give the actual emission per MJ or kg of input material.

9 “listed” means “listed as such” or “listed as a similar input”. Example 1: using another value for “N-fertiliser” equals taking another value for a standard value from the list of harmonised standard values (as synthetic N-fertiliser is listed), so the rules under point 2 have to be followed. Example 2: if urea is used as a fertiliser, then there is a “similar input” on the list of standard values, which is “Synthetic N-fertiliser”. Therefore, also in this example “urea as a fertiliser” the rules under point 2 shall be followed.

shown that this input was used in the production of the electricity, heating or cooling for which the GHG calculation was made[10]; and auditors are allowed and are able to verify this information.

- the use of this alternative standard value does not contradict any other calculation rule. In case of contradiction the other calculation rule prevails over this rule on use of alternative standard values. This can for instance be the case for electricity.

2.2.2 BioGrace list of additional standard values

The BioGrace consortium has developed a list of additional standard values. When using a standard value that does not come from the BioGrace-II list of standard values, it is recommended to take a number from this list of additional standard values - if available on this list - and to include the reference that is given in this list as reliable information on how the value was determined. Doing so, still the rules above (in paragraph 2.2.1 under points 1 and 2) shall be respected.

2.2.3 Standard value for fertiliser

The standard value for a fertiliser in the list of BioGrace-II standard values can only be used when making a calculation **using regional averaged input data** for cultivation.

When making an actual calculation for cultivation with **input data at the farm-level** and the **fertiliser type is *known*** the standard value for this specific type of fertiliser shall be applied (for instance by using a value from the BioGrace list of additional standard values).

When making an actual calculation for cultivation with **input data at the farm-level** and the **fertiliser type is *unknown*** the **highest standard value for that fertiliser shall be applied**. The highest values from the BioGrace list of standard values or additional standard values are:

N-fertiliser	3680 g CO_2/(kg N)	7.49 g CH_4/(kg N)	2.4 g N_2O/(kg N)	4567.8 g CO_{2eq}/(kg N)
P-fertiliser	1459 g CO_2/(kg P_2O_5)	3.7 g CH_4/(kg P_2O_5)	0.0 g N_2O/(kg P_2O_5)	1552 g CO_{2eq}/(kg P_2O_5)
K-fertiliser	588.7 g CO_2/(kg K_2O)	1.72 g CH_4/(kg K_2O)	0.014 g N_2O/(kg K_2O)	635.7 g CO_{2eq}/(kg K_2O)

Table 1: highest values for N-, P- and K-fertiliser from the BioGrace-II list of standard values or the BioGrace list of additional standard values

[10] For instance: when a specific type of N-fertiliser is used, then this shall be demonstrated by evidence that an auditor can check. For instance, a farmer must be able to show the purchase bills mentioning the specific fertiliser, or a farmer's association must be able to show the contracts for delivery of the specific fertiliser to a group of farmers.

2.3 Cut-off criteria

All emissions from processes and products used and associated with the system the economic operator has defined must be included in the GHG calculation. However, if the contribution of that input or process to the total emissions of the biofuel pathway is lower than 0.1 g $CO_{2,eq}$/MJ solid or gaseous biomass, it may be excluded.

As to avoid that a calculation, including finding a standard value, would be needed to show that the contribution is lower than 0.1 g $CO_{2,eq}$/MJ solid or gaseous biomass, this calculation rule can be complied with in the following way :

1. If an input is smaller than the mass or energy threshold[11] in table 2 below (in the same units as to be inputted in the BioGrace-II Excel tool), the contribution of the input may be excluded;
2. If there are several inputs that are relatively small, the sum of the inputs shall be below the mass or energy threshold to allow exclusion of the contribution of the inputs.
3. If the input is larger than the mass or energy threshold but it can be argued - for instance using standard values for similar inputs or using standard values that can be argued to be higher than the standard values for the input - that the emission of the input is below the 0.1 g $CO_{2,eq}$/MJ biomass, then the contribution of the input may be excluded.
4. If there are several small inputs this shall be demonstrated for the sum of the inputs for which the contribution is to be excluded.

Mass or energy threshold		
0.000005	kg/MJ	(this is equal to 0.005 g/MJ)
0.0002	MJ/MJ	(this is equal to 0.2 kJ/MJ)
10	MJ ha^{-1} $year^{-1}$	
0.3	kg ha^{-1} $year^{-1}$	

Table 2: mass or energy threshold

[11] The mass and energy thresholds were determined using the BioGrace tool in combination with the highest standard values from the list of standard values, expressed in g $CO_{2,eq}$/kg input and in g $CO_{2,eq}$/MJ input (pesticides and electricity from lignite, respectively). In combination with these standard values, an input which is smaller than the mass or energy threshold gives an emission lower than 0.1 g $CO_{2,eq}/MJ_{bio\text{-}energy}$

2.4 Combining disaggregated default values and actual values

A user may calculate greenhouse gas emissions of a biomass pathway by using disaggregated default values for cultivation, processing, transport and/or fuel in use. In the BioGrace-II Excel tool, this can be done by choosing “A” (actual values) or “D” (disaggregated default values) in the box next to the calculation result for cultivation, processing, transport and emissions from fuel in use.

2.5 Use of starting values in the BioGrace-II Excel tool

When the BioGrace-II Excel tool is downloaded, it contains starting values in the white boxes. These starting values are the values that have been used to calculate the default values in the JRC report[12], as is demonstrated by the BioGrace-II Excel tool. Actual GHG values are calculated by replacing starting values with actual input vales.

When changing a starting value into an actual value, all other starting values in that part of the biofuel production chain (either cultivation, processing, transport or fuel in use) shall be changed into actual values as well, including the starting values of other steps within the same part of the biofuel production chain (either cultivation, processing, transport or fuel in use).

Cultivation and processing can consist of several steps and transport does in most pathways consist of several steps. Both a cultivation and a processing step are defined as an operation at a distinct geographical location. A transport step is defined as the movement of a material from one cultivation or processing step to the next. A transport step can therefore consist of several transport modes (for instance transport by truck, followed by transport by ship). The separate steps are visible in the BioGrace-II Excel tool. The user of the tool must understand that this rule for changing starting values applies to all inputs for cultivation, all inputs for processing, all inputs for transport and/or all inputs for fuel in use.

Example: when a user gives an actual value for the yield of a crop (*eg* rapeseed or poplar as short rotation coppice), also actual input values must be given for all the other input values in the cultivation of the feedstock, which are (amongst others) the moisture content of the crop, the amount of diesel used, the amount of (N-, P-, K- and Ca-) fertiliser used, the amount of seed material and pesticides used, and the field N_2O emission. If the next step is related to feedstock production but is defined as a separate step (eg. “rapeseed drying” or “stemwood seasoning”) then actual input values have to be given also for the inputs in this step.

[12] Solid and gaseous bioenergy pathways: input values and GHG emissions. JRC: EUR 27215 EN

2.5.1 Empty (on purpose)

This paragraph is empty on purpose, as to keep the numbering of BioGrace-I and BioGrace-II calculation rules the same.

2.5.2 Starting values shall be unchanged if a disaggregated default value is chosen

Starting values shall not be changed in parts of the biofuel production pathway for which a disaggregated default value is chosen.

Example: if a disaggregated default value is chosen for "processing" in the pathway "Wood chips from stemwood", then none of the starting value in the steps "Chipping" and "Wood pellet/briquette production" shall be replaced by actual input numbers.

When the user wants to use actual values in any part of these steps then all the numbers in all these steps must be replaced by actual values (see calculation rule 2.5) and the "A" (Actual values") shall be selected next to "Processing" at the top of the calculation sheet.

2.6 Using the result(s) from previous and partial GHG calculations

Some voluntary certification schemes (that are used to show compliance with the sustainability criteria) allow that GHG calculations are made for part of the biofuel pathway and – after verification – are used as input in a new calculation for the rest of the production pathway.

In order to use the result from previous and partial GHG calculations in the BioGrace-II Excel tool:

- These results of the previous calculation shall be expressed in g $CO_{2,eq}$ per kg of feedstock (including moisture), in g $CO_{2,eq}$ per kg of intermediary product or in g $CO_{2,eq}$ per kg of final product.
- The economic operator that uses these previous and partial GHG calculations as input for the BioGrace-II Excel tool must have received, and must keep in his administration, a delivery note that shall contain the following information:
  - The result of the previous calculation
  - The GHG calculation tool, including version number, that was used to calculate the result of the previous calculation
  - A statement on what steps have been included in this calculation
  - Whether or not land use change has occurred and – if so – whether land use change has been included in the calculation
  - Whether improved agricultural management has been included in the calculation

- Once the European Commission has defined severely degraded or heavily contaminated land and if applicable: a statement that the feedstock was produced on severely degraded or heavily contaminated land, allowing to use the 29 g $CO_{2,eq}$/MJ bonus
- A statement that the calculation and the information on land use change has been verified by an independent verifier during an earlier audit, and that since that audit the feedstock and process inputs have not changed.

Values expressed in g $CO_{2,eq}$/kg energy carrier, which have been previously calculated and which have been verified by an independent auditor, may be put into the BioGrace-II tool. Changing such a value will overwrite all values and calculations in that step.

There are two different kinds of values that can be entered, for which the following requirements shall be taken into account:

1. <u>One or more unallocated results for individual steps</u>
   a. Result(s) for individual step(s) (like cultivation and/or transport) shall be entered in the cells with white background colour in column N for the corresponding step.
   b. In the result section (cells B8-G23) it shall be indicated in column E that an “individual result from a previous calculation” has been inputted, causing the result line(s) (A-F) for the individual step(s) in question to become orange coloured.[13]
2. <u>One result for multiple steps</u>
   a. One combined result for more than one step (like cultivation plus transport or like cultivation plus chipping) shall be entered in the cells with white background colour in column N for the last step in the combined result (so the combined result for cultivation plus chipping is put into the result in column N for the step “Chipping”).
   b. In the cells with white background colour in column N for the other steps that are included in the combined result, the value “0” shall be entered.
   c. In the result section (cells B8-G23) it shall be indicated in column E that a “combined result from a previous calculation” has been inputted. This shall be done for all the steps included in the combined result, causing the result lines (A-F) for these steps become orange coloured.[13]
   d. If a co-product is formed in one of the steps included in the combined result, then in the BioGrace Excel tool the allocation factor for this step shall be set to 100% towards the main product and 0% to the co-product. This shall be done by entering the value “100” into cell N8 in the calculation in the BioGrace Excel tool.

Land use change (e_l) as well as improved agricultural management (e_{sca}) shall be considered to be steps different from cultivation and as a result the combination of “cultivation” plus “land use change” as well as the combination “cultivation” plus “improved agricultural management” shall be considered to be

[13] This is explained in detail in the user manual.

multiple steps. Also for e_l and for e_{sca} it shall be indicated in row E when a “combined result from a previous calculation” has been inputted.[13]

2.7 Use of the sheet “user specific calculations”

The BioGrace-II Excel tool contains a sheet “User specific calculations” which allows users of the tool to make company- or user-specific calculations, such as converting company- or user-specific data into the format in which the data can be entered into BioGrace.

For the sheet “User specific calculations” the following calculation rules apply:

- The entire content of this sheet shall be subject to third party auditing
- Calculations made on this sheet shall be company/user specific
- The outcome of calculations made on this sheet shall be intermediate results that serve as input values in other BioGrace GHG calculation sheets (the sheets with the calculations on the biomass production pathways)
- This sheet shall not be used to calculate results to be entered in column N of other BioGrace GHG calculation sheets (“use of results from previous and partial GHG calculations” as explained in paragraph 2.6)
- All calculations made on this sheet shall comply with the BioGrace-II calculation rules.

3 Cultivation

3.1 Field N_2O emissions

When calculating emissions of N_2O from cultivation, both direct and indirect emissions shall be included.

Either the Global Nitrous Oxide Calculator[14] (GNOC) model developed by the JRC, or the IPCC guidelines from National Greenhouse Gas Inventories, Volume 4, Chapter 11 (2006) shall be used. There are two separate sheets in the BioGrace-II Excel tool for this.

If the crop for which calculations are being made is included in the GNOC model, the calculation shall be made in that model. At the front page of the GNOC website a list of the crops that are included in the model can be found. The calculation is not made within the Excel tool but directly at the GNOC website. However, when using the GNOC model the input fields on the sheet "N_2O emissions GNOC" shall be filled in, allowing a verifier to check the calculation.

For all other crops, the sheet "N_2O emissions IPCC" in the Excel tool shall be used.

3.2 Use of average values

For cultivation, it is allowed to use average values for geographical areas at the level of NUTS-2 areas or more fine-grained level. In the reports that had to be prepared in accordance with RED article 19.2, member states have listed average GHG emission values at such levels. For the BioGrace-II calculations this is relevant for bioliquids such as rapeseed oil or sunflower oil as listed in these reports.

If different feedstocks or feedstocks with different sustainability characteristics are used together in a biofuel process it is not allowed to make calculations based on averages of their different sustainability characteristics. For each feedstock with different sustainability characteristics a separate calculation has to be made. Please note that this is not valid for biogas co-digestion plants (see section 7).

[14] http://gnoc.jrc.ec.europa.eu/

3.3 Use of aggregated or measured values

For agricultural management (e_{ec} and e_l in the methodology) it is allowed to use either measured or aggregate values. When using aggregate values:

- The regional differences for these values shall be taken into consideration when using this data. For the EU, a value relevant for the NUTS2 level or more fine-grained level shall be used. For other countries a similar level would be applicable.
- Such numbers shall primarily be based on official statistical data from government bodies when available and of good quality. If not available, statistical data published by independent bodies may be used. As a third option, the numbers may be based on scientifically peer-reviewed work, with the precondition that data used lies within the commonly accepted data range when available.
- The data used shall be based on the most recent available data from the above-mentioned sources. Typically, the data shall be updated over time, unless there is no significant variability of the data over time.
- For fertiliser use, the typical type and quantity of fertiliser used for the crop in the region concerned may be used. Emissions from the production of fertiliser shall either be based on measured values or on technical specifications of the production facility. When the range of emissions values for a group[15] of fertiliser production facilities to which the facility concerned belongs is available, the most conservative emission number (highest) of that group shall be used.
- When a measured value for yields is used for the calculations, it is required to also use a measured value for fertiliser input and vice versa.

Economic operators shall make reference to the method and source used for determining actual values (e.g. average values based on representative yields, fertiliser input, N_2O emissions and changes in carbon stock).

3.4 Non artificial fertiliser

GHG emissions from a non-artificial fertiliser consist of emissions from its production and from its use. No emissions are allocated to the production of manure until the point of collection. However when field N_2O emissions are calculated, the contribution from manure is to be included according to the GNOC model which uses a combination of the IPCC tier 1 and tier 2, or the IPCC tier 1 methodology (see 3.1 above).

[15] It refers to for example a situation where an economic operator knows that the fertiliser was produced by a certain company in a certain country. That company has a number of fertiliser production facilities in that country for which the range of processing emissions are known; an economic operator can claim the most conservative number of emissions from the group of fertiliser production facilities.

3.5 Actual input data for use of fertilisers

If a GHG calculation is made using actual input data for mineral and/or organic fertilisers, then all mineral and organic fertilisers shall be taken into account that were used between the harvest of the previous crop and the harvest of the crop that is input for the calculation.

3.6 CO_2 emissions from acidification

When N-fertilizers are applied to the soil, they generate acid from being oxidised by bacteria. The acid reacts with the carbonates in the soil, releasing CO_2. Most farmers apply aglime to neutralise the acids, however, CO_2 emissions occur independently from aglime application due to reactions with carbonates naturally present in the soil. Therefore, the CO_2 emissions should be attributed to fertilizer input[16].

For calculating the CO_2 emissions, the following formulas shall be applied:

If soil pH > 6.4:

Formula 1.
Emissions attributed to aglime (kg CO_2 / ha) = (kg $CaCO_3$ applied/ha)*0.079 (kg CO_2 / kg $CaCO_3$) – (kg of N applied/ha)*0.59 (kg CO_2 / kg N)

If soil pH < 6.4:

Formula 2.
Emissions attributed to aglime (kg CO_2 / ha) = (kg $CaCO_3$ applied/ha)*0.44 (kg CO_2 / kg $CaCO_3$) – (kg of N applied/ha)*0.59 (kg CO_2 / kg N)

If the result is negative, the CO_2 emissions attributed to lime are zero.

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16 For further background information, see Edwards et al. 2013: Assessing GHG default emissions from biofuels in EU legislation

4 Processing emissions and end-use conversion

4.1 Use of actual values

Actual values for emissions from processing steps (e_p in the methodology) in the production chain must be measured or based on technical specifications of the processing facility. When the range of emissions values for a group of processing facilities to which the facility concerned belongs is available, the most conservative number of that group shall be used.

4.2 Allocation

When allocating between heat and electricity, allocation based on exergy shall be used, see section 4.2.1. When allocating between other co-products, the allocation shall be based on the energy content of the products, see section 4.2.3. *Figure 1* shows an example of how the different allocation methods are used in a production chain.

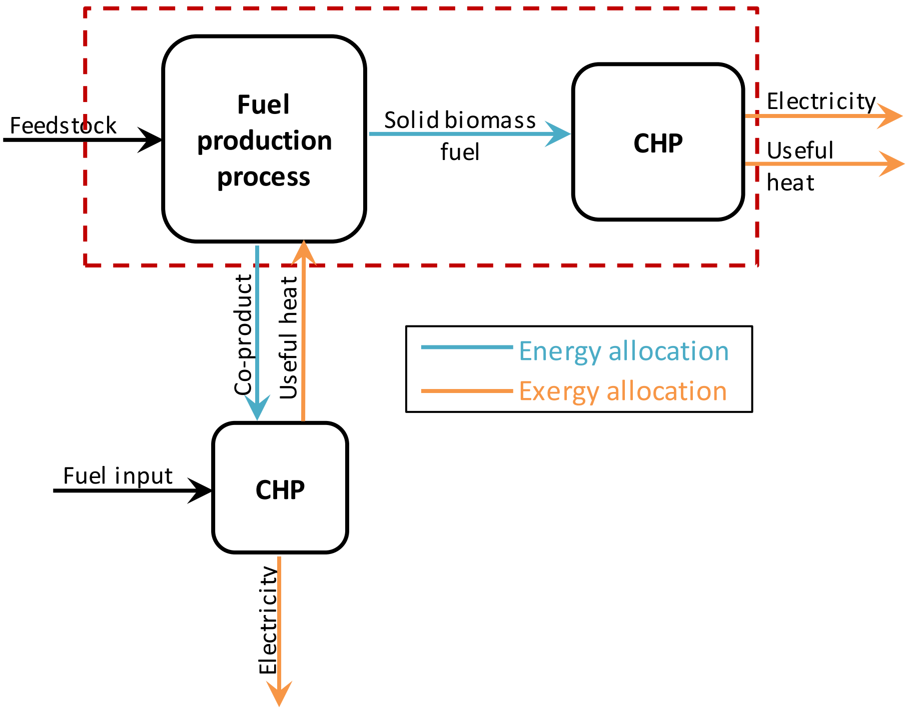

Figure 1: A fuel production chain including the final energy conversion. Blue arrows show in which cases allocation shall be based on energy content. Orange arrows show where allocation is based on the exergy principle.

The refinery rule stated in RED Annex V, point 18, and in the BioGrace I calculation rules says that allocation of emissions takes place after the step where no more feedback loops interlink with earlier parts in the process. This rule is only valid in refineries other than the combination of processing plants with boilers or CHPs providing heat and/or electricity to the processing plant. Boilers or CHPs shall not be considered included in a refinery.

Figure 1 illustrates the system in such a case. The processing of a co-product is interlinked with the fuel production process, but since the co-product processing occurs in a CHP which deliver useful heat to the fuel production process, the refinery rule is not valid and the CHP is treated as a separate system.

4.2.1 Allocation between electricity and heat produced in a CHP

[COM 2010(11), Annex 1, point 1b]:

For the electricity coming from energy installations delivering useful heat:

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

For the useful heat coming from energy installations delivering electricity:

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

/…/

Carnot efficiency, C_h, for useful heat at different temperatures:

$$C_h = \frac{T_h - T_0}{T_h}$$

When electricity and useful heat are produced simultaneously in a CHP the emissions shall be divided between the two or more energy carriers, by using exergy allocation. The GHG emissions from the final energy commodity (heat or electricity) are calculated by using the equations stated in the box above where

- $EC_{h,el}$ is the total greenhouse gas emissions from the final energy commodity [g $CO_{2,eq}$/$MJ_{heat, electricity}$],
- E is the total greenhouse gas emissions of the biomass before end-conversion [g $CO_{2,eq}$/$MJ_{biomass}$],
- C_{el} is the Carnot efficiency for electricity
- C_h is the Carnot efficiency for useful heat
- η_{el} is the electrical efficiency
- η_h is the thermal efficiency.

The thermal and electrical efficiencies shall be determined according to calculation rule defined in section 4.7. The Carnot efficiency for electricity, C_{el}, will in all cases be 1. The Carnot efficiency for useful heat, C_h, delivered at a temperature below 150 °C is always set to 0.3546. The Carnot efficiency for useful heat delivered at temperatures above 150 °C shall be determined by using the formula stated in the box above where

- T_h is the temperature, measured in absolute temperature (K) of the useful heat at point of delivery as final energy
- T_0 is the temperature of surroundings, set at 273 kelvin (equal to 0 °C)

The point of delivery shall be regarded as the point where the heat leaves the “gate” of the CHP or heating plant.

If heat is being delivered at several different temperatures above 150 °C, Carnot efficiencies and emission factors (EC_h) shall be calculated for the different heat qualities. If heat is being delivered at several different temperatures below 150 °C there is no need of dividing them into different parts since they will all have the same Carnot efficiency.

4.2.2 Allocation in the case of cooling being produced

The tool allows calculating the emission savings from the use of waste heat to provide cooling via an absorption chiller. Depending on whether additional electricity is produced, the allocation between heat and electricity, according to the rule in section 4.2.1, may be necessary. Only in a second step, heat is further transformed into cooling based on a cooling efficiency.

The efficiency is expressed as the seasonal coefficient of performance (SCOP). It is defined as the yearly cooling output, divided by the yearly heat input, see formula 3. The value should reflect an annual average efficiency.

Formula 3. Determining the SCOP

$$\mathrm{SCOP} = \frac{\text{Cooling output}}{\text{Heat input}}$$

Where

- Cooling output is defined as the annual cooling output [MWh/year]
- Heat input is defined as the annual heat demand of the absorption chiller [MWh/year]

4.2.3 Allocation between co-products other than electricity, heat or cooling.

Where a fuel production process produces, in combination, the fuel for which emissions are being calculated and one or more other co-products (not heat, cooling and/or electricity), the allocation shall be based on the energy content of the products. The energy content shall be determined by the lower heating value (LHV) of the whole product, not only the dry part, taking into account the latent heat of vaporisation of water:

Formula 4. Determining the lower heating value

$$LHV_{wet} = LHV_{dry} \cdot (1 - [mass\ \%\ of\ water]/100) - 2.441 \cdot [mass\ \%\ of\ water/100]$$

In which

- LHV_{wet} is the lower heating value of the wet biomass (MJ per kg wet biomass)
- LHV_{dry} is the lower heating value of the dry biomass (MJ per kg of dry biomass)
- [mass % of water] is the water content of the wet biomass, in percent of total mass of the wet biomass
- 2.441 is the latent heat of vaporisation of water at 25°C (MJ per kg water).

The emissions to be allocated are the emissions that arise up to and including the process step where a co-product is formed. The allocation takes place directly after the forming of a co-product. When leaving the process, the co-product takes the allocated emissions with it.

4.3 Electricity use

Emissions from using grid electricity shall be calculated from the average emission intensity for the country in which the electricity is taken from the grid. Country-average emission intensities for electricity shall be taken from the BioGrace list of additional standard values. It is not allowed to use the average emission intensity for the EU electricity mix.[17] Therefore when making an actual calculation in the BioGrace-II Excel tool a user-defined standard value for electricity shall be used.[18]

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[17] This rule therefore deviates from “Communication on the practical implementation …. [OJ C160, page 8]” which states that the most logical choice is to take the average emission intensity for the EU. The reason for deviating from “the most logical choice” from the Communication is that under other voluntary sustainability schemes it is allowed the use the national average emission intensity also for EU countries and because BioGrace aims to avoid disharmonised calculation rules.

[18] In the BioGrace-II Excel tool, the starting values (see also paragraph 2.5) for electricity are given for the parameter “EU electricity mix”. This is as to show how the GHG default values from the RED were calculated.

In case the BioGrace list of additional standard values does not contain an average value for the national grid for a country and such a value cannot be obtained from other sources, it is allowed to use the value for ”Other Africa”, “Other Asia” or “Other South and Central America” in the BioGrace list of additional standard values for countries in Africa, Asia and South and Central America, respectively.

Average emissions from a power plant can be applied only if the power plant is not connected with the grid. Emissions shall be averaged over the last year for which data are available.

It is not allowed to decrease the GHG emissions of electricity by using so-called “green certificates” or “guarantees of origin”.

4.4 Emissions of N_2O, CH_4 and CO_2 from the production unit

The GHG emissions that arise during the processing step include emissions from combustion of fossil fuels as well as any venting of methane and nitrous oxide to the atmosphere occurring during the process. If biomass is combusted during the processing, emissions of CH_4 and N_2O that occur during the combustion shall be accounted for, see section 4.8.

4.5 Handling of residues and waste

All operations that need to be carried out in order to dispose all waste and residues are included in the allocation between the biomass and the co-products. Waste and residues leave the system without any GHG emissions.

Waste and residues used for electricity, heating or cooling have zero GHG emissions up and until the point of collection. If the waste or residue need further processing before it can be used in the process, the emissions from that processing are to be allocated to that waste or residue.

4.6 CHP providing heat to the processing step

In the different pellets pathways in the Excel tool three types of CHP used for heat provision in the processing step can be chosen:

- Wood chip CHP (heat dim.)
- Wood chip boiler/CHP (act. calc)
- Wood pellet boiler/CHP (act. calc)

If the CHP that provides heat to the processing step is dimensioned to the heat demand of the processing, the *Wood chip CHP (heat dim.)* shall be used. If it is not dimensioned to the heat demand (*i.e.* it produces more heat than is needed in the processing step) the alternatives marked with *act. Calc*. shall be used.

Detailed information about heat provision calculation is included in the BioGrace-II Excel tool.

4.7 Electrical and thermal efficiency

[COM 2010(11), Annex 1, point 1b]:

η_{el} = The electrical efficiency, defined as the annual electricity produced divided by the annual fuel input.

η_{h} = The thermal efficiency, defined as the annual useful heat output […] divided by the annual fuel input.

In the BioGrace-II Excel tool the electrical and thermal efficiencies are calculated in the separate sheet "Calculate efficiencies". When using that sheet, this rule shall be respected.

When determining the electrical efficiency of a power plant the Formula 5 shall be used and relevant requirements stated in this rule shall be respected. When determining the thermal efficiency of a district heating plant the Formula 6 shall be used and relevant requirements stated in this rule shall be respected. When determining the electrical- and thermal efficiency of a combined heat and power plant (CHP) the Formula 5 and Formula 6 shall be used and all requirements below shall be respected.

Formula 5. Determining the electric efficiency

$$\eta_{el} = \frac{El - El_s - El_h}{F_f + B_f}$$

Formula 6. Determining the thermal efficiency

$$\eta_h = \frac{H - H_h - H_l}{F_f + B_f}$$

Where

- El is the gross electricity production (MWh/year)
- El_s is the total amount of start-up electricity used within the plant (MWh/year)
- El_h is the total amount of help system electricity (also known as "auxiliary electricity") used for electrical utilities belonging to the plant (MWh/year)

- F_f is the total amount of fossil fuel input (MWh/year). F_f shall be calculated as F_f = Mass (fossil fuel input) * LHV_{dry} (fossil fuel) * (1 – [mass percentage of water in fossil fuel]/100)
- B_f is the total amount of biomass fuel input during the period (MWh/year). B_f shall be calculated as B_f = Mass (biomass fuel input) * LHV_{dry} (biomass fuel) * (1 – [mass percentage of water in biomass fuel]/100)[19]
- H is the gross heat production (MWh/year) and is calculated according to Formula 7.
- H_h is the total amount of help system heat (also known as "auxiliary heat") used within the plant (preheating fuel or air) (MWh/year)
- H_l is the total amount of heat that does not leave the "gate" of the plant as useful heat, for example heat that is cooled off or other losses that occur before the "gate" of the plant. Losses that occur after the "gate" of the plant are neglected.
- $H-H_h-H_l$ is the useful heat delivered at the "gate" of the plant. 'Useful heat' shall mean heat produced in a cogeneration process to satisfy an economically justifiable demand for heat or cooling. 'Economically justifiable demand' shall mean the demand that does not exceed the needs for heat or cooling and which would otherwise be satisfied at market conditions by energy generation processes other than cogeneration.[20] The point of delivery for the useful heat is set at the "gate" of the plant due to feasibility reasons.

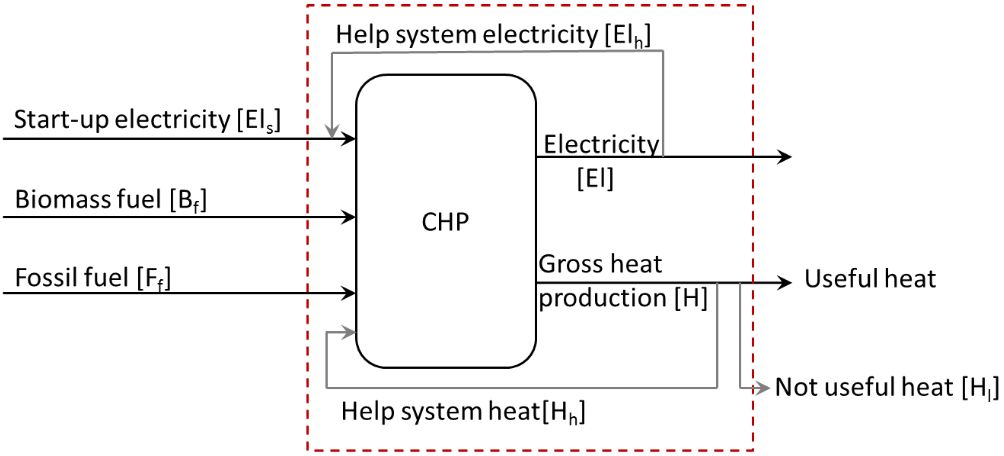

Figure 2: A schematic illustration of the CHP process. The gross heat production shall of course be calculated by taking the returning heat into account even though it is not included in this schematic illustration. This is done according to Formula 7.

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[19] The consequence of not taking into account the latent heat of vaporisation of water in this calculation (which could have been done by using the formula "*B_f = Mass (biomass fuel input) * (LHV_{dry} * (1 – [mass percentage of water]/100) – 2,441*[mass percentage of water]/100)*" in which 2,441 is the latent heat of vaporisation of water at 25°C expressed in MJ/kg) is that the amount of biomass fuel input, expressed in MWh/year, is still significant also in case the biomass fuel is very wet. Because of neglecting the latent heat of vaporisation of water, using a very wet biomass fuels will result in a very low electrical and thermal efficiencies when using Formulas 5 and 6. The reason for not taking into account the latent heat of vaporisation of water is further explained in the methodological background document.

[20] Directive 2012/27/EU of the European parliament and of the council of 25 October 2012 on energy efficiency.

Formula 7. Determining the gross heat production

$$H = \frac{C_P \cdot F \cdot \Delta T}{3.6 \cdot 10^9}$$

Where C_P is the heat capacity of the medium that is heated [J/(kg·K)]

- F is the flow rate of the medium that is heated [kg/year]
- ΔT the temperature difference in Kelvin: $T_{out} - T_{in}$ [K] [21]. T_{out} is measured at a point directly after the plant.
- The number $3.6 \cdot 10^9$ is to convert the unit of H from J to MWh which is the unit of input in the sheet Calculate efficiencies in the BioGrace-II Excel tool.

Any electricity consumed by utilities belonging to the CHP or power plant shall be counted as help electricity (also known as “auxiliary electricity”) (El_h) (when taken from the grid during operation of the plant or using internally produced electricity) and shall be subtracted from the amount of electricity generated (El). Such utilities can include utilities for conditioning of the fuel (e.g. coal mills for a coal plant), conveyer belts, pumps, lighting and compressors. The mentioned utilities shall not be considered as an exhaustive list of utilities that should be included.

When thermal energy is used for pre-heating the fuel, intake air or for other heat purposes within the heating plant or CHP[22], this heat shall be regarded as help system heat (also known as “auxiliary heat”) (H_h) and be subtracted from the heat produced by the power plant when calculating the amount of useful heat. The heat that does not leave the “gate” as useful heat (H_l), for example heat that is cooled off, shall also be subtracted.

Fossil fuel input includes any fossil fuel used for start-up, stopping and supporting the power plant, district heating plant or CHP.

When calculating the annual fuel input, the energy content shall be calculated by multiplying the lower heating value (on a dry basis) with the dry part of the annual fuel input. The lower heating value shall be the weighted average lower heating value for the fuel during the period for which the emissions are being calculated.

[21] In case of a CHP that delivers heat to a district heating network, T_{in} is the temperature of the returning district heating water.

[22] If the power plant is integrated with the production of the fuel, heat used for the production of the fuel shall also be subtracted from the total amount of delivered heat.

A reference-period of 365 consecutive days shall be used to avoid annual fluctuations in heat requirement or production cycles[23].

In cases where several useful heat qualities are produced, different heat efficiencies shall be calculated for the different heat qualities.

4.8 Emissions from the fuel in use

Emissions of CH_4 and N_2O that occur during the combustion of solid or gaseous biomass (either in the processing step or in the final conversion) shall be included in the total GHG-calculation. This is different from the approach to handling emission from biofuels in RED. Emissions of CO_2 from combustion of solid and gaseous biomass shall be set to zero similar to biofuels.

[23] If the plant has not been in operation for 365 days the calculations shall be based on real production data which is available. When doing so, a representative period must be taken (ie it is not allowed to determine the efficiency of a CHP only over winter months if the efficiency of the CHP is different in winter than in summer).

5 Land use change

For the calculation of carbon stock emissions from land use change, the rules laid down in Commission decision on guidelines for the calculation of land carbon stocks for the purpose of Annex V of Directive 2009/28/EC [OJ L151, page 19] shall be used. A template for this is included in the BioGrace Excel tool.

For determining if the bonus for restored degraded land 29 g CO_{2eq}/MJ shall apply, the definitions laid down by the COM of degraded land and heavily contaminated land must be considered[24].

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[24] The Commission has not yet (May 2015) defined whether land that falls within the scope of a national or regional recovery programme aimed at improving severely degraded or heavily contaminated land fulfils the criterion enabling to use the bonus.

6 Emission savings

6.1 Improved manure management

For manure as substrate a bonus of 45 $gCO_{2,eq.}$ / MJ manure is added for improved agricultural and manure management.

6.2 Soil carbon accumulation via improved agricultural methods

When calculating soil carbon accumulation due to improved agricultural methods, the method in chapter 5 for land use change shall be applied. The emissions shall be divided over 20 years.

7 Co-digestion

For biogas, produced in co-digestion plants, the GHG emissions shall be calculated in combination for the entire mixture within one co-digestion plant. When default values are available for the different substrates, a weighted average of the different default values is calculated.

7.1 Default values

SWD (2014)259, p. 21

In case of co-digestion of n different substrates in a biogas plant for the production of electricity or biomethane the typical and default values were calculated as follows:

$$E = \sum_1^n S_n \cdot E_n$$

Where:

E = emissions per MJ electricity or biomethane from biogas

S_n = Share of feedstock n in energy content

E_n = Emission in g CO_2/MJ from substrate n, see (a) below

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

Where:

P_n = energy yield [MJ] per kilogram of wet input of feedstock n, see (b) below

W_n = weighting factor of substrate n defined as:

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

Where:

I_n = Annual input to digester of substrate n [tonne of fresh matter]

AM_n = Average annual moisture of substrate n [kg water / kg fresh matter]

SM_n = Standard moisture for substrate n, see (c) below

[…]

Notes:

(a) For manure as substrate a bonus of 45 $gCO_{2,\,eq}$ / MJ manure is added for improved agricultural and manure management

(b) The Pn values were calculated as follows: $P_n = Y_n \cdot VS_n \cdot$ LHV(n)biogas

Where:

Y_n = yield of biogas [m3] per kg of volatile solids for feedstock n

VS_n = volatile solids content in feedstock n

LHV_{biogas} = 35.9 MJ/m3 * CH4 % vol.

P (maize) = 4.16

P (manure) = 0.50

P (biowastes) = 3.41

(c) The following moisture content was used: for manure 90%, for maize 65%, for biowaste 76%.

When default values are available for all substrates, i.e. when maize, wet manure and/or biowaste are co-digested, the emissions per MJ produced biogas shall be calculated according to the equations in the box above. Thus, the default emissions of each pathway are weighted together considering the theoretical specific energy yields of the different substrates.

Please note that this method is only allowed in the case of co-digesting maize, wet manure and/or biowaste.

7.2 Actual values

If other substrates than maize, wet manure and biowaste are co-digested an actual calculation of the emissions per MJ biogas shall be performed. All emissions associated with the biogas pathway (from cultivation to biogas) during one year are summed up and divided by the total biogas energy production during the same period. Formula 8 shows how the actual calculation of the emissions per MJ of biogas shall be done:

Formula 8. Actual calculation of emissions for biogas

$$E\ [CO_{2eq}/MJ_{biogas}] = \frac{(X_{F1}M_{F1} + X_{F2}M_{F2} + X_{F3}M_{F3}) + X_P + X_{TD} + X_U}{V\ * LHV}$$

Where

- X_{Fn} is the emissions from the feedstock stream n [$CO_{2,eq}$/kg]
- M_{Fn} is the quantity of the feedstock stream n [kg/year]
- X_P is the emissions from processing [$CO_{2,eq}$/year]
- X_{TD} is the emissions from transport and distribution [$CO_{2,eq}$/year]
- X_U is the emissions from fuel in use [$CO_{2,eq}$/year]
- V is the produced volume of biogas or biomethane during one year [Nm^3/year]
- LHV is the lower heating value of the biogas or biomethane [MJ/Nm^3]

Although there are disaggregated default values for biogas, maize and biowaste that could be used for the upstream emissions (e.g. for maize cultivation), these values may not be used if the substrates are co-digested with substrates for which there are no default values. In this case, actual values have to be used for all substrates.

BIOGRACE II

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Project funded by the Intelligent Energy Europe Programme

Contract number: IEE/11/733/SI2.616371

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Co-funded by the Intelligent Energy Europe Programme of the European Union

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