VCS Methodology

VM0044

BIOCHAR UTILIZATION IN SOIL AND NON-SOIL APPLICATIONS

Version 1.2

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Sectoral Scope 13: Waste Handling and Disposal

Version 1.0 of this methodology was developed by Biochar Works, Delaney Forestry Services, Forliance, and South Pole. The lead authors were Hannes Etter (South Pole), Andrea Vera (Forliance), Chetan Aggarwal (South Pole), Matt Delaney (Delaney Forestry Services), and Simon Manley (Biochar Works).

Version 1.1 of this methodology was developed by Verra.

Version 1.2 of this methodology was developed by Verra.

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1 SUMMARY DESCRIPTION

Additionality and Crediting Method	
Additionality	Activity Method
Crediting Baseline	Project Method

This globally applicable methodology provides criteria and procedures for the quantification of GHG benefits following the adoption of improved waste handling and disposal (WHD) of waste biomass. The project activity consists of three parts: 1) sourcing waste biomass, 2) producing biochar, and 3) utilizing biochar in soil or non-soil application.

The project activity must install and operate a new (greenfield) biochar production facility(ies) where GHG benefits are credited only for the biochar that is utilized in the eligible soil and non-soil applications. The start date of the project is defined as the first instance of biochar production.

The baseline scenario is the continuation of pre-project WHD where the waste biomass would either be left to decay or be combusted for purposes other than energy. This methodology applies the most conservative and operational approach by not considering emission reductions from changing the WHD practices at the sourcing stage. Thereby, the default net GHG emissions in the baseline scenario at the sourcing stage are considered zero (the most conservative assumption).

This methodology uses a standardized approach for the demonstration of additionality, following an activity method with the processing of waste biomass to biochar as the basis for a positive list. This approach stipulates that the total mass of waste biomass converted to biochar amounts to five percent or less of the total mass of waste biomass available worldwide.

The methodology employs a comprehensive monitoring and accounting framework that captures the GHG impacts in the three important stages of a biochar value chain: sourcing, production, and application (i.e., the use of biochar in soil or non-soil applications). The methodology also includes a section to address permanence of biochar, including decay rate and reversal risk from natural and non-natural risks (see Section 8.4).

Monitoring must be conducted for both the baseline and project scenarios. For emissions associated with the production stage, calculations are based on one or more monitored biochar production variables according to the parameters described (e.g., production temperature and biochar material properties), or use default values detailed in the methodology, according to the type of production technology. Eligible projects must document and prove the final application of biochar (see Section 9).

2 SOURCES

This methodology uses the most recent versions of the following tools:

CDM

- CDM *TOOL03: Tool to Calculate Project or Leakage CO_2 Emissions from Fossil Fuel Combustion*
- CDM *TOOL05: Baseline, Project and/or Leakage Emissions from Electricity Consumption and Monitoring of Electricity Generation*
- CDM *TOOL09: Tool to Determine the Baseline Efficiency of Thermal or Electric Energy Generation Systems*
- CDM *TOOL12: Project and Leakage Emissions from Transportation of Freight*
- CDM *TOOL16: Project and Leakage Emissions from Biomass*

VCS

- *VT0008 Additionality Assessment*

This methodology is based on the following sources:

- CDM methodology *AMS-III.L: Avoidance of methane production from biomass decay through controlled pyrolysis, v2.0*
- CDM methodology *Small-Scale Methodology AMS-III.E: Avoidance of methane production from decay of biomass through controlled combustion, gasification or mechanical/thermal treatment, v17.0*
- CDM methodology *AMS-III.BG: Emission reduction through sustainable charcoal production and consumption, v3.0*
- CDM Executive Board report *EB23 Annex 18: Definition of Renewable Biomass*

The following has also informed the development of the methodology:

- Intergovernmental Panel on Climate Change (IPCC) (2019) *Appendix 4: Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development*
- International Biochar Initiative (IBI) *Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil, v2.1*
- European Biochar Certificate (EBC) *Guidelines for a Sustainable Production of Biochar, v10.1*

3 DEFINITIONS

In addition to the definitions set out in the VCS *Program Definitions* document, the following definitions apply to this methodology.

Anaerobic decomposition
The microbial breakdown of organic material in the absence of oxygen. Organic compounds emitted during anaerobic decomposition are mainly methane (CH_4) and lesser amounts of carbon dioxide (CO_2). Examples of anaerobic decomposition include marine mud sediments and manure ponds.

Biochar
A solid and stabilized carbon material formed by the thermochemical processing of biomass in an oxygen-limited environment. These processes can be classified as either pyrolysis (in which oxidants are excluded), or gasification (in which oxidant concentrations are low enough to generate syngas). Both processes are considered interchangeably in this document. Biochar is considered a carbon sink when its soil applications (e.g., soil amendment on agricultural lands) or non-soil applications (e.g., cement, asphalt) can prove carbon-persistent over time.

Biogenic
A material that is produced by or originates from a living organism.

Chain of custody
The process by which inputs and outputs and associated information are transferred, monitored and controlled as they move through each step in the relevant supply chain. For biochar projects, the chain of custody refers to tracking and documentation from the sourcing stage (i.e., waste biomass) until the application stage (i.e., biochar use in soil or non-soil applications).

Dry weight basis
A measure of how much water is in a solid, expressed as the weight of water as a percentage of the completely dry solid. Procedures to determine biochar on a dry weight basis are outlined in International Biochar Initiative (IBI) *Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil* (hereinafter referred to as the *IBI Biochar Testing Guidelines*)[1] which uses ASTM *D1762-84 Standard Test Method for Chemical Analysis of Wood Charcoal* to determine dry weight of biochar products (see Table 1, page 13 of the *IBI Biochar Testing Guidelines*). In cases where moisture content of feedstocks is required, ASTM *D4442-20 Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials* can be used as a guide. The method involves drying samples to a constant weight in a ventilated oven at 102 to 105 °C.

[1] Available at https://biochar-international.org/standard-certification-training/biochar-standards/.

Feedstocks

The materials undergoing thermochemical processes to create biochar. Feedstock materials must be biogenic to qualify under this methodology and must comply with the applicability conditions (see Section 4).

Freight

The goods and materials (including waste materials) that are transported. Freight transportation under this methodology refers to trips for transporting waste biomass or biochar products. Transportation shall be grouped together as that using the same vehicle class and transporting freight between the same origin and destination.

Gasification

A technological process that converts carbon-based raw material into fuel gas. Gasification occurs in a gasifier, generally at temperatures greater than700 °C.

High-carbon fly ash from biomass

A by-product of biomass-based energy production, whereby the by-product is usually reinjected into the process. High-carbon fly ash (HCFA) from biomass is typically produced using boiler systems at lumber and other forestry-related facilities. The main components are ash and carbonized material.

Biomass ash, and fractions thereof, include bottom ash and fly ash. Some of these fractions may display physicochemical properties that are similar to biochar materials, including high organic carbon content fractions termed "high-carbon fly ash" (adapted from *IBI Biochar Testing Guidelines* Section 5.8, page 21).

High technology production facility

High technology production facilities are those that meet all of the following conditions based on the *European Biochar Certificate – EBC Guidelines for Sustainable Production of Biochar*[2] (hereinafter referred to as the *EBC Production Guidelines*): (a) the pyrolytic greenhouse gases produced during pyrolysis must be recovered or combusted—greenhouse gases are not allowed to escape into the atmosphere; (b) at least 70 percent of the heat energy produced by pyrolysis must be used[3] (taking into consideration heat transfer inefficiencies) to ensure that energy is recovered as well as biochar;[4] (c) pollution controls such as a thermal oxidizer or other emissions controls are present that meet local, national or international emission thresholds;[5] and (d) production temperature is measured and reported. If any of these conditions are not met, the facility is categorized as a low technology production facility.

Long-lived biochar products

The carbon storage from non-soil biochar application where the project proponent can prove that the average life is the average number of years a product is in use, with evidence from

[2] Available at https://www.european-biochar.org/en/ct/2-EBC-guidelines-documents.

[3] The 70% value is adapted from the EBC Production Guidelines.

[4] As an example, proof of this energy utilization requirement shall be demonstrated by calculating the lower heating value of the feedstock and the amount of biochar produced (adapted from the *EBC Production Guidelines*).

[5] In case of overlapping standards, the strictest regulations shall be fulfilled.

peer-reviewed literature. Project proponent must demonstrate that the biochar in non-soil applications is not combusted at the end of life of the product in which the biochar is utilized.

Low technology production facility
Low technology production facilities are those that do not meet all the conditions given under the definition of high technology production facility.

Non-soil applications
Use of biochar for other applications besides soil, for example as an additive in long-lasting products like concrete and asphalt or any other application with demonstrated long-term use and persistence. Biochar must be at least 50 percent carbon by dry weight basis to be used for non-soil applications (e.g., some activated carbon, due to excessive fossil fuel input, results in a loss of more than 50 percent of the original biochar carbon material and therefore would not be eligible).[6]

Organic carbon content
The amount of organic carbon permanently stored in the biochar as a mass proportion (in percent) based on the biochar dry weight.

Overstocked forest
The condition of having so many stems for a species and size that severe competition for growth resources has reduced growth, stressed trees, and put them at risk of insect, disease, or wildfire mortality (Helms, 1998).

Pyrolysis
The thermochemical decomposition of biogenic material or compounds under inert conditions in an oxygen-deficient environment (oxidants are excluded).

Waste biomass
The biomass, by-products, residues, and waste streams from agriculture, forestry and related industries, recycling economy, animal manure, and all others listed in Table 1. Any biomass residues meeting the feedstock requirements included in this methodology are eligible for biochar production and must comply with any required sustainable feedstock criteria (see Section 4).

4 APPLICABILITY CONDITIONS

The project activity must install and operate a new (greenfield) biochar production facility(ies) where the project proponent must 1) source waste biomass, 2) produce biochar and 3) ensure the biochar is utilized in soil or non-soil application. GHG benefits are credited only for the biochar that is utilized in the eligible soil and non-soil applications.

[6] Charcoal use is excluded. The rationale for the 50 percent requirement is to avoid erasing the sequestration benefits of biochar during upgrading the material to other non-soil uses.

Further, the project activities must meet the following conditions.

Technological scope

1) The methodology is applicable when biochar is produced from eligible waste biomass through a thermochemical process such as pyrolysis, gasification, and biomass boilers[7] and the biochar is subsequently applied to an end-use (soil or non-soil applications). Torrefaction and hydrothermal carbonization as processes of biochar production are excluded[8] from this methodology.

2) The methodology is applicable to projects using either low or high technology production facilities to produce biochar, as per the definitions of each provided in Section 3 of this methodology.

3) The biochar producers must have a health and safety program to protect workers from airborne pollutants and other hazards.

Eligible feedstocks and production

4) The feedstock used to produce biochar must meet all following conditions to be eligible:
   a) Feedstock must be purely biogenic waste biomass and not purpose-grown,
   b) Feedstock must have been otherwise left to decay or combusted for purposes other than energy production. Additional guidance on how to demonstrate fate of waste biomass in the absence of the project activity is provided in Appendix 2,
   c) Feedstock must not have been imported from other countries[9], and
   d) Feedstock must meet the sustainability conditions provided in Table 1. This table is not an exhaustive list of waste biomass examples.

Table 1 describes the categories of feedstock sourcing, the sustainability criteria that must be met for each feedstock source, and a non-exhaustive list of examples of feedstocks eligible under this methodology.

Table 1. List of eligible feedstocks for biochar production

Feedstock Sourcing Categories	Sustainability Criteria	Waste Biomass Examples (Not Exhaustive)
Agricultural waste biomass	a) Where project proponents are using agricultural waste biomass directly from fields and not from a	a) Tree, vine, and shrub pruning

[7] For the purpose of this methodology, the terms pyrolysis, gasification, and biomass boilers are used interchangeably.
[8] Both processes are excluded because they do not generate solid products that are significantly more persistent in soil than the original feedstock (Woolf et al., 2021).
[9] The methodology discourages transportation of waste biomass over long distances, especially among countries and between continents.

	centralized biomass-processing operation (e.g., food processing facilities), project proponents must provide documentation that the project activity is not leading to a decline in soil carbon stocks or a reduction in crop productivity, or that in the baseline agriculture waste biomass was burned without energy production (e.g., open burning of stubble). b) In the absence of documentation, feedstock removal is limited to no more than 50 percent of total residues to protect against soil degradation (Andrew, 2006; Battaglia et al., 2020).	b) Harvest residues such as straw, leaves, stalks, husk, pomace, kernels c) Fruit and vegetable residues
Food processing residues	a) Residues must be from food processing facilities. b) Production of residues per output of the facility must not have increased to be used specifically for the purpose of production of biochar.	a) Material from washing, cleaning, peeling, centrifugation, and separation processes b) Expired food residues c) Residues from processing in the food industry (e.g., coffee, tea, cocoa, tobacco)
Forestry and other wood processing	a) Wood-based feedstock sources coming from forest (as opposed to by-products of mill processing) must prove that biomass comes from sustainable sources and does not lead to deforestation or degradation. Examples of proof of sustainable use include sustainable management plans approved by a relevant state or regional authority, forestry certification such as the Programme for the Endorsement of Forest Certification (PEFC) or Forest Stewardship Council (FSC), or meeting the requirements of	a) Off-cuts, sawdust, and other material produced as a by-product of forest management or harvesting operations b) Any by-product from forest-based industries such as wood pallets and wood waste[11] c) Thinnings generated from forest wildfire fuel reduction activities or areas designated by state, provincial, or federal authorities as

[11] More details on biomass waste products can be found in Tripathi, N., Hills, C. D., Singh, R. S., & Atkinson, C J. (2019). Biomass waste utilization in low-carbon products: Harnessing a major potential resource. *npj Climate and Atmospheric Science, 2*, 35. https://doi.org/10.1038/s41612-019-0093-5

	renewable biomass as defined by the CDM (*EB23 Annex 18*).[10] b) When processed timber is used as feedstock for soil applications, it must not, for health and safety reasons, contain any paint residues, solvents or other contaminants including any potentially toxic impurities (EBC, 2022; Hedley et al., 2020).	overstocked d) Material from pruning or thinning of woody vegetation (not including merchantable timber) such as shade trees, orchards, windbreaks, stream buffers, silvopasture, or invasive removal on rangeland e) Diseased trees felled during plantation or woodland management f) Burned woody biomass g) Wastepaper and cardboards
Recycling economy	a) Feedstocks must comply with relevant thresholds for heavy metals and other contaminants as outlined in the latest version of the material standards or guidelines relevant for the project context (i.e., *IBI Biochar Testing Guidelines* or *EBC Production Guidelines*). The biomass is the non-fossil fraction of industrial or municipal waste (CDM *EB23 Annex 18*).	a) Urban/rural green cuttings, non-hazardous municipal green waste b) Biosolids from wastewater treatment c) Paper mill sludge
Aquaculture plants	a) Waste must be by-products of aquaculture. b) Project proponents must be demonstrated that waste invasive species such as water hyacinth (*Eichhornia crassipes*) were not purposely introduced in order to qualify as feedstock for biochar production.	a) Seaweed, algae waste products, aquatic invasive species (Plantae kingdom only)
Animal manure	a) Waste must be by-products of animal husbandry	a) Waste from swine, cattle, horse, and poultry farms

[10] Available at https://cdm.unfccc.int/EB/023/eb23_repan18.pdf

High-carbon fly ash from biomass	a) HCFA must be no more than 5 percent of the annual waste biomass throughput from the bioenergy facility. b) Project proponents must also provide information that an “affirmative” technology[12] was used to extract biochar prior to complete combustion of the waste biomass stream. c) Project proponents must further demonstrate that the biomass facilities did not use fossil fuel sources to replace the loss of biomass caloric value when material was diverted to the biochar project. d) The final material meets the *IBI Biochar Testing Guidelines*[13].	a) By-products of cogeneration facilities

5) Biochar made from a single or mixed eligible feedstock must comply with the latest version of the *IBI Biochar Testing Guidelines* or the *EBC Production Guidelines*.

6) The waste biomass used as feedstock to produce biochar and the resulting biochar to be utilized in soil or non-soil applications may be transported via ships, boats, and vehicles other than road transportation up to a distance of 200 km. However, it must only be transported by vehicles (i.e., road transportation) for distances more than 200 km as defined under CDM *TOOL12: Project and leakage emissions from transportation of freight*.

7) Mineral additives such as lime, rock minerals, and ash may comprise up to 10 percent of the mass when added. If the addition exceeds 10 percent on a dry weight basis, the biochar producer must present laboratory tests indicating that the final product meets *IBI Biochar Testing Guidelines* or *EBC Production Guidelines* thresholds for organic and inorganic contaminants.

8) Other evidence that may be used to demonstrate compliance with waste biomass sustainability criterion are biomass certification schemes such as the Roundtable on Sustainable Biomaterials (RSB), International Sustainability and Carbon Certification (ISCC) or any other certification scheme approved and/or endorsed by a relevant

[12] Affirmative technologies refer to diversion of “re-injection” HCFA that is removed from the combustion stream (for biochar harvesting purposes) instead of allowing complete combustion of the biomass feedstocks during a second pass through the boiler.
[13] Section 5.8 of the *IBI Biochar Standard v2.1*. Available at https://biochar-international.org/wp-content/uploads/2020/06/IBI_Biochar_Standards_V2.1_Final2.pdf

legislative body or international body such as the European Union,[14] CORSIA,[15] and national/state governments.

Eligible biochar end-use application criteria

9) Biochar is eligible to be utilized and accounted for under the methodology if it is being utilized within one year of its production. Biochar is subject to natural decay and the permanence of biochar is calculated for a period of 100 years. To adhere to the decay factor established for 100 years and prevent any decay before application, biochar must be utilized in soil or non-soil applications within the first year of its production.

10) Biochar is eligible to be used as a soil amendment on land other than wetlands. Eligible land types include cropland, grassland, vegetated urban soils, and forest. Biochar is eligible to be applied either to the soil surface or subsurface. For surface application, the biochar must be mixed with other substrates such as compost, manure or digestate from anaerobic digestion. For subsurface application, the biochar may be applied either as a unique soil amendment or mixed with other substrates. For any soil application, the biochar must:

    a) comply with biochar material standards to avoid the risk of transferring unwanted heavy metals and organic contaminants to soil. Project proponents must meet the *IBI Biochar Testing Guidelines* or *EBC Production Guidelines*,[16] or relevant national regulations for avoiding soil contamination.

    b) have a hydrogen to organic carbon molar ratio ($H:C_{org}$) of less than or equal to 0.7.

11) Biochar is eligible to be used in non-soil applications including but not limited to cement, asphalt, and any other applications where long-term storage of the biochar is possible. Only biochar produced in high technology production facilities, as defined under the methodology, is eligible to be used in non-soil applications.

12) Project proponents must demonstrate that biochar and/or final products are long-lived via credible evidence such as laboratory results, peer reviewed research papers or any other third party-evaluated product assessment, such as decay rate analysis, as applicable. The information provided must include the lifetime of the product in which biochar is stored long term. The resultant product must be compliant with

[14] Annex IX Directive (EU) 2018/2001 of the European Parliament and of the European Council of 11 December 2018 on the promotion of the use of energy from renewable sources. In particular, Annex IV sets out the minimum requirements for certifying waste and residues, grouped in the following categories (Annex IX): food-feed processing residues and waste; agricultural/forestry residues and waste; landscape care biomass; animal residues and waste; wastewater and derivatives; fats, oil and greases; others.

[15] The International Civil Aviation Organization (ICAO) under its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) approves certification schemes for eligible biofuels produced from eligible biomass, to be used in international aviation as part of emissions reduction targets of the international aviation industry. Waste biomass may be certified using the schemes approved by CORSIA.

[16] Available at https://www.european-biochar.org/media/doc/2/version_en_9_4.pdf

national/international product quality standards/specifications as applicable (e.g., the American Concrete Institute Standards in the US).

This methodology is not applicable under the following conditions:

13) The methodology must not be applied if biochar is used for energy purposes, burned as a fuel (e.g., as a substitute for charcoal or coke) or used in other soil or non-soil applications where biochar cannot be demonstrated to be a long-lived and persistent carbon sink.

14) Biochar must not be used in applications in which substantial amounts of the biochar are oxidized (e.g., burned or used as a reduction agent in steel production, processed into activated carbon, or other uses that are fossil fuel-intensive).

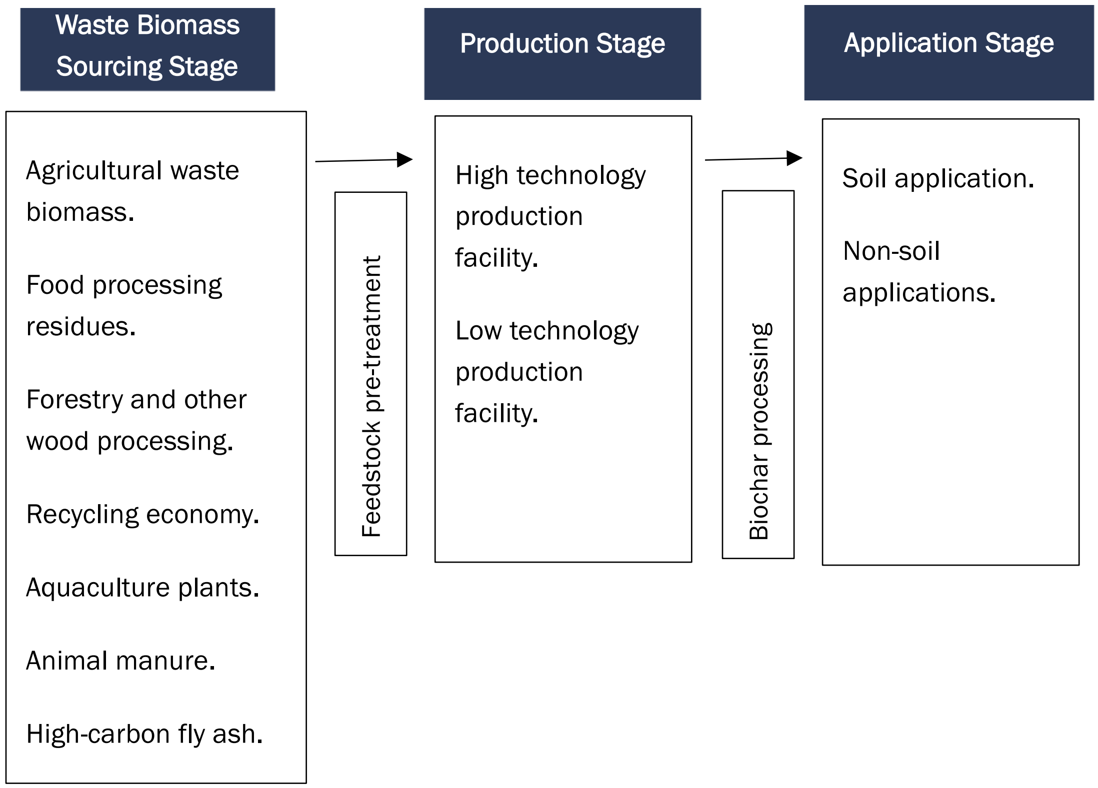
15) Non-soil applications are ineligible under the methodology if there is a loss of more than 50 percent of the carbon measured by dry weight basis (e.g., some activated carbon, due to excessive fossil fuel input, results in a loss of more than 50 percent of the original biochar carbon material and therefore would not be eligible).

5 PROJECT BOUNDARY

The spatial extent of the project boundary (Figure 1) encompasses the geographic area where:

1) Initial waste biomass is sourced;
2) Waste biomass is treated through eligible thermochemical technologies for the purpose of biochar production; and
3) The final application of biochar in soils or non-soils occurs.

Figure 1. Project boundary



The greenhouse gases included in or excluded from the project boundary are shown in Table 2 below.

Table 2. GHG sources included in or excluded from the project boundary

Source		Gas	Included?	Justification/Explanation
Baseline	Feedstock production	CO_2	No	Excluded. Waste biomass is considered renewable per eligibility conditions.
		CH_4	No	
		N_2O	No	
	Feedstock transportation	CO_2	Yes	Only CO_2 considered as per CDM *TOOL12*.
		CH_4	No	Expected to be *de minimis* if distance between sourcing site and production facility is less than 200 kilometers.
		N_2O	No	
		CO_2	No	Possible emissions from decay or combustion of biomass in
		CH_4	No	

	Combustion, aerobic and anaerobic decomposition of feedstocks	N_2O	No	the absence of project activity are excluded. Baseline emissions are assumed to be zero (a conservative assumption).
Project	Feedstock production	CO_2	No	Purpose-grown crops are ineligible, hence there are no emissions from feedstock production. Waste biomass is also considered renewable per the CDM renewable biomass definition (*EB23 Annex 18*) and applicability conditions (see Table 1).
		CH_4	No	
		N_2O	No	
	Pyrolysis, or thermochemical conversion (high technology systems)	CO_2	No	High technology systems require pollution controls (including avoidance of greenhouse gas emissions) and compliance with the technology criteria.
		CH_4	No	
		N_2O	No	
	Pyrolysis, or thermochemical conversion (low technology systems)	CO_2	No	Low technology systems are provided a default emission value based on published literature (Cornelissen et al., 2016).
		CH_4	Yes	
		N_2O	No	
	Electricity and/or fossil fuels consumed during eligible thermochemical process	CO_2	Yes	Included. Emissions associated directly with project activity.
		CH_4	No	Excluded as per provisions of CDM *TOOL03* and *TOOL05*.
		N_2O	No	
	Biochar transportation	CO_2	Yes	Only CO_2 considered as per CDM *TOOL12.*
		CH_4	No	Expected to be *de minimis* if distance between production facility and end-use destination is less than 200 kilometers.
		N_2O	No	
	Pre-treatment of feedstocks (e.g., grinding, drying)	CO_2	Yes	Included. Emissions associated directly with project activity.
		CH_4	No	Excluded as per provisions of CDM *TOOL03* and *TOOL05*.
		N_2O	No	
	Biochar application (e.g., preparation of biochar for final use)	CO_2	Yes	Included. Emissions associated directly with project activity.
		CH_4	No	

		N_2O	No	Excluded as per provisions of CDM *TOOL03* and *TOOL05*.

6 BASELINE SCENARIO

The baseline scenario is that in which, in the absence of the project activity, waste biomass is either left to decay or combusted for purposes other than energy production. The project proponent must provide credible evidence of the baseline scenario of waste biomass. Examples of evidence include but are not limited to annual government records, records of a waste disposal facility, and records of a production facility. In the absence of records, the project proponent must utilize data from existing literature, existing survey data of similar industries in the same region, or conduct its own survey.

7 ADDITIONALITY

The methodology uses a standardized approach for the demonstration of additionality, specifically an activity method, combined with an investment analysis. Project activities that are on the positive list are automatically deemed as additional provided they also demonstrate regulatory surplus and investment barriers as described below. The processing of waste biomass to biochar is the basis for a positive list in this methodology.

Project proponents applying this methodology must determine additionality using the procedure below.

Step 1: Regulatory Surplus

The project proponent must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the most recent version of the *VCS Standard* and *VCS Methodology Requirements*.

Where the project proponent demonstrates regulatory surplus for the project activity, proceed to the next step (positive list). Otherwise, the project activity is not additional.

Step 2: Positive List

The applicability conditions of this methodology represent the positive list. The project proponent must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed to comply with the positive list. The positive list was established using the activity penetration option (Option A in the *VCS Methodology Requirements*). The justification for the activity method and step-by-step explanation is provided in Appendix 1.

Where the project proponent demonstrates that the project activity meets all conditions of the positive list, proceed to the next step (investment analysis). Otherwise, the project activity is not additional.

Step 3: Investment Analysis

Project proponents must follow the procedures and requirements of the most recent version of VCS tool *VT0008 Additionality Assessment* to conduct an investment analysis (Step 3) through either an investment comparison analysis (Option 1) or benchmark analysis (Option 2).

Where the project proponent demonstrates that all conditions of the investment analysis per *VT0008* are met, the proposed project activity is additional. Otherwise, the project activity is not additional and is not eligible for crediting.

8 QUANTIFICATION OF REDUCTIONS AND REMOVALS

Biochar is made from a diverse array of feedstocks and may be produced with a wide variety of technologies. Life cycle assessment (LCA) studies of biochar indicate that the climate benefits of biochar material are highly variable and dependent on many factors. For example, if fossil fuel energy (diesel, gasoline, propane) is used to chip, grind, transport, and dry feedstocks then the GHG benefits of biochar to soil and non-soil applications may be reduced or eliminated (Hedley et al., 2020; Puettmann et al., 2017; Sahoo et al., 2021).

Biochar production systems vary substantially by technology type. During production, there are mix of emissions including carbon dioxide (CO_2), methane (CH_4) and soot. Carbon in biomass is biogenic, and part of the active natural carbon cycle. Because the CO_2 released during biochar production has been recently captured from the atmosphere and stored in plant tissues through photosynthesis, biomass is generally considered carbon neutral. However, emissions of CH_4 and soot have a more powerful global warming potential than CO_2 (Amonette et al 2021).

Eligible high technology production systems involve some form of post-pyrolysis combustion process such as funneling gases through an afterburner (to control CO_2 and CH_4 production), re-injection of gases into the pyrolysis system to increase efficiency of production, and/or using the excess heat produced to generate electricity or other useful purposes. (See Section 3 for complete definitions and eligibility conditions for high technology and low technology production facilities).

Eligible low technology production systems lack the same controls as high-technology production systems; however, project proponents must be able to demonstrate that the low-technology system used is minimizing CH_4 and soot production. Examples of low-technology systems that meet the criteria for minimizing CH_4 and soot are those that harness the natural convection processes to create a combustion zone above the pyrolysis zone, as excess methane may be produced, particularly at start-up and shut-down, that may counter the long-term sequestration benefits of biochar.

Biochar GHG benefits may increase if the syngas or bio-oil produced are used to replace fossil fuel-based (mainly coal) energy sources. However, the reverse may be true if diesel fuel or propane are used during production or processing of feedstocks. Furthermore, the methodology eliminates the use of technologies and feedstocks that lead to health and safety issues, unwanted environmental emissions, and contamination risk in soils.

Biochar materials are most used in soil applications; however, non-soil applications are increasingly common, for example as an asphalt additive or addition to concrete mixes. The total GHG benefits of biochar are therefore influenced both by the type of feedstocks or the technology used, and the potential fossil fuel inputs used to create the final product. GHG inputs may include fossil fuel or electrical energy used for waste biomass pre-treatment or biochar post-treatment.

Given the diversity and complexity of biochar GHG accounting, existing biochar certification programs like the European Biochar Certificate (EBC) and this methodology limit feedstock types, the technologies that may be used to produce biochar, and the type of products that qualify.

The methodology provides a complete, robust, and credible approach to quantifying net GHG removals resulting from biochar management, including at the stages of waste biomass sourcing, production, and application of biochar. Baseline and project emissions consider the flux of CH_4, N_2O, and CO_2 and are defined and quantified in terms of tonnes of CO_2e per year.

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 applied to a long term end-use (in soils or eligible non-soil applications).

8.1 Baseline Emissions

8.1.1 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 for purposes other than energy production in the year that the biochar is made within the project boundary.

Following the CDM *EB23 Annex 18: Definition of renewable biomass*, waste biomass may be classified as renewable. As the decay rate pathway of diverse feedstock types varies by region and time, the methodology defines the default net baseline emission avoidance as zero following a conservative scenario ($BE_{SS,y}$).

8.1.2 Production Stage

In the baseline scenario at production stage, no biochar is produced for the purpose of the project activity and therefore no GHG removals or related emissions are considered.

8.1.3 Application Stage

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 GHG removals or related emissions are considered.

8.2 Project Emissions

8.2.1 Sourcing Stage

At the sourcing stage, the methodology relies on the collection of waste biomass. Therefore, the emissions at the sourcing stage ($PE_{SS,y}$) are set to zero.

8.2.2 Production Stage

In the project scenario, the net GHG balance depends on the organic carbon content at the biochar production stage. Equation 1 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:

$$ER_{PS,y} = \sum_{t}\left(\left(\sum_{k} CC_{t,k,y} \times \frac{44}{12}\right) - \left(\sum_{p} PE_{PS,t,p,y}\right)\right) \quad (1)$$

Where:

$ER_{PS,y}$ = GHG emissions removals at production stage in year *y* (tCO_2e)

$CC_{t,k,y}$ = Organic carbon content on a dry weight basis for biochar type *t* used for application type *k* in year *y* (tonnes)

$PE_{PS,t,p,y}$ = Project emissions at production stage for production of biochar type *t* at production facility *p* in year *y* (tCO_2e)

$\frac{44}{12}$ = Coefficient to convert organic carbon to tCO_2e

As production facilities and technologies differ in terms of potential to measure and report relevant parameters, the methodology provides two options (low and high technology) to derive the respective parameters based on characteristics of the technology used in the production facility. Further, as the biochar produced may be utilized differently in the project activity (both in soil and in non-soil applications), different decay rates must be considered for the respective mass of biochar utilized amongst different applications.

8.2.2.1 Option P.1: High Technology Production Facility

High technology production facilities are defined in Section 3. If any of the conditions in this definition are not met, the production facility must be categorized immediately as a low technology production facility.

For all high technology facilities, organic carbon content of the produced biochar must be derived from material analysis conducted via established laboratory and standardized methods. Project proponents must determine organic carbon content on a dry weight basis using methods described in the latest version of the *IBI Biochar Testing Guidelines* or *EBC Production Guidelines* or other internationally/nationally accredited standards.

Step 1: Estimate organic carbon content ($CC_{t,k,y}$) of biochar for high technology facilities

The total organic carbon content of the produced biochar is the foundation for the GHG calculation. The value is derived from the mass of biochar, its respective organic carbon content, and the decay rate of organic carbon in the biochar taken over a period of 100 years (100-year permanence value which is based on 100-year global warming potential horizon).

The methodology provides default decay values when the biochar is used in soil applications. If the project proponent produces biochar for eligible non-soil applications, the project proponent must either provide a permanence value or utilize conservative default factors (i.e., the soil decay value).

The total organic carbon content on a dry weight basis attributable to the project activity is estimated as follows:

$$CC_{t,k,y} = \sum_{p} \left(M_{t,k,p,y} \times F_{Cp,t,p} \times PR_{de,k} \right) \quad (2)$$

Where:

$CC_{t,k,y}$ = Organic carbon content on a dry weight basis for biochar type *t* used for application type *k* in year *y* (tonnes). Biochar type is based on the feedstock used to produce the biochar.

$M_{t,k,p,y}$ = Mass on a dry weight basis of biochar type *t* for application type *k* produced at the production facility *p* in year *y* (tonnes)

$F_{Cp,t,p}$ = Organic carbon content of biochar type *t* produced in production facility *p* per tonne of biochar, taken on a dry weight basis (percent). For high technology production facilities, this is defined through laboratory material analysis of biochar.

$PR_{de,k}$ = Permanence adjustment factor due to decay of biochar per application type *k* (dimensionless)

$PR_{de,k}$ must be established for soil or non-soil end-use as follows:

- **Soil end-use**: See Table 3 which draws from IPCC (2019) and Woolf *et al*. (2021) and uses production temperatures T_{prod} to determine conservative defaults for $PR_{de,k}$.

Table 3. Default values for $PR_{de,k}$ from Table 4AP.2 of IPCC (2019)

Temperature	Default Value
High temperature pyrolysis and gasification (> 600 °C)	0.89
Medium temperature pyrolysis (450 – 600 °C)	0.80
Low temperature (350 – 450 °C)	0.65

- **Non-soil end-use**: Where no scientifically robust information on the permanence of organic carbon content is available, project proponents must use the soil application decay factor in Table 3. Project proponents may propose any other value for $PR_{de,k}$ as a substitute for the values in Table 3. The project proponent must provide at least one form of evidence of the proposed value of $PR_{de,k}$ following the requirements for default factors established in Section 2.5.2 of the latest version of the *VCS Methodology Requirements*. Where the scientific literature proposes different values of $PR_{de,k}$ the project proponent must adopt the lower value to ensure conservativeness. Documentation and information such as white papers or non-peer reviewed research papers are not considered as credible and appropriate forms of evidence.

Step 2: Estimate project emissions ($PE_{PS,p,y}$) for high technology production facilities

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

$$PE_{PS,p,y} = \left(P_{ED,p,y} + P_{EP,p,y} + P_{EC,p,y}\right) \times \frac{\sum_t \sum_k M_{t,k,p,y}}{M_{p,y}} \quad (3)$$

Where:

$PE_{PS,p,y}$ = Project emissions at the production stage for production of biochar at production facility *p* in year *y* (tCO_2e)

$P_{ED,p,y}$ = Emissions associated with the pre-treatment of waste biomass at production facility *p* in year *y* (tCO_2e)

$P_{EP,p,y}$ = Emissions associated with the conversion of waste biomass into biochar at production facility *p* in year *y* (tCO_2e)

$P_{EC,p,y}$ = Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis at production facility *p* in year *y* (tCO_2e)

$M_{t,k,p,y}$ = Mass on a dry weight basis of biochar type *t* for application type *k* produced at production facility *p* in year *y* (tonnes)

$M_{p,y}$ = Total mass of biochar on a dry weight basis produced in production facility *p* in year *y* (tonnes)

Determining $P_{ED,p,y}$: Emissions associated with pre-treatment of feedstock at production facility p in year y

Energy consumption for any necessary pre-treatment of waste biomass must be accounted for. This may include feedstock preparation (e.g., feedstock agglomeration, homogenization, pelletizing) either inside the production facility or in field preparation, drying of wet waste biomass, or other processes. If the energy source is renewable, $P_{ED,p,y}$ must be zero. Otherwise, it must be calculated as follows:

$$P_{ED,p,y} = P_{EDE,p,y} + P_{EDF,p,y} \quad (4)$$

Where:

$P_{ED,p,y}$ = Emissions associated with pre-treatment of feedstock at production facility *p* in year *y* (tCO_2e)

$P_{EDE,p,y}$ = Emissions associated with use of grid-connected electricity utilized for pre-treatment of waste biomass at production facility *p* in year *y* (tCO_2e). $P_{EDE,p,y}$ must be calculated as per the provisions of CDM *TOOL05: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation.*[17]

$P_{EDF,p,y}$ = Emissions associated with combustion of fossil fuels utilized for pre-treatment of waste biomass at production facility *p* in year *y* (tCO_2e). $P_{EDF,p,y}$ must be calculated as per the provisions of CDM *TOOL03: Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*[18]

Determining $P_{EP,p,y}$: Emissions associated with the thermochemical process at production facility p in year y for high technology facilities

Processing of waste biomass refers to the pyrolysis process, which fixes the organic carbon from biomass into permanent carbon in biochar. The value $P_{EP,p,y}$ accounts for the emissions

[17] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v3.0.pdf
[18] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v3.pdf

from pyrolysis, which are emitted into the atmosphere. In alignment with eligibility requirements for high technology production facilities, net emissions are considered *de minimis.*[19] Therefore,

$$P_{EP,p,y} = 0$$

Where:

$P_{EP,p,y}$ = Emissions associated with the conversion of waste biomass into biochar at production facility *p* in year *y* (tCO_2e)

Determining $P_{EC,p,y}$: Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis at production facility p in year y

When external energy is required to initiate and maintain the pyrolysis reactor, it must be accounted as project emissions. If the source of auxiliary energy is renewable, $P_{EC,p,y}$ must be zero. Otherwise, it must be calculated as follows:

$$P_{EC,p,y} = P_{ECE,p,y} + P_{ECF,p,y} \quad (5)$$

Where:

$P_{EC,p,y}$ = Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis at production facility *p* in year *y* (tCO_2e)

$P_{ECE,p,y}$ = Emissions associated with use of grid-connected electricity utilized for starting the reactor at production facility *p* in year *y* (tCO_2e). $P_{ECE,p,y}$ must be calculated as per CDM *TOOL05: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation.*

$P_{ECF,p,y}$ = Emissions associated with combustion of fossil fuels utilized for starting the reactor at production facility *p* in year *y* (tCO_2e). $P_{ECF,p,y}$ must be calculated as per the provisions of CDM *TOOL03: Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*

8.2.2.2 Option P.2: Low Technology Production Facility

Technologically less advanced production facilities usually have lower efficiency of converting organic carbon and often lack emissions controls during the production process. However, these also play an important role in carbon removal associated with production and use in certain cases, e.g., smallholder and farm level settings. Low technology production facilities are all production facilities that do not meet the conditions defined under high technology production.

[19] Following condition (a) of the definition of a high technology production facility, the ability to combust or recover pyrolysis gases, thereby limiting the emissions of methane to the atmosphere.

Step 1: Estimate organic carbon content ($CC_{t,k,y}$) of biochar for low technology facilities

As with high technology settings, in low technology settings the total organic carbon content of the produced biochar is the foundation of the GHG calculations. The value is derived from the mass of biochar, its respective organic carbon content, and the decay rate of organic carbon in the biochar taken over a period of 100 years (100-year permanence value).

For low technology production facilities, a conservative approach has been selected, related to the organic carbon content of biochar (F_{Cp}), based on feedstock type and heating temperature as provided in Table 4 which draws from IPCC *Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development.*[20] In Equation 6, permanence (the fraction of carbon in the biochar remaining after 100 years) is included.

$$CC_{t,k,y} = \sum_{p} \left(M_{t,k,p,y} \times F_{Cp,t,p} \times PR_{de,k} \right) \quad (6)$$

Where:

$CC_{t,k,y}$ = Organic carbon content on a dry weight basis for biochar type *t* used for application type *k* in year *y* (tonnes). Biochar type is based on the feedstock used to produce the biochar.

$M_{t,k,p,y}$ = Mass on a dry weight basis of biochar type *t* for application type *k* produced at production facility *p* in year *y* (tonnes)

$F_{Cp,t,p}$ = Organic carbon content of biochar type *t* produced in production facility *p* per tonne of biochar, taken on a dry weight basis (percent). For low technology production facilities. this is determined through laboratory material analysis of biochar where possible. Otherwise, values are obtained from Table 4 per type of feedstock. Where feedstocks are mixed, the most conservative value of the relevant feedstocks must be used.

$PR_{de,k}$ = Permanence adjustment factor due to decay of biochar to be defined for application type *k* (dimensionless). Biochar is subject to natural decay rate when used in soil applications such as in agriculture, forests, croplands, or grasslands. Many low technology production facilities do not measure the temperature at biochar production. A default value of 0.56[21] must be used where pyrolysis temperature is unknown. This follows a conservative approach for carbon permanence.

Determining F_{Cp}: Values for organic carbon content per tonne of biochar per production type

The organic carbon content must be determined in a qualified laboratory following *IBI Biochar Testing Guidelines* or *EBC Production Guidelines* on the production of biochar. However, project

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

[21] Value of 0.56 is used where the temperature of pyrolysis is not measured, recorded and reported. Default value taken from Figure 4Ap.1(b) in IPCC (2019) *Appendix 4: Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development*. Available at https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch02_Ap4_Biochar.pdf

proponents using low technology production facilities may adopt values from IPCC (2019) for different feedstocks and production types (Table 4). Further, project proponents may also refer to other scientific literature such as Woolf et al. (2021).

Table 4. Values for organic carbon content in biochar from Table 4AP.1 of IPCC (2019)

Feedstock	Production Process	Values for F_{Cp}
Animal manure	Pyrolysis	0.38
	Gasification	0.09
Wood	Pyrolysis	0.77
	Gasification	0.52
Herbaceous (grasses, forbs, leaves; excluding rice husks and rice straw)	Pyrolysis	0.65
	Gasification	0.28
Rice husks and rice straw	Pyrolysis	0.49
	Gasification	0.13
Nut shells, pits, and stones	Pyrolysis	0.74
	Gasification	0.40
Biosolids (paper sludge)	Pyrolysis	0.35
	Gasification	0.07

Step 2: Estimate project emissions $PE_{PS,p,y}$ for low technology production facilities

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

$$PE_{PS,p,y} = \left(P_{ED,p,y} + P_{EP,p,y} + P_{EC,p,y}\right) \times \frac{\sum_t \sum_k M_{t,k,p,y}}{M_{p,y}} \quad (7)$$

Where:

$PE_{PS,p,y}$ = Project emissions at the production stage at production facility *p* in year *y* (tCO_2e)

$P_{ED,p,y}$ = Emissions associated with the pre-treatment of waste biomass at production facility *p* in year *y* (tCO_2e)

$P_{EP,p,y}$ = Emissions associated with the conversion of waste biomass into biochar at production facility *p* in year *y* (tCO_2e)

$P_{ED,p,y}$ = Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis at production facility *p* in year *y* (tCO_2e)

Determining $P_{ED,p,y}$: Emissions associated with the pre-treatment of feedstock at production facility p in year y for low technology facilities

Energy consumption for necessary pre-treatment of waste biomass must be accounted for. This may include feedstock preparation (e.g., feedstock agglomeration, homogenization, pelletizing) either inside the production facility or in field preparation, drying of wet biomass, or other processes. If the energy source is renewable, $P_{ED,p,y}$ must be zero. Otherwise, it must be calculated as follows:

$$P_{ED,p,y} = P_{EDE,p,y} + P_{EDF,p,y} \tag{8}$$

Where:

$P_{ED,p,y}$ = Emissions associated with pre-treatment of feedstock at production facility *p* in year *y* (tCO_2e)

$P_{EDE,p,y}$ = Emissions associated with grid-connected electricity utilized for pre-treatment of waste biomass at production facility *p* in year *y* (tCO_2e). $P_{EDE,p,y}$ must be calculated as per the provisions of CDM *TOOL05: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation.*

$P_{EDF,p,y}$ = Emissions associated with combustion of fossil fuels utilized for pre-treatment of waste biomass at production facility *p* in year *y* (tCO_2e). $P_{EDF,p,y}$ must be calculated as per the provisions of CDM *TOOL03: Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*.

Determining $P_{EP,p,y}$: Emissions associated with the thermochemical process at production facility p in year y for low technology facilities

In the absence of direct emission measurements that can reliably measure and report project emissions, data from peer-reviewed literature must be used in the following equation:

$$P_{EP,p,y} = \sum_{k}\sum_{t}\left(F_e \times GWP_{CH4} \times M_{t,k,p,y}\right) \tag{9}$$

Where:

$P_{EP,p,y}$ = Emissions associated with the conversion of waste biomass into biochar at production facility p in year y (tCO_2e)

F_e = Average methane emissions from producing one tonne of biochar in year y (tCH_4/tonne). Values from Table 3 in Cornelissen et al. (2016)[22] may be used based on the corresponding kiln type (i.e., low technology production facility type). Where the kiln type is not listed a default average emission factor of 0.049 t CH_4/tonne may be conservatively used based on the value for traditional kilns

[22] Cornelissen, G., Pandit, N. R., Taylor, P., Pandit, B. H., Sparrevik, M., & Schmidt, H. P. (2016). Emissions and char quality of flame curtain "kon tiki" kilns for farmer-scale charcoal/biochar production. *PLoS ONE*, *11*(5), e0154617. https://doi.org/10.1371/journal.pone.0154617

since simple low-cost technologies are known to emit higher levels of CH_4.[23] Project proponent may propose more appropriate values based on scientific studies, research papers or any other credible documentation and/or information related to the utilized production technology.

GWP_{CH4} = Global warming potential of methane. Use value referenced in the latest version of the *VCS Standard*

$M_{t,k,p,y}$ = Mass on a dry weight basis of biochar type t and application type k produced at production facility p in year y (tonnes)

Determining $P_{EC,p,y}$: Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis

When external energy is required to initiate and maintain the pyrolysis reactor, it must be accounted as project emissions. If the source of auxiliary energy is renewable, $P_{EC,p,y}$ must be zero. Otherwise, it must be calculated as follows:

$$P_{EC,p,y} = P_{ECE,p,y} + P_{ECF,p,y} \tag{10}$$

Where:

$P_{EC,p,y}$ = Emissions due to the utilization of auxiliary energy for the purpose of pyrolysis at production facility p in year y (tCO_2e)

$P_{ECE,p,y}$ = Emissions associated with use of grid-connected electricity utilized for starting the reactor at production facility p in year y (tCO_2e). $P_{ECE,p,y}$ must be calculated as per CDM *TOOL05: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation.*

$P_{ECF,p,y}$ = Emissions associated with combustion of fossil fuels utilized for starting the reactor at production facility p in year y (tCO_2e). $P_{ECF,p,y}$ must be calculated as per the provisions of CDM *TOOL03: Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion.*

8.2.3 Application Stage

In the project scenario, emissions associated with processing and utilizing biochar after its production will have a potential impact on the overall emission removal potential. Equation 11 determines the GHG emissions at the application stage.

$$PE_{AS,y} = \sum_{k}\sum_{t}(E_{P,t,k,y} + E_{ap,t,k,y}) \tag{11}$$

[23] Woolf, D., Lehmann, J., Ogle, S., Kishimoto-Mo, A. W., McConkey, B., & Baldock, J. (2021). Greenhouse gas inventory model for biochar additions to soil. *Environmental Science & Technology*, *55*(21), 14795-14805.

Where:

$PE_{AS,y}$ = GHG emissions at application stage in year y (tCO_2e)
$E_{P,t,k,y}$ = Emissions from processing of biochar type t for application type k in year y (tCO_2e)
$E_{ap,t,k,y}$ = Emissions from utilization of biochar type t for application type k in year y (tCO_2e)

Determining $E_{P,k,y}$: Emissions associated with processing of biochar for application type k

In a scenario where biochar undergoes further processing (e.g., sizing, grinding, sifting) before final soil or non-soil application, project proponents must quantify energy-related emissions associated with grinding and other mechanical treatment of biochar. This methodology does not account for emissions related to the production or generation of materials with which biochar is mixed/infused for non-soil application (e.g., biochar-amended concrete or biochar-amended asphalt).

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

$$E_{P,k,y} = P_{EPE,k,y} + P_{EPF,k,y} \quad (12)$$

Where:

$E_{P,k,y}$ = Emissions from processing of biochar for application type k in year y (tCO_2e)
$P_{EPE,k,y}$ = Emissions associated with grid-connected electricity utilized for processing biochar for application type k in year y (tCO_2e). $P_{EPE,k,y}$ must be calculated as per the provisions of CDM *TOOL05: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation*.
$P_{EPF,k,y}$ = Emissions associated with combustion of fossil fuels utilized for processing of biochar for application type k in year y (tCO_2e). $P_{EPF,k,y}$ must be calculated as per the provisions of CDM *TOOL03: Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*.

Where there is no processing of biochar, $E_{P,k,y}$ must be zero.

Determining $E_{ap,k,y}$: Emissions associated with utilization of biochar for application k

$E_{ap,k,y}$ corresponds to emissions during the utilization of biochar for application type k in year y. GHG emissions resulting from fossil fuel combustion or mixing of biochar with fertilizer products are considered negligible. Thus, $E_{ap,k,y}$ is zero.[24]

8.3 Leakage Emissions

In the case of biochar use, leakage emissions are primarily attributed to transport emissions at various stages of the biochar life cycle. Emissions due to activity-shifting leakage or biomass

[24] As per CDM *AR-ACM0003 Afforestation and reforestation of lands except wetlands*. Available at https://cdm.unfccc.int/methodologies/DB/C9QS5G3CS8FW04MYYXDF0QDPXWM4OE

diversion are considered zero, as currently only waste biomass is eligible for biochar production. Quantification of leakage emissions are as follows:

$$LE_y = LE_{as,y} + LE_{bd,y} + LE_{ts,y} + LE_{tap,y} \quad (13)$$

Where:

LE_y = Total leakage emissions in year y (tCO_2e)

$LE_{as,y}$ = Leakage due to activity shift in year y (tCO_2e). Leakage due to activity shift is zero as use of purposely grown biomass for production of biochar is currently not allowed.

$LE_{bd,y}$ = Leakage due to biomass diversion in year y (tCO_2e). Leakage due to biomass (waste/residue) diversion is considered negligible since only biomass which would have been combusted or left to decay is utilized for biochar production.

$LE_{ts,y}$ = Leakage emissions from transportation of waste biomass from sourcing to biochar production facility in year y (tCO_2e). As per CDM *TOOL16: Project and leakage emissions from biomass*,[25] GHG emissions must be accounted for only if transportation distance is more than 200 km. Project proponent must use CDM *TOOL12: Project and leakage emissions from transportation of freight*[26] to calculate $LE_{ts,y}$

$LE_{tap,y}$ = Leakage emissions from transportation of biochar from the production facility to the site of end application in year y (tCO_2e). As per CDM *Tool 16: Project and leakage emissions from biomass*, GHG emissions must be accounted for only if transportation distance is more than 200 km. Project proponent must use CDM *TOOL12: Project and leakage emissions from transportation of freight* to calculate $LE_{tap,y}$.

Determining $LE_{ts,y}$: Emissions related to leakage from transportation of waste biomass from sourcing to biochar production facility

Project emissions from transportation of waste biomass from the place of origin to the biochar production site may have the following components:

i. Transport emissions from field to the production facility

$LE_{ts,y}$ is considered zero if transportation distance (to and from—round trip) is less than 200 km. Project emissions from transportation of biochar must be calculated as per the latest version of CDM *TOOL12: Project and leakage emissions from transportation of freight*.

Determining $LE_{tap,y}$: Emissions related to leakage from transportation of biochar from production facility to site of end-use application

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

i) Transport emissions from biochar facility to processing facility; AND

[25] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-16-v4.pdf
[26] Available at https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.1.0.pdf

ii) Transport emissions from processing facility to end-use site;

OR

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

$LE_{tap,y}$ is considered zero if transportation distance (to and from—round trip) is less than 200 km. Project emissions from transportation of biochar must be calculated as per the latest version of CDM *TOOL12: Project and leakage emissions from transportation of freight.*

8.4 Reversal Risk Mitigation

After the production of biochar, there exist sources of risk that could lead to reversals, i.e., loss of sequestered carbon in the biochar that has previously been verified. Prior to use in soil or non-soil applications, the produced biochar may be intentionally combusted for use as a fuel source. This risk is wholly mitigated by the requirement that biochar is used only in approved soil or non-soil applications (as per applicability conditions 5 and 7) with required end-use application monitoring (see Section 9.3). During and after use in soil or non-soil applications, there exist various natural and non-natural reversal risks which are mitigated in this methodology as discussed in the following sections.

8.4.1 Natural Risks

When biochar is utilized for soil applications, natural risks are associated with climatic and geological factors such as fires, floods, wind, and precipitation, among others. Of these, fire represents the most significant risk by far since it can result in the immediate loss of sequestered carbon due to the combustion of biochar. On the other hand, erosion by wind or water (flooding) poses the risk of transport of biochar outside of the project boundary and beyond the control of the project proponent.

All of these natural risks are substantially mitigated through the incorporation of the biochar into the soil subsurface, ideally to a minimum of 10 cm depth. However, projects may also apply biochar on the soil surface. In this case, the risk of loss due to fire or erosion (wind or water) is heightened since the biochar remains exposed on the soil surface. Risks can be mitigated by mixing biochar with other amendments such as manures and composts prior to surface application which reduces biochar's combustibility and erodibility (IBI, 2010). Hence, for surface application biochar must be mixed with other substrates according to applicability condition 5. With these mitigation approaches, risks of losses for soil applications are greatly reduced as substantiated by the scientific literature:

- **Loss due to combustion**: The nature of changes in soil during and after fires depends on both the temperatures reached at different soil depths and the degree of heating that the different soil components may withstand before being altered (González-Pérez et al., 2004). Temperatures during fires decrease dramatically with soil depth (Enninful & Torvi, 2008) and most loss of soil organic matter during wildfires is limited to the very top layer of soil (Boerner, 2009; Majder-Łopatka, 2019). Except for high-intensity wildfires in forest settings, the heat generated during a fire does not typically combust the organic matter in soils, particularly in agricultural settings. Furthermore, with subsoil application, studies have shown that biochar increases the resilience of the soil to different abiotic and biotic stressors. For example, application of biochar increases the water retention capacity of the soil (Głąb et al., 2016), thus itself acting as a risk mitigation against loss due to combustion. Thus, when biochar is applied into the soil subsurface the risk of its combustion decreases significantly, and when applied in combination with amendments to the soil surface its combustibility is further reduced (IBI, 2010).

- **Loss due to transport outside the project boundary**: Studies have shown that when biochar is applied into soils, it may reduce water runoff and overall soil erosion (Gholami et al., 2019; Lee et al., 2015) and thus transport of biochar outside the project boundary. Similarly, risk of wind erosion is greatly reduced by incorporating biochar into the subsurface of soil. Even so, some biochar could still be transported outside the project boundary due to erosion, but this does not directly imply that the sequestered carbon in the biochar will be lost to the atmosphere. Rather, biochar may be transported via overland flow or wind into waterways and eventually deposited into sediments where it is likely to persist for as long as or longer than the soil where it was originally applied.

When biochar is used for non-soil applications natural risks are considered minimal. Lee et al. (2019) have shown that when biochar is used in bio-composites such as those with inorganic clay, biochar reduces thermal conductivity, thus increasing the thermal resistance of the material to combustion. When biochar is incorporated into building materials such as mineral plasters, gypsum, or clay, the material is not prone to incineration; rather the biochar is protected against biological and chemical decay (Gupta & Kua, 2019). For this reason, other established biochar accounting programs (i.e., EBC) indicate that when biochar is incorporated into building materials such as concrete, lime plaster, gypsum or clay, combustion is nearly impossible (EBC, 2021).

8.4.2 Non-Natural Risks

Non-natural risks are those associated with project management, financial viability (for example, insufficient funds to complete the project cycle), government policies, or community and stakeholder resistance, among others.

- **Social risks** (i.e., community resistance or non-acceptability) are considered minimal since the methodology considers only waste biomass as an eligible feedstock for biochar production. Therefore, competing uses for feedstock will not exist and communities may be expected to find new livelihood and revenue stream opportunities from the introduction of biochar projects.

- **Project management and financial risks** are considered minimal due to the independence of annual removals achieved from project activities. It is possible that the project proponent may go bankrupt at some point after verification and issuance of carbon credits, or a project proponent may terminate the project before the end of the crediting period. In that event, non-natural risk due to project and financial viability are considered to have a minimal impact on project claims from the previous year because once utilized at the application stage (soil or non-soil applications), biochar will remain as a sequestered material. For example, biochar applied to agricultural soils will continue to act as a carbon sink irrespective of the fate of the project and/or continuation of biochar application in the case of project proponent bankruptcy. In the case of a non-soil application (e.g., biochar infused in cement), the carbon sink function will continue irrespective of activities in subsequent years (Akinyemi & Adesina, 2020). GHG benefits associated with biochar applied in year one of the project are not dependent on continuation of application of biochar in year two.

Given the mitigation measures for natural and non-natural risks in both soil and non-soil applications described above, this methodology considers reversal risk of verified biochar carbon sequestration negligible.

8.5 Net Reductions and Removals

Emission reductions at the sourcing stage are calculated as follows:

$$ER_{SS,y} = BE_{SS,y} - PE_{SS,y} \quad (14)$$

Where:

$ER_{SS,y}$ = GHG emission reductions at sourcing stage in year y (tCO_2e)

$BE_{SS,y}$ = Baseline emissions at sourcing stage in year y; conservatively assumed default value of zero (tCO_2e)

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

Net GHG emission reductions and removals are calculated as follows:

$$ER_y = ER_{SS,y} + ER_{PS,y} - PE_{AS,y} - LE_y \quad (15)$$

Where:

ER_y = Net GHG emissions reductions and removals in year *y* (tCO_2e)

$ER_{SS,y}$ = GHG emission reductions at sourcing stage in year *y* (tCO_2e)

$ER_{PS,y}$ = GHG emission removals at production stage in year *y* (tCO_2e)

$PE_{AS,y}$ = GHG emissions at application stage in year *y* (tCO_2e)

LE_y = Total leakage emissions in year *y* (tCO_2e)

9 MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	$F_{Cp,t,p}$
Data unit	Percent (%)
Description	Organic carbon content of biochar for each biochar type *t* produced in production facility *p* per tonne of biochar, on a dry weight basis
Equations	Equation 2, Equation 6
Source of data	At validation stage, both types of production facility may use default values provided in Table 4 and taken from IPCC (2019) *Appendix 4: Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development* or may provide peer-reviewed data.
Value applied	For high technology production facilities, value is determined from a material analysis. For low technology production facilities where F_{Cp} cannot be monitored, use values from Table 4.
Justification of choice of data or description of measurement methods and procedures applied	IPCC (2019) states global estimates of organic carbon content of biochar as a function of feedstock and heating temperature, therefore the value must be calculated based on a biochar material analysis or using default values (EBC, 2022).
Purpose of data	Calculation of project emissions
Comments	None

Data / Parameter	$PR_{de,k}$
Data unit	Dimensionless
Description	Permanence adjustment factor due to decay of biochar (dimensionless) to be defined for application type *k*
Equations	Equation 2, Equation 6
Source of data	EBC (2020) *Guidelines for the Certification of Biochar Based Carbon Sinks* IPCC (2019) *Appendix 4: Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development* Scientific studies, research papers, other credible documentation
Value applied	For high technology production facilities, project proponents must use Table 4 in this methodology.

	For low technology production facilities, project proponents must use a conservative default value of 0.56 (Figure 4Ap.1 in IPCC, 2019)
Justification of choice of data or description of measurement methods and procedures applied	Biochar is a stable material that may be used for soil and non-soil applications. As a material, it has a decay rate that must be accounted for. This parameter considers how much of the original carbon will remain in the biochar and may be accounted as a carbon sink after its final application. IPCC and EBC are internationally recognized and the data provided in the guidelines are peer reviewed.
Purpose of data	Calculation of project emissions
Comments	None

Data / Parameter	GWP_{CH4}
Data unit	tonnes CO_2e per tonne CH_4 (t CO_2e/t CH_4)
Description	Global warming potential of methane
Equations	Equation 9
Source of data	*IPCC Fifth Assessment Report*[27]
Value applied	28
Justification of choice of data or description of measurement methods and procedures applied	The *VCS Standard* requires that CH_4 is converted to CO_2e using the 100-year global warming potential derived from the most recent IPCC Assessment Report.
Purpose of data	Calculation of project emissions
Comments	N/A

Data / Parameter	F_e
Data unit	tonnes CH_4 per tonne biochar (t CH_4/t)
Description	Average methane emissions from producing one tonne of biochar in year *y* in a low technology production facility
Equations	Equation 9
Source of data	Table 3 in Cornelissen et al. (2016)
Value applied	0.049 tCH_4/tonne of biochar produced for unknown low technology production facility (i.e., kiln) type

[27] Intergovernmental Panel on Climate Change (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. R. K. Pachauri & L. A. Meyer (Eds.). IPCC. Available at https://www.ipcc.ch/report/ar5/syr/

	If kiln type is known and represented in Table 3, corresponding values may be used for F_e
Justification of choice of data or description of measurement methods and procedures applied	Methane emissions must be accounted for as methane is the main gas released from low technology production facilities. The value of methane emissions per tonne of biochar produced in a low technology production facility is derived from peer reviewed literature and deemed conservative.
Purpose of data	Calculation of project emissions
Comments	Use GWP_{CH4} value as described in the latest version of the *VCS Standard*

Data / Parameter	Biomass categories and quantities used for selection of the baseline scenario and production of biochar utilized in the project activity
Data unit	tonnes (t) on dry basis
Description	- Category (e.g., bagasse, rice husks, empty fruit bunches, agricultural waste); - Source (e.g., produced on-site, obtained from an identified biomass residue producer, obtained from a biomass residue market); - Fate in the absence of the project activity (see Appendix 2 for detailed procedures); - Documentation with sustainability criteria compliance for respective category as indicated in Table 1. Explain and document transparently in the project description which quantities of which biomass categories are used in which installation(s) under the project activity and what their baseline scenario is. Include the quantity of each category of biomass (tonnes). For selection of the baseline scenario, at validation, an ex-ante estimation of these quantities should be provided.
Equations	-
Source of data	On-site assessment of biomass categories and quantities
Description of measurement methods and procedures to be applied	Use weight meters. Adjust by moisture content in order to determine the quantity of dry biomass.
Frequency of monitoring/recording	Data monitored continuously and aggregated at least monthly
QA/QC procedures to be applied	Cross-check the measurements with an annual energy balance that is based on purchased quantities and stock changes.

Purpose of data	Monitoring of eligible biomass categories and quantities used as feedstock for production of biochar
Calculation method	N/A
Comments	None

9.2 Data and Parameters Monitored

Data / Parameter	$M_{p,y}$
Data unit	tonnes (t)
Description	Total mass on a dry weight basis of biochar produced in production facility p in year y
Equations	Equation 3
Source of data	On-site measurements
Description of measurement methods and procedures to be applied	Use weighing scales. Adjust the moisture content in order to determine quantity of dry weight biomass.
Frequency of monitoring/recording	Monitored continuously, recorded at least monthly
QA/QC procedures to be applied	Calibrate weighing scales as per manufacturer's specifications or at least every three years. Amount of biochar applied must be cross-checked with sales receipts and/or invoices or any other equivalent third-party evidence.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Each biochar quantity should be weighed separately for each biochar type t and each biochar production facility p. Moisture content should be monitored for each batch of biochar type t. The weighted average should be calculated for each monitoring period.

Data / Parameter	$M_{t,k,p,y}$
Data unit	tonnes (t)
Description	Mass on dry weight basis of biochar type *t* and application type *k* produced at production facility *p* in year *y*
Equations	Equation 2, Equation 3, Equation 6, Equation 9
Source of data	On-site measurements

Description of measurement methods and procedures to be applied	Use weighing scales. Adjust the moisture content in order to determine quantity of dry weight biomass.
Frequency of monitoring/recording	Monitored continuously, recorded at least monthly
QA/QC procedures to be applied	Calibrate weighing scales as per manufacturer's specifications or at least every three years. Amount of biochar applied must be cross-checked with sales receipts and/or invoices or any other equivalent third-party evidence.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	Each biochar quantity should be weighed separately for each biochar type t and each biochar production facility p. Moisture content should be monitored for each batch of biochar type t. The weighted average should be calculated for each monitoring period.

Data / Parameter	$F_{Cp,t,p}$
Data unit	Percent (%)
Description	Organic carbon content of biochar for each biochar type t produced in production facility p per tonne of biochar, taken on a dry weight basis
Equations	Equation 2, Equation 6
Source of data	Laboratory material analysis
Description of measurement methods and procedures to be applied	Laboratory material analysis following *IBI Biochar Testing Guidelines* or *EBC Production Guidelines* or other relevant guidelines on the production of biochar is required to determine F_{Cp} values on a regular basis.
Frequency of monitoring/recording	In alignment with the *IBI Biochar Testing Guidelines* testing must be performed: • Annually; or • After a material change in feedstock; or • After a material change in thermochemical production parameters; whichever is more frequent.
QA/QC procedures to be applied	Laboratory must be accredited and/or approved by the relevant national agency to conduct required material analysis.
Purpose of data	Calculation of project emissions
Calculation method	N/A

Comments	For low technology production, where organic carbon content of biochar cannot be sampled in alignment with the required standards, use the conservative values indicated in Table 4 as default values.

Data / Parameter	T_{prod}
Data unit	degrees Celsius (°C)
Description	Average annual production temperature during pyrolysis
Equations	N/A
Source of data	Data records of biochar production
Description of measurement methods and procedures to be applied	Use instruments with recordable electronic signal (digital or analog). Examples include thermocouple, thermoresistor or any other instrument as prescribed by relevant international or national standards.
Frequency of monitoring/recording	Continuous, aggregated to annual averages
QA/QC procedures to be applied	Periodic calibration against a primary device provided by an independent accredited laboratory is mandatory. Calibration and frequency of calibration is according to manufacturer's specifications.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	The average production temperature at which pyrolysis occurs will determine the stability of the biochar. It will be used to categorize the biochar in accordance with Table 3 to determine PR_{de}. For low-technology production where measuring the temperature is not feasible, or sampling of the organic carbon content of the biochar according to the required standards is not possible, use the conservative values indicated in Equation 7 as default values.

Data / Parameter	$H:C_{org}$
Data unit	Dimensionless
Description	Ratio of hydrogen to organic carbon
Equations	N/A
Source of data	Laboratory analysis
Description of measurement methods and procedures to be applied	Laboratory analysis following *IBI Biochar Testing Guidelines* or *EBC Production Guidelines*

Frequency of monitoring/recording	Each batch of biochar produced at the production facility
QA/QC procedures to be applied	Laboratory must be accredited and/or approved by the relevant national agency to conduct required material analysis.
Purpose of data	Used to demonstrate eligibility for use in soil applications. As per applicability condition 10, biochar used in soils must have an $H:C_{org}$ of less than 0.7.
Calculation method	N/A
Comments	None

Data / Parameter	WS_P
Data unit	Percent (%)
Description	Fraction of total waste heat utilized at biochar production facility *p*
Equations	N/A
Source of data	On-site records, estimated data from waste heat consumption in the facility
Description of measurement methods and procedures to be applied	As per most recent version of CDM *TOOL09: Determining the Baseline Efficiency of Thermal or Electric Energy Generation System*.
Frequency of monitoring/recording	Annual
QA/QC procedures to be applied	As per most recent version of CDM *TOOL09*: *Determining the Baseline Efficiency of Thermal or Electric Energy Generation System*.
Purpose of data	To qualify and ensure that biochar is produced in a high technology production facility.
Calculation method	N/A
Comments	See the definition of high technology production facility for the conditions that must be met for the production facility to qualify as high technology.

9.3 Description of the Monitoring Plan

The main objective of the monitoring is to prove the carbon sink from the final application of biochar and to quantify the emissions resulting from the project scenario during the project crediting period, prior to each verification. The project proponent must establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement stage outlining responsibility and timing requirements (e.g., mass of biochar produced and production date).

The project proponent must develop and apply a monitoring plan according to ISO 14064-2 principles of transparency and accuracy that allows the quantification and proof of GHG emissions at the three stages covered by this methodology: sourcing, production, and application.

Due to the complexity and uniqueness of monitoring biochar end-use applications, this section provides a list of resources that project developers may use for monitoring. Providing instruction on the type of monitoring system to use is outside the scope of this methodology.

Geographic information

To prevent double counting of carbon benefits (e.g., carbon credits accounting for both the soil organic carbon pool and for biochar application in soils), the final location of the site where the carbon sink is created must be known. This applies to soil and non-soil applications. As per *VCS Standard* rules, project location for non-AFOLU projects must be as follows: where there are a large number of project activity instances (e.g., fields where biochar will be applied to soils), at least one geodetic coordinate must be provided, together with sufficient additional geographic information (with respect to the location of the instances) to enable sampling by the validation/verification body.

Application type

For soil application, monitoring requires that all projects with soil end-use specify where the biochar has been applied. As mentioned above, project proponent must provide at least one geodetic coordinate for each instance.

For non-soil applications such as concrete or asphalt, the proof of application ends when the biochar is mixed into long-lasting material. Similar to soil application, the project proponent must provide at least one geodetic coordinate for each instance of the place where biochar was applied to or mixed to. Appropriate monitoring methods (e.g., statistically validated lifetime averages) must be used to ensure the proportion of the material containing biochar is still in use and has not been converted to CO_2.

Monitoring tools

To ensure that biochar would be applied either in soil or non-soil applications, the project proponent must verify that the application takes place using, for example, the following: tracking records, mobile or desktop applications, QR code, blockchain technology, non-fungible token (NFT), GPS use-location coordinates, or any other tracking software that allows for chain of custody record generation from the sourcing stage (i.e., waste biomass origin) to the end-use application of biochar in soils.

Where measurement and monitoring equipment is used during biochar production (e.g., to measure temperature), the project proponent must ensure that the equipment is calibrated according to current best practice (e.g., relevant industry standards, manufacturer specifications, or device supplier). Where a project proponent carries out a material laboratory analysis of biochar, they must ensure it follows international standards such as the most recent version of the *IBI Biochar Testing Guidelines* or *EBC Production Guidelines*

Data management

Quantitative sources of information and record keeping practices on biochar sourcing, production, and application stages must be chosen. The project proponent must have an offsite electronic back-up of all logged data. For example, monitoring data must provide information on biochar batch number, quantity, type of application, geographic location, and proof that the biochar will not be burned or pyrolyzed. The project proponent must provide access to all platforms and make all evidence available to the third-party verifier.

The monitoring plan must contain as a minimum the following information:

1) A description of each monitoring task to be undertaken, and the technical requirements therein;
2) Type of technology used to produce biochar;
3) Written logs of operation and maintenance of the project system;
4) Roles, responsibilities, and capacity of monitoring team and management.

QA / QC

Project proponents must also develop a QA/QC plan to add confidence that all measurements and calculations have been made properly. QA/QC measures that may be implemented include, but are not limited to:

1) Protecting monitoring equipment (sealed meters and data loggers) where applicable;
2) Protecting records of monitored data (hard copy and electronic storage);
3) Checking data integrity on a regular and periodic basis;
4) Comparing current estimates with previous estimates to check data integrity;
5) Providing sufficient training to personnel to perform activities related to the sourcing, production, and application of biochar.

All necessary documents must be collected and centrally stored by the project proponent and be available for verification at any time. Documents and records must be stored in a secure and retrievable manner for at least two years after the end of the project crediting period.

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APPENDIX 1: ACTIVITY METHOD

As described in Section 7, this methodology uses a standardized approach for the demonstration of additionality, specifically an activity method. Activity methods pre-determine additionality for given classes of project activities using a positive list.

The initial assessment of activity penetration indicates that there is not enough biochar production in any country that would put such penetration above the five percent threshold called for in the *VCS Methodology Requirements*. It is known that no country has a level of activity penetration higher than five percent currently due to biochar production constraints.

This standardized activity penetration method will be reassessed according to procedures outlined in the *VCS Methodology Development and Review Process*. Future reassessments will be based on national boundaries, focusing on countries where biochar made from waste biomass is actively implemented. Also, following a conservative scenario, where sub-national regulations or policies may impact the likelihood of the project activity being implemented, such boundaries may serve as the basis of the reassessment of the activity penetration level.

A1.1 Positive List

The project activity, production of biochar with waste biomass, is a relatively recent field with few fully commercial technologies. Therefore, the methodology uses an activity method for demonstrating additionality with the processing of waste biomass to biochar as the basis for a positive list. This approach stipulates that the total waste biomass converted to biochar amounts to less than five percent of the total waste biomass available worldwide. Five percent is the activity penetration threshold set by the *VCS Methodology Requirements* and is determined by taking the Observed Activity (OA) divided by the Maximum Adoption Potential (MAP). Where the result of this equation is less than five percent, the project activity may be considered additional.

Activity penetration is calculated as:

$$AP_y = \frac{OA_y}{MAP_y} \times 100 \qquad (16)$$

Where:

AP_y = Activity penetration of the project activity in year y (percent)

OA_y = Observed adoption of the project activity in year y

MAP_y = Maximum adoption potential of the project activity in year y

Maximum adoption potential (MAP) of the project activity in year y

The *VCS Methodology Requirements* defines MAP as "the total adoption of a project activity that could currently be achieved given current resource availability, technological capability, level of service, implementation potential, total demand, market access and other relevant factors within the methodology's applicable geographically defined market."

For the purposes of this methodology, the maximum adoption potential of this activity is the number of tonnes of waste biomass that could be converted to biochar worldwide. The carbon sequestration benefits of biochar have been extensively studied, however, the lack of a robust and widely accepted carbon methodology has limited access to carbon markets and to finance needed to scale the biochar sector. While there are enormous volumes of waste biomass available globally, commercial implementation constraints (e.g., necessary infrastructure for producing and distributing biochar) and limited market access mean that actual conversion of waste biomass into biochar is a fraction of its potential. This is expected to change as biochar producers and practitioners work to build data sets and complete research and development trials to prove the material's effectiveness and permanence. However, until data on the performance and cost competitiveness of biochar are proved definitively, market access will continue to constrain its use.

The United Nations Food and Agriculture Organization's (FAO) online FAOSTAT[28] database of forestry and agricultural statistics was queried for the total amount of "wood residues." Results indicated that in 2019, there were 336,858,637 cubic meters of wood residues reported by 94 countries worldwide (country reporting includes the US, UK, China, and Switzerland, as well as many in the Global South). Wood residues can be in different forms (from sawdust and other wood residues at sawmills to slash piles in the forest to firewood). According to the UK Forest Research agency:[29]

1) Industrial roundwood averages 1.43 cubic meters per tonne for softwoods and 1.25 cubic meters for hardwoods
2) Chips and sawdust are 1.48 cubic meters per tonne
3) Fuelwood is 1.38 cubic meters per tonne

For the sake of conservativeness, by taking the least dense metric of 1.25 cubic meters per tonne, there are an estimated 269,486,910 tonnes of wood residues produced globally on an annual basis.

The same database did not have any similar information on "crop residues," however it did report total crops produced globally (tonnes). In 2019, this was 11.9 billion metric tonnes. To be conservative, if only 10 percent of that value was crop residues, there would be over 1.1 billion tonnes a year (globally) potentially available for conversion to biochar.

Adding 269,486,910 tonnes of wood residues to 1.1 billion tonnes of crop residues = 1,369,486,910 tonnes.

Therefore, for the purposes of this methodology, the maximum adoption potential of this activity is limited to MAP_y = 1.369 billion tonnes.

Observed adoption of the project activity in year y (OA_y)

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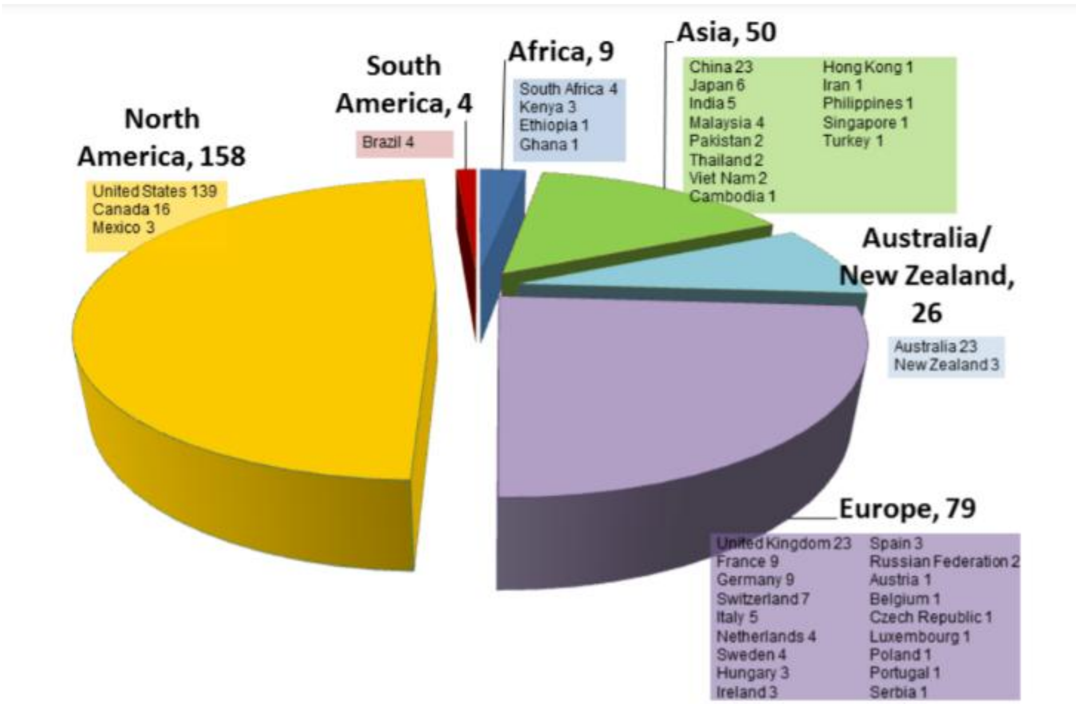
[28] FAOSTAT (2021). *Web Query*. http://www.fao.org/faostat/en/#data

[29] Forest Research (n.d.). *Conversion Factors*. Available at https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2016-introduction/sources/timber/conversion-factors/

According to the International Biochar Initiative *State of the Biochar Industry* report,[30] in 2015 a total of 85,000 metric tonnes of biochar was transacted globally (**Error! Reference source not found.**).

Figure 2. Geographic distribution of biochar producers from IBI (2015)



To be conservative, it is assumed that the 2015 IBI biochar report only captured half of the reported transaction volumes, meaning that an estimated 170,000 metric tonnes of biochar was produced.

Since the last IBI biochar report was published, China has begun to produce a significant amount of material. As of 2019, China was producing 500,000 metric tonnes a year (T. R. Miles pers. comm.). According to the National Alliance of Biochar Science and Technology Innovation in China, the country plans to reach 3,000,000 tonnes per year of biochar production in the coming years.

Using 170,000 metric tonnes (based on the 2015 IBI data) and an assumed growth rate of 10 percent per year for 2016 to 2021 gives 273,787 metric tonnes for all countries excluding China. Adding 500,000 tonnes to account for China's production, the total 2021 global estimate of biochar on an annual basis is 773,787 metric tonnes.

Global AP_y calculation for biochar

Therefore, the global AP_y for biochar is:

$$AP_y = \frac{OA_y}{MAP_y} \times 100$$

[30] International Biochar Initiative (2015). *State of the Biochar Industry.* International Biochar Initiative. Available at: https://biochar-international.org/state-of-the-biochar-industry-2015/

$$AP_y = \frac{773,787}{1,369,486,910} \times 100$$

$$AP_y = 0.06\%$$

$$AP_y = < 5\%$$

Given the current level of biochar production and waste biomass available annually, it is demonstrated that the activity penetration level of the project activity covered by this methodology is below the five percent threshold, and the project activity may be deemed additional.

Where the project activity has been commercially available in any area of the applicable geographic area for less than three years (i.e., it uses a new technology or measure), it must be demonstrated that the project activity faces barriers to its uptake, per the *VCS Methodology Requirements*. The analysis of commercial availability must be conducted at the national level and must assess the time period over which biochar made from waste biomass is available for commercial purchase in the project region.

APPENDIX 2: DEMONSTRATION OF FEEDSTOCK AS WASTE BIOMASS

This appendix provides procedures to demonstrate that the biochar feedstock was waste biomass in the baseline scenario (i.e., in the absence of the project activity) as required by the applicability conditions (see Section 4). This must be demonstrated at project validation.

Assessment of feedstock biomass use must cover the five years preceding the project start date. All qualitative and quantitative information on biomass use in the baseline scenario should be determined via consultation with the manager/landowner that the biomass is sourced from or with the contracted supplier (e.g., biomass broker/intermediary).

The following list specifies the allowable sources of information on biomass use in the baseline scenario with priority from higher to lower preference, as available. The principle of conservatism must be applied in all cases:

1) Where the source of biomass[31] can be identified, and the biomass is not used in the baseline scenario:

    a. Historical management plans, receipts, or other records from the areas where the biomass is sourced from showing that the biomass was not used for alternative purposes in the five years preceding the project start date. These may be supplemented with other forms of evidence such as remote sensing (e.g., satellite imagery) or documentation from comparable sourcing areas.

    OR

    b. Substantiation via a signed attestation from the manager/landowner or supplier stating that the biomass was not used for alternative purposes in the five years preceding the project start date. This includes new sources of biomass[32] that did not exist (e.g., residues from a new food processing mill) before the project start date. The attestation must not deviate from other available evidence such as remote sensing (e.g., satellite imagery) or documentation from comparable sourcing areas.

2) Where the source of biomass can be identified and (some or all) the biomass is used in the baseline scenario:

    a. Historical management plans, receipts, or other records from the areas where the biomass is sourced from showing that the biomass supply is sufficient to satisfy project

[31] Source of biomass should include information on both the entity providing the biomass (e.g., sawmill, grain mill) as well as the geographic area where it came from (e.g., forestry concession, agricultural field).

[32] New sources of biomass that did not exist before the project start date will not have historical management records.

demand without compromising future non-project biomass delivery commitments. This must be demonstrated through an analysis of historical biomass volumes delivered annually in the five years preceding the project start date combined with expected project- and non-project-related volumes for the duration of the project crediting period.

OR

b. Substantiation via a signed attestation from the manager/landowner or supplier stating that the available biomass supply is sufficient to satisfy project-related demand without compromising future biomass delivery commitments. This must be supplemented by an analysis of historical biomass volumes delivered annually in the five years preceding the project start date combined with expected project- and non-project-related volumes for the duration of the project crediting period. The attestation must not deviate from other available evidence such as remote sensing (e.g., satellite imagery) or documentation from comparable sourcing areas.

3) Where the source of biomass cannot be identified (e.g., the biomass is sourced from a biomass residue market with unknown producers):

   a. Demonstration that there is an abundant, unutilized surplus of the same or similar type of biomass in the project region. This must be demonstrated through an analysis showing that the total biomass quantity available is at least 25 per cent larger than the total biomass quantity used (including by the project facility) for that type of biomass. The analysis should be based on an ~~annual~~ assessment of biomass availability and use in the five years preceding the project start date. Where historical data is not available on an annual basis for the five years preceding the project start date, at least one year of data may be used as evidence. This should be complemented with additional evidence demonstrating that the available data is representative of the five years preceding the project start date. The project region should be adjusted to reflect characteristics specific to the biomass type and markets (e.g., wood residues for bioenergy production) where the project is located.

DOCUMENT HISTORY

Version	Date	Changes
v1.0	12 Aug 2022	Initial version released.
v1.1	05 Jul 2023	• Clarifications to eligible feedstocks in Section 4 • Clarifications to eligible land types for soil application in Section 4 • Corrections and clarifications to GHG sources included in the project boundary in Table 2 • Corrections to equations in Section 8 • Clarifications to parameters available at validation in Section 9 • Clarifications to standardized activity method reassessment procedures in Appendix 1 • Clarifications to the procedures to demonstrate that feedstocks are waste biomass in Appendix 2 • General improvements, corrections and clarifications
v1.2	27 June 2025	• Inclusion of Step 3: Investment Analysis for the additionality analysis • Adoption of current VCS methodology template