Methods of calculating greenhouse gas emissions: "actual value method" and "default value method"

This document is published by the Secretary of State for the Department for Energy Security and Net Zero under regulation 12 of the Green Gas Support Scheme Regulations 2021. It sets out the actual value method and default value method for calculating lifecycle greenhouse gas emissions associated with the production of biomethane from biogas.

Part A: Methods of calculating greenhouse gas emissions

1. Actual value method for single-feedstock biomethane plants

Greenhouse gas emissions from the production of biomethane not involving the co-digestion of different feedstocks shall be calculated as follows:

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

Where:

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

e_{ec} = emissions from the extraction or cultivation of raw materials;

e_l = annualised emissions from carbon stock changes caused by land use change;

e_p = emissions from processing;

e_{td} = emissions from transport and distribution;

e_u = emissions from the fuel in use;

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

e_{ccs} = emission savings from carbon capture and geological storage; and

e_{ccr} = emission savings from carbon capture and replacement.

Emissions from the manufacture of machinery and equipment shall not be taken into account.

2. Actual value method for co-digesting biomethane plants

In the case of co-digestion of n substrates in a biogas plant for the production of biomethane, actual greenhouse gas emissions of biogas and biomethane are calculated as follows:

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

Where:

E = total emissions from the production of the 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;

$e_{sca,n}$ =emission savings from improved agricultural management of feedstock n*;

e_p = emissions from processing;

$e_{td,product}$ = emissions from transport and distribution of biomethane;

e_u = emissions from the fuel in use;

e_{ccs} = emission savings from carbon capture and geological storage; and

e_{ccr} = emission savings from carbon capture and replacement.

* For e_{sca} a bonus of 45 $gCO_{2eq.}$ / MJ manure shall be attributed for improved agricultural and manure management in case animal manure is used as a substrate for the production of biogas and biomethane.

3. Default value method for co-digesting biomethane plants

In case of co-digestion of different substrates in a biogas plant for the production of biomethane the typical and default values of greenhouse gas emissions shall be calculated as follows:

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

Where:

E = GHG emissions per MJ biomethane produced from co-digestion of the defined mixture of substrates

S_n = Share of feedstock n in energy content

E_n = Emission in gCO_2/MJ for pathway n as provided in Part C of this document*

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

Where:

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

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 ***.

*For animal manure used as substrate, a bonus of 45 gCO_{2eq}/MJ manure (-54 kg CO_{2eq}/t fresh matter) is added for improved agricultural and manure management.

** The following values of P_n shall be used for calculating typical and default values:

P_{maize}: 4.16 [MJ_{biogas}/$kg_{\text{wet maize @ 65 \% moisture}}$]

P_{manure}: 0.50 [MJ_{biogas}/$kg_{\text{wet manure @ 90 \% moisture}}$]

$P_{biowaste}$:3.41 [MJ_{biogas}/$kg_{\text{wet biowaste @ 76 \% moisture}}$]

***The following values of the standard moisture for substrate SM_n shall be used:

SM_{maize}: 0.65 [kg water/kg fresh matter]

SM_{manure}: 0.90 [kg water/kg fresh matter]

$SM_{biowaste}$: 0.76 [kg water/kg fresh matter]

Part B: Interpretation

1. Greenhouse gas emissions from biomethane shall be expressed as follows:

   greenhouse gas emissions from biomass fuels E, shall be expressed in terms of grams of CO_2 equivalent per MJ of biomass fuel, gCO_{2eq}/MJ.

   Where the greenhouse gas emissions from the extraction or cultivation of raw materials e_{ec} are expressed in unit g CO_2eq/dry-ton of feedstock the conversion to grams of CO_2 equivalent per MJ of fuel, gCO_{2eq} /MJ shall be calculated as follows[1];

$$e_{ec}fuel_a \left[\frac{gCO_2eq}{MJ\ fuel}\right]_{ec} = \frac{e_{ec}feedstock_a\left[\frac{gCO_2eq}{t_{dry}}\right]}{LHV_a\left[\frac{MJ\ feedstock}{t\ dry\ feedstock}\right]} \cdot Fuel\ feedstock\ factor_a \cdot Allocation\ factor\ fuel_a$$

   Where

$$Allocation\ factor\ fuel_a = \left[\frac{Energy\ in\ fuel}{Energy\ fuel + Energy\ in\ co-products}\right]$$

$$Fuel\ feedstock\ factor_a = [Ratio\ of\ MJ\ feedstock\ required\ to\ make\ 1MJ\ fuel]$$

   Emissions per dry-ton feedstock shall be calculated as follows:

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

2. Green Gas Support Scheme participants are required to produce biomethane which has greenhouse gas emissions of less than 24gCO_2eq/MJ. This is based on a fossil fuel comparator, E, of 80 gCO2eq/MJ, and a greenhouse gas emission savings of 70%. Greenhouse gas emission savings from biomethane are calculated as follows:

   $SAVING = (E_F - E_B)/E_F$

   where

   E_B = total emissions from the biomethane; and

   E_F = total emissions from the fossil fuel comparator

3. The greenhouse gases taken into account for the purposes of part A shall be CO_2, N_2O and CH_4. For the purpose of calculating CO_2 equivalence, those gases shall be valued as follows:

   CO_2: 1

1 The formula for calculating greenhouse gas emissions from the extraction or cultivation of raw materials e_{ec} describes cases where feedstock is converted into biofuels in one step. For more complex supply chains, adjustments are needed for calculating greenhouse gas emissions from the extraction or cultivation of raw materials e_{ec} for intermediate products.

N_2O: 298

CH_4: 25

4. Emissions from the extraction, harvesting or cultivation of raw materials, e_{ec}, shall include emissions from the extraction, harvesting or cultivation process itself; from the collection, drying and storage of raw materials; from waste and leakages; and from the production of chemicals or products used in extraction or cultivation. Capture of CO_2 in the cultivation of raw materials shall be excluded. It is allowable to calculate averages based on local farming practises based for instance on data of a group of farms, as an alternative to using actual values.

5. For the purposes of the calculation referred to in Part A (1), emission savings from improved agriculture management e_{sca}, such as shifting to reduced or zero-tillage, improved crop/rotation, the use of cover crops, including crop management, and the use of organic soil improver (e.g. compost, manure fermentation digestate), shall 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 while taking into account the emissions where such practices lead to increased fertiliser and herbicide use[2].

6. Annualised emissions from carbon stock changes caused by land-use change, e_l, shall be calculated by dividing total emissions equally over 20 years. For the calculation of those emissions the following rule shall be applied:

$$e_l = (CS_R - CS_A) \times 3.664 \times 1/20 \times 1/P - e_B,$$ [3]

Where:

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'[4] and 'perennial cropland'[5] 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

[2] Measurements of soil carbon can constitute such evidence, e.g. by a first measurement in advance of the cultivation and subsequent ones at regular intervals several years apart. In such case, before the second measurement is available, increase in soil carbon would be estimated on the basis of representative experiments or soil models. From the second measurement onwards, the measurements would constitute the basis for determining the existence of an increase in soil carbon and its magnitude.
[3] 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
[4] Cropland as defined by IPCC
[5] Perennial crops are defined as multi-annual crops, the stem of which is usually not annually harvested such as short rotation coppice and oil palm

one year, the value attributed to CS_A shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever the earlier; and

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

e_B = bonus of 29 gCO_{2eq} /MJ biomass fuel if biomass is obtained from restored degraded land under the conditions provided for in point 7.

7. The bonus of 29 gCO_{2eq} /MJ shall be attributed if evidence is provided that the land:

   a) was not in use for agriculture in January 2008; and

   b) is severely degraded land, including such land that was formerly in agricultural use.

   The bonus of 29 gCO_{2eq} /MJ shall apply for a period of up to 20 years from the date of conversion of the land to agricultural use, provided that a steady increase in carbon stocks as well as a sizable reduction in erosion phenomena for land falling under (b) are demonstrated.

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.

9. Guidelines for the calculation of land carbon stocks drawing on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories — volume 4, shall serve as the basis for the calculation of land carbon stocks.

10. Emissions from processing, e_p, shall include emissions from the processing itself; from waste and leakages; and from the production of chemicals or products used in processing, including the carbon dioxide emissions corresponding to the carbon contents of fossil inputs, whether or not actually combusted in the process, and emissions from processing biogas into biomethane.

    In accounting for the consumption of electricity not produced within the solid or gaseous biomass fuel production plant, the greenhouse gas emission intensity of the production and distribution of that electricity shall be assumed to be equal to the average emission intensity of the production and distribution of electricity in a defined region. By derogation from this rule, producers may use an average value for an individual electricity production plant for electricity produced by that plant, if that plant is not connected to the electricity grid.

    Emissions from processing shall include emissions from drying of interim- products and materials where relevant.

11. Emissions from transport and distribution, e_{td}, shall include emissions from the transport of raw and semi-finished materials and from the storage and distribution of finished materials. Emissions from transport and distribution to be taken into account under point 5 shall not be covered by this point.

12. Emissions of CO_2 from fuel in use, $e_{u,}$ shall be taken to be zero. Emissions of non-CO_2 greenhouse gases (CH_4 and N_2O) from the fuel in use shall be included in the e_u factor.

13. Emission savings from carbon capture and geological storage, e_{ccs}, that have not already been accounted for in e_p, shall be limited to emissions avoided through the capture and storage of emitted CO_2 directly related to the extraction, transport, processing and distribution of biomethane or biomass fuel.

14. Emission savings from carbon 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.

15. Where a biomass fuel production process produces, in combination, the fuel for which emissions are being calculated and one or more other products ("coproducts"), greenhouse gas emissions shall be divided between the fuel or its intermediate product and the coproducts in proportion to their energy content (determined by lower heating value in the case of coproducts other than electricity and heat). The greenhouse gas intensity of excess useful heat or excess electricity is the same as the greenhouse gas intensity of heat or electricity delivered to the biomass fuel production process and is determined from calculating the greenhouse gas intensity of all inputs and emissions, including the feedstock and CH_4 and N_2O emissions, to and from the apparatus delivering heat or electricity to the biomethane production process.

16. For the purposes of the calculations referred to in point 15, all co-products shall be taken into account for the purposes of that calculation. No emissions shall be allocated to wastes and residues. Co-products that have a negative energy content shall be considered to have an energy content of zero for the purpose of the calculation.

    Wastes and residues, including tree tops and branches, straw, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined) and bagasse, shall be considered to have zero life-cycle greenhouse gas emissions up to the process of collection of those materials irrespectively of whether they are processed to interim products before being transformed into the final product.

Part C: Default value tables

Table 1 Typical and default values for biomethane

Biomethane production system	Technological option	Typical greenhouse gas emissions (g CO2eq/MJ)	Default greenhouse gas emissions (g CO2eq/MJ)
Biomethane from wet manure	Open digestate, no off-gas combustion[6]	-20	22
	Open digestate, off-gas combustion[7]	-35	1
	Close digestate, no off-gas combustion	-88	-79
	Close digestate, off-gas combustion	-103	-100
Biomethane from maize whole plant	Open digestate , no off-gas combustion	58	73
	Open digestate, off-gas combustion	43	52
	Close digestate, no off-gas combustion	41	51
	Close digestate, off-gas combustion	26	30
Biomethane from biowaste	Open digestate , no off-gas combustion	51	71
	Open digestate, off-gas combustion	36	50
	Close digestate, no off-gas combustion	25	35
	Close digestate, off-gas combustion	10	14

Table 2 Typical and default values – biomethane - mixtures of manure and maize: GHG emissions with shares given on a fresh mass basis

	Technological options	Typical	Default

[6] This category includes the following categories of technologies for biogas upgrade to biomethane: Pressure Swing Adsorption (PSA), Pressure Water Scrubbing (PWS), Membranes, Cryogenic, and Organic Physical Scrubbing (OPS). It includes an emission of 0.03 MJCH4/MJbiomethane for the emission of methane in the off-gases.

[7] This category includes the following categories of technologies for biogas upgrade to biomethane: Pressure Water Scrubbing (PWS) when water is recycled, Pressure Swing Adsorption (PSA), Chemical Scrubbing, Organic Physical Scrubbing (OPS), Membranes and Cryogenic upgrading. No methane emissions are considered for this category (the methane in the off-gas is combusted, if any).

Biomethane production system		(g CO2eq/MJ)	(g CO2eq/MJ)
Manure – Maize 80% - 20 %	Open digestate, no off-gas combustion	32	57
	Open digestate, off-gas combustion	17	36
	Close digestate, no off-gas combustion	-1	9
	Close digestate, off-gas combustion	-16	-12
Manure – Maize 70% - 30 %	Open digestate, no off-gas combustion	41	62
	Open digestate, off-gas combustion	26	41
	Close digestate, no off-gas combustion	13	22
	Close digestate, off-gas combustion	-2	1
Manure – Maize 60% - 40 %	Open digestate, no off-gas combustion	46	66
	Open digestate, off-gas combustion	31	45
	Close digestate, no off-gas combustion	22	31
	Close digestate, off-gas combustion	7	10