Certification of the carbon sink potential of biochar (Version 1)

Hans-Peter Schmidt[1*]*, Claudia Kammann*[2]*, Nikolas Hagemann*[1,3]

[1] Ithaka Institute, Ancienne Eglise 9, 1974 Arbaz, Switzerland
[2] Department of Applied Ecology, Hochschule Geisenheim University, Von-Lade-Str. 1, 65366 Geisenheim, Germany
[3] Agroscope, Environmental Analytics, Reckenholzstrasse 191, 8046 Zurich, Switzerland

*corresponding author: schmidt@ithaka-institut.org

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1. Basic principles

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 released again 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 introduced directly into 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.

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 to be removed from the C-sink register.

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.

In addition to the degradation rates of biochar applied to soil, emissions related to biomass production (planting, cultivating, harvesting, transportation, chipping), the pyrolytic transformation of the biomass, post-processing of the biochar (e.g. grinding, mixing, bagging) and its transport and application to soil or materials must be factored into the overall carbon balance. It would, therefore, be overly simplistic and insufficient to only use the remaining carbon content of biochar to assess its value as a C-sink. All greenhouse gas emissions along the biochar value chain must be subtracted as carbon equivalent expenditures from the amount of sequestered biochar carbon to provide an accurate carbon sink accounting.

1.1 Definition and calculation of the C-sink potential

When a packaged unit of biochar (e.g. a big bag or container) leaves 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. The size of this C-sink potential is calculated as part of the EBC certification process.

Once the biochar is sold, it could be destroyed by fire, or a customer could buy it for co-firing in a biomass power plant or use it as an 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 but would be lost.

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 point in time, 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.

The C-sink potential of biochar is calculated from the carbon content of the biochar minus all emissions caused by its production and use.

The C-sink potential is calculated as follows:

1) The carbon content of biochar is determined according to the EBC method and indicates the amount of organic carbon stored in the biochar as a proportion on a dry matter basis.
2) All greenhouse gas emissions caused by the production and processing of the biomass are recorded in CO_2eq for the entire production batch.
3) All greenhouse gas emissions caused by the pyrolysis plant and subsequent processing of the biochar are recorded in CO_2eq for the entire batch.

4) 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 determined total 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 that was emitted as CO_2eq to produce the total amount of biochar of a production batch.
5) The carbon expenditure is given as mass proportion (in %) 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.
6) The proportion of carbon expenditure is subtracted from the carbon content of the biochar, resulting in the C-sink potential in mass percent of the biochar (DM) – [see calculation examples below in the colored boxes].

The EBC C-sink potential thus 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 two colored boxes.

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

The overarching goal of C-sink certification 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. Therefore, the EBC defines the carbon neutrality of a 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 a 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.

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

2. Biomass categories

Only biochar produced from either residual materials or biomass provided from other C-neutral sources is eligible for C-sink certification. This results in specific requirements for the following six biomass categories, depending on the exact origin of the biomass.

The example of the 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 biomass can therefore be considered C-neutral discounting fertilizer and tractor emissions from planting, harvesting, transportation. If the Miscanthus grass is not burned but pyrolyzed, half of the carbon absorbed by the grass remains in the biochar, rendering the system not only neutral but also climate-positive. Thus, this biochar from the Miscanthus grass, which grows back in less than a year, is a C-sink for as long as it is not burned or otherwise decomposed. For certification, fertilizer and tractor emissions need to be included into the calculation of the C sink potential.

2.1 Agricultural biomasses

If annual biomass is grown on agricultural land specifically for pyrolytic and/or energetic use (see example in the colored box below), 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 extracted from the atmosphere. The harvested biomass can thus be considered C-neutral on the basis of one year (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 not only increase agricultural productivity, but also biodiversity, soil organic matter and enable removal of CO_2 from the atmosphere.

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 to 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 CO2eq for fertilization and (3.2 kg CO_2eq * 25 l=) 0.08 t CO_2eq for the diesel used. This results in (0.5 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 box below), the C-sink potential of the biochar is therefore 75% - 5.3% = 69.7%.

The inclusion of biomass as a full-fledged product of agriculture would also change the definition of agricultural residues. Straw, tomato, potato and 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 need to be accounted for. If mineral nitrogen fertilization was used to produce the biomass, its carbon footprint must be subtracted from the C sink value according to the formula 100 kg N = 1 t CO_2eq (Zhang et al., 2013). The input of fuels for cultivation and harvest must also be subtracted from the C-sink potential with a conversion factor of 3.2 kg CO_2eq per liter diesel (Juhrich, 2016). If the biomass is generally considered to be a crop residue, no carbon expenditures are accounted for until further notice.

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 from urban areas is also considered C-neutral.

Trees from forest gardens, orchard meadows, tree strips, and hedges for arable farming are often many decades old. They have to be managed in such a way 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, including the use of pesticides and fuels, must also be deducted from the C-sink potential (3.2 kg CO_2eq / l diesel (Juhrich, 2016)).

2.4 Biomass from forest management

An area is considered 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. The loss of wood has, therefore, to be balanced by the growth of forest wood on the referenced area unit. Furthermore, only a maximum of 80% of the harvested biomass should be removed from the forest to maintain the nutrient cycle and the biodiversity of the forest. 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.

In European forestry, there is currently no comprehensive forest assessment of area units of 100 ha or less. In fact, the reference area units are considerably larger than 10,000 ha and the forest regrowth is simply extrapolated using regional average values. If in regional forests such as the Black Forest or the Arlberg the standing biomass of forest is higher than the amount of biomass withdrawn, the withdrawn biomass is regarded as climate neutral according to the European Regulation [2018/841] (EU-Parliament, 2018). Ecologically, it is 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 EU LULUCF regulation (EU-Parliament, 2018), **all wood from forests whose regrowth demonstrably exceeds the removal, independent of the size and structure of the forest, is recognized as C-neutral input for the EBC certification of the C-sink potential.**

We would like to justify the decision to adhere to European forest legislation primarily because it does not make sense for the development of the C-sink economy to make the restrictions too strict and 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 us 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). With regard to forest wood use, the EBC standard will be updated to reflect the technical possibilities and political conditions in the course of 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 if these are 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 the wood harvest must be subtracted from the C-sink potential. The amount of diesel fuel required for this is calculated with the conversion factor of 3.2 kg CO2eq / l diesel (Juhrich, 2016).

It is assumed that no fertilization takes place in the forest, otherwise, the CO_2eq expenditure for fertilization and possible liming 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 approved 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.

3 Deductions for production-related emissions

3.1 Energy and fuel carbon expenditures for transportation, provision of the biomass and post-treatment of the biochar

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, pelletization, and drying of the biomass,

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

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

During certification, accounting of the consumption data for electricity and fuel for all these individual steps is requested. 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. The latter also applies if the pyrolysis plant itself generates electricity and feeds at least the amount of electricity equivalent to its consumption into the grid.

For the consumption of diesel or benzine fuel for transportation, chipping, drying, etc., the conversion factor of 3.2 kg CO_2eq / l fuel used by the German Ministry of the Environment is applied (Juhrich, 2016).

3.2 External energy for operating the pyrolysis plant (control and regulation technology, preheating, heating, conveyor technology)

Even though the production of biochar usually produces a surplus of energy from the combustion of the pyrolysis gases, external energy is always required to operate pyrolysis plants. Thus, electrical energy is required for the control and regulation technology as well as for conveying the biomasses and biochar. Depending on the type of plant, (fossil) fuel gas or electricity is also required to preheat the reactors.

Besides biochar, certain pyrolysis equipment can also produce pyrolysis oil and pyrolysis gas. When not using the pyrolytic gases to heat the reactors, external energy is required and its carbon footprint needs to be subtracted. The EBC does not allow the use of fossil fuels to drive the pyrolytic reactions except for preheating the reactor.

To calculate the CO_2 footprint of a pyrolysis plant, it is, therefore, necessary that each plant is equipped with its electricity meter. By means of the electricity meter, the effective electricity consumption per production batch is determined and converted into CO_2eq via the CO_2 emissions per KWh of the electricity mix used.

In a case where the energy balance of a biochar production facility is positive, meaning that measurably more electrical energy or fuel products are generated than are consumed, the positive energy balance may be attributed to renewable energy as emission reduction under appropriate governing agencies. However, the positive energy balance cannot serve to increase the C-Sink value and can only be used to potentially nullify C-Sink deductions where appropriate (e.g. electricity needed to run the pyrolysis).

The amount of fuel used to heat the pyrolysis reactors must be specified per batch and is converted into CO_2eq by fuel type (65 t CO_2eq per TJ (Juhrich, 2016)).

3.3 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 cleanly 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 (CH4) 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.

Methane has a global warming potential (GWP100) that is 34 times higher than that of CO_2 over a period of 100 years (Myrhe et al., 2013). However, as the crucial phase for limiting global warming is between now and 2050, the global warming potential over 20 years (GWP20) should be used instead of the GWP100 to promote the avoidance of these critical emissions. The GWP20 of methane is 86, which means that within the first 20 years after emission, the global warming effect of methane is 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 climate balance of pyrolysis plants.

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%, **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 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 flue gas. At a daily production of 3 t biochar the exhaust gas volume flow is 45,000 m^3. This results in methane emissions of 45,000 m^3 * 6.6 mg CH_4 / m^{-3} = 0.3 kg CH_4 per day. Using the GWP20 of 86 CO_2eq for methane, a daily CO_2eq of (0.3 kg CH_4 * 86 =) 25.5 kg results, corresponding to a carbon expenditure of (25.5 kg / 3 t =) 8.5 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 kg CO_2eq per t biochar (DM).
- The total **carbon expenditure for the pyrolysis** is converted from (45 kg + 8.5 kg + 30 kg =) 83.5 kg CO_2eq to (83.5 kg CO_2eq / 44u * 12u =) 22.8 kg C per t biochar (DM). This results in (22.8 kg C per 1000 kg biochar =) 2.3 mass percent.
- Including the carbon expenditure for the provision of biomass (see box above), this results in a **C-sink potential** of biochar at the factory gate of 75% (carbon content) - 5.3% (biomass expenditure) - 2.3% (pyrolysis expenditure) = 67.4%.
- 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} * 67.4% =) 193 kg carbon or (193 kg * 44u / 12u =) 707 kg CO_2eq. The C-sink potential can also be determined by the weight and water content of the packaging unit. A 381 kg big bag with a water content of 25% would therefore have a C-sink potential of (381 kg * (100%-25%) * 67.4% =) 193 kg carbon or (193 kg * 44u / 12u =) 707 kg CO_2eq.

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 on 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. The CO_2eq of methane emissions is calculated using GWP20 of 86.

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 to the EBC for review in advance.

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

To indicate the C-sink potential, the following parameters of the packaged biochar are required for each packaging unit:

- C-content
- H/C_{org} ratio
- Dry matter content
- Bulk density on a dry mater base and at a particle size < 3 mm

While the C-content and the H/C_{org} ratio can be taken directly from the EBC certificate analysis, the bulk density and the dry matter content of the biochar must be determined and declared by the producer for each packaging unit as specified in the EBC instruction manual which is developed for and agreed on with each producer during the initial audit.

4.1 Factory determination of the dry matter content *(to be finalized with exact method description by end of June 2020)*

It should be noted that both the water content and the bulk density of biochar can be subject to considerable fluctuations. While the water content varies primarily as a result of varying intensity of quenching at the discharge, absorption of air humidity, or air drying, the bulk density changes primarily as a result of abrasion during transfer and transport. If it cannot be ensured in the factory that the water content of the biochar does not vary by less than ± 3% when filled directly into the packaging units at the outlet of the pyrolysis plant, the dry matter content must be determined and reported separately for each packaging unit of more than 1 m^3 at the time of filling.

Frequent testing for dry matter comes with a considerable effort for the producers of biochar, however, it is indispensable to determine the C-sink potential. As biochar-based C-sinks will persist for centuries, even small deviations in the determination of the sequestered carbon amounts would have large impacts over time.

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

The C-sink potential of the EBC certificate is not a marketable CO_2-certificate to offset someone's individual or a company's GHG emissions but as the fundament to build marketable C-sink certificates upon.

From the moment a delivery unit filled with biochar (e.g. a bigbag) leaves the factory, a lot 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 in a pelleting process, the C-sink potential is reduced by the greenhouse gas emissions that result from these activities. If, for example, the biochar is burned 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. Only when the biochar is eventually applied to soil or included in measurable long-lasting materials can it be assumed that the C-sink will be stable for the long term.

The C-sink potential only reflects the current status of a carbon storage, i.e. it indicates the proportion of the dry weight of a biochar that could be converted into a C-sink once the biochar leaves the factory gate. As long as the packaged biochar remains closed and protected on the factory premises, the C-sink potential as such remains unchanged.

A biochar production company can register its EBC certified C-sink potential with EBC accredited C-sink brokers or trading platforms. Using a blockchain secured tracking system, the pathway of the biochar from the factory gate to the actual C-sink (e.g. insertion into soils or materials) has to be documented. From the moment the biochar has been incorporated into a carbon preserving matrix such as soil, asphalt, or concrete, the C-sink potential can be converted into a tradable C-sink certificate which accounts for all greenhouse gas emissions that occurred between the factory gate and the final C-sink. These C-sink certificates can then be sold and traded, and the EBC-certified biochar producer is thus remunerated for the climate service they initiated. Based on the C-sink certificates, CO_2 emissions can be offset or portfolios of C-sinks can be created. When doing so, the trading platforms must ensure the following:

1) Any emissions of greenhouse gases that occur during transport, further processing (e.g. grinding, mixing) and injection into a final storage site (e.g. soil, concrete, asphalt, etc.) after passing the factory gates of the EBC-certified company, must be deducted from the C-sink potential. The application of the biochar into substrates such as compost, litter, animal feed, fertilizer or cement, sand, clay, and lime is considered as starting point of a long term carbon sink as this precludes the destruction of the biochar and thus the loss of the carbon sink.
2) The life cycle of the final carbon deposit or the decomposition of biochar in the final deposit must be factored into the overall carbon accounting. When mixing biochar into soil substrates or feed which eventually enter agricultural or urban soils, the annual degradation rate of the biochar must be set according to the H/C_{org} ratio of the biochar (Camps-Arbestain et al., 2015; IPCC, 2019). In this way, the annual evolution of the C sink can be assessed over longer periods of 100 or 250 years and traded in time-dependent tranches.
3) Effective measures must be taken to avoid duplicate certification. For example, if biochar applied to soil has been certified as a C-sink, the owner of the land must not sell the biochar as a C-sink via soil organic matter certificates a second time. This must be confirmed and signed by the owner of the land or material where the biochar was applied. Biochar that cannot be traced shall not be listed as a C-sink in the trading system.

When biochar is incorporated into industrial materials such as plastics or asphalt, suitable monitoring methods (e.g. electronic tracking, satellites or statistically secured average values for the lifetime of the materials) must be used to ensure that the material containing the biochar is still in use and has not been converted into CO_2 by combustion.

A permanent sink can be assumed for the integration of biochar into building materials such as concrete, lime plaster, or clay. Those building materials make combustion impossible and hence protect the C-sink potential even better than soil against biological and chemical decomposition. For periods of 100 - 250 years, no degradation rate needs to be considered.

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 is introducing an accreditation protocol of C-sink traders and trading platforms.

To maintain a high level of credibility for biochar related C-sinks, producers of biochar are advised to sell EBC certified C-sink potentials only to EBC accredited C-sink traders.
Of course, a biochar manufacturer can also become accredited as a C-sink trader and thus sell CO_2 certificates to third parties.

6. Quoted literature

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