ASES ON-CHAIN PROTOCOL

METHODOLOGY FOR BIOCHAR PROJECTS

IV. Methodologies V2.0

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TABLE OF CONTENTS

INTRODUCTION

This methodology addresses GHG emissions reduction and removal assessment for projects producing biochar from agricultural, forestry, and livestock waste and applying it to the soil. It specifies the calculation procedures for baseline and project scenarios, considering the 3 stages of the biochar value chain: feedstock (waste) collection, biochar production, and end-application into the soil.

The pyrolysis of waste generated by the agro-industrial sector constitutes an important alternative for its valorization and the exploitation of its potential for climate change mitigation and land degradation. The use of this material, conventionally called biochar (charcoal of vegetable origin) increases the amount of organic matter in the soil, while modifying acidity conditions (pH). It also alters the cation exchange coefficients, allowing for improved yields in different types of crops. Due to its porous structure, biochar is also used as an additive in areas with low rainfall, where it has been shown to stabilize soil moisture levels. Additionally, the incorporation of biochar as a structuring and nutrient base material during the composting process has optimized the degradation of organic matter while reducing ammonium and greenhouse gas emissions. It is also known to be effective in reducing the absorption of heavy metals in contaminated agricultural soils. Finally, it is worth noting that the use of biochar as a soil additive and amendment is also considered a climate change mitigation strategy, given its capacity to sequester solid carbon in agricultural fields for hundreds and even thousands of years.

It is important to point out that the uses and applications of biochar are not risk-free. On the one hand, it is known that the production of this material by traditional methods is associated with significant environmental impacts due to the release of the resulting pyrolytic gases into the atmosphere. It has also been demonstrated that biochar can contain hazardous organic and inorganic compounds, such as polycyclic aromatic hydrocarbons, heavy metals, dioxins, and furans. Hence the need to implement appropriate control of the operating conditions of the pyrolysis process to reduce emissions while guaranteeing the quality, stability, and homogeneity of the biochar produced. For this reason, the use of biochar in soils is subject to compliance with certain conditions. Among the guidelines for sustainable biochar production issued by the European Biochar Foundation, special emphasis is placed on the use and integration of waste heat produced during carbonization. The recovery of waste heat avoids the discharge of pyrolytic gases into the environment while increasing the efficiency of the process. In addition, the integration of waste heat from the carbonization process into agro-industrial processes would make it possible to replace the use of fossil fuels currently used for thermal energy production. Based on the above, the production of biochar from agricultural residues and the emission of carbon credits are important opportunities to diversify the product portfolio and improve the environmental and financial performance of the sector.

In the following methodology for quantifying greenhouse gas (GHG) emission reductions from a biochar project, we employ a set of established procedures and formulas developed by a recognized authority in this field. The methodology draws upon the expertise and guidelines provided by Verra, a widely respected organization renowned for its contributions to the field of carbon accounting and emissions quantification. By utilizing the methodologies and formulas inspired by Verra's rigorous research and industry best practices, we aim to ensure transparency, accuracy, and adherence to internationally recognized standards.

I. Definitions

- **Pyrolysis:** Pyrolysis is a thermochemical treatment, which can be applied to any organic (carbon-based) product. It can be done on pure products as well as mixtures. In this treatment, material is exposed to high temperatures, and in the absence of oxygen goes through chemical and physical separation into different molecules. The decomposition takes place thanks to the limited thermal stability of chemical bonds of materials, which allows them to be disintegrated by heat.
- **Soil amendment:** Soil Amendment is any substance that is intended to change the chemical or physical characteristics of the soil. This does not include fertilizers, ag liming materials, pesticides, and unmanipulated animal/vegetable manures. Soil amendment's basic claims are to improve: Water retention. Permeability.
- **Low-technology:** According to this methodology, the term low technology refers to production facilities that have the following characteristics: (a) pyrolytic gases are primarily burned in the flame front; (b) emissions are not collected during the pyrolysis process; (c) less than 70% of the generated heat energy is regained; and (d) temperature during production is neither recorded nor reported.
- **High-technology:** This methodology defines high technology as production facilities that satisfy the following criteria: (a) the capability to burn or reclaim pyrolysis gases, which restricts the release of methane into the atmosphere; (b) the ability to utilize a minimum of 70% of the heat generated during biochar production; (c) the presence of pollution controls, such as a thermal oxidizer or other emissions controls, that meet local, national, or international emission standards; and (d) temperature during production is monitored and reported.
- **Carbon:** Vegetable carbon is produced by the carbonization of vegetable materials such as wood, cellulose residues, peat and coconut, and other shells. The raw material is carbonized at high temperatures and consists essentially of finely divided carbon.
- **Waste biomass:** Waste biomass means agricultural waste, sewage, woodwaste and gasses generated from the decomposition of organic materials, but does not include biogas or landfill gas.
- **Fixed carbon content:** Fixed carbon is the solid combustible residue that remains after a coal particle is heated and the volatile matter is expelled. The fixed-carbon content of a coal is determined by subtracting the percentages of moisture, volatile matter, and ash from a sample.
- **Feedstock:** Una materia prima se define como cualquier material biológico renovable que puede usarse directamente como combustible o convertirse en otra forma de combustible o producto energético.
- **Carbon Pool** A system that has the capacity to store or release carbon, including above-ground biomass, below-ground biomass, litter, dead wood and soil organic carbon.

- **Chain of custody (CoC)** is the path taken by products from sourcing to the point where biochar is sold and/or used for its end application, i.e. soil amendment. The CoC includes each stage of sourcing, processing, trading, and distribution where progress to the next stage of the supply chain involves a change of product ownership or handling. Any change of ownership in the supply chain of aOCP-certified biochar requires the establishment of effective CoC management systems at the level of the respective organization and their verification if the organization wants to make a claim about their products. aOCP certification of such management systems is designed to provide a credible assurance that products that are sold with an aOCP claim originate from well-managed forests, controlled sources, reclaimed materials, or a mixture of these. CoC thereby facilitates the transparent flow of goods made from such materials through the supply chain
- **Forest carbon sources.** Forests are considered sources when they emit more than they remove. Forests emit carbon through respiration and decay when disturbances (harvesting, fires, insects, storms, droughts, and floods) occur.

II. APPLICABILITY CONDITIONS

In order to be eligible for registration in the aOCP, biochar projects shall meet the following characteristics:

a) The type of Projects that may use this Methodology for the estimation of carbon removals and reductions from biochar produced from agroforestry waste and applied to soil are shown in Table 1.

TABLE 1. APPLICATION OF METHODOLOGY BY PROJECT TYPE

Type of project	Use of methodologies				
	Biochar	Carbon in vegetation	Carbon in soil	Biodiversity	Water
Regenerative agriculture	✓				
Forest management	✓				
Silvopastoral					
Urban forest					
Water restoration	✓				
Biochar	✓				

b) The Project complies with the eligibility requirements, rules, standards and methodologies of the aOCP Program;

c) The Project will start after registration in the aOCP. Biochar projects can only be of Modality A, as described in the Project standard;

d) Biochar end-use will be its application as a soil amendment. Before its integration into soil, it must be mixed with manure or compost. The mix should be applied at a minimum depth of 10 centimeters[1];

e) Feedstocks used for biochar production are waste from the agroforestry industry. Vegetal biomass shall not be produced explicitly for pyrolysis. Accepted feedstocks are shown in Table 3.

III. METHODOLOGICAL CONSIDERATIONS

III.1. PROJECT BOUNDARIES

This methodology provides a complete, robust and sound approach to quantifying net GHG emissions reduction and removals resulting from biochar projects, including the waste biomass sourcing, biochar production and biochar application for soil amendment stage. Baseline and project emissions consider the flux of CO_2, CH_4 and N_2O and are defined and quantified in terms of tonnes of CO_2e per monitoring period. According the guidelines from IPCC (2021)[2], the equivalence to CO_2 shall be calculated using the GWP-100, which is 27 ± 11 for non-fossil CH_4 and 233 ± 110 for N_2O .

To facilitate the future inclusion of further feedstocks and other biochar end-uses, the GHG quantification is set up in a framework, which allows a broad approach to estimate the climate impacts of the biochar value chain. This framework includes:

- The sourcing stage, where waste biomass is sourced and collected;
- The production stage, during which waste biomass is prepared (if applicable) and thermochemically converted into biochar and;
- The application stage, where the biochar is end-use is its application into soil as amendment.

Table 2 below identifies the GHG and its sources included or excluded from the project boundary.

[1] The objective of this measure is to minimize the risk of biochar loss due to forest fires, as well as water or wind erosion; this practice also brings additional benefits, such as improving the soil's water retention capacity and the availability of nutrients for plants.

[2] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf

TABLE 2. GHG SOURCES INCLUDED IN OR EXCLUDED FROM THE PROJECT BOUNDARY

Source		Gas	Included	Explanation
Baseline	Feedstock production (waste)	CO_2	✗	Only waste biomass is accepted as feedstock, so no explicit production.
		CH_4	✗	
		N_2O	✗	
	Combustion of feedstocks	CO_2	Optional	Default baseline is zero unless project proponent provides data for a baseline emission factor and provides required documentation (e.g., forest slash emission factors).
		CH_4	Optional	
		N_2O	Optional	
	Anaerobic decomposition of feedstock	CO_2	Optional	Considered negligible due to absence of oxygen.
		CH_4	Optional	Default baseline is zero unless project proponent provides data for a baseline emission factor and provides required documentation (e.g., anaerobic decomposition factors for manure lagoon ponds).
		N_2O	Optional	
	Aerobic decomposition of feedstock	CO_2	Optional	The default baseline is zero unless the project proponent provides data for a baseline emission factor and provides the required documentation (e.g., aerobic decomposition factors of unburned biomass).
		CH_4	Optional	
		N_2O	Optional	
Project	Feedstock production (waste)	CO_2	✗	Only waste biomass is accepted as feedstock, so no explicit production.
		CH_4	✗	Conservatively excluded
		N_2O	✗	Conservatively excluded
	Pre-treatment of feedstocks (e.g., grinding, drying)	CO_2	✓	Included. Emissions directly attributable to the project.
		CH_4	✓	
		N_2O	✓	
	Pyrolysis, or	CO_2	✗	

	thermochemical conversion (high technology systems)	CH_4	✗	High-tech systems require emission controls (including methane mitigation) and the use of more than 70% of pyrolysis energy.
		N_2O	✗	
	Pyrolysis, or thermochemical conversion (low technology systems)	CO_2	✓	Low technology systems are provided a default emission value based on published literature (Cornelissen et al., 2016).
		CH_4	✓	
		N_2O	✓	
	Electricity or fossil fuels consumed during pyrolysis	CO_2	✓	Included. Emissions associated directly to project activity.
		CH_4	✓	
		N_2O	✓	
	Biochar application (e.g., preparation of biochar for final use, machinery for soil works)	CO_2	✓	Included. Emissions associated directly to project activity.
		CH_4	✓	
		N_2O	✓	
	Biochar transportation	CO_2	✓	Included only if transport distance is greater than 200 Km.
		CH_4	✓	
		N_2O	✓	

IV. CARBON REDUCTIONS AND REMOVALS QUANTIFICATION

IV.1. BASELINE SCENARIO

In order to accurately assess the baseline scenario, it is necessary that the project proponent declares the origin of the feedstock that will be transformed into biochar, as well as the disposal practices before the biochar project starts. It shall be specified if the waste biomass used to be left to decay or was burnt and the distance it was transported (if that was the case).

This should be supported by evidence such as quantitative measurements (weight or volume) of the amount of waste biomass produced, documentation of the disposal method, such as landfilling, composting, or incineration, or documentation of any regulations or policies related to the disposal of waste biomass in the particular location. This data will be used to calculate the sum of the baseline emissions in a specific year (averaging the last 3 years).

IV.2. SOURCING STAGE ESTIMATIONS

Emissions at the feedstock sourcing stage are estimated as the sum of the difference between baseline emissions and project emissions in a given year according to the following equation:

$$ERss = \sum(\mathrm{BEss,y} - \mathrm{PEss,y}) \quad [1]$$

Where:

ER_{SS} Emissions at sourcing stage in year y (tCO_2e)

$BE_{SS,y}$ Baseline emissions at sourcing stage in year y, conservatively assumed as zero as the default value (tCO_2e). See equation [2].

$PE_{SS,y}$ Project emissions at sourcing stage in year y, (**conservatively assumed as zero** since biogenic source material is considered as renewable biomass) (tCO_2e).

GHG baseline emissions at the sourcing stage

The baseline scenario is the situation where, in the absence of the project activity, waste biomass would have been left to decay or would have been combusted until the end of the crediting period within the project boundary.

$$BEss,y = BED,y + BEC,y \quad [2]$$

Where:

BESS,y: Sum of the baseline emissions in year y (tCO_2e)

BED,y: Emissions due to the decomposition of waste biomass in year y (tCO_2e). Emissions due to decomposition of waste biomass must be calculated using CDM Methodological Tool 04: Emissions from Solid Waste Disposal Sites[3].

BEC,y: Emissions due to the combustion of waste biomass in year y (tCO_2e). Since waste biomass eligible under the methodology is renewable, emissions due to combustion of waste biomass is conservatively considered zero unless project proponent provides acceptable baseline emission factors.

IV.3. PRODUCTION STAGE ESTIMATIONS

The net GHG balance depends on the organic carbon content at the biochar production stage. The next equation summarizes the carbon balance at the production stage by comparing the difference between the stabilized carbon content in the biochar and the resulting project emissions from feedstock pre-treatment (where applicable) and from conversion of waste biomass into biochar. The former includes emissions from energy consumption of drying and pre-processing feedstocks, and the latter includes other relevant emissions from the production facilities. The project emission removals during production at the biochar facility are as follows:

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[3] CDM Tool 4: Emissions from Solid Waste Disposal Sites. Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v8.0.pdf

$$ERps = (\sum\left(CCy,t \times \frac{44}{12}\right)) - PEps \quad [3]$$

Where:

ER_{PS} GHG emissions reductions at production stage in year y (tCO_2e)

CC_{yt} Mass of fixed carbon for biochar type t used for application type t in year y (t C) . See equation [4], for high-tech facilities, or [9], for low-tech facilities.

44/12 Coefficient to translate mass of carbon into mass of CO_2.

PE_{PS} Project emissions at production stage for production of biochar type t at production facility p in year y (tCO_2e). See equation [5].

There are 2 general types of technology used to process biochar: high-tech and low-tech, for which different calculation methods will be used.

a) High-technology production facility (see *Definitions)*

Under this methodology, the estimated fixed carbon content of the biochar produced is determined from the analysis of materials conducted by established laboratories and standardized methods.

a.1) Estimate fixed carbon content (CC) of biochar for high technology facilities

The total fixed carbon content of the biochar produced is the basis for the GHG calculation. The value is derived from the mass of biochar, its respective carbon content and the decomposition rate of fixed carbon in the biochar taken over a 100-year period (100-year permanence value).

The methodology provides default decomposition values when biochar is used in land application. The total fixed carbon content attributable to the project activity is estimated as follows:

$$CCy,t = My,t \times Fcp \times PRde \quad [4]$$

Where:

$CC_{y,t,}$ Mass of fixed carbon in year y for biochar of feedstock and application type t (t C).

$M_{y,t}$ Mass of biochar of type t applied to the respective end-use in the year y (tonnes), see application stage.

F_{Cp} Organic carbon content of biochar for each production type per tonne of biochar. F_{Cp} for high technology production type defined through material analysis conducted in certified laboratories.

PR_{de} Permanence adjustment factor due to decay of biochar (dimensionless) to be defined as per end-use application.

For soil end-use application (the only application accepted under the aOCP). For biochar with $H:C_{org}$ <0.4, annual decay of 0.3% as per Budai *et al.*, 2013; Camps-Arbestain *et al.,* 2015; and as also adopted by European Biochar Certificate. As permanence is accounted over a period of 100 years, 74% of the original carbon content is accounted as removal. Value of 0.74 is considered as conservative default for $PR_{de.}$

Project proponents may propose any other value for PR_{de} as a substitute for the value of 74%. The project proponent must provide evidence of the proposed PR_{de} which must include scientific studies, research papers or any other credible documentation and/or information. Documentation and information such as white papers or non-peer reviewed research papers are not considered as credible and appropriate forms of evidence.

a.2) Estimate project emissions ($PE_{PS,y}$) for high technology production facilities

Emissions under the project scenario are determined using the following equation, which consider the GHG emissions of producing biochar and it shall be calculated as follows:

$$PEps, y = \sum\{ (\mathrm{PED, y} + \mathrm{PEP, y} + \mathrm{PEC, y}) \times \left(\frac{\mathrm{My,t}}{\mathrm{Mx,t}}\right)\} \quad [5]$$

Where:

$PE_{PS,y}$	Project emissions at the production stage in year y (tCO_2e).
$P_{Ed,y}$	Emissions associated with the pre-treatment of waste biomass in year y (tCO_2e). See equation [6].
$P_{Ep,y}$	Emissions associated with the conversion of waste biomass into biochar in year y (tCO_2e). See equation [7].
$P_{Ec,y}$	Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis (tCO_2e). See equation [8].
$M_{y,t}$	Mass of biochar of type t applied to the respective end-use in the year y (tonnes), see application stage.
$M_{x,t}$	Total mass of biochar produced in the production facility from feedstock of type t in year y (tonnes).

Emissions associated with the pre-treatment of feedstock in year y (P_{Edy})

Energy consumption for any necessary pre-treatment of waste biomass shall be accounted for. This can include feedstock preparation (e.g., feedstock agglomeration, homogenization, pelletizing) either inside the production facility or in the field preparation, drying of wet waste biomass, or other processes. If the energy source is renewable, $P_{ED,y}$, is not considered and the default value used shall be zero. $P_{ED,y}$ shall be calculated as follows:

$$\mathrm{PEd, y} = \sum(\mathrm{Qi, y, energy} \times \mathrm{COEFi, y}) \quad [6]$$

Where:

$P_{Ed,y}$	Emissions associated with pre-treatment of feedstock (tCO_2e)
$Q_{i,y,energy}$	Quantity of energy type *i* used to pre-treat feedstocks during the year *y* (mass or volume unit/yr)
	If the source of energy utilized for pre-treatment of waste biomass is grid connected electricity, $PE_{D,y}$ must be calculated as per CDM Methodological Tool 05: Baseline,

	project and/or leakage emissions from electricity consumption and monitoring of electricity generation15
$COEF_{i,y}$	CO_2 emission factor of energy type i in year y (tCO_2/mass or volume unit) [4].

Emissions associated with the thermochemical process (pyrolysis) in year y ($P_{EP,y}$) for high technology facilities

Processing of the waste biomass refers to the pyrolysis process, which fixed the carbon in the biochar. The respective value $P_{EP,y}$ accounts for the emissions from the pyrolysis process, which are emitted into the atmosphere. In alignment with eligibility requirements for high technology production facilities, net emissions are considered negligible. Therefore,

$$P_{Ep,y} = 0 \qquad [7]$$

Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis ($P_{EC,y}$)

When external energy is required to initiate and maintain the pyrolysis reactor, it shall be accounted for project emissions. If the source of auxiliary energy is renewable, $P_{EC,y}$ is not considered and default value used shall be zero. Otherwise, it shall be calculated as follows:

$$\mathrm{PEc,y} = \sum(\mathrm{Qi,y,energy} \times \mathrm{COEFi,y}) \qquad [8]$$

Where:

$P_{Ec,y}$	Emissions associated with starting the reactor in the year y (tCO_2e)
$Q_{i,y,energy}$	Quantity of energy type *i* used to initiate and/or maintain pyrolysis in year *y* (mass or volume unit/yr)
$COEF_{i,y}$	CO_2 emission factor of energy type *i* in year *y* (tCO_2/mass or volume unit). See footnote 4.

b) Low technology production facility (see *Definitions*)

Less advanced technical production facilities that have not been constructed according to industrial standards usually have a lower efficiency to convert organic carbon and often lack emissions controls during the production process.

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[4] For electricity, it can be retrieved from the latest publication by Carbon Footprint Ltd (2023), using the "Production fuel mix factor". Carbon footprint country specific electricity grid greenhouse gas emission factors. https://www.carbonfootprint.com/docs/2023_02_emissions_factors_sources_for_2022_electricity_v10.pdf . For fuel combustion, emission factors can be retrieved from Carbon emissions of different fuels (UK Forest Research): https://www.forestresearch.gov.uk/tools-and-resources/fthr/biomass-energy-resources/reference-biomass/facts-figures/carbon-emissions-of-different-fuels/ or Greenhouse Gases Equivalencies Calculator (US EPA): https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

b.1) Estimate fixed carbon content (CC) of biochar for low technology facilities

The total fixed carbon content of biochar produced is the basis of the GHG calculation. The value is derived from the mass of biochar, its respective carbon content, and the rate of decomposition of carbon fixed in the biochar taken over a period of 100 years (100-year permanence value).

For low-tech production facilities, a conservative approach related to the organic carbon content of the biochar (FCp), depending on the type of feedstock and the heating temperature. In the following formula, the permanence (the fraction of biochar remaining carbon after 100 years) is included.

$$CCy, t = My, t \times Fcp \times PRde \qquad [9]$$

Where:

$CC_{y.t}$	Mass of fixed carbon for biochar type t used for application type t in year y (t C).
$M_{y.t}$	Mass of biochar of type t applied to the respective end-use in the year y (tonnes), see application stage. The produced mass of biochar shall be determined in alignment with CDM tool 13 Option 1 using a weighing device or Option 2 without a weighing device
$F_{C.p}$	Organic carbon content of biochar for each production type per tonne of biochar. F_{Cp} for low technology production type when possible, determined through laboratory analysis. Otherwise, $F_{C.p}$ value is retrieved from Table 3 per type of feedstock for low technology production facility.
$PR_{d.e}$	Permanence adjustment factor due to biochar loss (dimensionless) in soils. Biochar is subject to a natural decomposition rate when used in soil applications such as agriculture, forests, croplands or pastures. Many low-tech production facilities do not measure temperature in biochar production. therefore a $PR_{d.e}$ default value of 0.56 shall be used when pyrolysis temperature is unknown, as established by IPCC (2019; Figure 4Ap.1)[5]. This value takes a conservative approach to carbon permanence.

Values for organic carbon content per tonne of biochar per production type (FCp)

The determination of the fixed carbon content (F_{Cp} value) should be determined in a qualified laboratory. However, project proponents using low technology production facilities can adopt the values from the IPCC (2019) for different feedstocks and production types, which are duplicated here for reference purposes.

[5] Available at https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch02_Ap4_Biochar.pdf

Table 3. Values for organic Carbon content in biochar (F_{Cp}). Source: IPCC (2019)[5].

Feedstock	Production Process	Values for F_{Cp}
Animal Manure	Pyrolysis	0.38 ± 49%
	Gasification	0.09 ± 53%
Wood	Pyrolysis	0.77 ± 42%
	Gasification	0.52 ± 52%
Herbaceous (grasses, forbs, leaves; excluding rice husks and rice straw)	Pyrolysis	0.65 ± 45%
	Gasification	0.28 ± 50%
Rice husks and rice straw	Pyrolysis	0.49 ± 41%
	Gasification	0.13 ± 50%
Nut shells, pits and stones	Pyrolysis	0.74 ± 39%
	Gasification	0.40 ± 52%
Biosolids (paper sludge)	Pyrolysis	0.35 ± 40%
	Gasification	0.07 ± 50%

b.2) Step 2: Estimate project emissions ($PE_{ps,y}$) for low technology facilities

Emissions under the project scenario are determined using the following equation:

$$PEps.y = \sum(Ped.y + Pep.y + Pec.y) \quad [10]$$

Where:

$PE_{ps.y}$ Project emissions at the production stage in year y (tCO_2e).

$P_{ed.y}$ Emissions associated with the pre-treatment of waste biomass in year y (tCO_2e). See equation [11].

$P_{ep.y}$ Emissions associated with the conversion of waste biomass into biochar in year y (tCO_2e). See equation [12].

$P_{ec.y}$ Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis (tCO_2e). See equation [13].

Emissions associated with the pre-treatment of feedstock in year y ($P_{ed,y}$) for low technology facilities

Energy consumption for necessary pre-treatment of waste biomass shall be accounted for. This can include feedstock preparation (e.g., feedstock agglomeration, homogenization, pelletizing) either inside the production facility or in the field preparation, drying of wet biomass, or other processes. If the energy source is renewable, $P_{ED,y}$ is not considered, and the default value used shall be zero. Otherwise, it shall be calculated as follows:

$$\mathrm{Ped, y} = \sum(\mathrm{Qi, y, energy} \ \times \ \mathrm{COEFi, y}) \qquad [11]$$

Where:

$P_{ed,y}$	Emissions associated with pre-treatment of feedstock (tCO2e).
SUM_i	Quantity of energy type *i* used to pre-treat feedstocks during the year y (mass or volume unit/yr). If the source of energy utilized for pre-treatment of waste biomass is grid connected electricity, $P_{ed,y}$ must be calculated.
$COEF_{i,y}$	CO_2 emission factor of energy type i in year y (tCO2/mass or volume unit). See footnote 4.

Emissions associated with the thermochemical process (pyrolysis) in year y ($P_{EP,y}$) for low technology facilities

In the absence of direct emission measurements which can reliably measure and report project emissions, the following data from the literature shall be used:

$$\mathrm{Pep, y} \ = \sum(\mathrm{Fe} \ \ \mathrm{x\,GWPCH4\,x} \ \ \mathrm{My, t}) \qquad [12]$$

Where:

$P_{EP,y}$ (tCO_2e)	Emissions associated with the conversion of waste biomass into biochar in year y
F_e	Average emissions from producing one tonne of biochar in the year y (tCO_2e/tonnes). Adopted values from Cornelissen *et al*. (2016) can be used where default average emission factor for CH_4 is 0.09 t CH_4/t biochar. The Global Warming Potential (GWP-100)[6] for CH_4 is 27 for non-fossil CH_4, 29.8 for fossil CH_4 and 233 ± 110 for N_2O. Project proponents may choose more appropriate values based on scientific studies, research papers or any other credible documentation and/or information related to the utilized production technology.

[6] See footnote 1.

GWP_{CH4} Global warming potential of methane.

$M_{y,t}$ Mass of biochar from feedstock of type t utilized within the project activity in the end-use application in year y (tonnes).

Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis ($P_{EC,y}$)

When external energy is required to initiate and maintain the pyrolysis reactor, it shall be accounted for project emissions. If the source of auxiliary energy is renewable, $P_{EC,y}$ is not considered and default value used shall be zero. Otherwise, it shall be calculated as follows:

$$Pec,y = \sum(\mathrm{Qi,y,energy} \times \mathrm{COEFi,y}) \quad [13]$$

Where:

$P_{EC,y}$ Emissions associated with starting the reactor in the year y (tCO_2e)

$Q_{i,y,energy}$ Quantity of energy type i used to initiate and/or maintain pyrolysis in year y (mass or volume unit/yr)

$COEF_{i,y}$ CO_2 emission factor of energy type i in year y (tCO_2/mass or volume unit). See footnote 4.

IV.4. Application stage estimation

Emissions at application stage refer to GHG emissions associated with the post-production and end-use application of biochar. In the baseline scenario at application stage, since no biochar was produced, no carbon emissions for this stage are considered.

In the project scenario, emissions associated with processing and utilizing biochar after its production will have a potential impact on the overall GHG emission removal calculation. The equation below determines the GHG emissions at the application stage:

$$ERas,p = Ep,y + Eap,y \quad [14]$$

Where:

$ER_{AS,P}$ Project emissions at application stage in year y (tCO_2e).

$E_{p,y}$ Emissions from processing of biochar in the year y (tCO_2e). See equation [15].

$E_{ap,y}$ Emissions from application of biochar in the year y (tCO_2e). See equation [16].

Emissions associated with processing of biochar (Ep,y)

In a scenario where biochar undergoes further processing (e.g., sizing, grinding, sifting) before final soil application, project proponents must quantify emissions related to grinding and other mechanical transformation of biochar energy related emissions.

If the energy source is renewable, $E_{p,y}$ is not considered and the default value used shall be zero. Otherwise, it shall be calculated as follows:

$$Ep, y = \sum(\mathrm{Qi, y, energy} \times \mathrm{COEFi, y}) \quad [15]$$

Where:

$E_{p,y}$ Emissions from processing of biochar in the year *y* (tCO_2e)

$Q_{i,y,energy}$ Quantity of energy type i used to biochar processing in the year y (mass or volume unit/yr)

$COEF_{i,y}$ CO_2 emission factor of energy type *i* in year *y* (tCO_2/mass or volume unit). See footnote 4.

When there is no processing of biochar $E_p = 0$.

Emissions associated with application of biochar (E_{ap})

E_{ap} corresponds to emissions during the application of biochar to the soil. GHG emissions resulting due to fossil fuel combustion and fertilizer application are considered negligible. Thus,

$$E_{ap} = 0 \quad [16]$$

IV.5. Leakage

Leakage in biochar use refers to anthropogenic GHG emissions beyond the project boundary caused by loss of biochar before final application/utilization and transport emissions during the biochar life cycle. Because only waste biomass is accepted as feedstock in this methodology, emissions from activity displacement, leakage, or biomass detour are not considered applicable. Negative leakage emissions can be quantified as follows.:

$$LE_y = LE_{bl} + LE_{ts} + LE_{tap} \quad [17]$$

Where:

LE_y Total leakage GHG emissions due to project activity in the year y (tCO_2e).

LE_{bl} Leakage due to loss of biochar intended for project activity in the year y (tCO_2e). See equation [18].

LE_{ts} Leakage emissions due to transport of waste biomass from sourcing to the biochar production facility in the year *y* (tCO_2e). GHG emissions need not be considered for transportation distances less than 200 km. The project proponent shall use *CDM Methodological Tool 12: Project and leakage emissions from transportation of freight*[7] to calculate LE_{ts}.

[7] CDM Methodological Tool 12: Project and leakage emissions from transport of freight. Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.1.0.pdf

LE_{tap}	Emissions related to leakage from transportation of biochar from the production facilities to the final application site in the year *y* (tCO_2e). Follow the same considerations as for LE_{ts}.

Emissions related to leakage due to loss of biochar (LE_{bl})

Loss of biochar refers to scenarios in which the biochar that was originally intended to be used in the eligible project activity is lost prior to its application and use. These scenarios include, but are not limited to, loss of biochar due to unexpected combustion of biochar in a storage facility or during transportation, or loss for any other purpose not intended in the proposed and implemented project activity.

Calculation for LE_{bl} can be:

a) The project proponent may consider emissions to be zero if able to demonstrate[8] that no biochar is lost prior to final application.

b) If more than 5% of the biochar is lost (e.g., during transport of the product) then leakage values must be calculated using the following formula:

$$LEbl = \sum(\mathrm{Mtl} \times \mathrm{FCp} \times \frac{44}{12}) \qquad [18]$$

Where:

LE_{bi}	Emission related to leakage due to loss of biochar in the year y (tCO_2e) .
M_{tl}	Mass of lost biochar of type *t* in the year *y* (tonnes).
F_{Cp}	Organic carbon content of biochar for each production type per tonne of biochar. F_{Cp} for high technology production type defined through material analysis conducted in certified laboratories. For low technology, retrieved from table 3.
44/12	Coefficient to translate C into CO_2e.

Emissions related to leakage from transportation of biochar from the production facilities to the final application site (LE_{tap})

Project emissions from transportation[9] of biochar from facility to end-use application may have the following components:

a) Transport emissions biochar facility to processing facility; AND

b) Transport emissions processing facility to end-use site;

[8] Project proponents shall adopt a sound mechanism to prove that the chain of custody has been properly kept and all records regarding mass, volume, distances, etc support emissions calculations. See more about approaches for keeping the Chain of Custody in the Monitoring section of this methodology.

[9] *See footnote 5*

OR

c) Transport emissions from biochar facility to end-use site.

LE_{tap} is not accounted for if transportation distance is less than 200 km.

IV.6. NET GHG EMISSION REDUCTIONS AND REMOVALS

Net GHG emission reduction and removals are calculated as follows:

$$ERy = ERss + ERps - ERas - LEy \quad [19]$$

Where:

ER_y	Net GHG emissions reduction and removals in year *y* (tCO_2e).
ER_{SS}	GHG emissions reductions at sourcing stage in year *y* (tCO_2e). See equation [1].
ER_{PS}	GHG reductions at production stage in year *y* (tCO_2e). See equation [3].
ER_{AS}	GHG emissions at application stage in year *y* (tCO_2e). See equation [14]
LE_y	Total leakage emissions in year *y* (tCO_2e). See equation [17].

V. MONITORING

According to the aOCP Procedures, it is the aOCP Operations Team who conducts Monitoring activities and provides the calculation of parameters that will be used by the Verifier to review the Project. In order for aOCP Operations Team to perform this calculations, it is necessary that the Project proponent provides a yearly Activity Report and the supporting evidence about the Chain of Custody [10]. The following information shall be reported for each production batch or application event:

- Total mass of each feedstock type used for biochar production.
- Transportation distance from the sourcing site of waste biomass to the biochar production facility, include volume of fuel or amount electricity consumed for this purpose.
- Energy consumption[11] for any necessary pre-treatment of waste biomass. This can include feedstock preparation (e.g., feedstock agglomeration, homogenization,

[10] Invoices, purchase agreements, dedicated tracking applications (ASES will release its own app for this purpose on the second trimester of 2023)

[11] Energy can be reported as volume of each fuel type or amount of electricity -if electricity is used, describe its origin (grid, local sources, etc))

pelletizing) either inside the production facility or in the field preparation, drying of wet waste biomass, or other processes. (volume of fuel or amount of electricity -if electricity is used, describe its origin (grid, local sources, etc)).

- Amount of energy[12] used to initiate and/or maintain pyrolysis.
- Total mass of biochar produced from each feedstock type.
- Mass of biochar applied to soil, of each feedstock type.
- Organic carbon content of each production batch. If produced in high-tech facilities, results of laboratory analysis shall be provided. If produced in low-tech facilities, this is optional, knowing that a conservative default (IPCC, 2019) value will be used.

There are several options available for establishing a chain of custody for biochar projects, including but not limited to:

- Third-party certification systems that provide traceability and accountability for the entire supply chain.
- Documentation of production methods and records of the origin, processing, and distribution of the biochar.
- Batch tracking systems that track the movement of biochar from production to application.
- On-site inspections and audits to verify the integrity of the biochar supply chain.
- Use of digital technologies such as blockchain to create a transparent and tamper-proof record of the biochar supply chain.

ASES will define the **monitoring plan** and inform the Project proponent at the time of pre-register to agree on it. It will contain the following information: - A description of each activity to be reported and the technical requirements therein; - Written logs of operation and maintenance of the project system; - Roles, responsibilities and capacity of monitoring team and management.

Project proponents must also develop a **QA/QC plan** to add confidence that all measurements and calculations have been made correctly, and where necessary, correct anomalous values, ensure completeness, perform independent checks on analysis results, and other safeguards as appropriate. QA/QC measures that may be implemented include, but are not limited to: - Protecting monitoring equipment (sealed meters and data loggers) where applicable; - Protecting records of monitored data (hard copy and electronic storage); - Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records); - Comparing current estimates with previous estimates as a ‘reality check’; - Providing sufficient training to personnel to perform activities related to the sourcing, production, and application of biochar, and; - Performing recalculations to ensure no mathematical errors have been made.

[12] *Idem*

	DOCUMENT HISTORY	
Version	**Date**	**Comments**
V2.0	28/06/2023	• Second version released for review by the aOCP Steering Committee under the aOCP Version 2.