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ANNEX VI

RULES FOR CALCULATING THE GREENHOUSE GAS IMPACT OF BIOMASS FUELS AND THEIR FOSSIL FUEL COMPARATORS

A. Typical and default values of greenhouse gas emissions savings for biomass fuels if produced with no net-carbon emissions from land-use change

WOODCHIPS					
Biomass fuel production system	Transport distance	Greenhouse gas emissions savings –typical value		Greenhouse gas emissions savings – default value	
		Heat	Electricity	Heat	Electricity
Woodchips from forest residues	1 to 500 km	93 %	89 %	91 %	87 %
	500 to 2 500 km	89 %	84 %	87 %	81 %
	2 500 to 10 000 km	82 %	73 %	78 %	67 %
	Above 10 000 km	67 %	51 %	60 %	41 %
Woodchips from short rotation coppice (Eucalyptus)	2 500 to 10 000 km	77 %	65 %	73 %	60 %
Woodchips from short rotation coppice (Poplar – Fertilised)	1 to 500 km	89 %	83 %	87 %	81 %
	500 to 2 500 km	85 %	78 %	84 %	76 %
	2 500 to 10 000 km	78 %	67 %	74 %	62 %
	Above 10 000 km	63 %	45 %	57 %	35 %
Woodchips from short rotation coppice (Poplar – No fertilisation)	1 to 500 km	91 %	87 %	90 %	85 %
	500 to 2 500 km	88 %	82 %	86 %	79 %
	2 500 to 10 000 km	80 %	70 %	77 %	65 %
	Above 10 000 km	65 %	48 %	59 %	39 %
Woodchips from stemwood	1 to 500 km	93 %	89 %	92 %	88 %
	500 to 2 500 km	90 %	85 %	88 %	82 %
	2 500 to 10 000 km	82 %	73 %	79 %	68 %
	Above 10 000 km	67 %	51 %	61 %	42 %
Woodchips from industry residues	1 to 500 km	94 %	92 %	93 %	90 %
	500 to 2 500 km	91 %	87 %	90 %	85 %
	2 500 to 10 000 km	83 %	75 %	80 %	71 %
	Above 10 000 km	69 %	54 %	63 %	44 %

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WOOD PELLETS (*)

Biomass fuel production system		Transport distance	Greenhouse gas emissions savings – typical value		Greenhouse gas emissions savings – default value	
			Heat	Electricity	Heat	Electricity
Wood briquettes or pellets from forest residues	Case 1	1 to 500 km	58 %	37 %	49 %	24 %
		500 to 2 500 km	58 %	37 %	49 %	25 %
		2 500 to 10 000 km	55 %	34 %	47 %	21 %
		Above 10 000 km	50 %	26 %	40 %	11 %
	Case 2a	1 to 500 km	77 %	66 %	72 %	59 %
		500 to 2 500 km	77 %	66 %	72 %	59 %
		2 500 to 10 000 km	75 %	62 %	70 %	55 %
		Above 10 000 km	69 %	54 %	63 %	45 %
	Case 3a	1 to 500 km	92 %	88 %	90 %	85 %
		500 to 2 500 km	92 %	88 %	90 %	86 %
		2 500 to 10 000 km	90 %	85 %	88 %	81 %
		Above 10 000 km	84 %	76 %	81 %	72 %
Wood briquettes or pellets from short rotation coppice (Eucalyptus)	Case 1	2 500 to 10 000 km	52 %	28 %	43 %	15 %
	Case 2a	2 500 to 10 000 km	70 %	56 %	66 %	49 %
	Case 3a	2 500 to 10 000 km	85 %	78 %	83 %	75 %
Wood briquettes or pellets from short rotation coppice (Poplar – Fertilised)	Case 1	1 to 500 km	54 %	32 %	46 %	20 %
		500 to 10 000 km	52 %	29 %	44 %	16 %
		Above 10 000 km	47 %	21 %	37 %	7 %
	Case 2a	1 to 500 km	73 %	60 %	69 %	54 %
		500 to 10 000 km	71 %	57 %	67 %	50 %
		Above 10 000 km	66 %	49 %	60 %	41 %
	Case 3a	1 to 500 km	88 %	82 %	87 %	81 %
		500 to 10 000 km	86 %	79 %	84 %	77 %
		Above 10 000 km	80 %	71 %	78 %	67 %

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WOOD PELLETS (*)						
Biomass fuel production system		Transport distance	Greenhouse gas emissions savings – typical value		Greenhouse gas emissions savings – default value	
			Heat	Electricity	Heat	Electricity
Wood briquettes or pellets from short rotation coppice (Poplar – No fertilisation)	Case 1	1 to 500 km	56 %	35 %	48 %	23 %
		500 to 10 000 km	54 %	32 %	46 %	20 %
		Above 10 000 km	49 %	24 %	40 %	10 %
	Case 2a	1 to 500 km	76 %	64 %	72 %	58 %
		500 to 10 000 km	74 %	61 %	69 %	54 %
		Above 10 000 km	68 %	53 %	63 %	45 %
	Case 3a	1 to 500 km	91 %	86 %	90 %	85 %
		500 to 10 000 km	89 %	83 %	87 %	81 %
		Above 10 000 km	83 %	75 %	81 %	71 %
Stemwood	Case 1	1 to 500 km	57 %	37 %	49 %	24 %
		500 to 2 500 km	58 %	37 %	49 %	25 %
		2 500 to 10 000 km	55 %	34 %	47 %	21 %
		Above 10 000 km	50 %	26 %	40 %	11 %
	Case 2a	1 to 500 km	77 %	66 %	73 %	60 %
		500 to 2 500 km	77 %	66 %	73 %	60 %
		2 500 to 10 000 km	75 %	63 %	70 %	56 %
		Above 10 000 km	70 %	55 %	64 %	46 %
	Case 3a	1 to 500 km	92 %	88 %	91 %	86 %
		500 to 2 500 km	92 %	88 %	91 %	87 %
		2 500 to 10 000 km	90 %	85 %	88 %	83 %
		Above 10 000 km	84 %	77 %	82 %	73 %

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WOOD PELLETS (*)

Biomass fuel production system		Transport distance	Greenhouse gas emissions savings – typical value		Greenhouse gas emissions savings – default value	
			Heat	Electricity	Heat	Electricity
Wood briquettes or pellets from wood industry residues	Case 1	1 to 500 km	75 %	62 %	69 %	55 %
		500 to 2 500 km	75 %	62 %	70 %	55 %
		2 500 to 10 000 km	72 %	59 %	67 %	51 %
		Above 10 000 km	67 %	51 %	61 %	42 %
	Case 2a	1 to 500 km	87 %	80 %	84 %	76 %
		500 to 2 500 km	87 %	80 %	84 %	77 %
		2 500 to 10 000 km	85 %	77 %	82 %	73 %
		Above 10 000 km	79 %	69 %	75 %	63 %
	Case 3a	1 to 500 km	95 %	93 %	94 %	91 %
		500 to 2 500 km	95 %	93 %	94 %	92 %
		2 500 to 10 000 km	93 %	90 %	92 %	88 %
		Above 10 000 km	88 %	82 %	85 %	78 %

(*) Case 1 refers to processes in which a natural gas boiler is used to provide the process heat to the pellet mill. Electricity for the pellet mill is supplied from the grid;
Case 2a refers to processes in which a woodchips boiler, fed with pre-dried chips, is used to provide process heat. Electricity for the pellet mill is supplied from the grid;
Case 3a refers to processes in which a CHP, fed with pre-dried woodchips, is used to provide electricity and heat to the pellet mill.

AGRICULTURE PATHWAYS

Biomass fuel production system	Transport distance	Greenhouse gas emissions savings – typical value		Greenhouse gas emissions savings – default value	
		Heat	Electricity	Heat	Electricity
Agricultural Residues with density < 0,2 t/m^3 (*)	1 to 500 km	95 %	92 %	93 %	90 %
	500 to 2 500 km	89 %	83 %	86 %	80 %
	2 500 to 10 000 km	77 %	66 %	73 %	60 %
	Above 10 000 km	57 %	36 %	48 %	23 %
Agricultural Residues with density > 0,2 t/m^3 (**)	1 to 500 km	95 %	92 %	93 %	90 %
	500 to 2 500 km	93 %	89 %	92 %	87 %
	2 500 to 10 000 km	88 %	82 %	85 %	78 %
	Above 10 000 km	78 %	68 %	74 %	61 %

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AGRICULTURE PATHWAYS

Biomass fuel production system	Transport distance	Greenhouse gas emissions savings – typical value		Greenhouse gas emissions savings – default value	
		Heat	Electricity	Heat	Electricity
Straw pellets	1 to 500 km	88 %	82 %	85 %	78 %
	500 to 10 000 km	86 %	79 %	83 %	74 %
	Above 10 000 km	80 %	70 %	76 %	64 %
Bagasse briquettes	500 to 10 000 km	93 %	89 %	91 %	87 %
	Above 10 000 km	87 %	81 %	85 %	77 %
Palm Kernel Meal	Above 10 000 km	20 %	-18 %	11 %	-33 %
Palm Kernel Meal (no CH_4 emissions from oil mill)	Above 10 000 km	46 %	20 %	42 %	14 %

(*) This group of materials includes agricultural residues with a low bulk density and it comprises materials such as straw bales, oat hulls, rice husks and sugar cane bagasse bales (not exhaustive list).

(**) The group of agricultural residues with higher bulk density includes materials such as corn cobs, nut shells, soybean hulls, palm kernel shells (not exhaustive list).

BIOGAS FOR ELECTRICITY (*)

Biogas production system		Technological option	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Wet manure [1]	Case 1	Open digestate [2]	146 %	94 %
		Close digestate [3]	246 %	240 %
	Case 2	Open digestate	136 %	85 %
		Close digestate	227 %	219 %
	Case 3	Open digestate	142 %	86 %
		Close digestate	243 %	235 %
Maize whole plant [4]	Case 1	Open digestate	36 %	21 %
		Close digestate	59 %	53 %
	Case 2	Open digestate	34 %	18 %
		Close digestate	55 %	47 %
	Case 3	Open digestate	28 %	10 %
		Close digestate	52 %	43 %

[1] The values for biogas production from manure include negative emissions for emissions saved from raw manure management. The value of e_{sca} considered is equal to – 45 g CO_2eq/MJ manure used in anaerobic digestion.

[2] Open storage of digestate accounts for additional emissions of CH_4 and N_2O. The magnitude of those emissions changes with ambient conditions, substrate types and the digestion efficiency.

[3] Close storage means that the digestate resulting from the digestion process is stored in a gas-tight tank and that the additional biogas released during storage is considered to be recovered for production of additional electricity or biomethane. No greenhouse gas emissions are included in that process.

[4] Maize whole plant means maize harvested as fodder and ensiled for preservation.

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BIOGAS FOR ELECTRICITY (*)

Biogas production system		Technological option	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Biowaste	Case 1	Open digestate	47 %	26 %
		Close digestate	84 %	78 %
	Case 2	Open digestate	43 %	21 %
		Close digestate	77 %	68 %
	Case 3	Open digestate	38 %	14 %
		Close digestate	76 %	66 %

(*) Case 1 refers to pathways in which electricity and heat required in the process are supplied by the CHP engine itself.
Case 2 refers to pathways in which the electricity required in the process is taken from the grid and the process heat is supplied by the CHP engine itself. In some Member States, operators are not allowed to claim the gross production for subsidies and case 1 is the more likely configuration.
Case 3 refers to pathways in which the electricity required in the process is taken from the grid and the process heat is supplied by a biogas boiler. This case applies to some installations in which the CHP engine is not on-site and biogas is sold (but not upgraded to biomethane).

BIOGAS FOR ELECTRICITY – MIXTURES OF MANURE AND MAIZE

Biogas production system		Technological option	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Manure – Maize 80 % - 20 %	Case 1	Open digestate	72 %	45 %
		Close digestate	120 %	114 %
	Case 2	Open digestate	67 %	40 %
		Close digestate	111 %	103 %
	Case 3	Open digestate	65 %	35 %
		Close digestate	114 %	106 %
Manure – Maize 70 % - 30 %	Case 1	Open digestate	60 %	37 %
		Close digestate	100 %	94 %
	Case 2	Open digestate	57 %	32 %
		Close digestate	93 %	85 %
	Case 3	Open digestate	53 %	27 %
		Close digestate	94 %	85 %

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BIOGAS FOR ELECTRICITY – MIXTURES OF MANURE AND MAIZE				
Biogas production system		Technological option	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Manure – Maize 60 % - 40 %	Case 1	Open digestate	53 %	32 %
		Close digestate	88 %	82 %
	Case 2	Open digestate	50 %	28 %
		Close digestate	82 %	73 %
	Case 3	Open digestate	46 %	22 %
		Close digestate	81 %	72 %

BIOMETHANE FOR TRANSPORT (*)			
Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Wet manure	Open digestate, no off-gas combustion	117 %	72 %
	Open digestate, off-gas combustion	133 %	94 %
	Close digestate, no off-gas combustion	190 %	179 %
	Close digestate, off-gas combustion	206 %	202 %
Maize whole plant	Open digestate, no off-gas combustion	35 %	17 %
	Open digestate, off-gas combustion	51 %	39 %
	Close digestate, no off-gas combustion	52 %	41 %
	Close digestate, off-gas combustion	68 %	63 %
Biowaste	Open digestate, no off-gas combustion	43 %	20 %
	Open digestate, off-gas combustion	59 %	42 %
	Close digestate, no off-gas combustion	70 %	58 %
	Close digestate, off-gas combustion	86 %	80 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

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BIOMETHANE – MIXTURES OF MANURE AND MAIZE (*)

Biomethane production system	Technological options	Greenhouse gas emissions savings – typical value	Greenhouse gas emissions savings – default value
Manure – Maize 80 % - 20 %	Open digestate, no off-gas combustion [1]	62 %	35 %
	Open digestate, off-gas combustion [2]	78 %	57 %
	Close digestate, no off-gas combustion	97 %	86 %
	Close digestate, off-gas combustion	113 %	108 %
Manure – Maize 70 % - 30 %	Open digestate, no off-gas combustion	53 %	29 %
	Open digestate, off-gas combustion	69 %	51 %
	Close digestate, no off-gas combustion	83 %	71 %
	Close digestate, off-gas combustion	99 %	94 %
Manure – Maize 60 % - 40 %	Open digestate, no off-gas combustion	48 %	25 %
	Open digestate, off-gas combustion	64 %	48 %
	Close digestate, no off-gas combustion	74 %	62 %
	Close digestate, off-gas combustion	90 %	84 %

(*) The greenhouse gas emissions savings for biomethane only refer to compressed biomethane relative to the fossil fuel comparator for transport of 94 g CO_2eq/MJ.

B. METHODOLOGY

1. Greenhouse gas emissions from the production and use of biomass fuels, shall be calculated as follows:

(a) Greenhouse gas emissions from the production and use of biomass fuels before conversion into electricity, heating and cooling, shall be calculated as:

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

Where

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

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

(1) 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 MJ CH_4/MJ biomethane for the emission of methane in the off-gases.

(2) 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).

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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; and

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

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

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

▼C1

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

▼B

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 this Annex (*)

▼C1

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

▼B

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 (***).

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(*) For animal manure used as substrate, a bonus of 45 g CO_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 [$MJ_{biogas}/kg_{wet\ maize\ @\ 65\ \%\ moisture}$]

P(Manure): 0,50 [$MJ_{biogas}/kg_{wet\ manure\ @\ 90\ \%\ moisture}$]

P(Biowaste) 3,41 [$MJ_{biogas}/kg_{wet\ biowaste\ @\ 76\ \%\ moisture}$]

(***) 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]

(c) In the case of co-digestion of n substrates in a biogas plant for the production of electricity or 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 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; and

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

▼B

(*) For e_{sca} a bonus of 45 g CO_2eq/MJ manure shall be attributed for improved agricultural and manure management in the case animal manure is used as a substrate for the production of biogas and biomethane.

(d) Greenhouse gas emissions from the use of biomass fuels in producing electricity, heating and cooling, including the energy conversion to electricity and/or heat or cooling produced, shall be calculated as follows:

(i) For energy installations delivering only heat:

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

(ii) For energy installations delivering only electricity:

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

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.

(iii) For the electricity or mechanical energy coming from energy installations delivering useful heat together with electricity and/or mechanical energy:

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

(iv) For the useful heat coming from energy installations delivering heat together with electricity and/or mechanical energy:

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

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 energy input, based on its energy content.

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η_h = The heat efficiency, defined as the annual useful heat output divided by the annual energy 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).

The Carnot efficiency, C_h, for useful heat at different temperatures is defined as:

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

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 (equal to 0 °C).

If the excess heat is exported for heating of buildings, at a temperature below 150 °C (423,15 kelvin), C_h can alternatively be defined as follows:

C_h = Carnot efficiency in heat at 150 °C (423,15 kelvin), which is: 0,3546

For the purposes of that calculation, the following definitions apply:

(i) ‘cogeneration’ shall mean the simultaneous generation in one process of thermal energy and electricity and/or mechanical energy;

(ii) ‘useful heat’ shall mean heat generated to satisfy an economical justifiable demand for heat, for heating or cooling purposes;

(iii) ‘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.

2. Greenhouse gas emissions from biomass fuels shall be expressed as follows:

(a) greenhouse gas emissions from biomass fuels, E, shall be expressed in terms of grams of CO_2 equivalent per MJ of biomass fuel, g CO_2eq/MJ;

(b) greenhouse gas emissions from heating or electricity, produced from biomass fuels, EC, shall be expressed in terms of grams of CO_2 equivalent per MJ of final energy commodity (heat or electricity), g CO_2eq/MJ.

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When heating and cooling are co-generated with electricity, emissions shall be allocated between heat and electricity (as under point 1(d)), irrespective if the heat is used for actual heating purposes or for cooling. ([1])

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, g CO_2eq /MJ, shall be calculated as follows ([2]):

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

Where

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

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

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

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

3. Greenhouse gas emissions savings from biomass fuels shall be calculated as follows:

   (a) greenhouse gas emissions savings from biomass fuels used as transport fuels:

   SAVING = $(E_{F(t)} - E_B)/E_{F(t)}$

   where

   E_B = total emissions from biomass fuels used as transport fuels; and

   $E_{F(t)}$ = total emissions from the fossil fuel comparator for transport

([1]) Heat or waste heat is used to generate cooling (chilled air or water) through absorption chillers. Therefore, it is appropriate to calculate only the emissions associated to the heat produced, per MJ of heat, irrespectively if the end-use of the heat is actual heating or cooling via absorption chillers.

([2]) The formula for calculating greenhouse gas emissions from the extraction or cultivation of raw materials eec 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 eec for intermediate products.

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(b) greenhouse gas emissions savings from heat and cooling, and electricity being generated from biomass fuels:

$$SAVING = (EC_{F(h\&c,el)} - EC_{B(h\&c,el)})/EC_{F\ (h\&c,el)}$$

where

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

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

4. The greenhouse gases taken into account for the purposes of point 1 shall be CO_2, N_2O and CH_4. For the purposes of calculating CO_2 equivalence, those gases shall be valued as follows:

CO_2: 1

N_2O: 298

CH_4: 25

5. 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. Estimates of emissions from agriculture biomass cultivation may be derived from the regional averages for cultivation emissions included in the reports referred to in Article 31(4) of this Directive or the information on the disaggregated default values for cultivation emissions included in this Annex, as an alternative to using actual values. In the absence of relevant information in those reports it is allowed 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.

Estimates of emissions from cultivation and harvesting of forestry biomass may be derived from the use of averages for cultivation and harvesting emissions calculated for geographical areas at national level, as an alternative to using actual values.

6. For the purposes of the calculation referred to in point 1(a), 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 residue 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 ([1]).

([1]) 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 a 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.

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7. 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:

$$e_l = (CS_R - CS_A) \times 3{,}664 \times 1/20 \times 1/P - e_B,$$ (1)

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' (2) and 'perennial cropland' (3) 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 CS_A 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); and

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 point 8.

8. The bonus of 29 g CO_2eq/MJ shall be attributed if evidence is provided that the land:

(a) was not in use for agriculture in January 2008 or any other activity; and

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

The bonus of 29 g CO_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 ensured.

9. '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.

(1) The quotient obtained by dividing the molecular weight of CO2 (44,010 g/mol) by the molecular weight of carbon (12,011 g/mol) is equal to 3,664.

(2) Cropland as defined by IPCC.

(3) 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.

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10. In accordance with point 10 of Part C of Annex V to this Directive, Commission Decision 2010/335/EU [1], which provides for guidelines for the calculation of land carbon stocks in relation to this Directive, drawing on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – volume 4, and in accordance with Regulations (EU) No 525/2013 and (EU) 2018/841, shall serve as the basis for the calculation of land carbon stocks.

11. 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 CO_2 emissions corresponding to the carbon contents of fossil inputs, whether or not actually combusted in the process.

    In accounting for the consumption of electricity not produced within the solid or gaseous biomass fuel production plant, the greenhouse gas emissions 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 way of 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.

12. 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.

13. Emissions of CO_2 from fuel in use, $e_{u,}$ shall be taken to be zero for biomass fuels. 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.

14. Emission savings from CO_2 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 biomass fuel if stored in compliance with Directive 2009/31/EC.

15. 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.

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[1] Commission Decision 2010/335/EU of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (OJ L 151, 17.6.2010, p. 19).

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16. Where a cogeneration unit – providing heat and/or electricity to a biomass fuel production process for which emissions are being calculated – produces excess electricity and/or excess useful heat, the greenhouse gas emissions shall be divided between the electricity and the useful heat according to the temperature of the heat (which reflects the usefulness (utility) of the heat). The useful part of the heat is found by multiplying its energy content with the Carnot efficiency, C_h, calculated as follows:

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

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 (equal to 0 °C).

If the excess heat is exported for heating of buildings, at a temperature below 150 °C (423,15 kelvin), C_h can alternatively be defined as follows:

C_h = Carnot efficiency in heat at 150 °C (423,15 kelvin), which is: 0,3546

For the purposes of that calculation, the actual efficiencies shall be used, defined as the annual mechanical energy, electricity and heat produced respectively divided by the annual energy input.

For the purposes of that calculation, the following definitions apply:

(a) ‘cogeneration’ shall mean the simultaneous generation in one process of thermal energy and electrical and/or mechanical energy;

(b) ‘useful heat’ shall mean heat generated to satisfy an economical justifiable demand for heat, for heating or cooling purposes;

(c) ‘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.

17. Where a biomass fuel production process produces, in combination, the fuel for which emissions are being calculated and one or more other products (‘co-products’), greenhouse gas emissions shall be divided between the fuel or its intermediate product and the co-products in proportion to their energy content (determined by lower heating value in the case of co-products 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

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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 cogeneration unit, boiler or other apparatus delivering heat or electricity to the biomass fuel production process. In the case of cogeneration of electricity and heat, the calculation is performed following point 16.

18. For the purposes of the calculations referred to in point 17, the emissions to be divided shall be $e_{ec} + e_l + e_{sca}$ + those fractions of e_p, e_{td}, e_{ccs} and e_{ccr} that take place up to and including the process step at which a co-product is produced. If any allocation to co-products has taken place at an earlier process step in the life-cycle, the fraction of those emissions assigned in the last such process step to the intermediate fuel product shall be used for those purposes instead of the total of those emissions.

►C1 In the case of biogas and biomethane, 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 purposes 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.

In the case of biomass fuels produced in refineries, other than the combination of processing plants with boilers or cogeneration units providing heat and/or electricity to the processing plant, the unit of analysis for the purposes of the calculation referred to in point 17 shall be the refinery.

19. For biomass fuels used for the production of electricity, for the purposes of the calculation referred to in point 3, the fossil fuel comparator $EC_{F(el)}$ shall be 183 g CO_2eq/MJ electricity or 212 g CO_2eq/MJ electricity for the outermost regions.

For biomass fuels used for the production of useful heat, as well as for the production of heating and/or cooling, for the purposes of the calculation referred to in point 3, the fossil fuel comparator $EC_{F(h)}$ shall be 80 g CO_2eq/MJ heat.

For biomass fuels used for the production of useful heat, in which a direct physical substitution of coal can be demonstrated, for the purposes of the calculation referred to in point 3, the fossil fuel comparator $EC_{F(h)}$ shall be 124 g CO_2eq/MJ heat.

For biomass fuels used as transport fuels, for the purposes of the calculation referred to in point 3, the fossil fuel comparator $E_{F(t)}$ shall be 94 g CO_2eq/MJ.

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C. DISAGGREGATED DEFAULT VALUES FOR BIOMASS FUELS

Wood briquettes or pellets

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value(g CO_2eq/MJ)				Greenhouse gas emissions – default value (g CO_2eq/MJ)			
		Cultivation	Processing	Transport	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport	Non-CO_2 emissions from the fuel in use
Wood chips from forest residues	1 to 500 km	0,0	1,6	3,0	0,4	0,0	1,9	3,6	0,5
	500 to 2 500 km	0,0	1,6	5,2	0,4	0,0	1,9	6,2	0,5
	2 500 to 10 000 km	0,0	1,6	10,5	0,4	0,0	1,9	12,6	0,5
	Above 10 000 km	0,0	1,6	20,5	0,4	0,0	1,9	24,6	0,5
Wood chips from SRC (Eucalyptus)	2 500 to 10 000 km	4,4	0,0	11,0	0,4	4,4	0,0	13,2	0,5
Wood chips from SRC (Poplar – fertilised)	1 to 500 km	3,9	0,0	3,5	0,4	3,9	0,0	4,2	0,5
	500 to 2 500 km	3,9	0,0	5,6	0,4	3,9	0,0	6,8	0,5
	2 500 to 10 000 km	3,9	0,0	11,0	0,4	3,9	0,0	13,2	0,5
	Above 10 000 km	3,9	0,0	21,0	0,4	3,9	0,0	25,2	0,5
Wood chips from SRC (Poplar – Not fertilised)	1 to 500 km	2,2	0,0	3,5	0,4	2,2	0,0	4,2	0,5
	500 to 2 500 km	2,2	0,0	5,6	0,4	2,2	0,0	6,8	0,5
	2 500 to 10 000 km	2,2	0,0	11,0	0,4	2,2	0,0	13,2	0,5
	Above 10 000 km	2,2	0,0	21,0	0,4	2,2	0,0	25,2	0,5

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Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)				Greenhouse gas emissions – default value (g CO_2eq/MJ)			
		Cultivation	Processing	Transport	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport	Non-CO_2 emissions from the fuel in use
Wood chips from stemwood	1 to 500 km	1,1	0,3	3,0	0,4	1,1	0,4	3,6	0,5
	500 to 2 500 km	1,1	0,3	5,2	0,4	1,1	0,4	6,2	0,5
	2 500 to 10 000 km	1,1	0,3	10,5	0,4	1,1	0,4	12,6	0,5
	Above 10 000 km	1,1	0,3	20,5	0,4	1,1	0,4	24,6	0,5
Wood chips from wood industry residues	1 to 500 km	0,0	0,3	3,0	0,4	0,0	0,4	3,6	0,5
	500 to 2 500 km	0,0	0,3	5,2	0,4	0,0	0,4	6,2	0,5
	2 500 to 10 000 km	0,0	0,3	10,5	0,4	0,0	0,4	12,6	0,5
	Above 10 000 km	0,0	0,3	20,5	0,4	0,0	0,4	24,6	0,5

Wood briquettes or pellets

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)				Greenhouse gas emissions – default value (g CO_2eq/MJ)			
		Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use
Wood briquettes or pellets from forest residues (case 1)	1 to 500 km	0,0	25,8	2,9	0,3	0,0	30,9	3,5	0,3
	500 to 2 500 km	0,0	25,8	2,8	0,3	0,0	30,9	3,3	0,3
	2 500 to 10 000 km	0,0	25,8	4,3	0,3	0,0	30,9	5,2	0,3
	Above 10 000 km	0,0	25,8	7,9	0,3	0,0	30,9	9,5	0,3

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Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)				Greenhouse gas emissions – default value (g CO_2eq/MJ)			
		Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use
Wood briquettes or pellets from forest residues (case 2a)	1 to 500 km	0,0	12,5	3,0	0,3	0,0	15,0	3,6	0,3
	500 to 2 500 km	0,0	12,5	2,9	0,3	0,0	15,0	3,5	0,3
	2 500 to 10 000 km	0,0	12,5	4,4	0,3	0,0	15,0	5,3	0,3
	Above 10 000 km	0,0	12,5	8,1	0,3	0,0	15,0	9,8	0,3
Wood briquettes or pellets from forest residues (case 3a)	1 to 500 km	0,0	2,4	3,0	0,3	0,0	2,8	3,6	0,3
	500 to 2 500 km	0,0	2,4	2,9	0,3	0,0	2,8	3,5	0,3
	2 500 to 10 000 km	0,0	2,4	4,4	0,3	0,0	2,8	5,3	0,3
	Above 10 000 km	0,0	2,4	8,2	0,3	0,0	2,8	9,8	0,3
Wood briquettes from short rotation coppice (Eucalyptus – case 1)	2 500 to 10 000 km	3,9	24,5	4,3	0,3	3,9	29,4	5,2	0,3
Wood briquettes from short rotation coppice (Eucalyptus – case 2a)	2 500 to 10 000 km	5,0	10,6	4,4	0,3	5,0	12,7	5,3	0,3
Wood briquettes from short rotation coppice (Eucalyptus – case 3a)	2 500 to 10 000 km	5,3	0,3	4,4	0,3	5,3	0,4	5,3	0,3

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Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$)				Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$)			
		Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use
Wood briquettes from short rotation coppice (Poplar – Fertilised – case 1)	1 to 500 km	3,4	24,5	2,9	0,3	3,4	29,4	3,5	0,3
	500 to 10 000 km	3,4	24,5	4,3	0,3	3,4	29,4	5,2	0,3
	Above 10 000 km	3,4	24,5	7,9	0,3	3,4	29,4	9,5	0,3
Wood briquettes from short rotation coppice (Poplar – Fertilised – case 2a)	1 to 500 km	4,4	10,6	3,0	0,3	4,4	12,7	3,6	0,3
	500 to 10 000 km	4,4	10,6	4,4	0,3	4,4	12,7	5,3	0,3
	Above 10 000 km	4,4	10,6	8,1	0,3	4,4	12,7	9,8	0,3
Wood briquettes from short rotation coppice (Poplar – Fertilised – case 3a)	1 to 500 km	4,6	0,3	3,0	0,3	4,6	0,4	3,6	0,3
	500 to 10 000 km	4,6	0,3	4,4	0,3	4,6	0,4	5,3	0,3
	Above 10 000 km	4,6	0,3	8,2	0,3	4,6	0,4	9,8	0,3
Wood briquettes from short rotation coppice (Poplar – no fertilisation – case 1)	1 to 500 km	2,0	24,5	2,9	0,3	2,0	29,4	3,5	0,3
	500 to 2 500 km	2,0	24,5	4,3	0,3	2,0	29,4	5,2	0,3
	2 500 to 10 000 km	2,0	24,5	7,9	0,3	2,0	29,4	9,5	0,3
Wood briquettes from short rotation coppice (Poplar – no fertilisation – case 2a)	1 to 500 km	2,5	10,6	3,0	0,3	2,5	12,7	3,6	0,3
	500 to 10 000 km	2,5	10,6	4,4	0,3	2,5	12,7	5,3	0,3
	Above 10 000 km	2,5	10,6	8,1	0,3	2,5	12,7	9,8	0,3

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Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$)				Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$)			
		Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use
Wood briquettes from short rotation coppice (Poplar – no fertilisation– case 3a)	1 to 500 km	2,6	0,3	3,0	0,3	2,6	0,4	3,6	0,3
	500 to 10 000 km	2,6	0,3	4,4	0,3	2,6	0,4	5,3	0,3
	Above 10 000 km	2,6	0,3	8,2	0,3	2,6	0,4	9,8	0,3
Wood briquettes or pellets from stemwood (case 1)	1 to 500 km	1,1	24,8	2,9	0,3	1,1	29,8	3,5	0,3
	500 to 2 500 km	1,1	24,8	2,8	0,3	1,1	29,8	3,3	0,3
	2 500 to 10 000 km	1,1	24,8	4,3	0,3	1,1	29,8	5,2	0,3
	Above 10 000 km	1,1	24,8	7,9	0,3	1,1	29,8	9,5	0,3
Wood briquettes or pellets from stemwood (case 2a)	1 to 500 km	1,4	11,0	3,0	0,3	1,4	13,2	3,6	0,3
	500 to 2 500 km	1,4	11,0	2,9	0,3	1,4	13,2	3,5	0,3
	2 500 to 10 000 km	1,4	11,0	4,4	0,3	1,4	13,2	5,3	0,3
	Above 10 000 km	1,4	11,0	8,1	0,3	1,4	13,2	9,8	0,3
Wood briquettes or pellets from stemwood (case 3a)	1 to 500 km	1,4	0,8	3,0	0,3	1,4	0,9	3,6	0,3
	500 to 2 500 km	1,4	0,8	2,9	0,3	1,4	0,9	3,5	0,3
	2 500 to 10 000 km	1,4	0,8	4,4	0,3	1,4	0,9	5,3	0,3
	Above 10 000 km	1,4	0,8	8,2	0,3	1,4	0,9	9,8	0,3

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Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$)				Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$)			
		Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use
Wood briquettes or pellets from wood industry residues (case 1)	1 to 500 km	0,0	14,3	2,8	0,3	0,0	17,2	3,3	0,3
	500 to 2 500 km	0,0	14,3	2,7	0,3	0,0	17,2	3,2	0,3
	2 500 to 10 000 km	0,0	14,3	4,2	0,3	0,0	17,2	5,0	0,3
	Above 10 000 km	0,0	14,3	7,7	0,3	0,0	17,2	9,2	0,3
Wood briquettes or pellets from wood industry residues (case 2a)	1 to 500 km	0,0	6,0	2,8	0,3	0,0	7,2	3,4	0,3
	500 to 2 500 km	0,0	6,0	2,7	0,3	0,0	7,2	3,3	0,3
	2 500 to 10 000 km	0,0	6,0	4,2	0,3	0,0	7,2	5,1	0,3
	Above 10 000 km	0,0	6,0	7,8	0,3	0,0	7,2	9,3	0,3
Wood briquettes or pellets from wood industry residues (case 3a)	1 to 500 km	0,0	0,2	2,8	0,3	0,0	0,3	3,4	0,3
	500 to 2 500 km	0,0	0,2	2,7	0,3	0,0	0,3	3,3	0,3
	2 500 to 10 000 km	0,0	0,2	4,2	0,3	0,0	0,3	5,1	0,3
	Above 10 000 km	0,0	0,2	7,8	0,3	0,0	0,3	9,3	0,3

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Agriculture pathways

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)				Greenhouse gas emissions – default value (g CO_2eq/MJ)			
		Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use	Cultivation	Processing	Transport & distribution	Non-CO_2 emissions from the fuel in use
Agricultural Residues with density < 0,2 t/m^3	1 to 500 km	0,0	0,9	2,6	0,2	0,0	1,1	3,1	0,3
	500 to 2 500 km	0,0	0,9	6,5	0,2	0,0	1,1	7,8	0,3
	2 500 to 10 000 km	0,0	0,9	14,2	0,2	0,0	1,1	17,0	0,3
	Above 10 000 km	0,0	0,9	28,3	0,2	0,0	1,1	34,0	0,3
Agricultural Residues with density > 0,2 t/m^3	1 to 500 km	0,0	0,9	2,6	0,2	0,0	1,1	3,1	0,3
	500 to 2 500 km	0,0	0,9	3,6	0,2	0,0	1,1	4,4	0,3
	2 500 to 10 000 km	0,0	0,9	7,1	0,2	0,0	1,1	8,5	0,3
	Above 10 000 km	0,0	0,9	13,6	0,2	0,0	1,1	16,3	0,3
Straw pellets	1 to 500 km	0,0	5,0	3,0	0,2	0,0	6,0	3,6	0,3
	500 to 10 000 km	0,0	5,0	4,6	0,2	0,0	6,0	5,5	0,3
	Above 10 000 km	0,0	5,0	8,3	0,2	0,0	6,0	10,0	0,3
Bagasse briquettes	500 to 10 000 km	0,0	0,3	4,3	0,4	0,0	0,4	5,2	0,5
	Above 10 000 km	0,0	0,3	8,0	0,4	0,0	0,4	9,5	0,5
Palm Kernel Meal	Above 10 000 km	21,6	21,1	11,2	0,2	21,6	25,4	13,5	0,3
Palm Kernel Meal (no CH_4 emissions from oil mill)	Above 10 000 km	21,6	3,5	11,2	0,2	21,6	4,2	13,5	0,3

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Disaggregated default values for biogas for the production of electricity

Biomass fuel production system		Technology	TYPICAL VALUE [g CO_2eq/MJ]					DEFAULT VALUE [g CO_2eq/MJ]				
			Cultivation	Processing	Non-CO_2 emissions from the fuel in use	Transport	Manure credits	Cultivation	Processing	Non-CO_2 emissions from the fuel in use	Transport	Manure credits
Wet manure [1]	case 1	Open digestate	0,0	69,6	8,9	0,8	– 107,3	0,0	97,4	12,5	0,8	– 107,3
		Close digestate	0,0	0,0	8,9	0,8	– 97,6	0,0	0,0	12,5	0,8	– 97,6
	case 2	Open digestate	0,0	74,1	8,9	0,8	– 107,3	0,0	103,7	12,5	0,8	– 107,3
		Close digestate	0,0	4,2	8,9	0,8	– 97,6	0,0	5,9	12,5	0,8	– 97,6
	case 3	Open digestate	0,0	83,2	8,9	0,9	– 120,7	0,0	116,4	12,5	0,9	– 120,7
		Close digestate	0,0	4,6	8,9	0,8	– 108,5	0,0	6,4	12,5	0,8	– 108,5
Maize whole plant [2]	case 1	Open digestate	15,6	13,5	8,9	0,0 [3]	—	15,6	18,9	12,5	0,0	—
		Close digestate	15,2	0,0	8,9	0,0	—	15,2	0,0	12,5	0,0	—

(1) The values for biogas production from manure include negative emissions for emissions saved from raw manure management. The value of e_{sca} considered is equal to – 45 g CO_2eq/MJ manure used in anaerobic digestion.
(2) Maize whole plant means maize harvested as fodder and ensiled for preservation.
(3) Transport of agricultural raw materials to the transformation plant is, according to the methodology provided in the Commission's report of 25 February 2010 on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling, included in the ‘cultivation’ value. The value for transport of maize silage accounts for 0,4 g CO_2eq/MJ biogas.

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Biomass fuel production system		Technology	TYPICAL VALUE [g CO_2eq/MJ]					DEFAULT VALUE [g CO_2eq/MJ]				
			Cultivation	Processing	Non-CO_2 emissions from the fuel in use	Transport	Manure credits	Cultivation	Processing	Non-CO_2 emissions from the fuel in use	Transport	Manure credits
	case 2	Open digestate	15,6	18,8	8,9	0,0	—	15,6	26,3	12,5	0,0	—
		Close digestate	15,2	5,2	8,9	0,0	—	15,2	7,2	12,5	0,0	—
	case 3	Open digestate	17,5	21,0	8,9	0,0	—	17,5	29,3	12,5	0,0	—
		Close digestate	17,1	5,7	8,9	0,0	—	17,1	7,9	12,5	0,0	—
Biowaste	case 1	Open digestate	0,0	21,8	8,9	0,5	—	0,0	30,6	12,5	0,5	—
		Close digestate	0,0	0,0	8,9	0,5	—	0,0	0,0	12,5	0,5	—
	case 2	Open digestate	0,0	27,9	8,9	0,5	—	0,0	39,0	12,5	0,5	—
		Close digestate	0,0	5,9	8,9	0,5	—	0,0	8,3	12,5	0,5	—
	case 3	Open digestate	0,0	31,2	8,9	0,5	—	0,0	43,7	12,5	0,5	—
		Close digestate	0,0	6,5	8,9	0,5	—	0,0	9,1	12,5	0,5	—

▼B

Disaggregated default values for biomethane

Biomethane production system	Technological option		TYPICAL VALUE [g CO_2eq/MJ]						DEFAULT VALUE [g CO_2eq/MJ]					
			Culti-vation	Processing	Upgrading	Transport	Compression at filling station	Manure credits	Culti-vation	Processing	Upgrading	Transport	Compression at filling station	Manure credits
Wet manure	Open digestate	no off-gas combustion	0,0	84,2	19,5	1,0	3,3	– 124,4	0,0	117,9	27,3	1,0	4,6	– 124,4
		off-gas combustion	0,0	84,2	4,5	1,0	3,3	– 124,4	0,0	117,9	6,3	1,0	4,6	– 124,4
	Close digestate	no off-gas combustion	0,0	3,2	19,5	0,9	3,3	– 111,9	0,0	4,4	27,3	0,9	4,6	– 111,9
		off-gas combustion	0,0	3,2	4,5	0,9	3,3	– 111,9	0,0	4,4	6,3	0,9	4,6	– 111,9
Maize whole plant	Open digestate	no off-gas combustion	18,1	20,1	19,5	0,0	3,3	—	18,1	28,1	27,3	0,0	4,6	—
		off-gas combustion	18,1	20,1	4,5	0,0	3,3	—	18,1	28,1	6,3	0,0	4,6	—
	Close digestate	no off-gas combustion	17,6	4,3	19,5	0,0	3,3	—	17,6	6,0	27,3	0,0	4,6	—
		off-gas combustion	17,6	4,3	4,5	0,0	3,3	—	17,6	6,0	6,3	0,0	4,6	—
Biowaste	Open digestate	no off-gas combustion	0,0	30,6	19,5	0,6	3,3	—	0,0	42,8	27,3	0,6	4,6	—
		off-gas combustion	0,0	30,6	4,5	0,6	3,3	—	0,0	42,8	6,3	0,6	4,6	—
	Close digestate	no off-gas combustion	0,0	5,1	19,5	0,5	3,3	—	0,0	7,2	27,3	0,5	4,6	—
		off-gas combustion	0,0	5,1	4,5	0,5	3,3	—	0,0	7,2	6,3	0,5	4,6	—

▼B

D. TOTAL TYPICAL AND DEFAULT VALUES FOR BIOMASS FUEL PATHWAYS

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
Woodchips from forest residues	1 to 500 km	5	6
	500 to 2 500 km	7	9
	2 500 to 10 000 km	12	15
	Above 10 000 km	22	27
Woodchips from short rotation coppice (Eucalyptus)	2 500 to 10 000 km	16	18
Woodchips from short rotation coppice (Poplar – Fertilised)	1 to 500 km	8	9
	500 to 2 500 km	10	11
	2 500 to 10 000 km	15	18
	Above 10 000 km	25	30
Woodchips from short rotation coppice (Poplar – No fertilisation)	1 to 500 km	6	7
	500 to 2 500 km	8	10
	2 500 to 10 000 km	14	16
	Above 10 000 km	24	28
Woodchips from stemwood	1 to 500 km	5	6
	500 to 2 500 km	7	8
	2 500 to 10 000 km	12	15
	Above 10 000 km	22	27
Woodchips from industry residues	1 to 500 km	4	5
	500 to 2 500 km	6	7
	2 500 to 10 000 km	11	13
	Above 10 000 km	21	25
Wood briquettes or pellets from forest residues (case 1)	1 to 500 km	29	35
	500 to 2 500 km	29	35
	2 500 to 10 000 km	30	36
	Above 10 000 km	34	41
Wood briquettes or pellets from forest residues (case 2a)	1 to 500 km	16	19
	500 to 2 500 km	16	19
	2 500 to 10 000 km	17	21
	Above 10 000 km	21	25

▼B

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
Wood briquettes or pellets from forest residues (case 3a)	1 to 500 km	6	7
	500 to 2 500 km	6	7
	2 500 to 10 000 km	7	8
	Above 10 000 km	11	13
Wood briquettes or pellets from short rotation coppice (Eucalyptus – case 1)	2 500 to 10 000 km	33	39
Wood briquettes or pellets from short rotation coppice (Eucalyptus – case 2a)	2 500 to 10 000 km	20	23
Wood briquettes or pellets from short rotation coppice (Eucalyptus – case 3a)	2 500 to 10 000 km	10	11
Wood briquettes or pellets from short rotation coppice (Poplar – Fertilised – case 1)	1 to 500 km	31	37
	500 to 10 000 km	32	38
	Above 10 000 km	36	43
Wood briquettes or pellets from short rotation coppice (Poplar – Fertilised – case 2a)	1 to 500 km	18	21
	500 to 10 000 km	20	23
	Above 10 000 km	23	27
Wood briquettes or pellets from short rotation coppice (Poplar – Fertilised – case 3a)	1 to 500 km	8	9
	500 to 10 000 km	10	11
	Above 10 000 km	13	15
Wood briquettes or pellets from short rotation coppice (Poplar – no fertilisation – case 1)	1 to 500 km	30	35
	500 to 10 000 km	31	37
	Above 10 000 km	35	41
Wood briquettes or pellets from short rotation coppice (Poplar – no fertilisation – case 2a)	1 to 500 km	16	19
	500 to 10 000 km	18	21
	Above 10 000 km	21	25
Wood briquettes or pellets from short rotation coppice (Poplar – no fertilisation – case 3a)	1 to 500 km	6	7
	500 to 10 000 km	8	9
	Above 10 000 km	11	13

▼B

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
Wood briquettes or pellets from stemwood (case 1)	1 to 500 km	29	35
	500 to 2 500 km	29	34
	2 500 to 10 000 km	30	36
	Above 10 000 km	34	41
Wood briquettes or pellets from stemwood (case 2a)	1 to 500 km	16	18
	500 to 2 500 km	15	18
	2 500 to 10 000 km	17	20
	Above 10 000 km	21	25
Wood briquettes or pellets from stemwood (case 3a)	1 to 500 km	5	6
	500 to 2 500 km	5	6
	2 500 to 10 000 km	7	8
	Above 10 000 km	11	12
Wood briquettes or pellets from wood industry residues (case 1)	1 to 500 km	17	21
	500 to 2 500 km	17	21
	2 500 to 10 000 km	19	23
	Above 10 000 km	22	27
Wood briquettes or pellets from wood industry residues (case 2a)	1 to 500 km	9	11
	500 to 2 500 km	9	11
	2 500 to 10 000 km	10	13
	Above 10 000 km	14	17
Wood briquettes or pellets from wood industry residues (case 3a)	1 to 500 km	3	4
	500 to 2 500 km	3	4
	2 500 to 10 000	5	6
	Above 10 000 km	8	10

▼B

Case 1 refers to processes in which a Natural Gas boiler is used to provide the process heat to the pellet mill. Process electricity is purchased from the grid.

Case 2a refers to processes in which a boiler fuelled with wood chips is used to provide the process heat to the pellet mill. Process electricity is purchased from the grid.

Case 3a refers to processes in which a CHP, fuelled with wood chips, is used to provide heat and electricity to the pellet mill.

Biomass fuel production system	Transport distance	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
Agricultural Residues with density < 0,2 t/m^3 (1)	1 to 500 km	4	4
	500 to 2 500 km	8	9
	2 500 to 10 000 km	15	18
	Above 10 000 km	29	35
Agricultural Residues with density > 0,2 t/m^3 (2)	1 to 500 km	4	4
	500 to 2 500 km	5	6
	2 500 to 10 000 km	8	10
	Above 10 000 km	15	18
Straw pellets	1 to 500 km	8	10
	500 to 10 000 km	10	12
	Above 10 000 km	14	16
Bagasse briquettes	500 to 10 000 km	5	6
	Above 10 000 km	9	10
Palm Kernel Meal	Above 10 000 km	54	61
Palm Kernel Meal (no CH_4 emissions from oil mill)	Above 10 000 km	37	40

(1) This group of materials includes agricultural residues with a low bulk density and it comprises materials such as straw bales, oat hulls, rice husks and sugar cane bagasse bales (not exhaustive list).

(2) The group of agricultural residues with higher bulk density includes materials such as corn cobs, nut shells, soybean hulls, palm kernel shells (not exhaustive list).

▼B

Typical and default values – biogas for electricity

Biogas production system	Technological option		Typical value	Default value
			Greenhouse gas emissions (g CO_2eq/MJ)	Greenhouse gas emissions (g CO_2eq/MJ)
Biogas for electricity from wet manure	Case 1	Open digestate [1]	– 28	3
		Close digestate [2]	– 88	– 84
	Case 2	Open digestate	– 23	10
		Close digestate	– 84	– 78
	Case 3	Open digestate	– 28	9
		Close digestate	– 94	– 89
Biogas for electricity from maize whole plant	Case 1	Open digestate	38	47
		Close digestate	24	28
	Case 2	Open digestate	43	54
		Close digestate	29	35
	Case 3	Open digestate	47	59
		Close digestate	32	38
Biogas for electricity from biowaste	Case 1	Open digestate	31	44
		Close digestate	9	13
	Case 2	Open digestate	37	52
		Close digestate	15	21
	Case 3	Open digestate	41	57
		Close digestate	16	22

(1) Open storage of digestate accounts for additional emissions of methane which change with the weather, the substrate and the digestion efficiency. In these calculations the amounts are taken to be equal to 0,05 MJ CH_4/MJ biogas for manure, 0,035 MJ CH_4/MJ biogas for maize and 0,01 MJ CH_4/MJ biogas for biowaste.

(2) Close storage means that the digestate resulting from the digestion process is stored in a gas tight tank and the additional biogas released during storage is considered to be recovered for production of additional electricity or biomethane.

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Typical and default values for biomethane

Biomethane production system	Technological option	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
Biomethane from wet manure	Open digestate, no off-gas combustion (1)	– 20	22
	Open digestate, off-gas combustion (2)	– 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

(1) 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 MJ CH_4/MJ biomethane for the emission of methane in the off-gases.

(2) 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).

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Typical and default values – biogas for electricity – mixtures of manure and maize: greenhouse gas emissions with shares given on a fresh mass basis

Biogas production system		Technological options	Greenhouse gas emissions – typical value (g CO_2eq/MJ)	Greenhouse gas emissions – default value (g CO_2eq/MJ)
Manure – Maize 80 % - 20 %	Case 1	Open digestate	17	33
		Close digestate	– 12	– 9
	Case 2	Open digestate	22	40
		Close digestate	– 7	– 2
	Case 3	Open digestate	23	43
		Close digestate	– 9	– 4
Manure – Maize 70 % - 30 %	Case 1	Open digestate	24	37
		Close digestate	0	3
	Case 2	Open digestate	29	45
		Close digestate	4	10
	Case 3	Open digestate	31	48
		Close digestate	4	10
Manure – Maize 60 % - 40 %	Case 1	Open digestate	28	40
		Close digestate	7	11
	Case 2	Open digestate	33	47
		Close digestate	12	18
	Case 3	Open digestate	36	52
		Close digestate	12	18

Comments

Case 1 refers to pathways in which electricity and heat required in the process are supplied by the CHP engine itself.

Case 2 refers to pathways in which the electricity required in the process is taken from the grid and the process heat is supplied by the CHP engine itself. In some Member States, operators are not allowed to claim the gross production for subsidies and case 1 is the more likely configuration.

▼B

Case 3 refers to pathways in which the electricity required in the process is taken from the grid and the process heat is supplied by a biogas boiler. This case applies to some installations in which the CHP engine is not on-site and biogas is sold (but not upgraded to biomethane).

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

Biomethane production system	Technological options	Typical value ($g\ CO_2eq/MJ$)	Default value ($g\ CO_2eq/MJ$)
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

Where biomethane is used as Compressed Biomethane as a transport fuel, a value of 3,3 g CO_2eq/MJ biomethane needs to be added to the typical values and a value of 4,6 g CO_2eq/MJ biomethane to the default values.