# ZEMBA RfP Attachment B

## ZEMBA LCA Guidelines and Proposal Requirements

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## Introduction and Overview of Requirements

ZEMBA requires best practice GHG emissions calculation, reporting, and verification for decarbonized maritime service attributes offered under this RfP. To achieve this, ZEMBA will require fuel sustainability certification as well as additional fuel deployment reporting and verification. Given that the International Maritime Organization (IMO) has not yet adopted a certifiable sustainability standard[1], ZEMBA will rely on existing fuel sustainability certification systems. The purpose of such certification is to independently and continuously verify the accurate representation of fuel GHG Life Cycle Assessment (LCA) values and that the fuel has been properly tracked throughout the full chain of custody, from the point of feedstock sourcing to the end-fate of the fuel. Additionally, the certification verifies that fuels minimize other negative social or environmental impacts, such as deforestation, biodiversity loss, or food insecurity.

**At the point of environmental attribute delivery, the winning Bidder will be contractually required to meet the following conditions:**

(1) Winning Bidders must procure fuel from suppliers certified to a relevant sustainability standard by an independent certification body accredited to one of the following standard holders:
  a. the Roundtable on Sustainable Biomaterials,
  b. the International Sustainability and Carbon Certification (ISCC), or
  c. another standard holder recognized by the European Commission.

Examples of relevant standards are RSB Global and ISCC Plus.

(2) Though the above-noted standards are highly aligned with the requirements of the IMO LCA Guidelines, Bidders must also provide additional data specific to the IMO LCA Guidelines and have such data audited by an independent, third-party verifier where ZEMBA deems necessary.

ZEMBA understands that certification may not yet be completed for all fuel producers supplying Respondents to this RfP**.**

**At the point of proposal submission, Bidders are required to:**

(1) List the estimated LCA value and related sustainability certification the fuel producer has already obtained or is expected to obtain by the first delivery date *for each proposed fuel*, under the Bid Scope and Assurance tab section 4.1.3 in the RfP excel spreadsheet and
(2) Provide, to the extent available, the following information *for each proposed fuel* in an attachment to the RfP excel spreadsheet:
  a. Fuel Pathway Description
  b. LCA Value Template
  c. Service-Related Information

**Proposal evaluation will include consideration of the extent to which the data was provided and any accompanying documentation, with a certified "Proof of Sustainability" or similar being looked upon most favourably. See below for details on what is required for each.**

[1] If and when the IMO adopts a fuel sustainability certification standard and verification system to accompany the IMO LCA Guidelines, ZEMBA will consider whether and how to utilize it with respect to this and future RfPs.

# ZEMBA LCA Guidelines

## LCA System Boundary

The following emissions are considered within the LCA system boundary for the zero-emissions shipping service:

- Emissions from Fuel Consumption (based on fuel LCA value and fuel consumption)
- Emissions per TEU-mile (based on distance travelled and TEUs shipped on zero-emissions fuel)

See below for elaboration on the two elements of the LCA system boundary.

### (1) Fuel LCA System Boundary

In alignment with the IMO LCA Guidelines[2], ZEMBA requires a Well-to-Wake (WtW) fuel LCA, which includes the emissions impacts from the following:

- Extraction, cultivation, or acquisition of feedstocks and raw materials
- Emissions from processing
- Emissions from transportation and distribution
- Emissions from the fuel in use (accounting for fuel slip)
- Annualized emissions from carbon stock changes caused by land-use change
- Annualized emissions savings from soil carbon accumulation via improved agricultural management
- Emissions savings from carbon dioxide capture and storage or utilization

As mentioned above, in the absence of a certifiable sustainability standard from the International Maritime Organization (IMO), ZEMBA will require use of existing sustainability certification systems - which largely align with and in some cases go beyond the requirements of the IMO LCA Guidelines - to assess, verify, and certify fuel LCA values.

To ensure full alignment with the IMO LCA guidelines and the capture of all emissions within the prescribed system boundary, ZEMBA requires disaggregated reporting and third-party verification of certain LCA values. These LCA values include the emissions impacts from the following:

- Emissions from fuel "slip", the fuel that escapes from the energy converter without being oxidized.
- Emissions credits from carbon dioxide capture and storage occurring on-board a vessel.

### (2) Shipping Service LCA System Boundary

In addition to requiring certification of the zero emissions fuel, prior to attribute delivery, ZEMBA will require the reporting and verification of additional information related to the deployment of the decarbonized service to allow the calculation of the LCA values for the shipping service emissions profile.

[2]Contained in IMO Resolution MEPC376(80) – See Annex I

## LCA Methodology

**In order to achieve sustainability certification, suppliers must follow the LCA methodology outlined by one of the eligible fuel sustainability certification systems.** Such methodologies are largely aligned with the IMO LCA Guidelines and include the following formula:

The WtW GHG emission factor (g $CO_{2eq}$ / $MJ_{(LCV)}$ fuel or electricity) is calculated according to below equation

$$GHG_{WtW} = GHG_{WtT} + GHG_{TtW} \text{ (in } CO_{2eq} / MJ_{(LCV)}\text{)}$$

Where:

| Term | Units | Explanation |
|---|---|---|
| $GHG_{WtT}$ | $gCO_{2eq}/MJ_{(LCV)}$ | Total Well-to-Tank GHG upstream emissions per energy unit of the fuel provided to the ship |
| $GHG_{TtW}$ | $gCO_{2eq}/MJ_{(LCV)}$ | Total Tank-to-Wake GHG downstream emissions per energy unit from the utilization of the fuel or per energy unit of electricity used in a consumer on board the ship |
| $GHG_{WtW}$ | $gCO_{2eq}/MJ_{(LCV)}$ | Total Well-to-Wake GHG emissions per energy unit of the fuel (provided and utilized onboard a ship) or electricity used in a consumer on board the ship |

**However, ZEMBA will apply the following adjustments if necessary when comparing proposals:**

<u>Slip emissions and On-board CCS</u>

Consistent with the IMO Guidelines, slip emissions and emissions credits from on-board carbon capture and storage (CCS) should be incorporated into the LCA value as follows:

$$GHG_{TtW} = \frac{\left(1 - \frac{C_{slip}}{100}\right) * \left(C_{fCO2} * GWP_{CO2} + C_{fCH4} * GWP_{CH4} + C_{fN2O} * GWP_{N2O}\right) + \left(\frac{C_{slip}}{100} * C_{sfx} * GWP_{fuelx}\right) - e_{oCCS}}{LCV}$$

Where:

| Term | Units | Explanation |
|---|---|---|
| $C_{fCO2}$ | g $CO_2$ / g fuel | $CO_2$ emission "conversion" factor for emissions of the combustion and/or oxidation process of the fuel used by the ship (g $CO_2$ / g fuel delivered in the engine) |
| $C_{fCH4}$ | g $CH_4$ / g fuel | $CH_4$ emission "conversion" factor for emissions of the combustion and/or oxidation process of the fuel used by the ship (g $CH_4$ / g fuel delivered in the engine)<br><br>For LNG/CNG: $C_{fCH4} = 0$ (the $C_{slip}$ is covering the role of $C_{fCH4}$) |
| $C_{fN2O}$ | g $N_2O$ / g fuel | $N_2O$ emission "conversion" factor for emissions of the combustion and/or oxidation process of the fuel used by the ship (g $N_2O$ / g fuel delivered in the engine) |
| $C_{sfx}$ | g GHG / g fuel | Factor accounting for the share of GHG in the components of the fuel (for LNG/CNG this value is 1.0) |
| LCV | MJ / g | Lower Calorific Value which is the amount of heat that would be released by the complete combustion of the fuel |
| $e_{oCCS}$ | g$CO_{2eq}$ / g fuel | Emission credit from carbon capture and storage, where capture of $CO_2$ occurs onboard. This should properly account for the emissions avoided through the capture and temporarily storage of emitted $CO_2$, if CCS occurs on-board |
| $C_{slip}$ | % total fuel mass (consumed in the energy converter) | Factor accounting for fuel (expressed in % of total fuel mass consumed in the energy converter) which escapes from the energy converter without being oxidized (including fuel that escapes from combustion chamber/oxidation process and from crankcase, as appropriate) |
| $GWP_{CO2}$ | g $CO_{2eq}$ / g $CO_2$ | Global Warming Potential of $CO_2$ over 100 years (based on the $5^{TH}$ IPCC Assessment Report) |
| $GWP_{CH4}$ | g $CO_{2eq}$ / g $CH_4$ | Global Warming Potential of $CH_4$ over 100 years (based on the $5^{TH}$ IPCC Assessment Report) |
| $GWP_{N2O}$ | g $CO_{2eq}$ / g $N_2O$ | Global Warming Potential of $N_2O$ over 100 years (based on the $5^{TH}$ IPCC Assessment Report) |
| $GWP_{fuelx}$ | g $CO_{2eq}$ / g GHG | Global Warming Potential of GHG in the components of the fuel over 100 years (based on the $5^{th}$ IPCC Assessment Report) |

**ZEMBA also requires the application of the following restrictions in calculating the LCA value:**

Emissions from Fuel Use: Default emissions factors for fuel use from the IMO LCA Guidelines[3] will be used when available to determine "emissions from fuel use" in the LCA value calculation. When default emissions factors are not provided in the IMO LCA Guidelines, default emissions factors from the FuelEU Maritime[4] regulation will be used. When default emissions factors from neither the IMO LCA Guidelines nor FuelEU Maritime are not available, default emissions factors from EU Renewable Energy Directive (EU RED II)[5] will be used.

Induced Land Use Change (ILUC)

For all the feedstocks which are not designated as waste, residue or by-product according to the ICAO CORSIA[6] feedstock categorization framework (and thus have a value of ILUC = 0), the **positive default values** from ICAO CORSIA must be used.[7] N**egative ILUC values will not be considered**.

[3] Contained in Appendix II of IMO Resolution MEPC376(80) – Attached as Appendix I to this document.
[4] See Annex II of Fuel EU Maritime Regulation – Attached as Appendix II to this document.
[5] See Annex V and VI of the EU RED II Regulation -Attached as Appendix III to this document.
[6] International Civil Aviation Organization (ICAO), Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)
[7] CORSIA default ILUC values can be found here: CORSIA Supporting Document "CORSIA Eligible Fuels_LCA_Methodology" (icao.int)

Carbon Dioxide Capture and Sequestration:

Geological sequestration of $CO_2$ captured at a processing unit in the supply chain processing the fuel's raw materials and finished fuel products can be deducted from the LCA value of the fuel **up to a value of zero**, as long as all other fuel requirements are met.

Soil Carbon Sequestration:

Carbon accumulation in soil caused by improved agricultural management during the cultivation of feedstocks **cannot be credited** towards the LCA value of the fuel and is resultingly listed as "0 gCO2e/MJ" in ZEMBA's LCA Value Template.

## Proposal Requirements

As stated in the Introduction to this document, Bidders are required to provide the following information for each proposed fuel, to the extent available, in an attachment to the RfP excel spreadsheet in the format described below:

(1) Fuel Pathway Description
(2) LCA Value Template
(3) Service-Related Information

See below for instructions.

### (1) Fuel Pathway Description

Bidders are required to clearly describe the fuel pathway, with the aim of providing, at a minimum, information on:

1. The type of feedstock and any other inputs used,
2. A description of the conversion process and technology used for producing the finished fuel,
3. Any other relevant information required to fully represent the fuel production process within the LCA system boundary, and
4. Fuel delivery and utilization, including fuel bunkering and intermediate transportation, storage, and distribution.

The fuel pathway description must include a description of each of the steps of the fuel life cycle. An example of a well-to-tank fuel system boundary is shown in Figure 1:

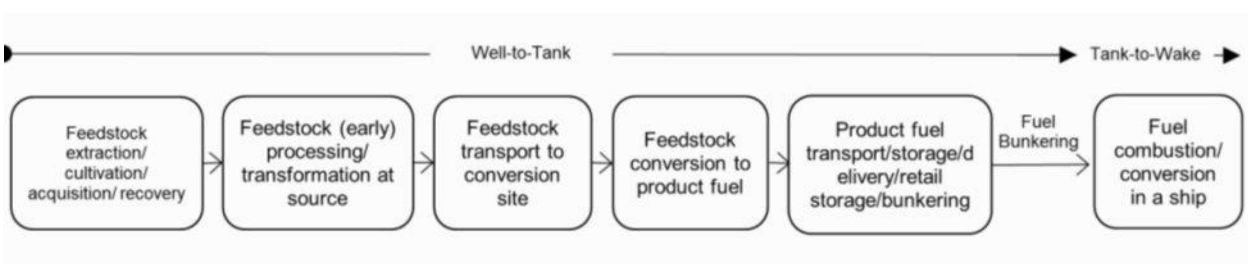


*Figure 1: Well-to-Wake Fuel System Boundary*

### (2) LCA Value Template

Respondents are required to provide the following information in the RfP response, to the extent available and supported by documentation wherever possible. If documentation supporting this information is not available at the time the Response is submitted, provide an explanation of how the information was obtained or estimated. Additionally, provide an explanation of how the Bidder is able to ensure such information will be available and certification obtained by the time attributes are to be delivered to ZEMBA members.

All LCA component values must follow the methodologies outlined by one of the sustainability standard holders noted in the section above.

| | LCA value (g/CO2e/MJ fuel) | Source/Model/Reference |
|---|---|---|
| **Fuel Life Cycle Emissions Factor (total)** | | |
| LCA Component Values: | | |
| Emissions from Feedstock (total) | | |
| ILUC | | Required: ICAO CORSIA default value[8] |
| Extraction/Acquisition/Cultivation | | |
| Processing | | |
| Emissions Credits from Biomass Growth | | |
| Soil Carbon Sequestration | 0 | Not permitted under ZEMBA LCA Guidelines |
| Emissions from Feedstock Processing and Conversion Process | | |
| Emissions from Fuel Use (total) | | IMO, FuelEU Maritime, or EU RED II Default Factors |
| Emissions from Fuel Slippage | | Required: IMO LCA Guidelines default value |
| Emissions from Transportation and Distribution (of the feedstock, intermediate products, or finished fuel) | | |
| Emissions Credits from Carbon Dioxide Capture and Sequestration or Utilization (CCS) (total) | | |
| Emissions Credits from CCS at Zero Emission Fuel Production Facility | | |
| Emissions Credits from CCS on vessel | | Required: Use of IMO Guidelines for modelling of CCS on board, if applicable |

## (3) Service-Related Information

As noted in the RfP, ZEMBA requires reporting and verification of the deployment of the decarbonized service, including through verification of the following data fields: (1) fuel bunkering, (2) fuel consumption, (3) cargo quantity in TEUs, and (4) distance travelled. Verification procedures will be developed in coordination with the winning bidder and will be carried out by a class society, e.g. Lloyds Register, American Bureau of Shipping, Det Norske Veritas, etc., on behalf of ZEMBA.

[8] CORSIA default ILUC values can be found here: [CORSIA Supporting Document "CORSIA Eligible Fuels_LCA_Methodology" (icao.int)]

To support the development of ZEMBA's verification procures, please provide a qualitative description of the format in which you propose to provide data and supporting documentation to ZEMBA, what systems could be used to monitor, record, and store the required data, and how that data could be made available to a selected third-party verifier.

| **Data Category** | **Supporting Documentation** | **Data Recording/Storage/Verification** |
|---|---|---|
| Proof of Fuel Delivery | Bunker Delivery Note | |
| Fuel Consumption Values | | |
| Cargo Quantity (#TEUs) | | |
| Distance Travelled | | |

## APPENDIX 2

## INITIAL DEFAULT EMISSION FACTORS PER FUEL PATHWAY CODE

| Order | Fuel type | Fuel Pathway Code | WtT GHG intensity ($gCO_{2eq}$/MJ) | LCV (MJ/g) | Energy Converter | $C_f$ $CO_2$ ($gCO_2$/g fuel) | $C_f$ $CH_4$ ($gCH_4$/g fuel) | $C_f$ $N_2O$ ($gN_2O$/g fuel) | $C_{slip}$ /$C_{fug}$ (mass %) | $e_c$ $gCO_{2eq}$/g fuel | TtW GHG intensity (gCO2eq/MJ) | NOTE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Heavy Fuel Oil (ISO 8217 Grades RME, RMG and RMK, 0.10 < S ≤ 0.50%) | HFO(VLSFO)_f_SR_gm | 16.8 | 0.0402 | ALL ICEs | 3.114 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 2 | Heavy Fuel Oil (ISO 8217 Grades RME, RMG and RMK exceeding 0.50% S) | HFO(HSHFO)_f_SR_gm | 14.9 | 0.0402 | ALL ICEs | 3.114 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 3 | Light Fuel Oil (ISO 8217 Grades RMA, RMB and RMD maximum 0.10% S) | LFO(ULSFO)_f_SR_gm | | 0.0412 | ALL ICEs | 3.151 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 4 | Light Fuel Oil (ISO 8217 Grades RMA, RMB and RMD, 0.10 < S ≤ 0.50%) | LFO(VLSFO)_f_SR_gm | | 0.0412 | ALL ICEs | 3.151 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 5 | Marine Diesel/Gas Oil (ISO 8217 Grades DMX, DMA, DMZ and DMB maximum 0.10 % S) | MDO/MGO(ULSFO)_f_SR_gm | 17.7 | 0.0427 | ALL ICEs | 3.206 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 6 | Marine Diesel/Gas Oil (ISO 8217 Grades DMX, DMA, DMZ and DMB, 0.10 < S ≤ 0.50%) | MDO/MGO(VLSFO)_f_SR_gm | | 0.0427 | ALL ICEs | 3.206 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 11 | Liquified Petroleum Gas (Propane) | LPG(Propane)_f_SR_gm | | 0.0463 | ALL ICEs | 3.000 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| 21 | Liquified Petroleum Gas (Butane) | LPG(Butane)_f_SR_gm | | 0.0457 | ALL ICEs | 3.030 | 0.00005 | 0.00018 | | | | Resolution MEPC.364(79) Fourth IMO GHG study |

| Order | Fuel type | Fuel Pathway Code | WtT GHG intensity ($gCO_{2eq}/MJ$) | LCV (MJ/g) | Energy Converter | $C_f$ $CO_2$ ($gCO_2$/g fuel) | $C_f$ $CH_4$ ($gCH_4$/g fuel) | $C_f$ $N_2O$ ($gN_2O$/g fuel) | $C_{slip}$ /$C_{fug}$ (mass %) | $e_c$ $gCO_{2eq}$/g fuel | TtW GHG intensity (gCO2eq/MJ) | NOTE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Liquefied Natural Gas (Methane) | LNG_f_SLP_gm | | 0.0480 | LNG Otto (dual fuel medium speed) | 2.750 | 0 | 0.00011 | 3.5/- | | | Resolution MEPC.364(79) Fourth IMO GHG study |
| | | | | | LNG Otto (dual fuel slow speed) | | | | 1.7/- | | | |
| | | | | | LNG Diesel (dual fuel slow speed) | | | | 0.15/- | | | |
| | | | | | LBSI (Lean-Burn Spark-Ignited) | | | | 2.6/- | | | |
| | | | | | Steam Turbines and boilers | | | | 0.01/- | | | |
| 33 | Liquefied Natural Gas (Methane) | LNG_b_AD_gm | | | LNG Otto (dual fuel medium speed) | 2.750 | | | | | | |
| | | | | | LNG Otto (dual fuel slow speed) | | | | | | | |
| | | | | | LNG Diesel (dual fuel slow speed) | | | | | | | |
| | | | | | LBSI (Lean-Burn Spark-Ignited) | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Steam Turbines and boilers | | | | | | | |
| 62 | Diesel (FAME) | FAME_b_TRE_gm_2ndgen | 20.8 | 0.0372 | ALL ICEs | | | | | | | |
| 77 | Renewable Diesel (HVO) | HVO_b_HD_gm_1stgen | 14.9 | 0.044 | ALL ICEs | | | | | | | |
| 105 | Hydrogen | H2_f_SMR_CCS_gm | | 0.12 | ALL ICEs<br>Fuel cell | 0 | | | | | | |
| 121 | Ammonia | NH3_rN2_fH2_HB_gm | | 0.0186 | ALL ICEs<br>Fuel cell | 0 | | | | | | |

# ANNEX II

Default emission factors

The default emission factors contained in the table below shall be used for the determination of the GHG intensity index referred to in Annex I of this Regulation, except where companies diverge from those default emission factors in application of Article 10(4) and (5) of this Regulation.

In the table below:

– TBM stands for To Be Measured,

– N/A stands for Not Available,

– The dash means not applicable,

– E is established in accordance with the methodologies laid down in Directive (EU) 2018/2001, Part C of Annex V and Part B of Annex VI.

Where a cell indicates either TBM or N/A, unless a value is demonstrated in accordance with Article 10, the highest default value of the fuel class in the same column shall be used.

Where, for a particular fuel class, all cells in the same column indicate either TBM or N/A, unless a value is demonstrated in accordance with Article 10, the default value of the least favourable fossil fuel pathway shall be used. This rule does not apply to column 9, where TBM or N/A refers to non-available values for the fuel consumer. In case of no default value, a certified value in accordance with Article 10(5) should be used.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| | | | WtT | TtW | | | | |
| Fuel Class | Pathway name | LCV $\left[\frac{MJ}{g}\right]$ | $CO_{2eq\,WtT}$ $\left[\frac{gCO2eq}{MJ}\right]$ | Fuel Consumer Unit Class | $C_{f\,CO_2}$ $\left[\frac{gCO2}{gFuel}\right]$ | $C_{f\,CH_4}$ $\left[\frac{gCH_4}{gFuel}\right]$ | $C_{f\,N_2O}$ $\left[\frac{gN_2O}{gFuel}\right]$ | $C_{slip}$ As % of the mass of the fuel used by the engine |
| Fossil | HFO<br>ISO 8217 Grades RME to RMK | 0,0405 | 13,5 | ALL ICEs | 3,114 | 0,00005 | 0,00018 | - |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | LFO<br>ISO 8217 Grades RMA to RMD | 0,041 | 13,2 | ALL ICEs | 3,151 | 0,00005 | 0,00018 | - |
| | MDO<br>MGO<br>ISO 8217 Grades DMX to DMB | 0,0427 | 14,4 | ALL ICEs | 3,206 | 0,00005 | 0,00018 | - |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| | | | WtT | TtW | | | | |
| Fossil | LNG | 0,0491 | 18.5 | LNG Otto (dual fuel medium speed) | 2,750 | 0 | 0,00011 | 3,1 |
| | | | | LNG Otto (dual fuel slow speed) | | | | 1,7 |
| | | | | LNG Diesel (dual fuel slow speed) | | | | 0,2 |
| | | | | LBSI | | | | 2,6[1] |
| | LPG | 0,046 | 7,8 | ALL ICEs | 3,030 Butane<br>3,000 Propane | TBM | TBM | N/A |
| | H2 (natural gas) | 0,12 | 132 | Fuel Cells | 0 | 0 | - | - |
| | | | | ICE | 0 | 0 | TBM | |
| | NH3 (natural gas) | 0,0186 | 121 | Fuel Cells | 0 | N/A | TBM | N/A |
| | | | | ICE | 0 | N/A | TBM | N/A |
| | Methanol (natural gas) | 0,0199 | 31,3 | ALL ICEs | 1,375 | TBM | TBM | - |

1 Figure extracted from the fourth IMO Greenhouse Gas Study: Fourth IMO GHG Study 2020 - Full report and annexes.pdf.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| | | | WtT | TtW | | | | |
| Biofuels | Ethanol Production Pathways of Directive (EU) 2018/2001 | Value as set out in Annex III of Directive (EU) 2018/2001 | $E - \frac{C_{fCO_2}}{LCV}$ | ALL ICEs | 1,913 | TBM | TBM | - |
| | Bio-diesel Production Pathways of Directive (EU) 2018/2001 | | | ALL ICEs | 2,834 | TBM | TBM | - |
| | Hydrotreated Vegetable Oil (HVO) Production Pathways of Directive (EU) 2018/2001 | | | ALL ICEs | 3,115 | 0,00005 | 0,00018 | - |
| | Liquefied Bio-methane as transport fuel (Bio-LNG) Production Pathways of Directive (EU) 2018/2001 | | | LNG Otto (dual fuel medium speed) | 2,750 | 0 | 0,00011 | 3,1 |
| | | | | LNG Otto (dual fuel slow speed) | | | | 1,7 |
| | | | | LNG Diesel (dual fuels) | | | | 0,2 |
| | | | | LBSI | | | | 2,6 |
| | Bio-methanol Production Pathways of Directive (EU) 2018/2001 | | | ALL ICEs | 1,375 | TBM | TBM | - |
| | Other Production Pathways of Directive (EU) 2018/2001 | | | ALL ICEs | 3,115 | 0,00005 | 0,00018 | - |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| | | | WtT | TtW | | | | |
| Biofuels | Bio-H2<br>Production Pathways of Directive (EU) 2018/2001 | Value as set out in Annex III of Directive (EU) 2018/2001 | N/A | Fuel Cells | 0 | 0 | 0 | - |
| | | | | ICE | 0 | 0 | TBM | |
| Renewable Fuels of Non-Biological Origin (RFNBO)<br>-<br>e-Fuels | e-diesel | 0,0427 | Ref. to Directive (EU) 2018/2001) | ALL ICEs | 3,206 | 0,00005 | 0,00018 | - |
| | e-methanol | 0,0199 | Ref. to Directive (EU) 2018/2001) | All ICEs | 1,375 | 0,00005 | 0,00018 | - |
| | e-LNG | 0,0491 | Ref. To Directive (EU) 2018/2001) | LNG Otto (dual fuel medium speed) | 2,750 | 0 | 0,00011 | 3,1 |
| | | | | LNG Otto (dual fuel slow speed) | | | | 1,7 |
| | | | | LNG Diesel (dual fuels) | | | | 0,2 |
| | | | | LBSI | | | | 2,6 |
| | e-H2 | 0,12 | Ref. to Directive (EU) 2018/2001) | Fuel Cells | 0 | 0 | 0 | - |
| | | | | ICE | 0 | 0 | TBM | |
| | e-NH3 | 0,0186 | N/A | Fuel Cells | 0 | N/A | TBM | N/A |
| | | | | ICE | 0 | N/A | TBM | N/A |
| | e-LPG | N/A | N/A | | N/A | N/A | N/A | N/A |
| | e-DME | N/A | N/A | | N/A | N/A | N/A | - |
| Others | Electricity | - | EU ENERGY MIX | On-shore power supply (OPS) | - | - | - | - |

Column 1 identifies the class of the fuels, namely fossils fuels, liquid biofuels, gaseous biofuels and e-fuels.

Column 2 identifies the name or the pathways of the relevant fuels within the class.

Column 3 contains the lower calorific value of the fuels in [MJ/g]. For liquid biofuels, values of energy content by weight (lower calorific value, MJ/kg) as set out in Annex III to Directive (EU) 2018/2001 shall be converted in MJ/g and used.

Column 4 contains the WtT GHG emission factors in [$gCO_{2eq}$/MJ]:

(a) For liquid biofuels, the default values shall be calculated by using the values of E established in accordance with the methodologies laid down in Directive (EU) 2018/2001, Part C of Annex V to that Directive for all liquid biofuels except bio-LNG and Part B of Annex VI to that Directive for bio-LNG, and on the basis of default values related to the particular biofuel used as a transport fuel and its production pathway, laid down in that Directive, Parts D and E of Annex V to that Directive for all liquid biofuels except bio-LNG and in Part D of Annex VI to that Directive for bio-LNG. However, the values of E need to be adjusted by subtracting the ratio of the values contained in column 6 ($C_f\_CO_2$) and column 3 (LCV). This is required under this Regulation, which separates the WtT and the TtW calculations, to avoid double counting of emissions;

(b) For RFNBO and other fuels not referred to in point (a) to be taken into account for the purpose referred to in Article 4(1) of this Regulation, default values are to be either calculated by using the methodology of the delegated act referred to in Article 28(5) of Directive (EU) 2018/2001, or, if applicable, a similar methodology if defined under a Union legal act concerning the internal markets in renewable and natural gases and in hydrogen, pursuant to Article 10(1) and (2) of this Regulation.

Column 5 identifies the main types/classes of fuel consumer units such as 2 and 4 strokes Internal Combustion Engines (ICE) Diesel or Otto cycle, Lean-Burn Spark-Ignited (LBSI) engines, fuel cells, etc.

Column 6 contains the emission factor $C_f$ for $CO_2$ in [$gCO_2$/gfuel]. Emission factors values as specified in Regulation (EU) 2015/757 shall be used. For all those fuels not contained in Regulation (EU) 2015/757, the default values are specified in the table.

Column 7 contains the emission factor $C_f$ for methane in [$gCH_4$/gfuel]. For LNG fuels, $C_f$ for methane are set to zero.

Column 8 contains the emission factor $C_f$ for nitrous oxide in [$gN_2O$/gfuel].

Column 9 identifies the part of fuel lost as fugitive and slipped emissions ($C_{slip}$) measured as % of the mass of fuel used by the specific fuel consumer unit. For fuels such as LNG for which the fugitive and slipped emissions exist, the amount of fugitive and slipped emissions as presented in the table is expressed in % of the mass of fuel used (Column 9). The values of $C_{slip}$ in the table are calculated at 50 % of the full engine load.

*ANNEX V*

**RULES FOR CALCULATING THE GREENHOUSE GAS IMPACT OF BIOFUELS, BIOLIQUIDS AND THEIR FOSSIL FUEL COMPARATORS**

A. TYPICAL AND DEFAULT VALUES FOR BIOFUELS IF PRODUCED WITH NO NET CARBON EMISSIONS FROM LAND-USE CHANGE

| Biofuel production pathway | Greenhouse gas emissions saving – typical value | Greenhouse gas emissions saving – default value |
|---|---|---|
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in conventional boiler) | 67 % | 59 % |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in conventional boiler) | 77 % | 73 % |
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in CHP plant (*)) | 73 % | 68 % |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in CHP plant (*)) | 79 % | 76 % |
| sugar beet ethanol (no biogas from slop, lignite as process fuel in CHP plant (*)) | 58 % | 47 % |
| sugar beet ethanol (with biogas from slop, lignite as process fuel in CHP plant (*)) | 71 % | 64 % |
| corn (maize) ethanol (natural gas as process fuel in conventional boiler) | 48 % | 40 % |
| corn (maize) ethanol, (natural gas as process fuel in CHP plant (*)) | 55 % | 48 % |
| corn (maize) ethanol (lignite as process fuel in CHP plant (*)) | 40 % | 28 % |
| corn (maize) ethanol (forest residues as process fuel in CHP plant (*)) | 69 % | 68 % |
| other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler) | 47 % | 38 % |
| other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*)) | 53 % | 46 % |
| other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*)) | 37 % | 24 % |
| other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*)) | 67 % | 67 % |

| Biofuel production pathway | Greenhouse gas emissions saving – typical value | Greenhouse gas emissions saving – default value |
|---|---|---|
| sugar cane ethanol | 70 % | 70 % |
| the part from renewable sources of ethyl-tertio-butyl-ether (ETBE) | Equal to that of the ethanol production pathway used | |
| the part from renewable sources of tertiary-amyl-ethyl-ether (TAEE) | Equal to that of the ethanol production pathway used | |
| rape seed biodiesel | 52 % | 47 % |
| sunflower biodiesel | 57 % | 52 % |
| soybean biodiesel | 55 % | 50 % |
| palm oil biodiesel (open effluent pond) | 32 % | 19 % |
| palm oil biodiesel (process with methane capture at oil mill) | 51 % | 45 % |
| waste cooking oil biodiesel | 88 % | 84 % |
| animal fats from rendering biodiesel (**) | 84 % | 78 % |
| hydrotreated vegetable oil from rape seed | 51 % | 47 % |
| hydrotreated vegetable oil from sunflower | 58 % | 54 % |
| hydrotreated vegetable oil from soybean | 55 % | 51 % |
| hydrotreated vegetable oil from palm oil (open effluent pond) | 34 % | 22 % |
| hydrotreated vegetable oil from palm oil (process with methane capture at oil mill) | 53 % | 49 % |
| hydrotreated oil from waste cooking oil | 87 % | 83 % |
| hydrotreated oil from animal fats from rendering (**) | 83 % | 77 % |
| pure vegetable oil from rape seed | 59 % | 57 % |
| pure vegetable oil from sunflower | 65 % | 64 % |
| pure vegetable oil from soybean | 63 % | 61 % |
| pure vegetable oil from palm oil (open effluent pond) | 40 % | 30 % |
| pure vegetable oil from palm oil (process with methane capture at oil mill) | 59 % | 57 % |

| Biofuel production pathway | Greenhouse gas emissions saving – typical value | Greenhouse gas emissions saving – default value |
|---|---|---|
| pure oil from waste cooking oil | 98 % | 98 % |

(*) Default values for processes using CHP are valid only if all the process heat is supplied by CHP.

(**) Applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009 of the European Parliament and of the Council [1], for which emissions related to hygenisation as part of the rendering are not considered.

B. ESTIMATED TYPICAL AND DEFAULT VALUES FOR FUTURE BIOFUELS THAT WERE NOT ON THE MARKET OR WERE ON THE MARKET ONLY IN NEGLIGIBLE QUANTITIES IN 2016, IF PRODUCED WITH NO NET CARBON EMISSIONS FROM LAND-USE CHANGE

| Biofuel production pathway | Greenhouse gas emissions saving - typical value | Greenhouse gas emissions saving - default value |
|---|---|---|
| wheat straw ethanol | 85 % | 83 % |
| waste wood Fischer-Tropsch diesel in free-standing plant | 85 % | 85 % |
| farmed wood Fischer-Tropsch diesel in free-standing plant | 82 % | 82 % |
| waste wood Fischer-Tropsch petrol in free-standing plant | 85 % | 85 % |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 82 % | 82 % |
| waste wood dimethylether (DME) in free-standing plant | 86 % | 86 % |
| farmed wood dimethylether (DME) in free-standing plant | 83 % | 83 % |
| waste wood methanol in free-standing plant | 86 % | 86 % |
| farmed wood methanol in free-standing plant | 83 % | 83 % |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 89 % | 89 % |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 89 % | 89 % |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 89 % | 89 % |
| Methanol from black-liquor gasification integrated with pulp mill | 89 % | 89 % |
| the part from renewable sources of methyl-tertio-butyl-ether (MTBE) | Equal to that of the methanol production pathway used | |

[1] Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation) (OJ L 300, 14.11.2009, p. 1).

C. METHODOLOGY

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

(a) greenhouse gas emissions from the production and use of biofuels 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 use of the fuel; |
| $e_{ec}$ | = | 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 $CO_2$ 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) Greenhouse gas emissions from the production and use of bioliquids shall be calculated as for biofuels (E), but with the extension necessary for including the energy conversion to electricity and/or heat and cooling produced, 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 bioliquid before end-conversion.

$\eta_{el}$ = The electrical efficiency, defined as the annual electricity produced divided by the annual bioliquid input based on its energy content.

$\eta_h$ = The heat efficiency, defined as the annual useful heat output divided by the annual bioliquid 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 bioliquid before end-conversion.

$\eta_{el}$ = The electrical efficiency, defined as the annual electricity produced divided by the annual fuel input based on its energy content.

$\eta_h$ = The heat efficiency, defined as the annual useful heat output divided by the annual fuel input based on its energy content.

$C_{el}$ = Fraction of exergy in the electricity, and/or mechanical energy, set to 100 % ($C_{el}$ = 1).

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

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:

(a) 'cogeneration' means the simultaneous generation in one process of thermal energy and electricity and/or mechanical energy;

(b) 'useful heat' means heat generated to satisfy an economical justifiable demand for heat, for heating and cooling purposes;

(c) 'economically justifiable demand' means the demand that does not exceed the needs for heat or cooling and which would otherwise be satisfied at market conditions.

2. Greenhouse gas emissions from biofuels and bioliquids shall be expressed as follows:

(a) greenhouse gas emissions from biofuels, E, shall be expressed in terms of grams of $CO_2$ equivalent per MJ of fuel, g $CO_2$eq/MJ.

(b) greenhouse gas emissions from bioliquids, EC, in terms of grams of $CO_2$ equivalent per MJ of final energy commodity (heat or electricity), g $CO_2$eq/MJ.

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

([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.

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

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

where

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

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

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

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

3. Greenhouse gas emissions savings from biofuels and bioliquids shall be calculated as follows:

(a) greenhouse gas emissions savings from biofuels:

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

where

| | | |
|---|---|---|
| $E_B$ | = | total emissions from the biofuel; and |
| $E_{F(t)}$ | = | total emissions from the fossil fuel comparator for transport |

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

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; and

$EC_{F(h\&c,el)}$ = 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 or cultivation of raw materials, $e_{ec}$, shall include emissions from the extraction 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

([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.

the use of regional averages for cultivation emissions included in the reports referred to in Article 31(4) 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.

6. For the purposes of the calculation referred to in point 1(a), greenhouse gas emissions 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].

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:

$e_l = (CS_R - CS_A) \times 3{,}664 \times 1/20 \times 1/P - e_B$, [2]

where

| | | |
|---|---|---|
| $e_l$ | = | annualised greenhouse gas emissions from carbon stock change due to land-use change (measured as mass (grams) of $CO_2$-equivalent per unit of biofuel or bioliquid energy (megajoules)). 'Cropland' [3] and 'perennial cropland' [4] 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 biofuel or bioliquid energy per unit area per year) and |
| $e_B$ | = | bonus of 29 g $CO_2$eq/MJ biofuel or bioliquid if biomass is obtained from restored degraded land under the conditions laid down in point 8. |

8. The bonus of 29 g $CO_2$eq/MJ shall be attributed if evidence is provided that the land:

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

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

The bonus of 29 g $CO_2$eq/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.

(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.
(2) 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.
(3) Cropland as defined by IPCC.
(4) 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.

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.

10. The Commission shall review, by 31 December 2020, guidelines for the calculation of land carbon stocks ([1]) drawing on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – volume 4 and in accordance with Regulation (EU) No 525/2013 and Regulation (EU) 2018/841 of the European Parliament and of the Council ([2]). The Commission guidelines shall serve as the basis for the calculation of land carbon stocks for the purposes of this Directive.

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 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 the fuel in use, $e_u$, shall be taken to be zero for biofuels and bioliquids.

    Emissions of non-$CO_2$ greenhouse gases ($N_2O$ and $CH_4$) of the fuel in use shall be included in the $e_u$ factor for bioliquids.

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 fuel if stored in compliance with Directive 2009/31/EC of the European Parliament and of the Council ([3]).

15. Emission savings from $CO_2$ capture and replacement, $e_{ccr}$, shall be related directly to the production of biofuel or bioliquid 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.

16. Where a cogeneration unit – providing heat and/or electricity to a 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)

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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).

([2]) Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU (OJ L 156, 19.6.2018, p. 1).

([3]) Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (OJ L 140, 5.6.2009, p. 114).

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 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 fuel production process and is determined from calculating the greenhouse 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 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 calculation 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.

In the case of biofuels and bioliquids, 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 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 biofuels, for the purposes of the calculation referred to in point 3, the fossil fuel comparator $E_{F(t)}$ shall be 94 g $CO_2$eq/MJ.

For bioliquids used for the production of electricity, for the purposes of the calculation referred to in point 3, the fossil fuel comparator $EC_{F(e)}$ shall be 183 g $CO_2$eq/MJ.

For bioliquids 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 $EC_{F(h\&c)}$ shall be 80 g $CO_2$eq/MJ.

D. DISAGGREGATED DEFAULT VALUES FOR BIOFUELS AND BIOLIQUIDS

Disaggregated default values for cultivation: '$e_{ec}$' as defined in Part C of this Annex, including soil $N_2O$ emissions

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| sugar beet ethanol | 9,6 | 9,6 |
| corn (maize) ethanol | 25,5 | 25,5 |
| other cereals excluding corn (maize) ethanol | 27,0 | 27,0 |
| sugar cane ethanol | 17,1 | 17,1 |
| the part from renewable sources of ETBE | Equal to that of the ethanol production pathway used | |
| the part from renewable sources of TAEE | Equal to that of the ethanol production pathway used | |
| rape seed biodiesel | 32,0 | 32,0 |
| sunflower biodiesel | 26,1 | 26,1 |
| soybean biodiesel | 21,2 | 21,2 |
| palm oil biodiesel | 26,2 | 26,2 |
| waste cooking oil biodiesel | 0 | 0 |
| animal fats from rendering biodiesel (**) | 0 | 0 |
| hydrotreated vegetable oil from rape seed | 33,4 | 33,4 |
| hydrotreated vegetable oil from sunflower | 26,9 | 26,9 |
| hydrotreated vegetable oil from soybean | 22,1 | 22,1 |
| hydrotreated vegetable oil from palm oil | 27,4 | 27,4 |
| hydrotreated oil from waste cooking oil | 0 | 0 |
| hydrotreated oil from animal fats from rendering (**) | 0 | 0 |
| pure vegetable oil from rape seed | 33,4 | 33,4 |
| pure vegetable oil from sunflower | 27,2 | 27,2 |
| pure vegetable oil from soybean | 22,2 | 22,2 |
| pure vegetable oil from palm oil | 27,1 | 27,1 |
| pure oil from waste cooking oil | 0 | 0 |

(**) Applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

Disaggregated default values for cultivation: '$e_{ec}$' – for soil $N_2O$ emissions only (these are already included in the disaggregated values for cultivation emissions in the '$e_{ec}$' table)

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| sugar beet ethanol | 4,9 | 4,9 |
| corn (maize) ethanol | 13,7 | 13,7 |
| other cereals excluding corn (maize) ethanol | 14,1 | 14,1 |
| sugar cane ethanol | 2,1 | 2,1 |
| the part from renewable sources of ETBE | Equal to that of the ethanol production pathway used | |
| the part from renewable sources of TAEE | Equal to that of the ethanol production pathway used | |
| rape seed biodiesel | 17,6 | 17,6 |
| sunflower biodiesel | 12,2 | 12,2 |
| soybean biodiesel | 13,4 | 13,4 |
| palm oil biodiesel | 16,5 | 16,5 |
| waste cooking oil biodiesel | 0 | 0 |
| animal fats from rendering biodiesel (**) | 0 | 0 |
| hydrotreated vegetable oil from rape seed | 18,0 | 18,0 |
| hydrotreated vegetable oil from sunflower | 12,5 | 12,5 |
| hydrotreated vegetable oil from soybean | 13,7 | 13,7 |
| hydrotreated vegetable oil from palm oil | 16,9 | 16,9 |
| hydrotreated oil from waste cooking oil | 0 | 0 |
| hydrotreated oil from animal fats from rendering (**) | 0 | 0 |
| pure vegetable oil from rape seed | 17,6 | 17,6 |
| pure vegetable oil from sunflower | 12,2 | 12,2 |
| pure vegetable oil from soybean | 13,4 | 13,4 |
| pure vegetable oil from palm oil | 16,5 | 16,5 |
| pure oil from waste cooking oil | 0 | 0 |

(**) Note: applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

Disaggregated default values for processing: '$e_p$' as defined in Part C of this Annex

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in conventional boiler) | 18,8 | 26,3 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in conventional boiler) | 9,7 | 13,6 |
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in CHP plant (*)) | 13,2 | 18,5 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in CHP plant (*)) | 7,6 | 10,6 |
| sugar beet ethanol (no biogas from slop, lignite as process fuel in CHP plant (*)) | 27,4 | 38,3 |
| sugar beet ethanol (with biogas from slop, lignite as process fuel in CHP plant (*)) | 15,7 | 22,0 |
| corn (maize) ethanol (natural gas as process fuel in conventional boiler) | 20,8 | 29,1 |
| corn (maize) ethanol, (natural gas as process fuel in CHP plant (*)) | 14,8 | 20,8 |
| corn (maize) ethanol (lignite as process fuel in CHP plant (*)) | 28,6 | 40,1 |
| corn (maize) ethanol (forest residues as process fuel in CHP plant (*)) | 1,8 | 2,6 |
| other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler) | 21,0 | 29,3 |
| other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*)) | 15,1 | 21,1 |
| other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*)) | 30,3 | 42,5 |
| other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*)) | 1,5 | 2,2 |
| sugar cane ethanol | 1,3 | 1,8 |
| the part from renewable sources of ETBE | Equal to that of the ethanol production pathway used | |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| the part from renewable sources of TAEE | Equal to that of the ethanol production pathway used | |
| rape seed biodiesel | 11,7 | 16,3 |
| sunflower biodiesel | 11,8 | 16,5 |
| soybean biodiesel | 12,1 | 16,9 |
| palm oil biodiesel (open effluent pond) | 30,4 | 42,6 |
| palm oil biodiesel (process with methane capture at oil mill) | 13,2 | 18,5 |
| waste cooking oil biodiesel | 9,3 | 13,0 |
| animal fats from rendering biodiesel (**) | 13,6 | 19,1 |
| hydrotreated vegetable oil from rape seed | 10,7 | 15,0 |
| hydrotreated vegetable oil from sunflower | 10,5 | 14,7 |
| hydrotreated vegetable oil from soybean | 10,9 | 15,2 |
| hydrotreated vegetable oil from palm oil (open effluent pond) | 27,8 | 38,9 |
| hydrotreated vegetable oil from palm oil (process with methane capture at oil mill) | 9,7 | 13,6 |
| hydrotreated oil from waste cooking oil | 10,2 | 14,3 |
| hydrotreated oil from animal fats from rendering (**) | 14,5 | 20,3 |
| pure vegetable oil from rape seed | 3,7 | 5.2 |
| pure vegetable oil from sunflower | 3,8 | 5,4 |
| pure vegetable oil from soybean | 4,2 | 5,9 |
| pure vegetable oil from palm oil (open effluent pond) | 22,6 | 31,7 |
| pure vegetable oil from palm oil (process with methane capture at oil mill) | 4,7 | 6,5 |
| pure oil from waste cooking oil | 0,6 | 0,8 |

(*) Default values for processes using CHP are valid only if all the process heat is supplied by CHP.

(**) Note: applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

Disaggregated default values for oil extraction only (these are already included in the disaggregated values for processing emissions in the '$e_p$' table)

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| rape seed biodiesel | 3,0 | 4,2 |
| sunflower biodiesel | 2,9 | 4,0 |
| soybean biodiesel | 3,2 | 4,4 |
| palm oil biodiesel (open effluent pond) | 20,9 | 29,2 |
| palm oil biodiesel (process with methane capture at oil mill) | 3,7 | 5,1 |
| waste cooking oil biodiesel | 0 | 0 |
| animal fats from rendering biodiesel (**) | 4,3 | 6,1 |
| hydrotreated vegetable oil from rape seed | 3,1 | 4,4 |
| hydrotreated vegetable oil from sunflower | 3,0 | 4,1 |
| hydrotreated vegetable oil from soybean | 3,3 | 4,6 |
| hydrotreated vegetable oil from palm oil (open effluent pond) | 21,9 | 30,7 |
| hydrotreated vegetable oil from palm oil (process with methane capture at oil mill) | 3,8 | 5,4 |
| hydrotreated oil from waste cooking oil | 0 | 0 |
| hydrotreated oil from animal fats from rendering (**) | 4,3 | 6,0 |
| pure vegetable oil from rape seed | 3,1 | 4,4 |
| pure vegetable oil from sunflower | 3,0 | 4,2 |
| pure vegetable oil from soybean | 3,4 | 4,7 |
| pure vegetable oil from palm oil (open effluent pond) | 21,8 | 30,5 |
| pure vegetable oil from palm oil (process with methane capture at oil mill) | 3,8 | 5,3 |
| pure oil from waste cooking oil | 0 | 0 |

(**) Note: applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

Disaggregated default values for transport and distribution: '$e_{td}$' as defined in Part C of this Annex

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in conventional boiler) | 2,3 | 2,3 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in conventional boiler) | 2,3 | 2,3 |
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in CHP plant (*)) | 2,3 | 2,3 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in CHP plant (*)) | 2,3 | 2,3 |
| sugar beet ethanol (no biogas from slop, lignite as process fuel in CHP plant (*)) | 2,3 | 2,3 |
| sugar beet ethanol (with biogas from slop, lignite as process fuel in CHP plant (*)) | 2,3 | 2,3 |
| corn (maize) ethanol (natural gas as process fuel in CHP plant (*)) | 2,2 | 2,2 |
| corn (maize) ethanol (natural gas as process fuel in conventional boiler) | 2,2 | 2,2 |
| corn (maize) ethanol (lignite as process fuel in CHP plant (*)) | 2,2 | 2,2 |
| corn (maize) ethanol (forest residues as process fuel in CHP plant (*)) | 2,2 | 2,2 |
| other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler) | 2,2 | 2,2 |
| other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*)) | 2,2 | 2,2 |
| other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*)) | 2,2 | 2,2 |
| other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*)) | 2,2 | 2,2 |
| sugar cane ethanol | 9,7 | 9,7 |
| the part from renewable sources of ETBE | Equal to that of the ethanol production pathway used | |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| the part from renewable sources of TAEE | Equal to that of the ethanol production pathway used | |
| rape seed biodiesel | 1,8 | 1,8 |
| sunflower biodiesel | 2,1 | 2,1 |
| soybean biodiesel | 8,9 | 8,9 |
| palm oil biodiesel (open effluent pond) | 6,9 | 6,9 |
| palm oil biodiesel (process with methane capture at oil mill) | 6,9 | 6,9 |
| waste cooking oil biodiesel | 1,9 | 1,9 |
| animal fats from rendering biodiesel (**) | 1,7 | 1,7 |
| hydrotreated vegetable oil from rape seed | 1,7 | 1,7 |
| hydrotreated vegetable oil from sunflower | 2,0 | 2,0 |
| hydrotreated vegetable oil from soybean | 9,2 | 9,2 |
| hydrotreated vegetable oil from palm oil (open effluent pond) | 7,0 | 7,0 |
| hydrotreated vegetable oil from palm oil (process with methane capture at oil mill) | 7,0 | 7,0 |
| hydrotreated oil from waste cooking oil | 1,7 | 1,7 |
| hydrotreated oil from animal fats from rendering (**) | 1,5 | 1,5 |
| pure vegetable oil from rape seed | 1,4 | 1,4 |
| pure vegetable oil from sunflower | 1,7 | 1,7 |
| pure vegetable oil from soybean | 8,8 | 8,8 |
| pure vegetable oil from palm oil (open effluent pond) | 6,7 | 6,7 |
| pure vegetable oil from palm oil (process with methane capture at oil mill) | 6,7 | 6,7 |
| pure oil from waste cooking oil | 1,4 | 1,4 |

(*) Default values for processes using CHP are valid only if all the process heat is supplied by CHP.
(**) Note: applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

Disaggregated default values for transport and distribution of final fuel only. These are already included in the table of 'transport and distribution emissions $e_{td}$' as defined in Part C of this Annex, but the following values are useful if an economic operator wishes to declare actual transport emissions for crops or oil transport only).

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in conventional boiler) | 1,6 | 1,6 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in conventional boiler) | 1,6 | 1,6 |
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| sugar beet ethanol (no biogas from slop, lignite as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| sugar beet ethanol (with biogas from slop, lignite as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| corn (maize) ethanol (natural gas as process fuel in conventional boiler) | 1,6 | 1,6 |
| corn (maize) ethanol (natural gas as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| corn (maize) ethanol (lignite as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| corn (maize) ethanol (forest residues as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler) | 1,6 | 1,6 |
| other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*)) | 1,6 | 1,6 |
| sugar cane ethanol | 6,0 | 6,0 |
| the part of ethyl-tertio-butyl-ether (ETBE) from renewable ethanol | Will be considered to be equal to that of the ethanol production pathway used | |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| the part of tertiary-amyl-ethyl-ether (TAEE) from renewable ethanol | Will be considered to be equal to that of the ethanol production pathway used | |
| rape seed biodiesel | 1,3 | 1,3 |
| sunflower biodiesel | 1,3 | 1,3 |
| soybean biodiesel | 1,3 | 1,3 |
| palm oil biodiesel (open effluent pond) | 1,3 | 1,3 |
| palm oil biodiesel (process with methane capture at oil mill) | 1,3 | 1,3 |
| waste cooking oil biodiesel | 1,3 | 1,3 |
| animal fats from rendering biodiesel (**) | 1,3 | 1,3 |
| hydrotreated vegetable oil from rape seed | 1,2 | 1,2 |
| hydrotreated vegetable oil from sunflower | 1,2 | 1,2 |
| hydrotreated vegetable oil from soybean | 1,2 | 1,2 |
| hydrotreated vegetable oil from palm oil (open effluent pond) | 1,2 | 1,2 |
| hydrotreated vegetable oil from palm oil (process with methane capture at oil mill) | 1,2 | 1,2 |
| hydrotreated oil from waste cooking oil | 1,2 | 1,2 |
| hydrotreated oil from animal fats from rendering (**) | 1,2 | 1,2 |
| pure vegetable oil from rape seed | 0,8 | 0,8 |
| pure vegetable oil from sunflower | 0,8 | 0,8 |
| pure vegetable oil from soybean | 0,8 | 0,8 |
| pure vegetable oil from palm oil (open effluent pond) | 0,8 | 0,8 |
| pure vegetable oil from palm oil (process with methane capture at oil mill) | 0,8 | 0,8 |
| pure oil from waste cooking oil | 0,8 | 0,8 |

(*) Default values for processes using CHP are valid only if all the process heat is supplied by CHP.
(**) Note: applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

Total for cultivation, processing, transport and distribution

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in conventional boiler) | 30,7 | 38,2 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in conventional boiler) | 21,6 | 25,5 |
| sugar beet ethanol (no biogas from slop, natural gas as process fuel in CHP plant (*)) | 25,1 | 30,4 |
| sugar beet ethanol (with biogas from slop, natural gas as process fuel in CHP plant (*)) | 19,5 | 22,5 |
| sugar beet ethanol (no biogas from slop, lignite as process fuel in CHP plant (*)) | 39,3 | 50,2 |
| sugar beet ethanol (with biogas from slop, lignite as process fuel in CHP plant (*)) | 27,6 | 33,9 |
| corn (maize) ethanol (natural gas as process fuel in conventional boiler) | 48,5 | 56,8 |
| corn (maize) ethanol, (natural gas as process fuel in CHP plant (*)) | 42,5 | 48,5 |
| corn (maize) ethanol (lignite as process fuel in CHP plant (*)) | 56,3 | 67,8 |
| corn (maize) ethanol (forest residues as process fuel in CHP plant (*)) | 29,5 | 30,3 |
| other cereals excluding maize ethanol (natural gas as process fuel in conventional boiler) | 50,2 | 58,5 |
| other cereals excluding maize ethanol (natural gas as process fuel in CHP plant (*)) | 44,3 | 50,3 |
| other cereals excluding maize ethanol (lignite as process fuel in CHP plant (*)) | 59,5 | 71,7 |
| other cereals excluding maize ethanol (forest residues as process fuel in CHP plant (*)) | 30,7 | 31.4 |
| sugar cane ethanol | 28,1 | 28.6 |
| the part from renewable sources of ETBE | Equal to that of the ethanol production pathway used | |
| the part from renewable sources of TAEE | Equal to that of the ethanol production pathway used | |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| rape seed biodiesel | 45,5 | 50,1 |
| sunflower biodiesel | 40,0 | 44,7 |
| soybean biodiesel | 42,2 | 47,0 |
| palm oil biodiesel (open effluent pond) | 63,5 | 75,7 |
| palm oil biodiesel (process with methane capture at oil mill) | 46,3 | 51,6 |
| waste cooking oil biodiesel | 11,2 | 14,9 |
| animals fats from rendering biodiesel (**) | 15,3 | 20,8 |
| hydrotreated vegetable oil from rape seed | 45,8 | 50,1 |
| hydrotreated vegetable oil from sunflower | 39,4 | 43,6 |
| hydrotreated vegetable oil from soybean | 42,2 | 46,5 |
| hydrotreated vegetable oil from palm oil (open effluent pond) | 62,2 | 73,3 |
| hydrotreated vegetable oil from palm oil (process with methane capture at oil mill) | 44,1 | 48,0 |
| hydrotreated oil from waste cooking oil | 11,9 | 16,0 |
| hydrotreated oil from animal fats from rendering (**) | 16,0 | 21,8 |
| pure vegetable oil from rape seed | 38,5 | 40,0 |
| pure vegetable oil from sunflower | 32,7 | 34,3 |
| pure vegetable oil from soybean | 35,2 | 36,9 |
| pure vegetable oil from palm oil (open effluent pond) | 56,3 | 65,4 |
| pure vegetable oil from palm oil (process with methane capture at oil mill) | 38,4 | 57,2 |
| pure oil from waste cooking oil | 2,0 | 2,2 |

(*) Default values for processes using CHP are valid only if all the process heat is supplied by CHP.
(**) Note: applies only to biofuels produced from animal by-products classified as category 1 and 2 material in accordance with Regulation (EC) No 1069/2009, for which emissions related to hygenisation as part of the rendering are not considered.

E. ESTIMATED DISAGGREGATED DEFAULT VALUES FOR FUTURE BIOFUELS AND BIOLIQUIDS THAT WERE NOT ON THE MARKET OR WERE ONLY ON THE MARKET IN NEGLIGIBLE QUANTITIES IN 2016

Disaggregated default values for cultivation: '$e_{ec}$' as defined in Part C of this Annex, including $N_2O$ emissions (including chipping of waste or farmed wood)

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| wheat straw ethanol | 1,8 | 1,8 |
| waste wood Fischer-Tropsch diesel in free-standing plant | 3,3 | 3,3 |
| farmed wood Fischer-Tropsch diesel in free-standing plant | 8,2 | 8,2 |
| waste wood Fischer-Tropsch petrol in free-standing plant | 8,2 | 8,2 |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 12,4 | 12,4 |
| waste wood dimethylether (DME) in free-standing plant | 3,1 | 3,1 |
| farmed wood dimethylether (DME) in free-standing plant | 7,6 | 7,6 |
| waste wood methanol in free-standing plant | 3,1 | 3,1 |
| farmed wood methanol in free-standing plant | 7,6 | 7,6 |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 2,5 | 2,5 |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 2,5 | 2,5 |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 2,5 | 2,5 |
| Methanol from black-liquor gasification integrated with pulp mill | 2,5 | 2,5 |
| the part from renewable sources of MTBE | Equal to that of the methanol production pathway used | |

Disaggregated default values for soil $N_2O$ emissions (included in disaggregated default values for cultivation emissions in the '$e_{ec}$' table)

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| wheat straw ethanol | 0 | 0 |
| waste wood Fischer-Tropsch diesel in free-standing plant | 0 | 0 |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| farmed wood Fischer-Tropsch diesel in free-standing plant | 4,4 | 4,4 |
| waste wood Fischer-Tropsch petrol in free-standing plant | 0 | 0 |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 4,4 | 4,4 |
| waste wood dimethylether (DME) in free-standing plant | 0 | 0 |
| farmed wood dimethylether (DME) in free-standing plant | 4,1 | 4,1 |
| waste wood methanol in free-standing plant | 0 | 0 |
| farmed wood methanol in free-standing plant | 4,1 | 4,1 |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 0 | 0 |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 0 | 0 |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 0 | 0 |
| Methanol from black-liquor gasification integrated with pulp mill | 0 | 0 |
| the part from renewable sources of MTBE | Equal to that of the methanol production pathway used | |

Disaggregated default values for processing: '$e_p$' as defined in Part C of this Annex

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| wheat straw ethanol | 4,8 | 6,8 |
| waste wood Fischer-Tropsch diesel in free-standing plant | 0,1 | 0,1 |
| farmed wood Fischer-Tropsch diesel in free-standing plant | 0,1 | 0,1 |
| waste wood Fischer-Tropsch petrol in free-standing plant | 0,1 | 0,1 |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 0,1 | 0,1 |
| waste wood dimethylether (DME) in free-standing plant | 0 | 0 |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| farmed wood dimethylether (DME) in free-standing plant | 0 | 0 |
| waste wood methanol in free-standing plant | 0 | 0 |
| farmed wood methanol in free-standing plant | 0 | 0 |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 0 | 0 |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 0 | 0 |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 0 | 0 |
| methanol from black-liquor gasification integrated with pulp mill | 0 | 0 |
| the part from renewable sources of MTBE | Equal to that of the methanol production pathway used | |

Disaggregated default values for transport and distribution: '$e_{td}$' as defined in Part C of this Annex

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| wheat straw ethanol | 7,1 | 7,1 |
| waste wood Fischer-Tropsch diesel in free-standing plant | 10,3 | 10,3 |
| farmed wood Fischer-Tropsch diesel in free-standing plant | 8,4 | 8,4 |
| waste wood Fischer-Tropsch petrol in free-standing plant | 10,3 | 10,3 |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 8,4 | 8,4 |
| waste wood dimethylether (DME) in free-standing plant | 10,4 | 10,4 |
| farmed wood dimethylether (DME) in free-standing plant | 8,6 | 8,6 |
| waste wood methanol in free-standing plant | 10,4 | 10,4 |
| farmed wood methanol in free-standing plant | 8,6 | 8,6 |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 7,7 | 7,7 |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 7,9 | 7,9 |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 7,7 | 7,7 |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| methanol from black-liquor gasification integrated with pulp mill | 7,9 | 7,9 |
| the part from renewable sources of MTBE | Equal to that of the methanol production pathway used | |

Disaggregated default values for transport and distribution of final fuel only. These are already included in the table of 'transport and distribution emissions $e_{td}$' as defined in Part C of this Annex, but the following values are useful if an economic operator wishes to declare actual transport emissions for feedstock transport only).

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|
| wheat straw ethanol | 1,6 | 1,6 |
| waste wood Fischer-Tropsch diesel in free-standing plant | 1,2 | 1,2 |
| farmed wood Fischer-Tropsch diesel in free-standing plant | 1,2 | 1,2 |
| waste wood Fischer-Tropsch petrol in free-standing plant | 1,2 | 1,2 |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 1,2 | 1,2 |
| waste wood dimethylether (DME) in free-standing plant | 2,0 | 2,0 |
| farmed wood dimethylether (DME) in free-standing plant | 2,0 | 2,0 |
| waste wood methanol in free-standing plant | 2,0 | 2,0 |
| farmed wood methanol in free-standing plant | 2,0 | 2,0 |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 2,0 | 2,0 |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 2,0 | 2,0 |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 2,0 | 2,0 |

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| methanol from black-liquor gasification integrated with pulp mill | 2,0 | 2,0 |
| the part from renewable sources of MTBE | Equal to that of the methanol production pathway used | |

Total for cultivation, processing, transport and distribution

| Biofuel and bioliquid production pathway | Greenhouse gas emissions – typical value ($g\ CO_2eq/MJ$) | Greenhouse gas emissions – default value ($g\ CO_2eq/MJ$) |
|---|---|---|
| wheat straw ethanol | 13,7 | 15,7 |
| waste wood Fischer-Tropsch diesel in free-standing plant | 13,7 | 13,7 |
| farmed wood Fischer-Tropsch diesel in free-standing plant | 16,7 | 16,7 |
| waste wood Fischer-Tropsch petrol in free-standing plant | 13,7 | 13,7 |
| farmed wood Fischer-Tropsch petrol in free-standing plant | 16,7 | 16,7 |
| waste wood dimethylether (DME) in free-standing plant | 13,5 | 13,5 |
| farmed wood dimethylether (DME) in free-standing plant | 16,2 | 16,2 |
| waste wood methanol in free-standing plant | 13,5 | 13,5 |
| farmed wood methanol in free-standing plant | 16,2 | 16,2 |
| Fischer-Tropsch diesel from black-liquor gasification integrated with pulp mill | 10,2 | 10,2 |
| Fischer-Tropsch petrol from black-liquor gasification integrated with pulp mill | 10,4 | 10,4 |
| dimethylether (DME) from black-liquor gasification integrated with pulp mill | 10,2 | 10,2 |
| methanol from black-liquor gasification integrated with pulp mill | 10,4 | 10,4 |
| the part from renewable sources of MTBE | Equal to that of the methanol production pathway used | |

*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 % |

| 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 % |

| 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 % |
| 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 % |

WOOD PELLETS (*)

| Biomass fuel production system | | Transport distance | Greenhouse gas emissions savings – typical value | | Greenhouse gas emissions savings – default value | |
|---|---|---|---|---|---|---|
| | | | Heat | Electricity | Heat | Electricity |
| | 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/m³ (*) | 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/m³ (**) | 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 % |
| 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 % |

| AGRICULTURE PATHWAYS | | | | | |
|---|---|---|---|---|---|
| Biomass fuel production system | Transport distance | Greenhouse gas emissions savings – typical value | | Greenhouse gas emissions savings – default value | |
| | | Heat | Electricity | Heat | Electricity |
| 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 $CO_2$eq/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.

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 % |

| 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 $CO_2$eq/MJ.

| 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 $CO_2$eq/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;

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

   $e_p$ = emissions from processing;

[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).

$e_{td}$ = 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:

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

where

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

$S_n$ = Share of feedstock n in energy content

$E_n$ = Emission in g $CO_2$/MJ for pathway n as provided in Part D of this Annex (*)

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

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 g $CO_2$eq/MJ manure (– 54 kg $CO_2$eq/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]

(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. |

(*) 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. |
| $\eta_{el}$ | = | The electrical efficiency, defined as the annual electricity produced divided by the annual fuel input, based on its energy content. |
| $\eta_h$ | = | 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.

$\eta_{el}$ = The electrical efficiency, defined as the annual electricity produced divided by the annual energy input, based on its energy content.

$\eta_h$ = 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 $CO_2$eq/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 $CO_2$eq/MJ.

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]

---

[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.

Where the greenhouse gas emissions from the extraction or cultivation of raw materials $e_{ec}$ are expressed in unit g $CO_2$eq/dry-ton of feedstock, the conversion to grams of $CO_2$ equivalent per MJ of fuel, g $CO_2$eq /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

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

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

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

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

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

(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.

([1]) 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.

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]).

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:

$e_l = (CS_R - CS_A) \times 3{,}664 \times 1/20 \times 1/P - e_B$, ([2])

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' ([3]) and 'perennial cropland' ([4]) 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 $CO_2$eq/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 $CO_2$eq/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 $CO_2$eq/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.

10. In accordance with point 10 of Part C of Annex V to this Directive, Commission Decision 2010/335/EU ([5]), 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.

([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.
([2]) 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.
([3]) Cropland as defined by IPCC.
([4]) 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.
([5]) 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).

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.

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 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.

    In the case of biogas and biomethane, all co-products that do not fall under the scope of point 7 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 $CO_2$eq/MJ electricity or 212 g $CO_2$eq/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 $CO_2$eq/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 $CO_2$eq/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 $CO_2$eq/MJ.

C. DISAGGREGATED DEFAULT VALUES FOR BIOMASS FUELS

Wood briquettes or pellets

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 |
| 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 |

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 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 $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 |
| 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 |

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 (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 |
| 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 |

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 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 |
| 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 |
| 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 |

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| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 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 |

Agriculture pathways

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 |

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | | | | Greenhouse gas emissions – default value (g $CO_2$eq/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 |
| 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 |

Disaggregated default values for biogas for the production of electricity

| Biomass fuel production system | | Technology | TYPICAL VALUE [g $CO_2$eq/MJ] | | | | | DEFAULT VALUE [g $CO_2$eq/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 |

(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 $CO_2$eq/MJ manure used in anaerobic digestion.

| Biomass fuel production system | | Technology | TYPICAL VALUE [g $CO_2$eq/MJ] | | | | | DEFAULT VALUE [g $CO_2$eq/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 |
| Maize whole plant (1) | case 1 | Open digestate | 15,6 | 13,5 | 8,9 | 0,0 (2) | — | 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 | — |
| | 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 | — |

(1) Maize whole plant means maize harvested as fodder and ensiled for preservation.
(2) 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 $CO_2$eq/MJ biogas.

Disaggregated default values for biomethane

| Biomethane production system | Technological option | | TYPICAL VALUE [g $CO_2$eq/MJ] | | | | | | DEFAULT VALUE [g $CO_2$eq/MJ] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cultivation | Processing | Upgrading | Transport | Compression at filling station | Manure credits | Cultivation | 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 | — |

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 |

| 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 |

| Biomass fuel production system | Transport distance | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/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 |

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 $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/MJ) |
|---|---|---|---|
| Agricultural Residues with density < 0,2 t/m³ (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/m³ (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 |

Typical and default values – biogas for electricity

| Biogas production system | Technological option | | Typical value | Default value |
|---|---|---|---|---|
| | | | Greenhouse gas emissions (g $CO_2$eq/MJ) | Greenhouse gas emissions (g $CO_2$eq/MJ) |
| Biogas for electricity from wet manure | Case 1 | Open digestate (3) | – 28 | 3 |
| | | Close digestate (4) | – 88 | – 84 |
| | Case 2 | Open digestate | – 23 | 10 |
| | | Close digestate | – 84 | – 78 |
| | Case 3 | Open digestate | – 28 | 9 |
| | | Close digestate | – 94 | – 89 |

(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).
(3) 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.
(4) 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.

| Biogas production system | Technological option | | Typical value Greenhouse gas emissions (g $CO_2$eq/MJ) | Default value Greenhouse gas emissions (g $CO_2$eq/MJ) |
|---|---|---|---|---|
| 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 |

Typical and default values for biomethane

| Biomethane production system | Technological option | Greenhouse gas emissions – typical value (g $CO_2$eq/MJ) | Greenhouse gas emissions – default value (g $CO_2$eq/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 |

(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).

| 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 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 |

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.

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 | Default value |
|---|---|---|---|
| | | (g $CO_2$eq/MJ) | (g $CO_2$eq/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 $CO_2$eq/MJ biomethane needs to be added to the typical values and a value of 4,6 g $CO_2$eq/MJ biomethane to the default values.