EBC-Guidelines for the Certification of Biochar Based Carbon Sinks

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Table of contents

1. Introduction of C-sink certification

The certification of C-sinks represents a decisive step towards the implementation of climate change mitigation based on scientific evidence. Current CO_2 certificates usually certify the reduction of emissions compared to a reference scenario and thus help to avoid emissions. On the other hand, the certification of C-sinks guarantees the storage of carbon in the terrestrial system, which can be verified at any time. C-sinks are thus the result of the active removal of CO_2 from the atmosphere. Complete and batch-accurate tracking of each sequestered unit of carbon must be ensured to guarantee the removal of CO_2 from the atmosphere and to quantify C-sinks. This tracking must cover the removal from the atmosphere (carbon capture), all necessary transports and transformations, and the final storage.

1.1 Principles of biochar-based C-sinks

Plant biomass consists of approximately 50% carbon, which the plant removes during its lifecycle from the atmosphere in the form of CO_2. With the energy from sunlight, the plant separates the carbon (C) from the up-taken CO_2 and builds it into organic molecules such as glucose, cellulose, or lignin.

When plant biomass is burnt or decomposed, the assimilated carbon is re-released as CO_2. However, if the plant biomass is pyrolyzed, only about half of the plant carbon becomes volatile and escapes as combustible gas. The other half is transformed into a very persistent, solid form of carbon (biochar) that degrades extremely slowly under natural conditions. Provided that the biochar is not burned, a comparably large portion of its carbon remains in the terrestrial system for several centuries and thus represents a terrestrial carbon sink (C sink).

If biochar is applied directly to soils or indirectly into agricultural soils via its use in animal feed, livestock bedding, slurry management, compost, or anaerobic digesters, a conservative average degradation rate of 0.3% per year may be assumed for higher temperature biochars with a H : C_{org} ratio below 0.4 (following: Budai et al., 2013; Camps-Arbestain et al., 2015). Thus, 100 years after soil application, 74% of the original carbon in biochar could still be accounted for as sequestered carbon. The annual rate of 0.3% is based on the most conservative metanalytical estimate for biochar carbon degradation published to date. Other sources determined significantly lower degradation rates depending on the degree of pyrolysis and the experimental design (IPCC, 2019; Kuzyakov et al., 2014; Lehmann et al., 2015; Zimmerman and Gao, 2013). In the absence of more reliable methods and long-term experiments, however, it is appropriate to use conservative projections and calculate the climate-relevant effect of C sinks with a sufficient safety margin. Instead of an annual depletion

rate, the Intergovernmental Panel on Climate Change defines a proportion of permanent carbon that is not mineralized over 100 years, depending on the pyrolysis temperature (IPCC, 2019). However, this underestimates the climate impact of the biochar-based C-sink in the first decades after its production.

If biochar is used in construction materials as a sand substitute or as an additive in asphalt and plastics, it can also be assumed that the biochar persists and remains a C-sink for as long as the material itself persists. Only when the biochar containing material is disposed of, destroyed, or decomposed may the sequestered carbon be released back to the atmosphere again, causing the C-sink to lose its value and would have to be removed from the C-sink register.

To provide for an accurate depiction of the climate impact of a biochar-based C-sink, all direct and indirect GHG emissions caused by biomass cultivation, harvesting, transportation, crushing, pyrolysis, pyrogas combustion, milling, blending, and soil or material incorporation must be included in the overall balance.

1.2 The concept of EBC C-sink certification

The creation of a C-sink occurs in three main steps: (1) removal of carbon (CO_2) from the atmosphere, (2) transformation of the carbon into a stable form that can be stored, and (3) safe, long-term storage, e.g., in the soil or in materials (carbon capture, transformation and storage). In order to calculate the carbon footprint for biochar along these three steps and thus determine the tradable value as a C-sink, all greenhouse gases emitted during cultivation of the biomass, the pyrolysis process and up to the packaging of biochar are recorded. In addition, laboratory analysis is used to determine the quality and C content of the biochar in EBC-accredited laboratories.

The greenhouse gas emissions caused by biochar production, quantified from planting the biomass to the packaging of the biochar, are then converted from CO_2eq into the rate of carbon expenditure (= CO_2eq / 44u * 12u) per ton of biochar. This carbon expenditure rate is then subtracted from the carbon content of the biochar, which results in the value of the C-sink of the biochar at the factory gate.

The necessary controls at the production site are carried out by the state-accredited control body bio.inspecta AG / q.inspecta GmbH.

The EBC only calculates the C-sink value up to the factory gate. From there on, the C-sink broker has to ensure the tracking. All greenhouse gases emitted from the time of leaving the factory gate until the biochar is applied to soil or mixed into long-lasting construction materials must be accounted for and subtracted from the C-sink value. The EBC accredited

C-sink broker finally enters the ultimate C-sink value of the applied biochar into the EBC's C-sink registry.

The control requirements and calculation templates for certifying the overall balance of a C-sink are detailed in the following guidelines.

Frame 1: Terminology in regard to carbon and climate effects

C-neutral: A system is considered C-neutral if it removes as much carbon from the atmosphere as it releases over a defined period of time (reference period). The amount of carbon stored in the system remains constant and does not reduce carbon stocks elsewhere. Such a system could be a forest or an agricultural area, or even an entire region including cities, forests, moors, lakes and agricultural land.

Climate-neutral: A system is considered climate-neutral if it does not cause any global warming over a reference period. The sum of all greenhouse gases emitted by the system (CO_2, CH_4, N_2O, etc.) is as large as the removal of greenhouse gases from the atmosphere. The quantity of greenhouse gases emitted or withdrawn is expressed in CO_2 equivalents (CO_2eq).

Climate-positive: A system is considered to be climate-positive if, over a reference period, more CO_2eq is withdrawn from the atmosphere than have been emitted back into the atmosphere. A climate-positive system contributes to the mitigation of global warming during the reference period.

Climate-negative: A system is considered to be climate-negative if, over a reference period, its total emissions of greenhouse gases are greater than the removal of CO_2eq from the atmosphere. The system contributes to global warming.

In the context of the C-sink economy, the use of the terms C-negative, C-positive and negative emissions is confusing and counterintuitive, because the atmosphere is used as the reference point and the assessment as "negative" (as in "negative emissions") refers to the removal (= minus) of CO_2 from the atmosphere. Positive CO_2-emissions would thus refer to a system that leads to an increase in the CO_2 content of the atmosphere, although this would of course be considered negative from a climate protection perspective. To avoid any misunderstandings, the EBC guidelines use the terms C-neutral, climate-positive and climate-negative.

1.3 Definition and calculation of the C-sink potential

> *The C-sink potential of a packaging unit of biochar is defined as the amount of carbon it contains minus the carbon expenditure of its production, i.e., all GHG-emissions caused by its production. It thus includes the complete carbon footprint of the biochar at the factory gate, i.e., when it leaves the production site.*

When a packaged unit of biochar (e.g., a big bag or container) passes the factory gate of the production site, the biochar as such does not yet represent a certified C-sink. It only has, at this stage, the ***potential*** **to become a certified C-sink.**

Until the final creation of the C sink in soil or a long-lasting material, further emissions (transport with fossil energy) and partial losses (e.g., use in cat feed that ends up in waste incineration through disposal) may occur and must be included. Also, total losses are still possible: e.g., biochar could be destroyed by fire, or a customer could buy it for co-firing in a biomass power plant or use it as a reducing agent for steel production. In any of these cases, the carbon would be released as CO_2 back into the atmosphere, and the C-sink potential would not be realized.

Biochar only becomes a long-term C-sink when it can no longer be burned or when it is used in products with a long life cycle. When biochar eventually reaches the soil after it was used as livestock bedding, as a compost additive or as part of similar substrates, or when it becomes a component of concrete or similar non-combustible, or at least long-lasting composite materials, can it be considered a long-term terrestrial C-sink with mathematically/statistically definable life cycle or degradation rates. Until this crucial moment, when the carbon in the biochar enters a long-term and definable life cycle, the carbon in the biochar only represents a C-sink potential and is calculated as follows:

- The carbon content of the biochar is determined according to the EBC method. It indicates the amount of organic carbon stored in the biochar as a mass proportion (in %) based on the biochar's dry weight.
- All greenhouse gas emissions caused by biochar production are recorded in CO_2eq for the entire EBC production batch (usually the production of one year, see EBC certification guidelines). This includes:
    a) Emissions from the provision of the biomass (cf. Chap. 2)
    b) Emissions from the storage of the biomass (cf. Chap. 3)
    c) Emissions from the pyrolysis process and other equipment at the production site (cf. Chap. 5).

Methane (CH_4) and nitrous oxide (N_2O) emissions are converted into CO_2eq according to their 20-year global warming potential by a factor of 86 and 300, respectively. Since methane is oxidized to C-neutral CO_2 after a few years in the atmosphere, methane emissions can be compensated by other, short-term and thus cheaper C-sink certificates (cf. Chap. 1.4). This is not possible for nitrous oxide due to its long residence time; it must be deducted from the biochar C-sink.

- To include all emissions not covered under point 2, a margin of safety of 10% of all greenhouse gas emissions covered under 2) is added (cf. Chap. 6).
- Using the factor 0.2727 (ratio of the atomic mass of carbon and the molecular mass of carbon dioxide = 12 u / 44 u = 0.2727), the total determined amount of CO_2eq is converted into atomic carbon and results in the carbon expenditure. The carbon expenditure of a production batch indicates the "C-costs", i.e., it provides the amount of carbon emitted as CO_2eq to produce the total amount of biochar of a production batch.
- The carbon expenditure is given as mass proportion based on the dry weight of the biochar. It is calculated by dividing the total amount of carbon expenditure per batch by the dry weight of the total amount of biochar produced per batch.
- The proportion of carbon expenditure is subtracted from the biochar's carbon content, resulting in the C-sink potential in mass percent of the biochar (DM) – (cf. Frame 4).

Thus, the EBC C-sink potential accounts for the complete CO_2 footprint of the biochar from the origin of the biomass until it leaves the premises on which the EBC-certified pyrolysis plant operates. The C-sink potential indicates the proportion by dry weight of a given amount of biochar that can be converted into a long-term C-sink. Practical calculation examples are provided below in the colored frames (Frame 3 & 4).

1.4 Methane emissions

Although the concentration of methane in the atmosphere is around 200 times lower than that of CO_2, methane currently contributes about 16% to global warming. However, the average residence time of methane in the atmosphere is only about nine years, after which it is oxidized to CO_2 (Prather et al., 2012). In this short period, however, methane has a climate impact that is over 200 times greater than that of CO_2 in the same time. To compare these different effects of greenhouse gases and the varying duration of their effectiveness, the

global warming potential (GWP) of the gases is calculated for a specified period of time. In recent decades, a period of 100 years has been predominantly used for this purpose (GWP100), but there is no scientific basis for choosing this timespan rather than any other (Fuglestvedt et al., 2003). The determination of the time frame of reference is a political and socio-economic decision in order to evaluate and compare the effectiveness of climate change mitigation measures (Myrhe et al., 2013). The unit of GWP in each case is CO_2eq (CO_2 equivalents).

The decades up to 2050 are the decisive period for limiting anthropogenic global warming. Since methane emissions have a particularly severe impact during this period, the calculation of methane's climate impact should not be diluted by setting a reference frame of 100 years. Therefore, the EBC chooses the 20-year reference frame (GWP20) for methane to promote actions that help avoid these critical GHG emissions. This decision better reflects the comparatively short but intense impact of methane and is in line with recommendations from various organizations and scientists (Balcombe et al., 2018). The Intergovernmental Panel on Climate Change (IPCC) specifies the GWP20 of methane as 86. Consequently, within the first 20 years after the emission, methane's climate-warming effect is 86 times greater than that of CO_2 over the same period. Therefore, 1 kg of methane is assigned an effect of 86 kg CO_2eq under the EBC C-sink certificate.

Methane emissions can be offset by reducing the C-sink potential of biochar, as is mandatory for all other production-related GHG emissions. However, since the duration of biochar-based C-sinks is several centuries, and the emission effect of C-neutral methane, i.e. methane from carbon neutral biomass, lasts only a few years, offsetting the short-term GWP20 of methane with long-term C-sinks, which have a negative GWP of many centuries, is hardly justifiable, neither economically nor physically.

However, the comparatively short lifetime of methane in the atmosphere and the use of GWP20 for methane also means that the climate impact of methane can be compensated with equally short-term measures. To address this, the EBC offers the option of offsetting the methane emissions generated during biomass storage (Section 3) and pyrolysis (Section 4.3) with short-term C-sinks, provided they guarantee at least 20 years of carbon storage. A comprehensive list of qualified measures and corresponding allowances will be prepared by the EBC during 2021 and then continuously updated. It will include reforestation measures, the creation of forest gardens, the use of wood as a building material, or the use of biochar for more short-lived products (e.g., in plastics for sewage pipes, electrical wiring, or car bodies).

1.5 Definition of the C-neutrality of the biomass input material

C-sink certification's overarching goal is to increase the total amount of carbon stored in the terrestrial system and thus reduce the concentration of greenhouse gases in the atmosphere. Therefore, when certifying C sinks, it must be ensured that the certified C sink is not created at the expense of another C sink. Thus, the EBC defines the carbon neutrality of biomass as follows:

> *A feedstock material (biomass) for the generation of a C-sink is considered C-neutral if it is either the residue of a biomass processing operation or if the biomass removal did not, over the reference period, lead to the reduction of the total carbon stock of the system in which the biomass had been grown.*

Biochar produced from biomass whose harvesting resulted in the destruction or depletion of a natural C-sink (e.g., clear-cutting a forest) or has contributed to the disappearance of an existing sink (e.g., inappropriate agricultural practices on bog soil) has no C-sink value and cannot be recognized as a climate service. Emissions resulting from the provision of biomass (fuel consumption, N_2O from fertilizer) affect the carbon footprint and are compensated by deductions in the C-sink calculation (cf. chapters 1.1 and 2 and 6).

For the calculation and certification of the EBC C-sink potential, only C-neutral biomass input materials are permitted.

Frame 2: Examples for the determination of biomass carbon neutrality.

The example of a single tree

If the last remaining tree on an island is felled, chopped and processed into biochar in a pyrolysis plant, 50% of the carbon originally stored in the living tree is lost to the atmosphere by burning bio-oil and pyrogas and 50% is retained in the biochar. If a new tree grows to similar size of the previous tree, the sum of the event would be climate positive. However, if no new tree is planted or regrown, then the sum of the event is climate negative.

Biochar can only have a positive effect on the climate if the production of the biomass used to produce it was at least carbon neutral. In other words, only when the biomass was re-grown where it was harvested, i.e., in the same system, can the biochar that was produced from it be recognized as a carbon sink. This is one of the essential principles of the EBC certification of the C-sink potential.

The example of a Miscanthus plantation

If one hectare of Miscanthus grass is planted and harvested for the first time after a few months and then burned to produce energy, the amount of CO_2 produced during combustion is exactly the same as the amount that the harvested Miscanthus grass had removed from the atmosphere during its first growth cycle. The combustion of the harvested biomass can therefore be considered C-neutral if fertilizer and tractor emissions from planting, harvesting, transportation are discounted. However, if the harvested Miscanthus grass is not burned but pyrolyzed, half of the carbon absorbed by the grass remains in the biochar, rendering the system not merely neutral but climate positive. Thus, the biochar from the harvested Miscanthus grass, which grows back in less than a year, is a C-sink as long as it is not burned or otherwise decomposed. For C-sink certification, all fertilizer and tractor emissions need to be included into the calculation of the C sink potential.

2. Approved biomasses and carbon expenditures for their production

Only biochar produced from either residual materials or biomass provided from other C-neutral sources is eligible for C-sink certification. Depending on the type of biomass and the way it is produced, specific criteria for C-neutrality apply. Therefore, EBC C-sink defines six biomass categories:

(1) Agricultural biomasses

(2) Organic residues from food processing

(3) Wood from landscape conservation, short rotation plantations, arable forestry, forest gardens, field margins, and urban areas

4) Biomass from forest management

(5) Wood waste

(6) Other biogenic residues

The production of biomass usually causes emission that need to be accounted for as carbon expenditures of the C-sink:

- If mineral nitrogen fertilization was used to produce the biomass, its carbon footprint, including soil-borne N_2O emissions, must be accounted for according to the formula 100 kg N = 1 t CO_2eq (Zhang et al., 2013).
- If pesticides were used, a flat value of 94 kg CO_2eq per hectare (Audsley et al., 2009) is applied for their production-related emissions.
- The input of fuels for cultivation and harvest must also be subtracted from the C-sink potential with a conversion factor of 2.7 kg CO_2eq per liter diesel (Juhrich, 2016).

However, to keep the C-sink certification process lean and appropriate to the developmental stage of the nascent industry, the comparably low emissions for cultivation, harvest and plant protection are included in the margin of safety (Chapter 6). Still, fertilization and transportation of the biomass from its origin to the pyrolysis plant needs to be quantified and accounted as carbon expenditures.

2.1 Agricultural biomasses

If annual biomass is grown on agricultural land specifically for pyrolytic and/or energetic use (see example in Frame 2), it can be assumed that after one year at the latest, the same amount of biomass will have grown again on the same area, which means that approximately the same amount of CO_2 will again be removed from the atmosphere. The harvested biomass can thus

be considered C-neutral based on a one-year period (reference period for annuals) so that a C-sink can be created by producing biochar from these biomasses.

The planting of mixed and perennial crops, as well as of agroforestry and meadows, which in addition to biomass production may promote the build-up of soil organic matter, is preferable to the cultivation of monocultures for biomass production. In principle, biomass from crop residues and companion plants should be recognized as a full-fledged tradable agricultural product ("carbon harvest"). The production of food and feed should be synergistic with the production of additional biomass. This would increase farm productivity and enhance biodiversity, soil organic matter, and enable the removal of CO_2 from the atmosphere.

The inclusion of biomass as a full-fledged product of agriculture would also change the definition of agricultural residues. Straw, tomato, potato, cabbage stalks, and leaves, or vine and tree prunings should be considered an essential part of the agricultural carbon crop. The dry weight of any of these biomass types also contains 50 % carbon. Using pyrolysis, more than half of this carbon can be converted into long-term C-sinks instead of being lost as CO_2 in a relatively short period through decomposition or combustion, as is still common practice in some parts of the world. The use of biomass from companion plants and crop residues would be a key component of climate farming and critical to limiting climate change. It is, however, not recommendable to completely remove all crop residues from the field and thus reduce the important ecological function of soil cover and organic matter recycling. Rather, the aim is to integrate biomass as an agricultural product into the field management plan while preserving its central ecological functions and replenishment of soil organic matter.

All biomass from crop residues and companion plants from agricultural activities are considered to be C-neutral input material. However, it has to be ensured that the removal of harvest residues does not decrease soil organic carbon stocks (Whitman et al., 2011).

If biomass was deliberately grown to produce biochar, i.e., it was the single or main product of this field, carbon expenditures for fertilization need to be accounted for. The carbon footprint of fertilization must be subtracted from the C sink value according to the formula 100 kg N = 1 t CO_2eq (Zhang et al., 2013). All other cultivation related GHG-emissions are included in the margin of safety (cf. chapter 6).

Frame 3: Calculations of the carbon footprint for biomass production

Example for the calculation of the carbon expenditure for the provision of biomass

- On one hectare, 10 t biomass are produced using 50 kg N and 25 l diesel, which are processed into 3 t biochar (dry matter = DM) with a carbon content of 75%.
- The carbon expenditure amounts to (0.05 t N * 100 t CO_2eq * t-1 N =) 0.5 t CO_2eq for fertilization and (2.7 kg CO_2eq * 25 l=) 0.08 t CO_2eq for the diesel used. This results in (0.50 t CO_2eq + 0.08 t CO_2eq =) 0.58 t CO_2eq (0.16 t C).
- The production of 3 t of biochar consumes 0.16 t C for the biomass supply, which corresponds to (0.16 t / 3 t =) 5.3 mass percent (based on the dry substance of the biochar).
- Conditional on the deduction of further emissions caused by pyrolysis and after-treatment (see Frame 4), the C-sink potential of the biochar is therefore 75% - 5.3% = 69.7% (meaning 100 kg dry biochar would have a C-sink potential of 69.7 kg Carbon or 255.6 kg CO_2eq).
- The figures are rounded to the nearest 0.1%.

2.2 Organic residues from food processing

Pomace, nutshells, fruit stones, coffee grounds, and other organic residues from food processing are considered C-neutral input materials because the CO_2 footprint of food production has to be credited to the production of primary products (e.g., wine, olive, or any other kind of oil, fruit juice, coffee, etc.).

2.3 Wood from landscape conservation, short rotation plantations, arable forestry, forest gardens, field margins, and urban areas

If trees or hedges on agricultural land are pruned or trimmed, but not felled, and thus grow back from their roots, the biomass is considered C-neutral. Biomass from nature conservation landscape management, including disaster debris removal, roadside greenery, and urban areas, is also considered C-neutral.

Trees from forest gardens, orchard meadows, tree lines, and hedges for arable farming are often decades old. They have to be managed so that the amount of wood removed per unit area does not exceed the amount of the annual regrowth.

If trees have been newly planted on agricultural land for biomass production (e.g., short-rotation coppices, landscape conservation water management, or agroforestry), the harvested biomass can be considered C-neutral at the time of harvest. However, it must be ensured that biomass production is maintained on the corresponding area either through new planting or rejuvenation.

If mineral N fertilization was used to produce the biomass, its carbon footprint must be subtracted from the C-sink potential according to the formula 100 kg N = 1 t CO_2eq (Zhang et al., 2013). The carbon expenditure for cultivation and harvesting is included in the margin of safety (cf. chapter 6).

2.4 Biomass from forest management

An area is considered a forest when it presents a canopy density of more than 75%. For efficient control of sustainable forest growth, the forest area units should not exceed 100 ha. The total biomass of an existing commercial forest of max. 100 ha must not decrease when the harvested biomass is used for the development of C-sinks. Therefore, the loss of wood has to be balanced by the growth of forest wood on the referenced area unit. Furthermore, only a maximum of 80% of the harvested biomass must be removed from the forest to maintain the nutrient cycle and forest biodiversity. The degree of canopy cover must not fall below 75% as a result of the timber harvest.

If, for example, the annual regrowth of a 100 ha spruce forest amounts to 650 t (dry matter = DM), only a maximum of 650 t DM per year should be felled, of which a maximum of 520 t DM (80%) should be removed from the forest for wood processing and wood use.

There is currently no comprehensive forest assessment of area units of 100 ha or less in European forestry. The reference area units are considerably larger than 10,000 ha, and the forest regrowth is extrapolated using regional average values. Suppose in regional forests such as the Black Forest in Germany or the Arlberg in Austria, the forest's standing biomass is higher than the amount of biomass withdrawn. In that case, the withdrawn biomass is regarded as climate neutral according to the European Regulation [2018/841] (EU-Parliament, 2018). Ecologically, it is at least questionable that, e.g., a densifying mountain forest is allowed to compensate for clear-cutting in a more accessible valley. However, until the expected reform of the EU LULUCF regulation (EU-Parliament, 2018), **all wood from forests whose regrowth demonstrably exceeds the removal, independent of its size and structure, is recognized as C-neutral input for the EBC certification of the C-sink potential.**

We want to justify the decision to adhere to European forest legislation primarily because it does not make sense for developing the C-sink economy to make the restrictions too idealistic

from the start. If the EU nations promote bioenergy as climate-neutral and allow the regrowth of their forests to be counted as C-sinks, it is not up to the EBC to classify the same biomass as not climate-neutral. Nevertheless, it is our conviction that forests and forest wood should be used more efficiently for the generation of C-sinks than by simply pyrolyzing the extracted biomass (Song et al., 2018). The EBC standard will be updated concerning forest wood use to reflect the technical possibilities and political conditions in the coming years.

If the climate neutrality of a forest is not ensured by the official LULUCF reports of the EU member states or by regional legislation, proof can also be provided by *Program for the Endorsement of Forest Certification* (PEFC) or *Forest Stewardship Council* (FSC) certification. Otherwise, the forest wood is not accepted as biomass input for the production of EBC certified biochar. Accordingly, no EBC C-sink potential of biochar produced from that biomass can be certified.

If during forest establishment denser stands are planted and gradually thinned out as they grow, the wood removed in this way is considered a C-neutral input because this measure accelerates the growth of the remaining trees and increases the total accumulation of carbon.

The CO_2eq expenditure for forest maintenance and timber harvesting is included in the overall balance via the 10% safety margin for scope 3 emissions (cf. chapter 6).

It is assumed that no fertilization takes place in the forest, otherwise, the CO_2eq expenditure for fertilization would have to be deducted from the C-sink potential.

2.5 Wood waste

Wood waste from forestry (e.g., bark, crowns, branches, roots), wood processing (e.g., sawdust, offcuts), and recycled construction and service wood (e.g., lumber, pallets, furniture) are considered C-neutral. Strictly speaking, it would also be necessary to ensure that the wood used for these wood waste materials and wastes originally comes from sustainable forestry with third-party verification such as PEFC or PFC. However, traceability is not always possible in these cases. Moreover, it is, of course, better if the wood waste is used to build up C-sinks instead of being combusted.

2.6 Other biogenic residues

For the other biomass on the EBC positive list, a C-neutral initial value can generally be assumed. This is, however, considered individually during the certification procedure depending on the feedstock used. New feedstock categories will be added for C-sink certification as required or requested.

Animal manures and sewage sludge become increasingly important as biomass feedstock for pyrolysis and, thus, for the creation of pyrogenic C-sinks. The EBC certification of these feedstock classes is in preparation. In the meantime, C-sink potentials based on the pyrolytic products from animal manures and sewage sludge can already be assessed and certified.

3. Storage of biomass feedstock

If moist biomasses are stored for too long in piles that are too large, uncontrolled self-heating occurs. In this process, the biomass is microbially degraded, similar to composting, which results in the loss of carbon as CO_2. Depending on the biomass and storage conditions, emissions of CH_4 and N_2O may also occur.

Especially in biomass power plants, it is common practice that the self-heating of wood chips is used to dry them. A review of 14 scientific studies on the C-degradation of woodchips during storage has shown that depending on storage conditions, wood species, and wood moisture content, between 0.6 to 4.3% of the biomass carbon is degraded per month (Whittaker et al., 2016). For wood chip piles larger than 1 m^3, biodegradation of the wood leads to oxygen consumption inside the pile, which eventually leads to anaerobic degradation (fermentation) and thus methane emissions. How high the actual methane emissions are, depends on factors such as temperature, humidity, pile volume, type and age of the wood, and its C:N ratio. Measurements have shown that up to 20% of the gaseous carbon produced during storage inside the pile is transformed into methane (Pier and Kelly, 1997). However, Jaeckel et al. (2005) found that methanotrophic microorganisms in the heap's better aerated near-surface layers degrade between 46% and 98% of the methane produced in the core before it can escape as an emission to the atmosphere. Scientific studies of actual methane emissions from wood chip storage are sparsely available and often incomplete, so generalizations regarding storage emissions have to be made cautiously (Ferrero et al., 2011).

However, storage emissions can be effectively avoided. Even if this involves additional effort and possibly also costs, the avoidance of emission losses has the beneficial side effect of losing less of the biomass's calorific value. The following measures are generally recommended for biomass storage and, if implemented correctly, would avoid any deductions for biomass storage in the calculation of the C-sink potential:

- Wood and other biomass should be chipped only a few days and at a maximum of four weeks before pyrolysis. The storage of logs is considered unproblematic with regard to methane emissions; coarse wood (thinner logs, branches, cuttings, etc.) should be stored as airy as possible and not mixed with green waste.
- If just-in-time chipping is not possible, the wood chips or biomass should be dried as soon as possible with the waste heat from pyrolysis and stored dry with a maximum of 20% residual moisture. If the biomass is sufficiently dry, biodegradation does not take place or is slowed down considerably.

- The pelletization of biomasses and their dry storage also leads to dry, stable, and thus storable biomasses.
- Alternatively, the wood chips or the biomasses can be stored in small, well-ventilated containers such as lattice boxes (max. 2 m^3). Due to sufficient ventilation, anaerobic degradation and thus methane emissions can be prevented.

If none of these recommendations can be implemented, it must be assumed that there are substantial methane emissions that are not covered by the margin of safety and therefore must be calculated as follows:

We assume for the storage of moist wood chips and sawdust that 2.5% of the biomass carbon is degraded per month, of which 20% are transformed into methane. 75% of this methane gets microbially degraded in the storage pile and is not released to the atmosphere. We thus calculate that per month of moist storage (2.5% * 20% * 25% * 16u / 12u =) 0.15% (rounded) of the biomass C is emitted as methane.

For the storage of moist non-woody biomasses such as straw, crop residues, pomace, etc., but also wood waste with high content of green plant material, data on methane emissions during uncontrolled composting are applied. According to the IPCC methodology, 10 g of CH_4 emissions are generated per kilogram of biomass (DM) during complete composting (Pipatti et al., 2006). This corresponds to about 1.5% of the carbon contained in the biomass. Assuming that a conventional windrow composting process takes an average of 6 months (Pier and Kelly, 1997) this results in an emission rate for methane of (1.5% / 6 =) 0.25%.

Thus, for the storage of wood chips and sawdust with more than 25% moisture for more than one month, CH_4 emissions of 0.15% of the original C-content are imputed per month, and for all other biomasses, 0.25% of the original biomass C-content. Methane emissions that may already occur during the first month of biomass storage are sufficiently covered by the general margin of safety (10% of total CO_2eq - see Chap. 6).

For example, if the wood chips that are used as feedstock for pyrolysis have a water content above 25% and are stored in a large pile for an average of two and a half months prior to pyrolytic processing, a C loss of ((2.5-1) months * 0.15% =) 0.225% of the total C of the pyrolyzed biomass is assumed.

For an annual processing of 4000t (DM) of wood chips with a C-content of 48%, the methane emissions to be estimated for a 2.5-month storage without preceded drying would correspond to (4000 t * 48% * 0.15% CH_4 * (2.5-1) months =) 4.3 t CH_4, whereby (4.3 t CH_4 * 86 tCO_2eq/ t CH4=) 372 t CO_2eq would have to be credited as annual GHG emissions for the storage effect.

If 4000 t (DM) of grape marc with a C-content of 48% were processed, the methane emissions to be estimated for 2.5 months of storage without prior drying would correspond to (4000 t * 48% C * 0.25% CH_4 * 1.5 months =) 7.2 t CH_4, with which (7.2 t CH4 * 86 t CO_2eq/ t CH_4=) 619 t CO_2eq would have to be credited as GHG emissions for the annual storage effect.

For the storage period, not only the storage on the premises of the pyrolysis plant is considered, but the entire storage period of the biomass be it at the harvest site or at the site of any biomass processor or trader. For example, for processing of pomace, the start time of storage is considered to be the emptying of the wine press. For wood chips, the moment of chipping applies. During control, the logistics of biomass processing and its transport must be fully traceable.

During the EBC on-site control visit, the core temperature of the biomass has to be measured. In case of temperatures of more than 5°C above ambient temperature, which cannot be plausibly explained e.g., by diurnal fluctuations, the above formula is applied for the calculation of the accruing GHG emissions. The instruction manual may also specify an in-house temperature monitoring of the stored biomasses (e.g., daily measurement of the core temperature of one or more biomass storage facilities).

4. Deductions for production-related emissions

4.1 Energy and fuel consumption for transportation, preparation of the biomass, the pyrolysis process and post-treatment of the biochar

Even though biochar production usually produces an energy surplus, since the pyrolysis gases are burned and used for energy generation, external energy is usually required to operate pyrolysis plants. For example, electrical power is necessary for control systems as well as for conveying the biomass and biochar. Depending on the type of plant, (fossil) fuel gas or electricity is also required for preheating the reactors. Certain plant types produce pyrolysis oil and pyrolysis gas in addition to biochar but use electrical energy to heat the biomass. Consequently, to calculate the pyrolysis plant's carbon footprint, each plant must be equipped with its electricity meter.

The energy and fuel-related carbon expenditure for the entire process chain from the provision of the biomass to the packaging of the biochar is calculated in CO_2eq and deducted from the C-sink value of the biochar. This concerns in particular:

(1) Transportation of the biomass to the pyrolysis plant,

(2) Chipping, homogenization, pelletizing, and drying of the biomass,

(3) Post pyrolysis treatment of the biochar (e.g., grinding, pelletizing),

(4) Transport of the biochar to the collection depot (factory gate).

Accounting for electricity and fuel consumption for all these individual steps is necessary for the certification. The conversion of electricity consumption into CO_2eq is based on the specific information provided by the contractual energy provider or the average CO_2eq value of the regional electricity mix used. If renewable energy is used, a CO_2eq footprint of zero is assumed. If the pyrolysis plant itself generates at least as much electricity on an annual average as is consumed in the production facility, a CO2eq of zero is assumed for electricity consumption.

The amount of fuels used to heat the pyrolysis reactors are to be reported per batch and are converted to CO2eq by fuel type (65 t CO_2eq per TJ (Juhrich, 2016))

For the consumption of diesel or benzine fuel for transportation, chipping, drying, etc., the conversion factor of 2.7 kg CO_2eq / l diesel fuel used by the German Ministry of the Environment is applied (Juhrich, 2016).

4.2 Energy surpluses

If the energy balance of a biochar production facility is positive, i.e., measurably more electrical and/or thermal energy is produced than consumed, the positive energy balance can be credited as an emissions reduction with the appropriate agencies, but not within the EBC. The positive energy balance cannot neither increase the C-sink potential nor offset emissions from biomass supply (see Chapter 7).

4.3 Methane emissions during the pyrolysis process

During pyrolysis, the pyrolysis gases are usually oxidized in a suitably designed combustion chamber. The combustion products, consisting mainly of CO_2, are emitted. If the pyrolysis process is well adjusted and the combustion chamber is of high quality, the pollutants in the exhaust gas stream can be kept very low. Concerning the net climate impact, the emission of methane is particularly important to measure. The other combustion products of the pyrolysis gas, such as CO, NOx, SOx, particulate matter, etc., are also harmful to the environment, but according to the IPCC, they do not have a clear greenhouse gas effect (IPCC, 2013) and are therefore not accounted for in the calculation of the C-sink potential, at least not for the time being.

As explained in chapter 1.2, for the conversion of the global warming effect of methane, the GWP20 is credited with a factor of 86. Within the first 20 years after emission, the climate-warming effect of methane is thus 86 times greater than that of CO_2 over the same period.

Due to this very high GWP20 of methane, even very small methane emissions during the pyrolysis process have a major impact on the carbon footprint of biochar production. In pyrolysis plants without controlled post-combustion of the pyrolysis gases (e.g., Kon-Tiki or traditional charcoal kilns), the global warming effect of methane emissions can even exceed the climate-positive effect of biochar for the first 20 years. For this reason, it is particularly important to systematically control and reduce methane emissions wherever possible.

The measurement of low methane emissions below 5 ppm of a given flue gas is technically very complex. A continuous measurement over an entire year of production would involve costs that would be significantly higher than the projected revenue for the development of C-sinks. As the emissions from individual plants cannot be adequately monitored and a few individual measurements are not representative enough, pyrolysis equipment type certification has been introduced to assess the carbon footprint of pyrolysis plants.

Frame 4: Calculation of pyrolytic carbon expenditures.

Example for the calculation of the carbon expenditure of pyrolysis (continued)

- With an annual production of 500 t of biochar (dry substance = DM) with a carbon content of 75.0%, **50,000 kWh of electricity** are used to operate the pyrolysis plant. The local electricity mix emits 450 g CO_2eq per kWh. Thus, the carbon expenditure for the electricity consumption is 50,000 kWh * 0.45 kg CO_2eq $(kWh)^{-1}$ = 22.5 t CO_2eq per year. Converted to one ton of biochar, this results in (22.5 t CO_2eq / 500 t =) 45.0 kg CO_2eq per ton of biochar produced.
- Emission measurement of pyrolysis results in a **methane content of 10 ppm** (6.6 mg CH_4 m^{-3}) in the exhaust gas for 7000 operating hours per year at a volume flow of 1500 m^3 per hour. This results in methane emissions per annual batch of 1500 m^3/h * 7000 h * 6,6 mg CH_4 / m^{-3} = 69,3 kg CH_4. Using the GWP20 of 86 CO_2eq for methane, a carbon expenditure of 11.9 kg CO_2eq per t of biochar (DM).
- To preheat the pyrolysis reactors, **5 t of liquefied petroleum gas (LPG)** with a CO_2eq of 3 t CO_2eq t^{-1} are consumed per year. This results in a carbon expenditure of 15 t CO_2eq per year or 30.0 kg CO_2eq per t biochar (DM).
- The total **carbon expenditure for the pyrolysis** is converted from (45.0 kg + 11.9 kg + 30.0 kg =) 86.9 kg CO_2eq to (86.9 kg CO_2eq / 44u * 12u =) 23.7 kg C per t biochar (DM). This results in (23.7 kg C per 1000 kg biochar =) 2.4 mass percent.
- Including the carbon expenditure for the provision of biomass (see Frame 3), this results in a **C-sink potential** of biochar at the factory gate of (75% (carbon content) - 5.3% (biomass expenditure) - 2.4% (pyrolysis expenditure) =) 67.3%.
- A big bag with 1.3 m^3 biochar, a bulk density (based on DM and a particle size < 3 mm) of 0.22 t m^{-3} would have a C-sink potential of (1.3 m^3 * 0.22 t m^{-3} * 67.3% =) 192.3… kg carbon or (192 kg * 44u / 12u =) 705 kg CO_2eq. The C-sink potential can also be determined by the weight and water content of the packaging unit. A 350 kg big bag with a water content of 25% would therefore have a C-sink potential of (350 kg * (100%-25%) * 67.3% =) 176.6 kg carbon or (193 kg * 44u / 12u = 647.7 ≈) 648 kg CO_2eq.

However, measuring methane emissions below 5 ppm is technically very complex. Continuous measurement over an entire production year would incur costs that would be significantly higher than the projected revenues for setting-up C-sinks. Since emissions from individual plants can only be poorly monitored and a few individual measurements may not be representative enough, type certification has been introduced to assess the carbon footprint of pyrolysis plants.

To carry out a pyrolysis equipment type certification, at least three pyrolysis plants of the same type from the same manufacturer must be in commercial operation at different sites. For each of these three plants, at least two independent, state-accredited emission measurements including CH_4 or C_xH_x must be available. From these measurements, a statistical mean value

with standard deviation is calculated. The average methane emission of this type of plant is then set to be the mean value plus the standard deviation. If the emission measurement for methane or C_xH_x is below the measuring accuracy of the instruments, the limit value is taken as the average methane emission. The methane emissions included in the calculation are thus higher than the calculated average and provide a sufficiently high safety margin to cover any potential emission peaks, e.g. in start-up and shut-down of operation. The measured values for methane emissions are given in ppm of the flue gas (i.e., combusted pyrolysis gas) and converted into g CH_4 per ton of biochar via the waste gas flow per mass unit of biomass input.

Upon request, individual measurements of methane emissions from individual installations may also be available. For this purpose, a detailed measurement strategy with precise details of the measurement technology, measurement intervals, and measurement accuracy must be submitted in advance to the EBC for review.

5. Mandatory data for the certification of the C-sink potential

If a pyrolysis plant is certified according to the EBC C-sink standard, the physical goods, i.e. the biochar must provide the following mandatory information on the packaging and delivery bill:

1. Due to the EBC certification, which usually precedes the C-sink certification, the QR code of the respective EBC batch must be printed on each packaging unit. This QR code refers to the EBC website, which documents the most important analytical data of the corresponding biochar batch. The certified C-sink potential is also displayed there.
2. Since the C-sink potential refers to water-free biochar, the dry weight of the biochar must be indicated for each packaging unit. The dry weight is the mass of the dry substance and is stated rounded to 1 kg per m^3 biochar.

5.1 On-site measurement of the dry matter content of biochar

It should be noted that the water content of biochar can be subject to considerable fluctuations at the time of sale or even directly at the discharge of the pyrolysis plant. Reasons for this can be a fluctuating intensity of the quenching at the discharge, the absorption of air humidity or air drying. Therefore, it is not possible to determine the C-sink potential simply on the basis of the fresh weight (wet mass) of the biochar and the dry matter content analyzed once per batch during the annual EBC-accredited laboratory analysis.

The bulk density can also vary within a batch, mainly due to variations in the particle size distribution of the pyrolyzed biomasses and abrasion during transfer and transport of the biochar. Thus, a volumetric determination of the dry weight of the produced biochar is also not appropriate.

Therefore, the reliable and regular determination of the dry matter (DM) content is a prerequisite to indicate the dry weight and thus the C-sink potential of a packaging unit of biochar. This is a considerable effort for biochar producers, which is, however, unavoidable in order to maintain verifiability and thus confidence in this C-sink method.

For each sub-quantity of max. 10 m^3 of biochar, at least 20 individual sub-samples must be taken using a sampling drill stick. Combining a minimum of 20 sub-samples must yield at least a total sample volume of 10 liters of biochar. The individual sub-samples can be taken either from a collected pile or container of max. 10 m^3 of biochar or from each of several big bags presenting a total amount of max. 10 m^3. The combined sample is weighed using a balance with a precision of at least 1 gram. The biochar is dried at 110 °C for at least 16 hours and

weighed again. Weighing must be carried out immediately (max. 1 minute) after removal from the 110 °C drying oven. Otherwise, moisture may condense on the biochar and falsify the result. Appropriate protective gloves must be provided. This method simplifies the usual DIN 51718 and ISO 589, which may equally be followed, and corresponds to their principles, taking into account the material properties of biochar.

The dry matter content (DM) is calculated by dividing the net weight after drying with the net weight before drying.

$$\text{DM [\%]} = \frac{net\ weight\ after\ drying}{net\ weight\ before\ drying}$$

If, for example, big bags of 1.3 m^3 are used for storing the biochar, a maximum of seven big bags may be combined for one sampling. At least three sub-samples have to be taken with the sampling drill stick from each of the seven big bags. All 7x3 subsamples are then combined and weighed as described above, dried, and weighed again. If the 10-liter sample weighs 3.057 kg before drying and 2.139 kg after drying, the dry matter content is (2.139 kg / 3.057 kg =) 69.970%. This value is rounded to full percentages for further calculations (here: 70%). The DM content determined in this way must then be multiplied by each big bag's individually balanced weight (see example in Table 1). This results in each big bag's respective dry weight, with which each big bag must then be labeled. For instance, if a big bag weighs 200 kg (fresh weight, net weight) and has a determined DM content of 70%, the dry weight is (200 kg * 70% =) 140 kg. It is rounded to whole kilograms.

For the described DM determination via drying of a representative sample, a relatively large drying oven and correspondingly accurate balances are required. Still, the effort for 10 m^3 or seven big bags is manageable. Weighing of the big bags should be done on the same day as the sampling.

Deviations from the procedure described here can be regulated in the EBC instruction manual, e.g. if the dry weight is determined via a deviating method. If a plant can prove that the dry matter content does not change by more than ±2% over extended periods and production quantities, larger intervals between measurements can be authorized. If biochar with a particle size of more than 30 mm is produced, the subsamples' volume must be increased.

Tab. 1: Example of calculation of dry weight of a series of seven big bags.

Serial number of big bag	Volume	Weighed weight	Dry matter content	Dry weight
Big bag 2020-490	1,3 m3	195 kg	70%	137 kg
Big bag 2020-491		200 kg		140 kg
Big bag 2020-492		200 kg		140 kg
Big bag 2020-493		210 kg		147 kg
Big bag 2020-494		195 kg		137 kg
Big bag 2020-495		200 kg		140 kg
Big bag 2020-496		200 kg		140 kg

6. Margin of Safety

In the calculation of carbon footprints, the emissions accounted for are usually divided into Scope 1 (direct emissions at the production site, in this case, combustion of pyrolysis gas, methane emissions during biomass storage, combustion of natural gas for preheating the reactors), Scope 2 (indirect emissions from externally purchased energy, in this case mainly electricity) and Scope 3 (further indirect emissions, in this case, e.g., production of purchased biomasses and transport). For the EBC C-sink potential, the emissions from Scope 1 and 2 are fully recorded. In contrast, from Scope 3, only the emissions from biomass production and its transport are directly quantified Other indirect emissions from Scope 3 are not recorded individually due to their comparatively low volume, but are instead included in the calculation with a flat margin of safety. This includes, for example, the emissions caused by:

- Production and disposal of polypropylene big bags,
- Electricity for the operation and cooling of the company's external computer servers,
- Potential methane emissions during the first month of storage of the biomass,
- Fuel consumption by employees for commuting to work and for business trips,
- Marketing department activities including trade shows and conference attendance,
- Operation of chainsaws or harvesters for felling and peeling trees and for digging up roots,
- Emissions from machine fuels during cultivation of agricultural land and plant protection measures,
- The greenhouse gases produced in growing the food served in the cafeteria,
- Production, maintenance, repair, and disposal of pyrolysis equipment, transport vehicles, warehouses, and other machinery.

There are many small, indirect scope 3 emissions that need to be included when creating a perfect carbon footprint. Compared to the total amount of CO_2eq from Scope 1 & 2 as well as from biomass provision in Scope 3, and to the vast amount of carbon accumulated in biomasses, the remaining indirect emissions in Scope 3 play only a minor role. To account for all these GHG emissions that are not directly quantified, a flat margin of safety is defined. The margin of safety generally amounts to 10% of the total emissions from biochar production deducted from the C-sink value and is rounded to 0.1%. This is a high, industry-standard margin for the inherent uncertainty of the overall process that allows EBC to be sure to keep the certification process lean and efficient without misappropriating emissions.

Thus, if the biomass provision (5.3% - see Box 3) and the pyrolysis process (2.4% - see Box 4) result in total GHG input that equals 7.7% of the C-content of the produced biochar, the margin of safety for the indirect emissions not quantified in the system is (10% * 7.7% =) 0.8% of the C-content of the biochar and is additionally subtracted from the C-sink potential accordingly.

7. Climate neutral energy

When determining the C-sink potential, the total amount of GHG emissions caused during the biomass production, storage, and pyrolysis process is recorded as CO_2eq. The corresponding amount of carbon is subtracted from the C-content of the biochar. This means that all other products of the pyrolysis process (pyrolysis oil, pyrolysis gas, or the thermal energy and electricity obtained from it) are to be regarded as climate-neutral since all GHG emissions have already been accounted for with the biochar. The total power generated as heat or electricity during pyrolysis is therefore climate neutral.

The European Emissions Trading Scheme (EU-ETS), through which CO_2 emission allowances are traded, is based on the assumption, as are most platforms for voluntary CO_2 compensation, that fossil energy will be replaced by climate-neutral energy, thereby indirectly reducing CO_2 emissions. Based on this idea, which is anchored in the Kyoto Protocol as well as in the Paris Climate Treaty, CO_2 certificates are generated for the production of climate-neutral energy. Companies or private individuals can buy them to offset their emissions, i.e., to obtain quasi climate pollution rights. The general hope of policymakers is that this will provide market-based leverage to make fossil energy more expensive and climate-neutral energy cheaper to reduce emissions overall.

Thus, there is a fundamental difference between C-sinks and emission reductions/pollution rights. C-sinks, such as those created by the production and application of biochar, have actively removed CO_2 from the atmosphere and stored the carbon in the terrestrial system over the long term. This climate service has been documented and can also be physically verified through various means. On the other hand, the generation of climate-neutral energy only avoids emissions compared to a reference scenario, e.g., a coal-fired power plant. Only through such a reference scenario can a value for the emission reduction be determined, while it cannot be measured physically. The atmosphere's CO_2 content is not reduced by the generation of climate-neutral energy but ensures at best that less anthropogenic greenhouse gases are emitted into the atmosphere.

For the reasons explained above, the EBC only issues certificates for C-sink potentials but does not issue CO_2 certificates for the generation of climate-neutral energy. The EBC only certifies the amount of carbon that has been effectively and measurably stored and thus prevented from returning to the atmosphere.

The EBC certificate nevertheless indicates the amount of climate-neutral thermal and electrical energy generated in MWh per year as well as the amount of pyrolysis oils produced in tons (DM) per year, if applicable.

8. Use and trading of biochar-based C-sinks by accredited brokers and trading platforms

The C-sink potential of the EBC certificate is the prerequisite for generating marketable C-sink certificates. However, it only represents the status of the C-sink at the factory gate.

From the moment a packaging unit filled with biochar (e.g., a big bag = super sack) leaves the factory site, many things can happen that may reduce or eliminate the C-sink potential of the traded biochar. If fossil fuels are burned for the transport of biochar or electricity is consumed during pelleting or any other process, the C-sink potential is reduced by the greenhouse gas emissions that result from these activities. If the biochar is burned, for example, as charcoal, processed into activated carbon, or used as a reducing agent in steel production, a significant amount of carbon would be lost to the atmosphere. Therefore, only when the biochar is eventually applied to soil or included in traceable long-lasting materials can it be assumed that the C sink will be preserved in a calculable and controllable way in the long term.

To generate a full C-sink certificate, an accredited tracking system is required to record all carbon losses from the factory gate to incorporation into the soil or a long-term stable material and to deduct them from the certified C-sink potential. The tracking system to be accredited by the EBC can be developed and implemented by C-sink brokers and trading platforms. In this context, biochar manufacturers can also act as C-sink brokers themselves. The following basic principles must be observed:

1) For as long as the packaging unit is stored closed and protected on the factory premises, the C-sink potential remains unchanged.
2) After leaving the site of biochar production, any greenhouse gas emissions that occur during transport, further processing (e.g., grinding, blending), and placement in a final storage site (e.g., soil, concrete, asphalt, etc.) must be deducted from the C-sink potential.
3) Incorporating biochar into substrates such as compost, litter, feed, fertilizer or cement, sand, clay, and lime is considered a creation of a carbon sink. From this moment on, the combustion of the biochar and thus the loss of carbon can be practically excluded. The EBC will publish a binding positive list of such possible C-sink materials and applications, which can be extended upon request and after appropriate review.
4) To prevent duplicate certifications, the final location and owner of the site where the C-sink is created should be registered. Ideally, the registration would be done in a central C-sink registry, which has to be developed. This applies to

agricultural applications (here, the specific piece of land where the biochar or substrate containing biochar was applied would need to be recorded via GPS) as well as material applications (e.g., the particular house would need to be registered with address or GPS data for biochar in construction material). Recording the location and site owner of the C-sink is essential both for subsequent monitoring (e.g., measuring the biochar content of the soil) and for compensating the site owner for climate services by maintaining and preserving the C-sink (e.g., C-preserving management of the soil, maintenance of the house).

5) If the registration of the geographical location and site owner of the C-sink is not possible or practicable, but the biochar is nevertheless shown to have been introduced into a matrix that precludes combustion (e.g., compost, biogas slurry, cement, etc., see above), the sink is considered a diffuse C-sink. It is not possible to physically verify the fate of the C-sink. Nevertheless, it can safely be assumed that the carbon used in this way remains a terrestrial C-sink. However, there is a fundamental risk of double certification, especially through the certification of soil organic matter ("humus certificates"), because the usual measurements used to quantify soil carbon will also account biochar as soil organic carbon. However, as long as there are no official soil organic carbon / "humus" certificates in place, and as biochar is usually applied at maximum rates of only two t per hectare and year, which can hardly be measured using usual methods for measuring soil carbon, the risk of double certification is currently considered to be low.

6) In the present version 2.0 of the EBC guidelines for C-sink certification the geographic localization of C-sinks is not yet mandatory, and no qualitative distinction is made between diffuse and localized C-sinks. The tracking systems of the few accredited brokers of C-sinks are not yet prepared for this. Moreover, there is not yet sufficient consensus on the theoretical and technical basis for the tracking. Therefore, the EBC is defining a transitional period until June 2022 for the implementation of the geographical localization of C-sinks.

7) If a packaging unit of biochar or a product containing biochar is traded, and its C-sink value has already been sold elsewhere, it must be indicated on the packaging and the delivery bill that the C-sink value of the biochar has already been compensated. The product is therefore carbon neutral and can no longer be declared or traded as a C-sink or CO_2 certificate. This reference should at least be made by printing the following EBC-registered seal: "Carbon Sink Registered".

8) The right to use the EBC "Carbon Sink Registered" seal is acquired by registration of the corresponding C-sink by an EBC-accredited C-sink dealer.

9) For example, farmer purchases 10 m^3 of biochar whose C-sink value has already been sold by the distributor or manufacturer to a C-sink broker. In that case, the farmer cannot again use the C-sink value of the purchased biochar to offset emissions from, for example, his potato production or livestock and advertise the potatoes as climate positive. The sale of biochar without its C-sink value is subject to declaration. The purchaser of biochar without a C-sink value must therefore be informed accordingly, otherwise it would be product fraud.

10) The life cycle of the final C-sink or the degradation of the biochar in the final C-sink must be accounted for. When incorporated into soils or blended into substrates and feeds that will eventually be incorporated into agricultural or urban soils, the annual rate of biochar degradation must be applied according to the H/C_{org} ratio of the biochar (Camps-Arbestain et al., 2015; IPCC, 2019) and must be at least 0.3%. In this way, the C sink's annual evolution can also be specified over more extended periods of 100 or 250 years or traded in annual tranches.

11) When biochar is incorporated into industrial materials such as plastics or asphalt, appropriate monitoring methods (e.g., electronic tracking, satellites, or statistically validated lifetime averages) must be used to ensure what proportion of the material containing biochar is still in use and has not been converted to CO_2 by combustion. From these data, an appropriate degradation rate should be formulated.

12) For incorporating biochar into building materials such as concrete, mineral plasters, gypsum, or clay, a permanent sink can be assumed. Building materials make incineration impossible, thermal waste treatment is not provided for and thus protects embedded biochar against biological and chemical degradation

far better than the soil. For periods of 100 - 250 years, no degradation rate must be considered for this purpose.

To ensure that the tracking system works without leakage and that only high quality, verifiable C-sinks are sold as a climate service, the EBC has introduced an accreditation protocol of C-sink brokers and trading platforms.

Manufacturers of biochar are advised to sell the EBC-certified C-sink values only to EBC-accredited C-sink dealers. This is the only way to guarantee that only the amount of carbon actually removed from the atmosphere in the form of CO_2 is certified and sold as a C-sink.

Of course, a biochar manufacturer can also become accredited as a C-sink broker and thus sell CO_2 certificates to farmers or building contractors, for example, or to third parties, or offset its own emissions.

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