BIOGRACE II

Specific features of the BioGrace II tools

GHG calculation course for verifier trainers (solid and gaseous biomass)

Contents

1. CHP/boiler modules

2. Methodology for cooling

3. Description of the 3 Co-digestion sheets

4. Exercises

GHG calculation course for verifier trainers

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1. CHP/boiler modules

GHG calculation course for verifier trainers (solid and gaseous biomass)

CHP and boilers – general principles

What is a CHP?
- CHP stands for Combined Heat and Power.
- CHP integrates the production of electricity and steam simultaneously, from the same fuel (e.g. natural gas, pellets, wood chips, straw).

Which emissions are considered for calculations?
- Emissions from the fuel used at the CHP/boiler plant.
  - o Note1: Waste and residues used for electricity, heating or cooling have zero GHG emissions up and until the point of collection.

- GHG Emissions from fuel combustion in the CHP/boiler plant (*see § 4.4 and 4.8 of the BG II calculation rules document*):
  - o CO_2, CH_4 and N_2O emissions from fossil fuels
  - o CH_4 and N_2O emissions from biofuels

CHP and boilers – general principles

Which modules of the production pathway can include CHP or boilers ?

- In the General settings module : main output and configuration (e.g. pellets)
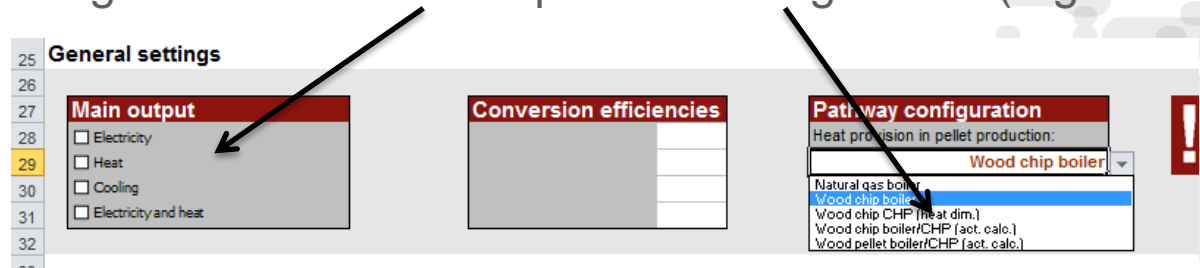
- o Note 1: « Wood chip CHP (heat dim) » should be selected if the CHP is fuelled with wood chips and produces just the amount of heat needed in the pellet production pathway
- o Note2: for biomethane pathways, there is no possibility to select CHP or boiler in the main output.
- In the final conversion module and/or in « processing » modules for some pathways

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Calculation rules: boundaries of the system for CHP/boilers

- According to the EC methodology, the CHP/boilers used during the final conversion step are included in the system boundaries (marked in red in the figure below), but the ones used during the production process should be considered outside of the production pathway boundaries

- It means that for CHP/boilers used during the production process, GHG emissions should be calculated only for the electricity and/or heat that is used in the production process
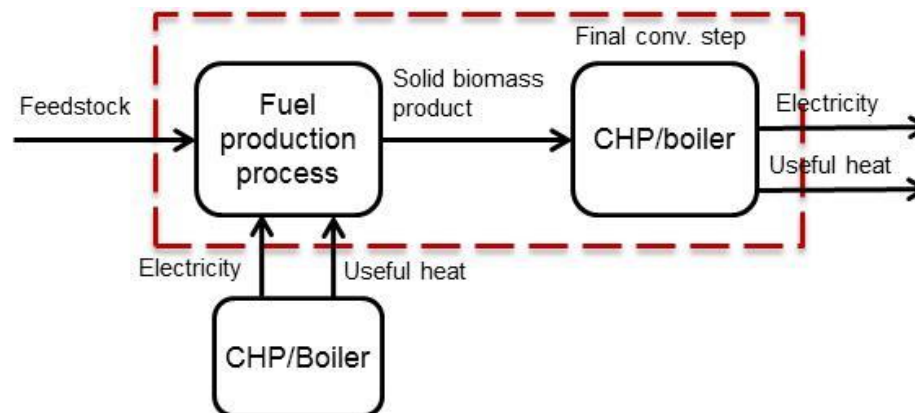
Calculation rules: boundaries of the system for CHP/boilers

- **Example of calculation for a natural gaz boiler (NG boiler)**

    - Useful heat consumed: 0,2 MJ/MJ solid biomass product

    - Thermal efficiency of NG boiler: 90% MJheat / MJNatural gaz

    - GHG emissions from supply (including CO_2 emissions due to combustion): 72 g CO_{2eq}/MJ

    - CH_4 and N_2O emissions from NG boiler: 1 g CO_{2eq}/MJ

Total GHG emissions due to NG boiler ($E_{NGboiler}$):

$E_{NGboiler}$= 0,2/90%*(72+1)

$\qquad$ =16,2 g CO_{2eq}/MJ solid biomass product

Note: We will check in the exercises how to make the calculation if the boiler is fuelled with wood chips coming from the production process

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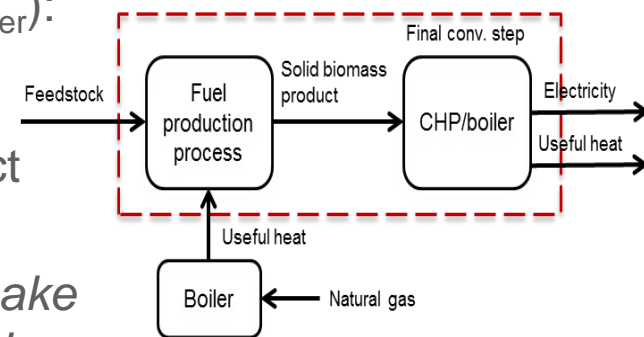
Calculation rules: GHG emissions allocation for CHP

Allocation rules between several temperatures of heat OR between heat and electricity produced in a CHP

- *See § 4.2.1 of the Calculation rules document*
- Allocation methodology is based on the exergy of products and coproducts
- Exergy is a thermodynamic concept that describes the maximum useful work that can be done by the available energy
- The use of exergy for allocation enables to take into account the temperature of the heat produced: 1MJ of heat at 150°C has a different exergy than 1MJ of heat at 200°C

- Note: for co-products other than electricity, heat or cooling, the allocation is based on the energy content, in accordance with RED methodology (*See § 4.2.3 of the Calculation rules document*)

Calculation rules: calculation of exergy allocation for the production of heat and electricity (1/3)

Formula used to calculate the allocation (*See § 4.2.1 of the Calculation rules document*)

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

Where:

- $EC_{h\ or\ el}$ is the total greenhouse gas emissions from the final energy commodity (in g CO_2,eq/MJheat, or electricity),
- E is the total greenhouse gas emissions of the biomass before end-conversion (in 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, defined as the annual electricity produced divided by the annual fuel input.
- η_h is the thermal efficiency, defined as the annual **useful** heat output divided by the annual fuel input.

Calculation rules: calculation of exergy allocation for the production of heat and electricity (2/3)

Hypothesis used for the calculation

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

Where:

- Carnot efficiency for electricity (C_{el}) =1
- Carnot efficiency for heat (C_h) = $\frac{T_h - T_0}{T_h}$
    - T_0 = 273 K
    - If T_h< 150° C, then C_h = 0,3546 (value calculated for T_h=150° C)
- Definition of useful heat (necessary to calculated η_h):
    - For the final energy conversion step: heat that fulfills economically justifiable demand;
    - For the processing step: heat that is used during the final energy carrier production process.

Calculation rules: calculation of exergy allocation for the production of heat and electricity (3/3)

Example of calculation

Instructions:
"A CHP is fed with biomass fuel with upstream emissions of 100g $CO_{2,eq}$/MJ. The electric efficiency is 25 % and the useful heat efficiency is 50 %. The temperature of the delivered heat is 120˚C".

Calculated the GHG emissions for electricity and heat

Answer:
Since the heat temperature is below 150 ˚C the Carnot factor is set at 0.3546.

$$EC_{el} = \frac{E}{\eta_{el}}\left(\frac{C_{el}\cdot\eta_{el}}{C_{el}\cdot\eta_{el}+C_h\cdot\eta_h}\right) = \frac{100}{0.25}\left(\frac{1\cdot0.25}{1\cdot0.25+0.3546\cdot0.5}\right) = 234\left[\frac{g}{MJ_{el}}\right]$$

$$EC_h = \frac{E}{\eta_h}\left(\frac{C_h\cdot\eta_h}{C_{el}\cdot\eta_{el}+C_h\cdot\eta_h}\right) = \frac{100}{0.5}\left(\frac{0.5\cdot0.3546}{1\cdot0.25+0.3546\cdot0.5}\right) = 83.0\left[\frac{g}{MJ_{heat}}\right]$$

1 MJ biomass fuel
100 g CO_{2eq} emissions [E]

CHP

0.25 MJ electricity
234 g CO_{2eq}/MJ_{el}

0.5 MJ heat at 120°C
83.0 g CO_{2eq}/MJ_{heat}
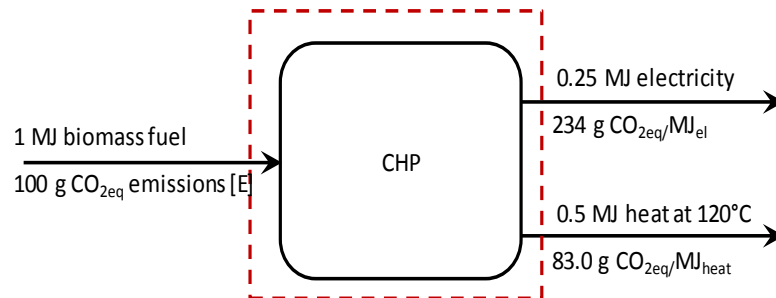
How to make CHP calculations within the BioGrace II tool for the final conversion step ? (1/3)

- Where to make the calculation ?
    - Either in a specific pathway
    - Or using the "Final conv. Only" sheet

    The calculation is the same in both cases

- The following slides will use the "Final conv. Only" sheet for the step by step example

- This sheet is especially useful for companies that have bought the biomass energy carrier and make the final energy conversion

- Please open the tool and follow the instructions

How to make CHP calculations within the BioGrace II tool for the final conversion step ? (2/3)

- Information needed to use the sheet "Final conv. Only":

1) Information on the **type of final energy carrier** (give a small description) **and the total GHG emissions from all previous steps** of the pathway

2) Fill in the "General settings" box: main output and conversion efficiencies

   ⇒ note: the sheet "Calculate efficiencies" is dedicated to the calculation of thermal and electric efficiencies (see next slides)

3) Complete the module on emissions from final conversion

4) Check the result of the total GHG emission reductions given at the bottom of the results box.

How to make CHP calculations within the BioGrace II tool for the final conversion step ? (3/3)

- **Exercises: calculate the GHG emission reduction using the "Final conv. Only"**

- **Instructions:**

"A company bought wood chips from forestry residues. The certificate indicates that the total GHG emissions up to the gate of the company equal to 35g CO_{2eq}/MJ wood chips. The company produces heat and electricity from a CHP with the following efficiencies 50 % for heat production and 25% for electricity production. The heat produced is 200° C."

Answer: see Excel file (Final conv. only (2))
GHG emissions reductions are 59% for heat and electricity

Slide 14
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How to use the "Calculate efficiencies" sheet of the BioGrace II tool ? (1/2)

- This sheet aims at providing information on the thermal and/or electrical efficiency for the use of boilers or CHP either for the processing step of the final conv. step

- If several CHP/boilers are used, this sheet should be duplicated to help the verifier

- Step by step description of the use of this sheet (please open the BG tool):

    1) Fill in the description of the annual input

    2) Fill in the description of the annual output

    3) Report results in the pathways or in the "final conv. Only" sheet

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How to use the "Calculate efficiencies" sheet of the BioGrace II tool ? (2/2)

- **Exercises: calculate the electrical and thermal efficiencies and allocation factors**

- **Instructions:**

"A company produces 4600 MWh of heat at 100° C, 400 MWh of heat at 250° C and 2200 MWh of electricity using 1000 tons of pellets (18MJ/kg at 10%H) and 2000 tons of SRF Wood chips (19MJ/kg at 50%H).
- 4% of electricity is used for start up, and electricity losses represent 1%
- 10% of heat (at 100° C) is used for pre-heating and heat losses represent 1%
- 10% of heat (at 250° C) is used for pre-heating and heat losses represent 1%

Answer: see excel file (Calculate efficiencies (exo-0))

Efficiencies: n_{el} = 21,4%; $n_{h,tot}$= 45,5%

Alloc factor :
- Elec = 56%
- Heat (100° C) = 39%
- Heat (250° C) = 5%

2. Methodology for cooling

How to make calculation for the production of cooling (1/2) ?

Allocation in the case of cooling being produced
- *See § 4.2.2 of the Calculation rules document*
- Cooling is made from waste heat, so heat production is always the first step
- Two steps for calculating the allocation:
  - First step: allocation between heat and electricity or between several heats (see methodology for CHP)
  - Second step: heat is further transformed into cooling based on a cooling efficiency expressed as the seasonal coefficient of performance (SCOP)

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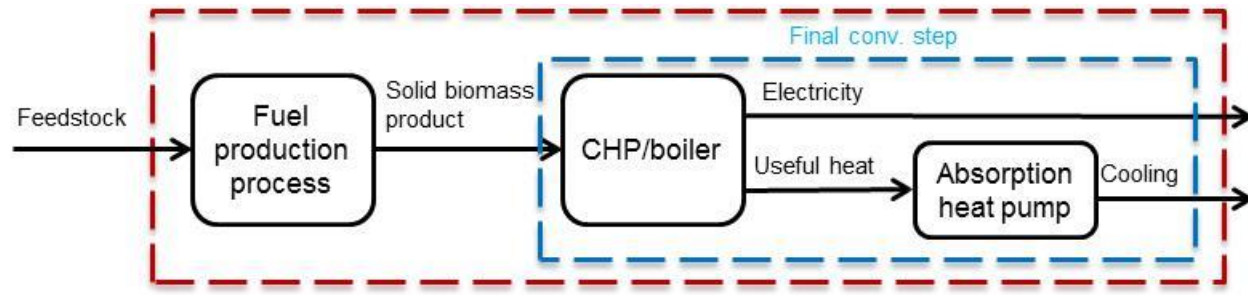
How to make calculation for the production of cooling (1/2) ?
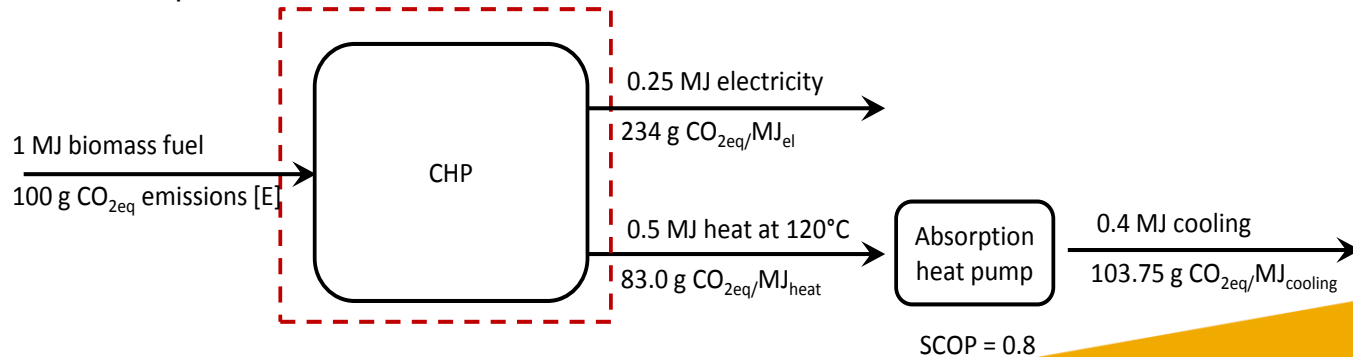
Example of calculation

Intrusctions:
"A CHP is fed with biomass fuel with upstream emissions of 100g $CO_{2,eq}$/MJ. The electrical efficiency is 25 % and the useful heat efficiency is 50 %. The temperature of the delivered heat is 120˚C. The absorption heat pump consumes each year 5MJ of heat at 120˚C to produce 4MJ of cooling. The absorption heat pump consumes all the heat that is produced by the CHP."

Calculated the GHG emissions for electricity and cooling.

Answer:
Since the heat temperature is below 150 ˚C the Carnot factor is set at 0.3546.

- 1 MJ biomass fuel
- 100 g CO_{2eq} emissions [E]
- CHP
- 0.25 MJ electricity
- 234 g CO_{2eq}/MJ_{el}
- 0.5 MJ heat at 120°C
- 83.0 g CO_{2eq}/MJ_{heat}
- Absorption heat pump
- 0.4 MJ cooling
- 103.75 g CO_{2eq}/$MJ_{cooling}$
- SCOP = 0.8

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3. The 3 Co-digestion sheets

Why is there 3 different sheets for co-digestion in the BioGrace II tool ?

Purpose of the 3 sheets

- "Co-dig_default" for **calculating new default values** for the production of biogas or biomethane from maize, wet manure and biowaste only

- "Bg-co-dig_actual" for **calculating actual GHG emissions** for the **production of biogas** from a combination of any biomass

- "Bm-co-dig_actual" for **calculating actual GHG emissions** for the **production of biomethane** from a combination of any biomass

- Please open the tool for a more detailed explanation on how to use each sheet *(also see § 6.6 of the User Manual)*

Thank you for your attention

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